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BIOMASS YIELD ENHANCEMENT OF DHAINCHA (*SESBANIA* SPECIES) THROUGH CULTURAL PRACTICES

S.C. CHANDA[1,2], M.A. RAZZAK[1], M.A. HOSSAIN[1], A.K.M. GOLAM SARWAR[1,]*

*E-mail: drsarwar@bau.edu.bd

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ABSTRACT. Three separate field experiments were conducted to exploit biomass yield potential of dhaincha (*Sesbania* species) by different cultural practices. A total of six accessions from three *Sesbania* species, *viz*. *S. bispinosa* (#05, 71, 77 and 109), *S. cannabina* (#28) and *S. sesban* (#81), were used as experimental materials. Experimental treatments were population densities, *viz*. 180, 240 and 300 plants m^{-2}; sowing dates, *viz*. 30 April, 15 May, 30 May and 15 June, and fertilizer doses, *viz*. 0 (without N/control), 10, 20 and 30 kg N ha^{-1}. All the experiments were designed following randomized complete block design with three replications. Experiments on population density and sowing dates were conducted in control condition (without any fertilizer application). The N-fertilizer was applied as top dress at 30 days after sowing (DAS) and crops were harvested at 60 DAS. The maximum biomass (10.07 t ha^{-1}) was obtained from 240 plants m^{-2}. At 30 April sowing, plants produced the tallest height (199.69 cm), widest base diameter (1.02 cm), highest fresh weight (62.07 t ha^{-1}) and biomass yield (14.73 t ha^{-1}). There were no significant differences in biomass yield and yield contributing descriptors between 20 and 30 kg N ha^{-1}. Among the species, *S. bispinosa* was the best performer in terms of biomass yield and yield contributing descriptors. It may be concluded that *S. bispinosa* (accession #71) could be cultivated with the population density 240 plants m^{-2}, at 30 April, without any fertilizer application. In case of later sowing/cultivation, the 20 kg N ha^{-1} could be applied for the maximization of biomass yield.

Keywords: green manure crop; population density; sowing time; fertilizer management; total dry matter.

[1] Laboratory of Plant Systematics, Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, Bangladesh
[2] Department of Agriculture Extension, Sirajganj, Bangladesh

INTRODUCTION

In optimum condition, a soil contains approximately 5% organic matter (Brady and Weil, 2007). Soil organic matter (SOM) encompasses all of the organic components of a soil, including living biomass (intact plant and animal tissues and microorganisms), dead roots and other plant residues and dead tissues, and soil humus. It is critical for the stabilization of soil structure, retention and release of plant nutrients and maintenance of water-holding capacity, thus making it a key indicator not only for agricultural productivity, but also environmental resilience. The decomposition of SOM further releases mineral nutrients, thereby making them available for plant growth (van der Wal and de Boer, 2017), while better plant growth and higher productivity contribute to ensuring food security. According to the experts, the presence of organic matter in Bangladesh soil is very low, avg. 1.0-1.5% against the requirement of 5% (Khan, 2018).

Application/addition of (green) plant residues is one of the most convenient and traditional means to increase the SOM content. Plant residues contain 60 - 90% moisture. The remaining biomass consists of carbon (C), oxygen (O), hydrogen (H) and small amounts of sulphur (S), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca) and magnesium (Mg) (Bot and Benites, 2005). Although present in small amounts, these nutrients are very important from the viewpoint of soil fertility management.

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 (Sangeetha *et al*., 2011). Three species of *Sesbania*, *viz*. *S. sesban* (L.) Merr., *S. bispinosa* (Jacq.) Wight and *S. cannabina* (Retz.) Pers., are commonly known as dhaincha in Bangladesh. Incorporating dhaincha in to farming systems leads to better opulence at the farm level. These plants afford extraordinary products as biomass, firewood, bio-fuel, animal fodder and feed, fencing as well as medicines for human being (Bhusara *et al*., 2016). Dhaincha also fixes atmospheric N to soil through *Rhizobium*-legume symbiosis. The main constraint of dhaincha cultivation in Bangladesh is the unavailability of land in the intensive cultivation systems. Rice (Boro) - Rice (T. Aman) is one of the most common cropping patterns in Bangladesh. Between Boro harvest and Aman rice transplantation, the land remains fallow for more or less than 80 days (Khan *et al*., 2004; Chanda and Sarwar, 2017a). This fallow time may be used as an opportunity for dhaincha cultivation for biomass production to improve the health and fertility of Bangladesh soil. All sorts of cultural/agronomic practices should be implied to maximize the biomass yield within this short period of time. Hitherto, information on cultural practices for enhancement of dhaincha biomass yield is scanty (Chanda and Sarwar, 2017b; Chanda *et al*., 2018a). Keeping all these things in mind, the present experiments were conducted to find out standard cultural practices, *viz*. plant population density, sowing time and fertilizer management, for maximizing biomass yield from dhaincha green manure crops (*Sesbania* species).

MATERIALS AND METHODS

Three separate experiments were conducted at the Field Laboratory, Department of Crop Botany, Bangladesh Agricultural University, during April to July, 2017. All these experiments were laid on following randomized complete block design with three replications and unit plot size was 10 m^2 (4 m × 2.5 m). A total of six accessions representing three *Sesbania* species, *viz*. *S. bispinosa* (#05, 71, 77 and 109), *S. cannabina* (#28) and *S. sesban* (#81), were used as experimental materials. Experimental treatments were (i) population densities, *viz*. 180, 240 and 300 plants m^{-2} (no fertilizer used), (ii) sowing dates, *viz*. 30 April, 15 May, 30 May and 15 June (no fertilizer used) and (iii) different nitrogenous fertilizer doses, *viz*. control (no fertilizer), 10 kg, 20 kg and, 30 kg N ha^{-1}. Experiments on (i) population density and (ii) sowing dates were conducted in control condition (without any fertilizer application). Both P_2O_5 and K_2O @10 kg ha^{-1} were applied during final land preparation and a full dose of N was used as top dress at 30 days after sowing (DAS). The experiment on population density was commenced on 10 May and fertilizer managements on 20 May, 2017. The weather data during crop growing period was presented in *Table 1*.

At 60 DAS, the data on plant height, base diameter, shoot fresh weight ($plant^{-1}$ and m^{-2}) and biomass yield ($plant^{-1}$ and m^{-2}) were recorded from 10 randomly selected plants. The fresh weight and biomass yield were measured by a digital balance and fresh sample were dried at $72^0 \pm 2^0$C for 72 hrs. Data were analyzed statistically following the analysis of variance (ANOVA) technique, using Statistix 10 software package. The difference of treatment means were compared with the Duncan's New Multiple Range Test at 5% probability (Gomez and Gomez, 1984).

Table 1 - Environment parameters of experimental site during crop growing periods

Month	Temperature (^{0}C)		Relative humidity (%)		Rain-fall (mm)	Sun-shine (hrs)	Soil tempera-ture (^{0}C at 5 cm
	Maxi-mum	Mini-mum	Maxi-mum	Mini-mum			
April/2017	30.39	22.23	92.90	67.10	122	7.4	36.89
May/2017	32.72	24.05	92.97	65.42	283	6.2	31.21
June/2017	31.89	25.72	94.53	73.70	491	3.9	31.00
July/2017	31.30	25.80	86.00	75.00	426	3.0	31.07

RESULTS

Enhancement of biomass yield through different plant densities

Plant height, base diameter, fresh weight and biomass yield were significantly influenced by different plant population densities (*Fig. 1*) and accessions (*Fig. 2*) and/or in combination (*Table 2*).

The accession #71 produced the tallest plant (169.33 cm), base diameter (0.94 cm), fresh weight (92.67 g plant^{-1}) and biomass yield (19.83 g plant^{-2}) at 180 plants m^{-2} of population density.

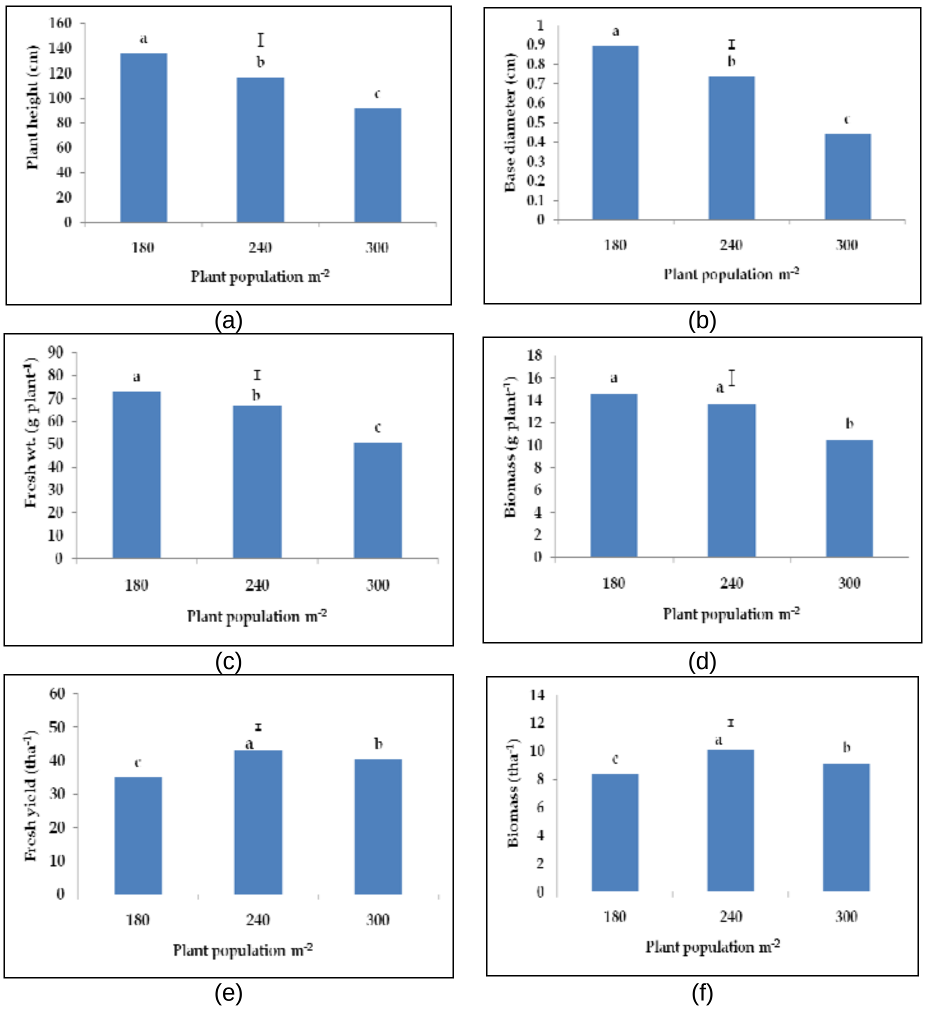


Figure 1 - Growth descriptors influenced by different plant population of dhaincha accessions: (a) Plant height (cm), (b) Base diameter (cm), (c) Fresh weight (g plant^{-1}), (d) Biomass (g plant^{-1}), (e) Fresh yield (t ha^{-1}), (f) Biomass (t ha^{-1}); Bar represent LSD at 0.05; n= 10.

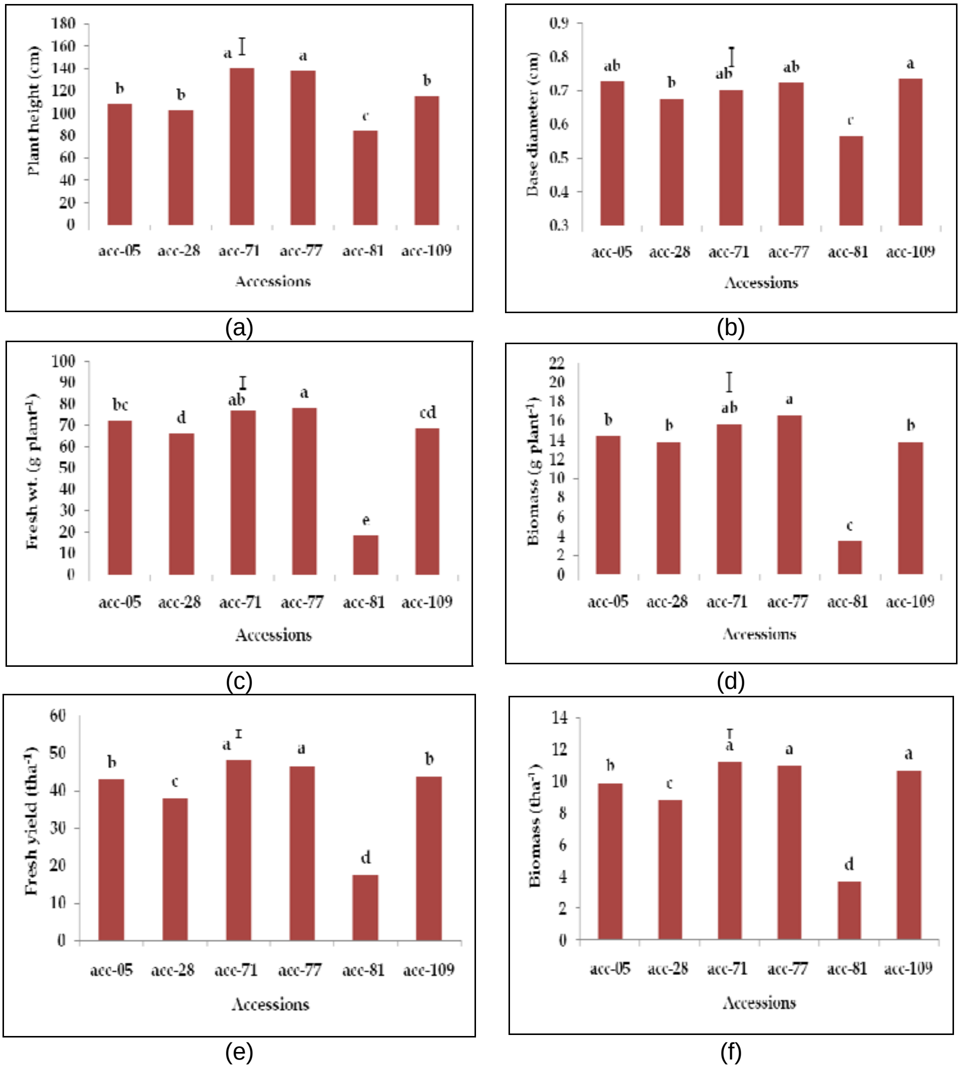


Figure 2 - Growth descriptors influenced by different dhaincha accessions: (a) Plant height (cm), (b) Base diameter (cm), (c) Fresh weight (g plant^{-1}), (d) Biomass (g plant^{-1}), (e) Fresh yield (t ha^{-1}), (f) Biomass (t ha^{-1}); Bar represent LSD at 0.05; n=10.

However, the fresh (53.10 t ha^{-1}) and biomass yield (12.33 t ha^{-1} was the highest at 240 plants m^{-2} of population density (*Table 2*). The lowest plant height (71.33 cm), base diameter (0.40 cm), fresh (16.33 g plant^{-1}) and biomass weight (3.17 g plant^{-1}), fresh (18.50 t ha^{-1}) and biomass yield (3.78 t ha^{-1}) was obtained from accession #81 with 300 plants m^{-2} of population density (*Table 2*).

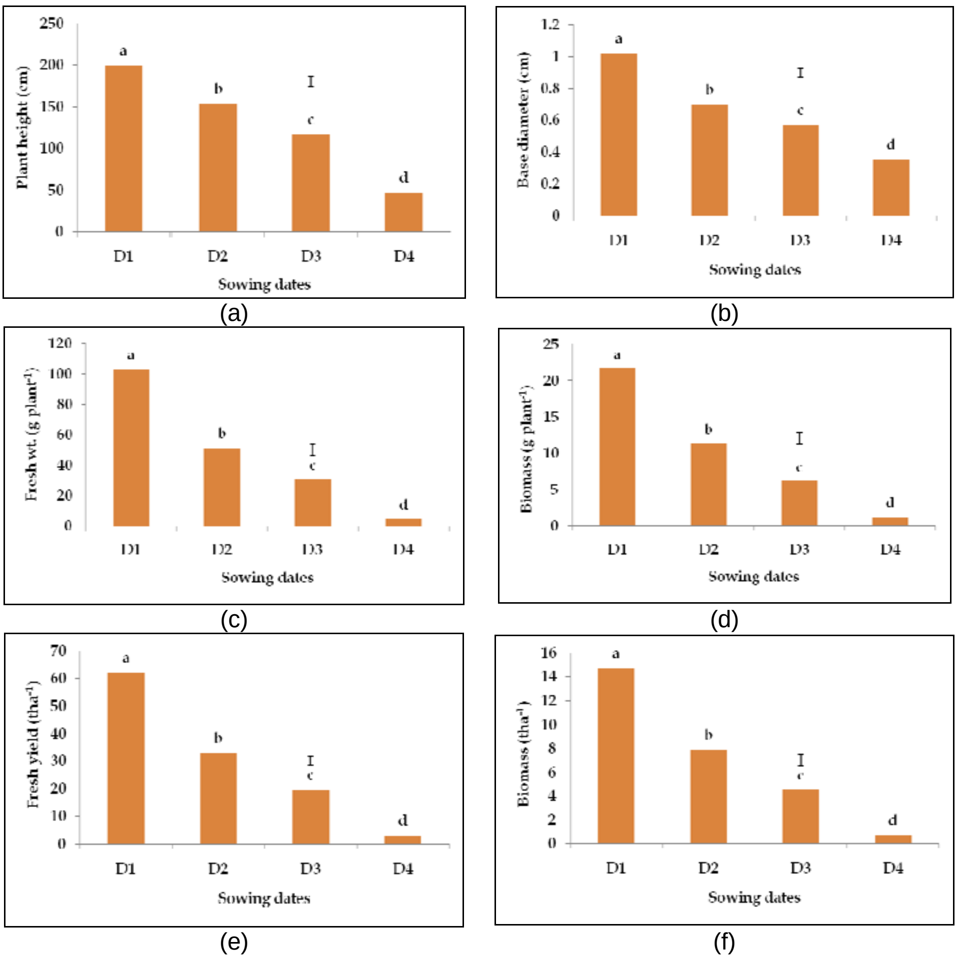
Table 2 - Effect of different plant populations on yield of dhaincha accessions.
P_1 = 180 plants^{-2}, P_2 = 240 plants^{-2}, P_3 = 300 plants m^{-2}

Treatment	Plant height (cm)	Base diameter (cm)	Fresh weight (g plant^{-1})	Biomass (g plant^{-1})	Fresh yield (t ha^{-1})	Biomass yield (t ha^{-1})
Acc#05× P_1	124.67 c-e	0.927 a	78.33 c-e	15.6 b-d	35.97 h	8.60 gh
Acc#28× P_1	125.67 c-e	0.890 ab	71.33 d-g	14.83 c-e	35.42 h	8.45 h
Acc#71× P_1	169.33 a	0.940 a	92.67 a	18.67 ab	43.70 d-f	10.43 d-f
Acc#77× P_1	162.00 ab	0.947 a	90.67 ab	19.83 a	42.03 ef	10.15 d-f
Acc#81× P_1	101.67 e-h	0.697 de	19.50 j	3.73 h	15.03 j	3.39 i
Acc#109× P_1	132.00 cd	0.947a	82.67 bc	15.13 cd	37.73 gh	9.43 f-h
Acc#05× P_2	112.33 d-f	0.790 cd	75.67 c-e	14.50 c-f	47.13 b-d	11.07 b-d
Acc#28× P_2	104.33 e-g	0.717 cd	70.00 e-g	14.73 c-f	41.20 fg	9.50 fg
Acc#71× P_2	141.67 bc	0.727 cd	83.00 bc	16.83 a-c	53.10 a	12.33 a
Acc#77× P_2	140.00 bc	0.767 cd	80.00 cd	16.73 a-c	49.85 ab	11.80 a-c
Acc#81× P_2	79.33 g-i	0.607 e	18.40 j	3.57 h	18.90 i	3.87 i
Acc#109× P_2	121.00 c-e	0.800 bc	72.33 d-f	15.83 b-d	48.40 bc	11.83 ab
Acc#05× P_3	87.33 f-i	0.467 f	62.00 gh	13.00 d-g	45.32 c-e	10.00 ef
Acc#28× P_3	78.33 hi	0.423 f	55.67 hi	11.50 fg	37.27 h	8.57 gh
Acc#71× P_3	111.00 d-f	0.443 f	57.00 hi	11.83 e-g	47.67 bc	10.83 b-e
Acc#77× P_3	112.33 d-f	0.460 f	63.67 f-h	13.17 d-g	48.07 bc	11.03 b-e
Acc#81× P_3	71.33 i	0.400 f	16.33 j	3.17 h	18.50 ij	3.78 i
Acc#109× P_3	92.33 f-i	0.460 f	49.67 i	10.47 g	44.97 c-e	10.77 c-e
$CV_{0.05}$	13.44	8.43	9.19	15.05	5.34	6.85
S_E	25.61	0.097	9.65	3.24	3.50	1.05

In a column, same letter (s) do not differ significantly at $P< 0.05$, as per Duncan's Multiple Range Test.

Enhancement of biomass yield through different sowing dates

Plant height, base diameter, fresh weight and biomass yield were also significantly influenced by sowing dates (*Fig. 3*) and different accessions (*Fig. 4*) and/or in combination (*Table 3*). The tallest plant (224.99 cm), base diameter (1.136 cm), fresh weight (25.27 g plant^{-1}) fresh yield (73.93 t ha^{-1}) and biomass yield (17.60 t ha^{-1}) were produced by accession #71 at 30 April sowing (*Table 3*). However, the highest fresh weight and biomass (123.33 g and 25.62 g plant^{-1}, respectively) showed in accession #77 at 30 April sowing. Moreover, it was statistically insignificant in accession #71 and 77. Significantly the shortest plant (36.33 cm), base diameter (0.26 cm), fresh (2.83 g plant^{-1}) and biomass weight (0.85 g plant^{-1}), fresh (1.78 t ha^{-1}) and biomass yield (0.38 t ha^{-1}) produced the accession #81 at 15 June sowing (*Table 3*).



D_1= 30 April D_2 = 15 May D_3 = 30 May D_4 = 15 June

Figure 3 - Growth descriptors) influenced by different sowing dates of dhaincha accessions: (a) Plant height (cm), (b) Base diameter (cm), (c) Fresh weight (g plant^{-1}), (d) Biomass (g plant^{-1}), (e) Fresh yield (t ha^{-1}), (f) Biomass (t ha^{-1}); Bar represent LSD at 0.05; n= 10

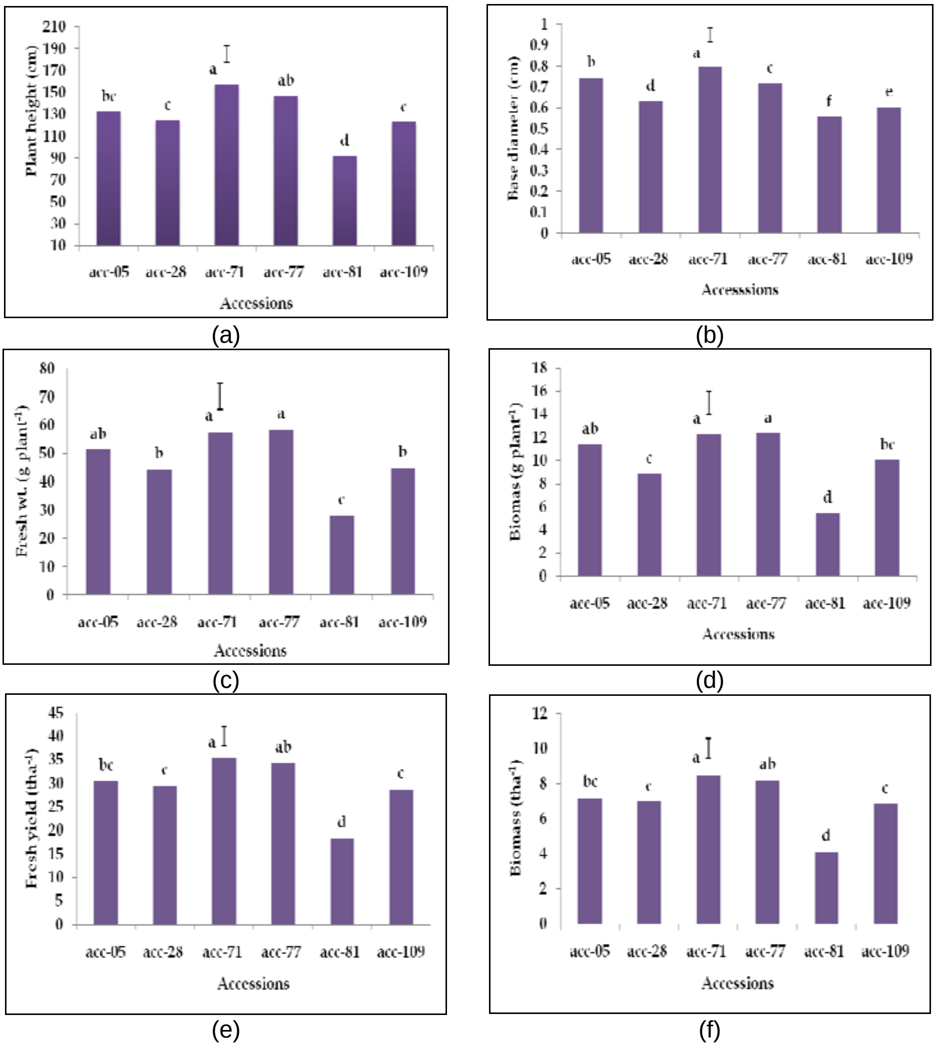


Figure 4 - Growth descriptors influenced by different dhaincha accessions: (a) Plant height (cm), (b) Base diameter (cm), (c) Fresh weight (g plant^{-1}), (d) Biomass (g plant^{-1}), (e) Fresh yield (t ha^{-1}), (f) Biomass (t ha^{-1}); Bar represent LSD at 0.05; n=10

Enhancement of biomass yield through nitrogen fertilizer

Plant height, base diameter, fresh weight and biomass yield were also significantly influenced by different nitrogenous fertilizer doses (*Fig. 5*) and accessions (*Fig. 6*) and/or in combination (*Table 4*). The tallest plant (197.67 cm) was observed in fertilizer dose 30 kg N ha^{-1} and base diameter (0.92 cm) in 20 kg N ha^{-1} with accession #77 (*Table 4*).

Table 3 - Effect of different dates of sowing on yield of dhaincha accessions.
D_1 = 30 April, D_2 = 15 May, D_3 = 30 May, D_4 = 15 June

Treatment	Plant height (cm)	Base diameter (cm)	Fresh weight (g plant^{-1})	Biomass (g plant^{-1})	Fresh yield (t ha^{-1})	Biomass yield (t ha^{-1})
Acc#05× D_1	220.63 ab	1.090 ab	111.63 ab	25.22 a	66.28 ab	15.72 ab
Acc#28× D_1	206.67 a-c	0.993 b-d	101.67 bc	20.34 b	60.67 bc	14.45 bc
Acc#71× D_1	224.99 a	1.136 a	118.33 ab	25.27 a	73.93 a	17.60 a
Acc#77× D_1	206.98 a-c	1.016 a-c	123.33 a	25.62 a	70.30 a	16.82 a
Acc#81× D_1	144.97 f-i	0.917 c-e	73.33 de	12.97 cd	45.17 d	10.63 d
Acc#109× D_1	193.87 b-d	0.979 b-d	90.00 cd	20.39 b	56.10 c	13.17 c
Acc#05× D_2	173.80 d-f	0.878 c-e	68.33 ef	14.65 c	40.50 de	9.52 de
Acc#28× D_2	136.33 h-j	0.692 fg	38.33 h-k	8.45 e-g	33.17 ef	7.72 e-g
Acc#71× D_2	172.00 d-g	0.818 ef	65.00 ef	14.41 c	38.07 de	9.48 de
Acc#77× D_2	180.13 c-e	0.861 de	61.67 e-g	13.12 cd	35.40 ef	8.46 d-f
Acc#81× D_2	115.28 i-k	0.636 gh	21.67 j-m	5.50 f-h	14.33 hi	3.23 ij
Acc#109× D_2	142.67 g-j	0.641 gh	53.33 f-h	11.47 c-e	35.07 ef	8.90 d-f
Acc#05× D_3	95.77 kl	0.643 gh	33.33 i-k	7.54 ef	21.90 g	4.90 hi
Acc#28× D_3	113.73 jk	0.531 hi	32.93 i-k	5.33 f-i	20.83 gh	4.77 hi
Acc#71× D_3	155.47 e-h	0.677 fg	39.07 h-j	8.01 e-g	24.53 g	5.87 gh
Acc#77× D_3	153.00 e-h	0.688 fg	45.00g hi	9.49 d-f	28.776 fg	6.85 f-h
Acc#81× D_3	69.87l m	0.410 i-k	15.00l mn	2.43 h-j	11.37 i-k	2.12 j-l
Acc#109× D_3	113.67 jk	0.478 ij	31.67 i-l	7.07 fg	20.70 gh	4.87 hi
Acc#05× D_4	38.80 n	0.366 j-l	5.00 mn	1.18 ij	3.076 kl	0.75 kl
Acc#28× D_4	42.26 mn	0.309 kl	4.50 mn	1.27 ij	3.11 kl	0.77 kl
Acc#71× D_4	77.57 l	0.550 g-i	7.20 mn	1.53 h-j	4.50 j-l	1.08 j-l
Acc#77× D_4	46.43 mn	0.311 kl	4.17 mn	1.20 ij	2.48 l	0.62 kl
Acc#81× D_4	36.33 n	0.260 l	2.83 n	0.85 j	1.78 l	0.38 l
Acc#109× D_4	41.33 mn	0.323 kl	4.23 mn	1.11 j	2.82 l	0.53 kl
$CV_{0.05}$	14.13	12.93	23.25	25.26	17.43	19.79
S_E	30.03	0.144	18.14	4.17	8.42	2.27

In a column, same letter (s) do not differ significantly at $P < 0.05$, as per Duncan's Multiple Range Test.

The shortest plant (111 cm) and base diameter (0.58 cm) were found in control with accession #81. The accession #05 with 20 kg N ha^{-1} fertilizer dose produced the highest fresh weight and biomass (84.67 and 20.00 g plant^{-1}, respectively). Fresh and biomass yield was statistically identical in fertilizer dose 20 kg N ha^{-1} and 30 kg N ha^{-1} (*Table 4*). Statistical identical results were observed in fresh weight (82.00 and 82.17 g plant^{-1}, respectively), fresh and biomass yield (43.22 and 10.82 t ha^{-1}) of accession #71 with 20 kg N ha^{-1} and 30 kg N ha^{-1}.

The lowest value of fresh weight and biomass (21.17 and 5.33 g plant^{-1}, respectively) and fresh and biomass yield (13.97 and 3.20 t ha^{-1}, respectively) was found in control with accession #81 (*Table 4*).

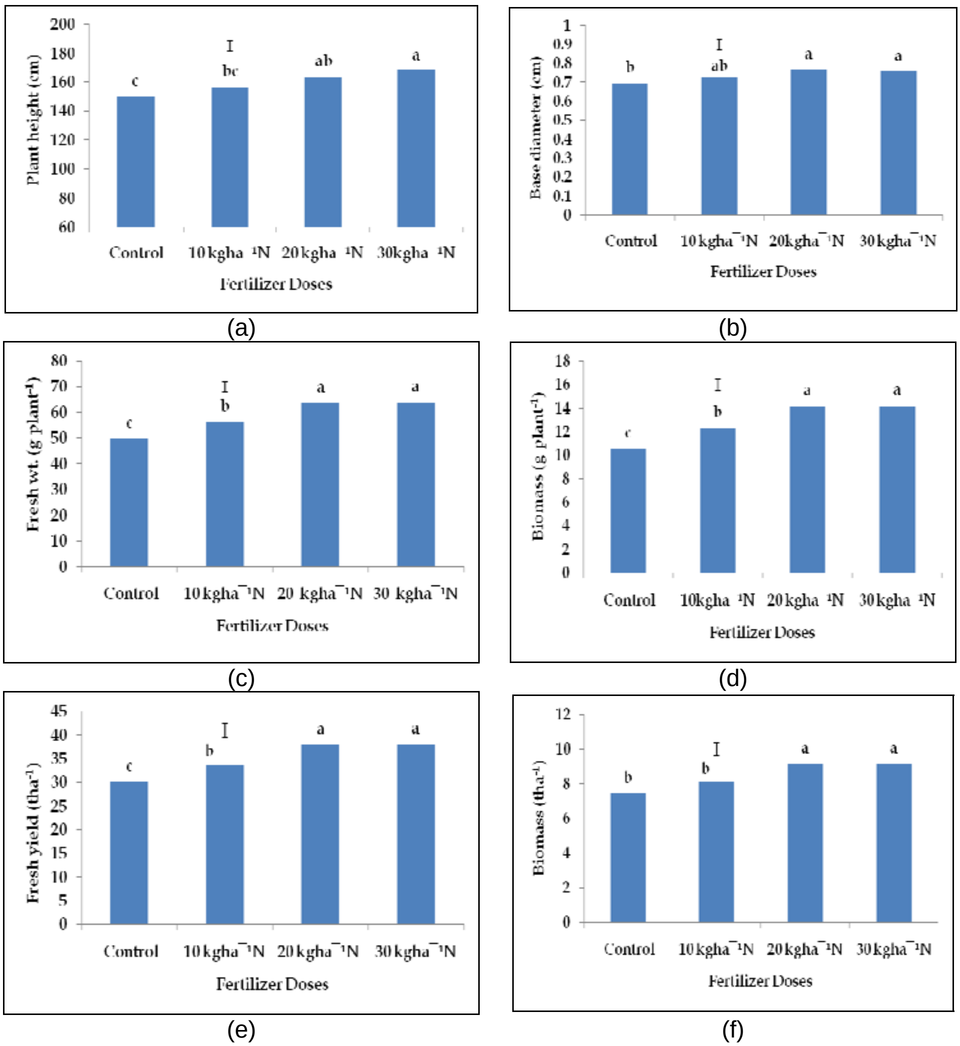


Figure 5 - Growth descriptors influenced by different fertilizer doses of dhaincha accessions: (a) Plant height (cm), (b) Base diameter (cm), (c) Fresh weight (g plant^{-1}), (d) Biomass (g plant^{-1}), (e) Fresh yield (t ha^{-1}), (f) Biomass (t ha^{-1}); Bar represent LSD at 0.05); n= 10

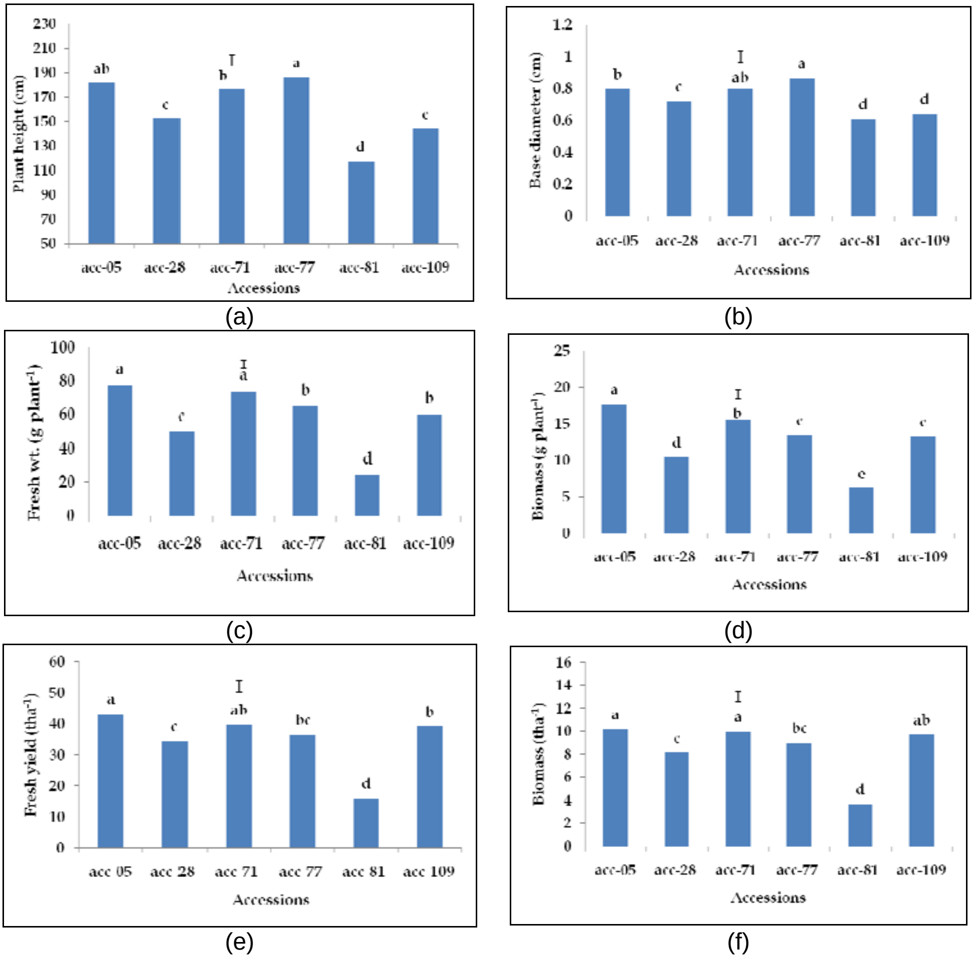


Figure 6 - Growth descriptors influenced by different dhaincha accessions: (a) Plant height (cm), (b) Base diameter (cm), (c) Fresh weight (g plant^{-1}), (d) Biomass (g plant^{-1}), (e) Fresh yield (t ha^{-1}), (f) Biomass (t ha^{-1}); Bar represent LSD at 0.05); n=10.

DISCUSSION

Enhancement of biomass yield through different plant population densities

Biomass yield was significantly increased for the plant density from 180 to 240 plants m^{-2} and it decreased with the increasing plant density (300 plants m^{-2}) (*Figs. 1 and 2*). Desai and Halepyati (2007) reported that biomass and fresh weight of *Sesbania* species increased both in growth duration (12 and 24 months after sowing) and plant density (10-40 thousands plants ha^{-1}). Close spacing increases early interplant competition and hence reduces plant weight and yield (Talukder and Chanda, 2001). The wide spacing enhances linearly increasing impact on the performance of individual plant and produced the highest biomass (Raper and Kramer, 1987). The plants grown with wider spacing have a lot of space around resulting less inter-plant competition. It draws the sufficient nutrition and had a lot of solar radiation to furnish photosynthesis process (Baloch *et al*., 2002).

Table 4 - Effect of different fertilizer doses on yield of dhaincha accessions.
N_0 = Control, N_1 = 10 kg N ha^{-1}, N_2 = 20 kg N ha^{-1}, N_3 = 30 kg N ha^{-1}

Treatment	Plant height (cm)	Base diameter (cm)	Fresh weight (g plant^{-1})	Biomass (g plant^{-1})	Fresh yield (t ha^{-1})	Biomass yield (t ha^{-1})
Acc#05× N_0	169.67 c-f	0.760 c-g	67.50 c-e	13.80 d-f	38.17 c-f	9.22 b-e
Acc#28× N_0	141.67 ij	0.687 e-i	39.67 j	7.83 hi	28.33 g	6.85 f
Acc#71× N_0	168.00 d-g	0.750 c-h	61.00 d-h	13.17 d-f	32.73 fg	8.60 de
Acc#77× N_0	173.67 b-f	0.780 c-f	57.17 e-i	11.83 fg	32.33 fg	7.98 d-f
Acc#81× N_0	111.00 l	0.580 i	21.17 k	5.33 i	13.97 h	3.20 g
Acc#109× N_0	138.33 jk	0.627 hi	52.50 hi	11.30 fg	34.67 e-g	8.70 de
Acc#05× N_1	177.67 b-e	0.783 b-e	74.00 bc	17.17 b	41.50 a-e	9.70 a-d
Acc#28× N_1	148.67 h-j	0.710 d-i	47.67 ij	9.90 gh	33.00 fg	7.82 ef
Acc#71× N_1	174.00 b-f	0.780 c-f	70.00 cd	14.83 b-d	38.03 c-f	9.60 a-d
Acc#77× N_1	182.33 a-d	0.840 a-d	63.33 d-g	13.13 d-f	35.80 d-f	8.87 c-e
Acc#81× N_1	115.67 l	0.600 i	23.17 k	5.97 i	15.25 h	3.50 g
Acc#109× N_1	142.00 ij	0.640 g-i	58.17 e-h	12.83 d-f	37.43 c-f	9.17 b-e
Acc#05× N_2	186.67 a-c	0.837 a-d	84.67 a	20.00 a	47.08 a	11.07 a
Acc#28× N_2	157.67 f-i	0.733 c-h	55.00 g-i	12.00 e-g	37.67 c-f	8.87 c-e
Acc#71× N_2	180.00 a-d	0.843 a-c	82.00 ab	17.17 b	43.22 a-c	10.82 ab
Acc#77× N_2	191.67 ab	0.920 a	68.83 cd	14.50 c-e	38.77 c-f	9.60 a-d
Acc#81× N_2	119.00 l	0.620 hi	26.17 k	6.80 i	17.33 h	4.03 g
Acc#109× N_2	147.67 h-j	0.647 g-i	64.83 c-f	14.50 c-e	42.87 a-d	10.55 ab
Acc#05× N_3	191.67 ab	0.807 a-e	83.33 ab	19.83 a	46.17 ab	10.80 ab
Acc#28× N_3	161.67 e-h	0.740 c-h	55.83 f-i	12.33 d-g	38.50 c-f	9.12 b-e
Acc#71× N_3	185.67 a-d	0.823 a-d	82.17 ab	17.00 bc	43.23 a-c	10.83 ab
Acc#77× N_3	197.67 a	0.913 ab	69.67 cd	14.50 c-e	38.97 b-f	9.62 a-d
Acc#81× N_3	122.67 kl	0.623 hi	26.50 k	6.93 i	17.48 h	4.05 g
Acc#109× N_3	150.00 g-j	0.650 f-i	65.17 c-f	14.57 b-e	43.02 a-d	10.55 ab
$CV_{0.05}$	6.94	10.74	10.04	12.47	12.76	12.41
S_E	18.22	0.130	9.62	2.62	7.30	1.73

In a column, same letter (s) do not differ significantly at $P < 0.05$, as per Duncan's Multiple Range Test.

The canopy of the crop would be bushy at early vegetative stage and resulting biomass yield might be decreased. The growth duration and leaf area determine the overall of solar radiation intercepted by the canopy, as well as influences the amount of photosynthesis, finally biomass production (Kumari, 2012). Biomass yield and yield contributing descriptors also varied due to the genetic makeup of dhaincha accessions (Chanda and Sarwar, 2017a). Srivastava and Kumar (2013) observed that plant population density stress had significantly affected on biological yield of *Sesbania* species.

Yield contributing factors did not totally dependent upon the performance of individual plant, but also on plants population per unit area. The interaction effect between accessions and plant populations was significant (*Table 2*). Result reveals that the biomass yield of accessions influenced by plant population. Both plant height and base diameter were higher at 180 plants m^{-2} treatment. However, more plant population occupied in 240 plants m^{-2}, compared to 180 plants m^{-2} treatment resulting higher biomass yield in 240 plants m^{-2} treatment (*Table 2*). Nevertheless, the treatment 300 plants m^{-2} was more densely than previous two treatments, for that reason, plant height and base diameter was smaller and finally biomass yield was lower than 240 plants m^{-2}. Excess plant population induced intra-competition for different natural resources, resulting shorter plant and base diameter, hence, biomass yield might decrease. Srivastava and Kumar (2013) reported that planting densities significantly influenced the yield contributing descriptors, *viz.* plant height, base diameter, number of leaves, leaf length and biomass yield, of *S. cannabina*. Yield contributing descriptor of *Sesbania* increased with the increasing of seed rate up to certain levels and thereafter declined (Chanda and Sarwar, 2017b).

These results were supported by Rahaman *et al.* (2016) and Naidu *et al.* (2017). It was observed that accession #71 with 240 plants m^{-2} produced maximum biomass and accession #81 with 180, 240 and 300 plants m^{-2} minimum biomass.

Enhancement of biomass yield through different sowing dates

Sowing date emerged as an important determining factor for the biomass yield of dhaincha accession (*Figs. 3 and 4*). Between Boro harvest and succeeding crop cultivation, the land remains fallow for a period of about 60-80 days. This fallow land could be use for green manuring with dhaincha. But delay sowing reduced the biomass yield (Chanda *et al.*, 2018a). The yield reduction with delayed sowings would be adverse effects on lower biomass yield. The reduction in yield with delayed sowing dates can be influenced the environmental conditions, *viz.* temperature, sunshine hours, rainfall, soil microenvironment, during the vegetative growth and development of the crop (*Table 1*). Plant height, base diameter, fresh weight and biomass progressively increased with advancement in the age of harvest and it significantly differed due to sowing date from 30 April to 15 June (Chanda *et al*., 2018a). This result matched with the earlier results of Naidu *et al*. (2017). The significant variation in biomass yield of early sowing over later sowing dates could be contributed to the higher biomass production (*Table 3*). Furthermore, growth and development of plant at vegetative stage, compared to latter sowing dates might possess biomass expression loss of the crop (Sangeetha *et al*., 2011). The plant, as well as yield contributing descriptors, can be decreased due to more number of rainy and cloudy days throughout the crop growing periods. Consequently, sunshine hours per day are may be reduced and, ultimately, biomass yield may decrease.

Kumar *et al*. (2006) stated that the early sowing crop, due to more congenial field conditions, especially sunshine hour, soil moisture and rainfall during the crop period than that in late sowing crop.

At early sowing, the biomass accumulation was higher at 60 DAS, compared to later sowing. The favorable weather condition enhanced growth and development period leading to increase in plant height, base diameter and leaf area and, ultimately, higher biomass yield. Field condition is favorable during 30 April to 15 May for dhaincha seed sowing (*Table 1*). Thus, seed sowing during this time favorable crop growth and development leading to higher biomass yield. This better crop growth could be attributed to suitable weather condition during this period. Naidu *et al*. (2017) stated that crop growth and yield varied due to the genotypic effect of the crop. Crop growth and net assimilation rate are enhanced to higher biomass yield (Kumar *et al*., 2005). Interaction effect of different dates of sowing and accessions on biological yield was statistically significant. The result indicated that adequate soil moistures, longer sunshine hours have contributed to the improvement in growth descriptors leading to higher biomass yield (*Table 3*). However, excessive rainfall might create an unfavorable condition and stress for the vegetative growth of the plant. Numerically the highest biomass yield was recorded with the combination of 30 April sowing date along with accession #71. However, the lowest biomass yield was recorded from 15 June sowing date along with accession #81. This favored growth, as well as biomass yield could be attributed to the combination of environment and genetic make-up of the crop (Chanda *et al*., 2018b). Ladha *et al*. (1996) reported that dhaincha produces 2.8 to 9.9 t ha^{-1} biomass on different DAS.

Kalidurai (1998) stated that *S. aculeata* recorded higher biomass of 51.4 and 73.4 g plant $^{-1}$ within 40 and 50 DAS, respectively.

Enhancement of biomass yield through nitrogen fertilizer

Nitrogenous fertilizers enhance the vegetative growth and make plants succulent, *i.e.* produce higher amount of easily decomposable (in soil) biomass in short time. Biomass producing descriptors were enhanced with the increasing doses of N fertilizers (*Fig. 5*). The fertilizer dose 30 kg N ha^{-1} produced the tallest plant, base diameter, fresh and biomass weight, fresh and biomass yield. However, the statistical similar result was found in 20 kg N ha^{-1} and 30 kg N ha^{-1} fertilizer doses for biomass weight plant^{-1}, fresh and biomass yield (*Fig. 6*). It indicated that the 20 kg N ha^{-1} fertilizer dose was economically optimum dose for higher biomass production. The control treatment plot of dhaincha accessions produced least biomass yield and yield contributing descriptors (*Fig. 6*). Variation in biomass yield might be related to the management practices and genetic factors (Chanda *et al.*, 2018c). Thus, the biomass yield may be increased with application of optimum fertilizer dose.

Fertilizer management practice is one of the most important cultural factors, which affecting plant growth and biomass yield (*Table 4*). Fertilizer treatments had significant effect on all studied of plant and yield descriptors (plant height, base diameter, fresh and biomass weight, fresh and biomass yield). After incorporation of dhaincha in to the soil, the succeeding crop did not require any additional fertilizer for growth and development (Rajay, 2010). The accessions #05 showed the highest biomass yield, followed by the accession #77, 71, 109, 28 and 81. It could be attributed to the N fertilizer treatments on accessions. With the increasing of fertilizer doses, biomass yield of both accession #28 and 81 was increased significantly. Kanyama-Phiri *et al.* (1993) observed that N and P fertilization significantly increased canopy height, growth rate, number of primary branches per plant, stem diameter, leaf and biomass yield in *Sesbania* plant.

The interaction effect between accessions and N fertilizer treatments significantly affected the biomass yield of dhaincha accessions (*Table 4*). There were wide genetic diversity among the accessions and N fertilizers were significantly affected most of the studied descriptors. It might be happened that these yield contributing characters mostly control by the non-additive effects of genes and N fertilizers application. Application of 10-15 kg N ha^{-1} helped the crop to grow faster, crop leads to succulent and may help to easy decompose in to the soil and phosphorus is essential for sound growth of dhaincha (Pandey *et al.*, 2013). The results reveal that accession #05 and 71 with 10 kg N ha^{-1} fertilizer treatment were statistically insignificant with control. However, accession #05, 71, 77 and 109 showed statistically insignificant result with 30 kg N ha^{-1} fertilizers to 20 kg N ha^{-1}.

CONCLUSION

Among the *Sesbania* species, *S. bispinosa* was the best performer in terms of biomass yield and yield contributing descriptors. It may be concluded that *S. bispinosa* (accession #71) could be cultivated at 30 April with the population density 240 plants m^{-2} without any fertilizer application. In case of later cultivation/sowing, the 20 kg N ha^{-1} could be applied for the maximization of biomass yield.

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