Annual Biomass Production, Chemical Composition and *In- sacco* Degradability of Different Cultivars of *Moringa oleifera*

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***Abstract*— *Types of plant cultivars and seasons often affect production and productivity of fodder biomass and nutritional quality to animals. Selection of suitable cultivars and better understanding of year round biomass production are indispensable for improving quality feed supply to animals. Black Seed Moringa (BSM-L) and White Seed Moringa (WSM), the two local cultivars and Black Seed Moringa (BSM-T) cultivar of Thailand origin of Moringa oleifera were cultivated in the fodder research field of the Bangladesh Livestock Research Institute (BLRI) during the period of 19 August 2014 to 23 December 2015. An agronomical trial was conducted to determine the biomass yield of the three cultivars in different seasons of a year under common agronomical practices. The effect of the cultivars on the daily relative growth rate (RGR), chemical composition and in-sacco dry matter (DM) degradability were also evaluated. The cultivar response to biomass production performances, chemical composition and nutritional values were analyzed in an ANOVA of a Randomized Block Design (RBD), while the differences in the rate and extent of the DM degradability in-sacco determined using three rumen cannulated bulls were analyzed in an ANOVA of 3x3 Latin Square Design. The annual biomass yield of BSM-L tops (114.5 t/ha fresh; 22.7 t/ha DM) was significantly higher than that of WSM (29.0 t/ha fresh; 5.80 t/ha DM) or BSM-T (83.5 t/ha fresh; 16.0 t/ha DM). No significant difference in chemical composition (224.9, 222.4 & 223.8 g.kg^{-1} DM of crude protein (CP), respectively, and 450.9, 455.3 & 435.4 g.kg^{-1} DM of neutral detergent fiber, respectively) or nutritional value (47.4, 46.7 & 45.3% of potential, and 62.8, 64.2 and 63.6% of effective degradability of dry matter) was found for the cultivars. BSM-L had a significantly higher survivability (97.2%), prune number per plant (3.50) and RGR (15.6 mg DM/day) than WSM (25.0%, 2.30 & 4.20 mg DM/day) or BSM-T (55.6%, 3.10 & 10.8 mg DM/day) respectively. The hot and dry, and hot and humid climate having a Heat Index (HI) range of 25º to 35º F and monthly total rainfall of 130 mm to 332 mm were suitable for cultivation of all the Moringa cultivars. It was concluded that considering biomass production and its quality in terms of chemical composition and nutritional values, Black Seed Moringa (Moringa oleifera) may be cultivated as a plant fodder crop for the production of feed for ruminant animals.*

***Keywords*— Moringa cultivars, Biomass, Season, Nutritional values, Chemical composition.**

I. INTRODUCTION

Demand and supply gaps of feeds and fodders [1] and seasonal and regional variations in biomass availability [1] often limit ruminant production and productivity in many developing countries including Bangladesh. Besides, the gradual transformation of subsistence animal farming to input-supported systems is intensifying farmers' demand for high biomass yielding and quality feeds and fodders. Fodder production against the backdrop of the decreasing cultivable land and growing competitions for land use, especially for cereal crop production, is undoubtedly a daunting task in most developing countries. A fodder crop, if at all is competitive to the existing cereal crops considering its biomass production, nutritive value, feeding response to animals, and profitability, may be introduced into existing cropping systems in some selected regions of the country, especially where livestock production is being intensified[1]. Moringa (*Moringa oliefera*) a native plant that grows fast round-the-year [2] produces biomass of high nutritional attributes [3] boosts milk and meat production of cattle (30 to 40%) [4, 5] improves product quality [6-8] and supports animal health [9-12] may be considered as one of the fodder crops for cultivation. It produces high quality

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biomass, has higher pruning efficiencies and lower defoliations [13, 14]. Shajna or Bajna, local titles of available Moringa cultivars are used for production of drumsticks, but their comparative production performances of biomass, both in terms of quantity and quality, in variable climatic conditions in a year is not known yet. Moreover, conventional local Moringa cultivars, especially used for harvesting drumsticks, may not be suitable for repeated lopping of branch tops and leaves, for using as feed/fodder. Thus, selection of cultivar(s) of Moringa plants, having comparatively high productivity of biomass throughout the year with chemical compositions and nutritional values suitable for feeding of animals, is of utmost important for the introduction of Moringa plant as a fodder crop.

The present study, thus, was undertaken to identify Moringa cultivar that may be cultivated in different seasons of a year as a plant fodder crop for the production of biomass of high nutritional values for the feeding of ruminant animals.

II. MATERIALS AND METHODS

2.1. Location and agro-climate of the experimental site:

The agronomical trial was conducted at the Cattle Research Station of the Bangladesh Livestock Research Institute (BLRI) from 19 August 2014 to 23 December 2015. The station was located at 23°42'0" N, 90°22'30" E at an altitude of 4 m above the sea level. The clayey textured soil of the station is strongly acidic (pH 4.5-5.7) containing a very little (<1.5%) organic matter and it belongs to the Madhupur Tract Agro-ecological Zone (AEZ-28) of Bangladesh. During the experimental period, the day temperature ranged from 21^0C to 35^0C and humidity ranged from 50% to 75%.

2.2. Preparation of experimental plots:

Three different cultivars of Moringa were used in the present programme. The seeds of the two cultivars, White Seed Moringa (WSM)) and Black Seed Moringa (BSM-L) were collected from selected local sources. The third cultivar having black seeds was collected from Thailand (BSM-T). The three cultivars of Moringa (taxonomical identification not completed yet) are entitled according to their seed color, considered as a major phenotypic difference. The seeds of three cultivars were tested for determining the rate of germination and it ranged from 65.0 to 75.0%. Two seeds in each polythene pouch containing sandy alluvial soil were sown, and saplings were raised up to an age of five weeks. The saplings were transplanted in predesigned experimental plots. Before transplantation, the soil of the plots was ploughed and fertilized with a basal dose of cattle dung at the rate of 3.0 t/ha and a mixture of TSP (Triple Super Phosphate) and MP (Murate of Potash) of a ratio of 30:15 kg per hectare. The urea N at the rate of 90kg/ha was top dressed when the plants were initially established in the research field and it was repeated at each harvest. All other agronomical practices e.g. weeding, irrigation etc were common for all cultivars.

2.3. Experimental layout design and treatment:

A uniformly plain land area of 97.2 m^2 was divided into four blocks, each of 24.3 m^2 separated by 1.0 meter wide walking alleys. Each block was again divided into three experimental plots, each of 8.1 m^2 for the planting of 90 saplings at a space of 0.3 m x 0.3 m per sapling. The blocks and plots were arranged in a Randomized Block Design (RBD) to determine the production responses of the three cultivars of Moringa.

2.4. Yield determination and sample collection:

After a post-transplantation growth period of 90 days, branch tops with leaves were harvested at a 60 days interval keeping an average stem height from the ground of 40 cm. The plants were allowed to grow after each cut and fertilized accordingly. A total of six cuts were given. The biomass yield of each of the three cultivars in six(6) different cuts of a year (Dec-Jan, Feb-Mar, Apr-May, Jun-July, Aug-Sep and Oct-Nov) was added to determine the annual yield of biomass production. Survival rate (% of saplings grew after transplantation), the number of prunes per plant, defoliation rate (% of total leaf biomass defoliated), and the growth rate of biomass were determined at different harvesting times. Fresh tops were harvested avoiding any surface water on plants and weighed on a top loading balance and the fresh yield per plot was recorded. Fresh yield (kg or ton) was converted to DM yield $plot^{-1}$ ha^{-1} according to the equation of DM yield $plot^{-1}$ = Weight of fresh material × (%) DM.

2.5. Chemical analysis:

The tops were manually separated into stems and leaves to determine stem to leaf ratio and weighed accordingly. Representative samples of tops, stem or leaves were taken to determine fresh dry matter, total ash, crude protein (CP) and ether extract (EE) according to AOAC [15]; and neutral detergent Fiber (NDF) or acid detergent Fiber (ADF) and acid detergent lignin (ADL) according to Van Soest [16]. All the analyses were done in the animal nutrition laboratory of the BLRI. The tops and stems were chopped manually at a range of 0.03 m to 0.05 m, dried in the sun, and milled for chemical analyses of the biomass of different harvests.

2.6. The determination of Relative Growth Rate (RGR) and HI (Heat Index):

The data on rainfall, temperature and humidity were collected during the period of 14 September 2014 to 23 September 2015. The relative growth rate (RGR) of different cultivars was calculated using the equation of $RGR = \frac{lnW_2 - lnW_1}{t_2 - t_1}$ described by Hoffmann and Poorter [17]; where, ln = natural logarithm, t_1 = time one (in days), t_2 = time two (in days), W_1= Dry weight of plant at time one (in grams), W_2= Dry weight of plant at time two (in grams). Heat Index, a measure of how hot it really feels when relative humidity is factored in with the actual air temperature, was calculated from the HI chart of National Weather Service of the US Department of Commerce [18].

2.7. The rumen kinetic parameters of Moringa tops:

Three local growing bulls of an average live weight of 225 kg fitted with rumen cannulae (14 cm diameter & 9 cm length) were used to determine rumen degradability *in-sacco* of dry matter of Moringa tops. The animals were fed Napier and German grass mix *ad libitum* and the roughages were supplemented with locally mixed concentrate mix of wheat bran, sesame oil cake, Kheshari (*Lathyrus sativus*) bran, di-alcium phosphate (DCP) and common salt at the rate of 1.0% of the live weight. Having the animals adjusted to the diet for at least three weeks Dacron bags (7x16 cm, pore size 45 µm) containing the samples (2 g each) of three Moringa tops (oven dried, milled and passed through a sieve of 1.0 mm size) were incubated in the rumen following the method described by Ǿrskov[19]. Considering animals and three periods as replication the samples of Moringa tops of three cultivars were incubated at 0, 8, 16, 24, 48 and 72 hrs in the rumen. Each hour of incubation of a sample of each cultivar was repeated in three animals in a period, and the incubations were repeated in three different periods. The degradation kinetics of DM were determined by fitting the disappearance values to the equation $P= a+ b (1-e^{-ct})$ Ørskov and McDonald [20], where P represents the disappearance after time t. Least-squares analyses were used for the estimation of rapidly degradable fraction (a), slowly degradable fraction (b) and the rate of degradation (c). The effective degradability (ED) of Moringa tops were estimated using the equation of McDonald [21], where ED= a+bc/(c+k), and 0.05 rate constant (k) was considered.

2.8. Statistical analysis:

Considering the three Moringa cultivars as treatment, their responses to biomass production performances (yield, growth rate, pruning efficiency and ratio of botanical fractions), and nutrient yield and contents (DM, CP, ADF, NDF or ADL) were analyzed in an ANOVA of a Randomized Block Design (RBD) using general linear model of SPSS-17.0 statistical software program in a computer. Any significant differences in the rate and extent of the DM degradability *in-sacco* of Moringa tops of different cultivars were analyzed using an ANOVA of 3x3 Latin Square Design.

2.9. Seasonal effect on Moringa production:

The average HI was 20, 23, 31, 30, 29 and 29°F, and monthly total rainfall was reported as 12, 86.5, 332, 364, 130 and 28 mm during December-January, February-March, April-May, June-July, August-September, and October-November harvesting periods, respectively (Fig1), and the fresh tops yield (t/ha/cut) varied according to the variations in HI and rainfall in a year. The yield was the lowest (average 0.76 t/ha/harvest) during the dry (monthly total rainfall 12.0 mm) and cool (HI 20^0F) months (December to January) of a year. The yield peaked during the dry and hot period, from April to May (average 23.4 t/ha/harvest) with the rise of HI (31^0F) and rainfall (332 mm). A further increase in rainfall affected peak productions (17.2 to 22.4 t/ha/cut) during the hot and humid months of the year.

III. RESULTS

The effect of different cultivar of Moringa on survival rate (%), the number of prunes per plant, growth rate (kg/ha/day) and defoliation rate (%) are shown in Table 1. The survivability of BSM-L was the highest (97.2%) followed that of BSM-T (55.6%) and WSM (25.0%); and the difference between the cultivars were significant (P<0.001). A similar trend was found in the RGR of the cultivars (15.6, 10.7 & 4.2 mg/day, respectively, P<0.001). Both the black seed cultivars having a significantly higher average number of prunes (3.5 vs. 3.1 prunes/plant) were bushier than WSM. The average defoliation rate of all the cultivars varied from 2.4 to 4.0% and it did not differ significantly (P<0.46).
Table 1.

3.1. Biomass yield:

The effect of three different cultivars on fresh or dry matter (DM) yield of tops, leaf and stem fractions of Moringa and their leaf to stem ratios are shown in Table 2. The annual fresh (114.51 t/ha) and dry matter (22.73 t/ha) yield of BSM-L tops were significantly (*P*<0.001) higher than that of BSM-T (83.52 t/ha and 16.03 t/ha) or WSM (29.01 t/ha and 5.79 t/ha). Similarly, the annual fresh or dry matter yield of stem (75.82 t/ha and13.19 t/ha) was the highest for BSM-L, followed by BSM-T (51.61 t/ha and 9.07 t/ha) and WSM (18.24 t/ha and 3.75 t/ha) and the difference was significant (*P*<0.001). The annual fresh or dry matter yield of leaves was 38.7 t/ha and 8.50 t/ha for BSM-L and 31.9 t/ha and 7.62 t/ha for BSM-T and differed significantly (*P*<0.05) between the two cultivars. Both BSM-T and BSM-L had a significantly (*P*<0,001) higher fresh or DM yield of leaves than that of WSM (10.6 t/ha and 2.3 t/ha). The average leaf to stem ratio of BSM-L was 0.45 and it reflects that almost a half of the whole tops dry matter was shared by leaves. The ratio varied from 0.56 to 0.58 for WSM and BSM-T. Nevertheless, the variation in the leaf to stem ratio among the cultivars was not significant (*P*<0.42) (Table 2).

Table 2.

Table 3 shows the chemical composition of different biological fractions of the three Moringa cultivars. BSM-L had a significantly (*P*<0.05) higher fresh dry matter of tops (206.3 g kg^{-1}) than BSM-T (191.9 g kg^{-1}) and lower (*P*<0.05) fresh leaf dry matter (222.5 g kg^{-1}) than the latter (235.0 g kg^{-1}) or WSM (233.5.0 g kg^{-1}). The ash content of BSM-L (66.8 g kg^{-1}) was significantly (*P*<0.01) lower than BSM-T (83.4 & 77.4 g kg^{-1}, respectively). All other chemical components (CP, ADF, NDF, EE and ADL) in the tops, stem or leaves of three cultivars did not differ significantly (*P*>0.05). Their average contents for the three cultivars were 223.7, 419.8, 442.8, 277.3 & 208.2 g kg^{-1}, respectively for tops; 124.8, 632.5, 711.5, 87.4 and 248.2 g kg^{-1}, respectively, in stem; and 299.4, 215.2, 343.3, 106.2 and 326.8 g kg^{-1}, respectively in leaves (Table 3).

Table 3.

3.2. Degradation kinetics:

Table 4 shows that the calculated soluble fraction (a) was significantly higher for BSM-L tops (23.0%) than BSM-T (20.9%) and WSM (21.53%); while the rate constant (c=0.08) of BSM-L was significantly (*P*<0.001) lower than that of the later two cultivars (0.12 and 0.13, respectively). The rate of rumen dry matter degradation of WSM tops was the highest (0.13, *P*<0.01) followed by 0.12 of BSM-T and 0.08 of BSM-L. The potential (b) or effective degradability of tops of the three cultivars ranged from 45.3 to 47.4 %, and 62.8 to 64.2 % at a rate constant of 0.05 passage rate and their differences among the cultivars was not significant (*P*>0.05).

Table 4.

3.3. Seasonal effect on Moringa production:

The average HI was 20, 23, 31, 30, 29 and 29ºF, and monthly total rainfall was reported as 12, 86.5, 332, 364, 130 and 28 mm during December-January, February-March, April-May, June-July, August-September, and October-November harvesting periods, respectively (Fig1), and the fresh tops yield (t/ha/cut) varied according to the variations in HI and rainfall in a year. The yield was the lowest (average 0.76 t/ha/harvest) during the dry (monthly total rainfall 12.0 mm) and cool (HI 20^0F) months (December to January) of a year. The yield peaked during the dry and hot period, from April to May (average 23.4 t/ha/harvest) with the rise of HI (31^0F) and rainfall (332 mm). A further increase in rainfall affected peak productions (17.2 to 22.4 t/ha/cut) during the hot and humid months of the year.

Fig1. And Fig2.

The daily RGR of all three cultivars was affected by seasons, and it varied from 0.61 mg to 2.88 mg in dry & cool months and rose to daily 8.86 mg to 13.26 mg in dry and hot months (Fig2). With the rise of HI and rainfall, the RGR of BSM-L was the highest (0.61 to 10.47) followed by BSM-T (1.03 to 8.86) and WSM (2.88 to 13.26).

IV. DISCUSSION

Identification of locally and regionally available best cultivar(s) and a better understanding of trade-offs and synergies of production performances between climatic variations are indispensable for Moringa fodder production. The motivation for using Moringa fodder is that it has the potential for being an alternate crop to cereals as well as soybean. Except for the rate of defoliation, a genotypic characteristic of Moringa, both the Black Seed Moringa cultivars (BSM-L) performed better in terms of survivability, the number of prunes/plant and daily biomass growth. Having a higher survivability of saplings (97.2 vs. 55.6%) and similar pruning ability to that of BSM-T (3.5 vs. 3.1 prunes/plant), BSM-L had the highest daily biomass growth (72.9 kg/ha vs. 51.2 kg/ha). The yield of fresh or DM of the tops or stem of BSM-L was the highest. It was leafier (stem: leaf; 0.45 vs. 0.58 or 0.56 of BSM-T and WSM) than the other cultivars (Table 2). Nevertheless, the leaves of BSM-L had a comparatively lower DM content

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(222 g kg^{-1} vs. 235 g kg^{-1} in BSM-T and 233 g kg^{-1} in WSM). It decreases differences between the leaf DM yield of BSM-L and BSM-T and make the difference non-significant (P>0.05) (Table 2). A higher survivability of *M. oleifera* and its growth have also been reported [2, 3, 7, 22, 23].

Hot and dry and hot and humid seasons compared to dry and cool months were suitable for Moringa fodder production. The HI above 23^0 F and monthly total rainfall at a range of 86.5 to 332 mm favored growth (Fig 2) and the production of Moringa fodder. A continuous downpour, even at a monthly rainfall range of 332 to 364 mm, may reduce growth rate and biomass production. Nouman [13] reported a suitable ambient temperature range of 27^0C to 35^0C in Nicargua. Moreover, Moringa can grow on a wide range of soils [24] and may not compete with floodplain arable fertile land used mostly for staple food crop production.

Table 5 shows the comparative production performances of DM and CP of BSM-L with other conventional and unconventional feeds and fodders. BSM-L produces a higher amount of DM (23.6 t) and CP (5.31 t) per hectare per year compared to other available conventional (12.7 t and 1.26 t of *Lathyrus sativus* and 6.60 t and 0.69 t of *Vigna mongu* per ha and per year) or unconventional (15.6 t & 1.64 t of *Vigna unguiculata*, 10.7 t & 2.15 t of *Leuchena leucocephala* and 17.3 t &1.75 t of *Sesbania sesban* per ha and per year) fodder crops in Bangladesh. The CP yield per hectare per year of BSM-L is about six times higher than that of soybean meal (0.93 t) produced on hectare of land (Table 5).

The average CP content of Moringa leaves of three cultivars was 299.4 g kg^{-1} DM. Similar CP levels between 290 and 320 g.kg^{-1} was reported by Al-Mashri [25] and Soliva [26]. The CP of stem did not vary significantly among the cultivars and the average content was 124.8 g kg^{-1}. The CP content of even Moringa stem of different cultivars was higher than that of Napier or Guinea grass (109.0 g kg^{-1} DM and 91.7 g kg^{-1} DM, respectively; [27, 28]. The CP contents of Moringa tops reported in this study are within the range of 193.0 to 264.0 g kg^{-1} DM, reported earlier [25, 29, 30, 31, 32, 33, 34, 35].

The CP of Moringa tops containing leaf to stem ratio of 0.53:1 of the present study was 22.4% (Table 3). When it was compared with other feed sources (Table 5) it was found that except Soybean meal (51.8%) the CP content of others varied from 10.1% in Sesbania to 20.2% in *Leucaena leucocephala*. The average ADF (419.8 g kg^{-1}), NDF (442.8 g kg^{-1}) or ADL (208.2 g kg^{-1}) content of the tops of three different cultivars were similar to those reported by Makkar and Becker [29]; Foidle [31]; Aregheore [32] and Al-Mashri [25]. However, different stem to leaf ratio of a harvest affected the level of different cell wall components in different cultivars of Moringa.

Table 5.

The soluble biomass (a) of Moringa tops in the rumen was 21.8% and its potential degradable (b) fraction was 46.1%, and the extent of rumen DM degradability (a+b) was 67.8%. The extent of rumen degradability of CP of similar type of Moringa feed (stem+leaf) was 69.8% [36] (Table 6) compared to 85.3% of Berseem. It was even lower than the extent of rumen N degradability of Soybean meal, Leucaena and Alfalfa hay (94.2%, 80.9% and 92.8%, respectively; Table 6). It also shows that the effective degradability of Moringa CP in the rumen was only 55.1% and it was lower than the CP degradability of Berseem (67.7%) or the effective N degradability of Soybean meal, Leuceana and Alfalfa hay (65%, 45.0% and 79.0%, respectively) in the rumen. The total tract digestibility of CP of similar Moringa tops was 74.4% in cattle [37]. Thus, it may be estimated that at least 19.3% (differences in CP degradability in the rumen and digestibility in the total tract) of Moringa CP was digested in the lower gut and escaped microbial degradation.

The methionine and lysine content in the CP of Moringa feed was 0.66% and 7.69% and their contents were similar to those in other feed resources (Table 6). However, the methionine content in the CP of Moringa leaf was reported as 1.5% [30]. Makkar and Becker [29] stated that its leaf protein has the amino acid profile comparable to that of the WHO/FAO/UNO standard protein for growing children. Foidl [38]; Sanchez-Machado [39] and Moyo[40] reported that Moringa contains high quality protein, due to the presence of high levels of essential amino acids.

Table 6.

Thus, considering biomass production and its quality in terms of chemical composition and nutritional values to animals Black Seed Moringa may be cultivated as a plant fodder crop for the production of feed for ruminant animals.

V. CONCLUSION

The local cultivar, Black Seed Moringa (*Moringa oleifera*) had the highest production of high quality biomass; and hot and dry, and hot and humid seasons are the best period for Moringa fodder production. Other agronomical practices like cutting height, weeding, irrigation, cropping density etc may affect Moringa biomass production and their impacts under local conditions need to be evaluated through further research.

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Table.1: Performances of survivability and growth of different cultivars of Moringa oleifera (means±SE; n=4)

Parameters	Moringa cultivars			Significance		
	BSM-T	WSM	BSM-L	Overall mean	Overall SE	Level
Survival rate (%)	55.6^{b} ± 10.1	25.0^{c} ± 5.3	97.2^{a} ± 2.7	59.3	9.6	P<0.00
No of prunes/plant	3.1^{a} ± 0.2	2.3^{b} ± 0.2	3.5^{a} ± 0.1	2.9	0.2	P<0.01
Annual RGR (mg/day)	10.8^{a} ± 1.8	4.2^{b} ± 3.0	15.6^{a} ± 1.2	7.4	2.76	P<0.00
Defoliation rate (%)	2.6 ± 0.14	3.7 ± 0.9	3.1 ± 0.6	3.1	0.4	P<0.46

BSM-T= Black Seed Moringa of Thailand; WSM= White Seed Moringa; BSM-L= Black Seed Moringa of local origin

Table.2: Biomass production and composition of botanical fractions of different Moringa oleifera cultivars

Parameters	Moringa cultivars			Significance		
	BSM-T	WSM	BSM-L	Overall mean	Overall SE	Level
Fresh yield(t ha^{-1}year^{-1})						
Tops	83.5^{b}±12.0	29.0^{c}±6.7	114.5^{a}±4.7	75.7	11.5	P<0.00
Stem	51.6^{b}±9.7	18.2^{c}±4.9	75.8^{a}±4.5	48.5	7.9	P<0.00
Leaf	31.9^{b}±2.5	10.6^{c}±1.7	38.7^{a}±1.3	27.1	3.7	P<0.00
Dry matter yield(t ha^{-1}year^{-1})						
Tops	16.0^{b}±2.3	5.8^{c}±1.3	23.6^{a}±1.1	14.9	2.3	P<0.00
Stem	9.1^{b}±1.7	3.8^{c}±1.0	13.2^{a}±0.8	8.7	1.3	P<0.01
Leaf	7.6^{a}±0.6	2.3^{b}±0.4	8.5^{a}±0.3	6.1	0.8	P<0.00
Leaf: Stem	0.58±0.10	0.56±0.06	0.45±0.02	0.53	0.04	P<0.42

BSM-T= Black Seed Moringa from Thailand; WSM= White Seed Moringa of local origin; BSM-L= Black Seed Moringa of local origin

Table.3: Chemical composition of different Moringa cultivars and their botanical fractions

Parameters	Moringa cultivars			Significance		
	BSM-T	WSM	BSM-L	Overall mean	Overall SE	Level
DM(g kg^{-1})						
Tops	191.9^{b}± 2.3	198.6^{ab} ± 5.51	206.3^{a} ± 1.1	198.9	2.54	P<0.05
Stem	161.5± 3.5	162.9± 5.3	165.7 ± 4.3	163.4	2.36	P<0.80
Leaf	235.02^{a} ± 2.7	233.50^{a} ± 2.4	222.4 ± 2.20^{b}	230.3	2.13	P<0.01
Ash(g kg^{-1})						
Tops	83.4^{a}± 0.6	77.4^{b} ± 1.4	66.8^{c}± 1.7	75.8	2.1	P<0.01
Stem	70.0± 3.8	67.8± 2.2	63.3 ± 3.3	67.1	1.86	P<0.35
Leaf	86.6 ± 2.8	79.6 ± 1.1	80.7 ± 2.5	82.3	1.51	P<0.11
CP(g kg^{-1} DM)						
Tops	223.8±1.7	222.4±1.9	224.9±2.3	223.7	1.1	P<0.68
Stem	126.1±4.5	122.2±2.6	126.2±5.2	124.8	2.31	P<0.75
Leaf	305.1±3.4	296.8±4.0	296.3±2.8	299.4	2.17	P<0.32
ADF(g kg^{-1} DM)						
Tops	422.6±51.1	422.1±7.8	414.7±0.4	419.8	13.43	P<0.97

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Stem	619.6±5.4	656.1±17.7	622.0±10.2	632.5	9.23	P<0.20
Leaf	212.65±2.5	217.75±7.3	215.08±4.9	215.2	2.56	P<0.31
			NDF(g kg^{-1} DM)			
Tops	435.4^{b}±0.75	455.3^{a}±1.12	450.9^{a}±3.40	447.2	6.58	P<0.934
Stem	724.7±6.2	707.2±9.1	702.7±7.4	711.5	5.44	P<0.24
Leaf	351.3±3.8	339.9±4.2	338.6±1.4	343.3	2.97	P<0.13
			EE(g kg^{-1} DM)			
Tops	277.1±1.9	277.8±0.3	277.1±1.9	277.3	0.72	P<0.92
Stem	87.7±0.4	86.5±1.5	87.9±0.7	87.4	0.51	P<0.37
Leaf	106.3±0.8	105.8±0.5	106.3±0.8	106.2	0.35	P<0.83
			ADL(g kg^{-1} DM)			
Tops	205.5±1.4	209.1±0.9	209.8±0.7	208.2	0.96	P<0.11
Stem	232.8±1.30	231.8±1.3	231.6±0.1	248.2	0.53	P<0.48
Leaf	332.6±3.4	328.7±0.5	319.1±8.8	326.8	3.52	P<0.43

BSM-T= Black Seed Moringa of Thailand; WSM= White Seed Moringa; BSM-L= Black Seed Moringa of local origin;
DM, Dry Matter; CP, Crude Protein; ADF, Acid Detergent Fiber; NDF, Neutral Detergent Fiber; EE, Ether Extract; ADL, Acid Detergent Lignin;

Table.4: Rumen degradation kinetics of different Moringa cultivars

Parameters	**Moringa cultivars**			**Significance**		
	BSM-T	WSM	BSM-L	Overall mean	Overall SE	Level
a	20.9^{b}±0.7	21.5^{ab}±0.2	23.0^{a}±0.2	21.81	0.37	P<0.03
b	45.3±1.7	46.7±1.3	47.4±0.6	46.1	0.73	P<0.50
c	0.12^{a}±0.01	0.13^{a}±0.05	0.08^{b}±0.07	0.11	0.08	P<0.01
Effective degradability (%)	63.6±0.4	64.2±1.1	62.8±0.52	63.5	0.51	P<0.14
RSD	2.9±0.9	2.4±0.7	4.4±0.5	3.27	0.49	P<0.23

BSM-T= Black Seed Moringa of Thailand; WSM= White Seed Moringa of local origin; BSM-L= Black Seed Moringa of local origin;

Table.5: Biomass yield and crude protein content cultivated fodder in Bangladesh

Feeds & Fodders	Harvest composition	DM (t /yr/ha)	CP content & yield		Sources
			g.kg^{-1} DM	t/yr/ha	
Lathyrus sativus	Whole plant with soft pods	12.7	152.0	1.96	Rahman *et al* (2015)
Vigna mongu	Whole plant with soft pods	6.6	105	0.69	
Vigna unguiculata	Whole plant	15.6	105	1.64	**Unpublished data, BLRI 1995*
Sesbania sesban	Tops with stem &leaves	17.3	101	1.75	
Leuchena leucocephala	Intermittently cut tops with stem & leaves	10.7	202	2.15	
Soybean meal	Oil extracted grain biomass	1.8	518	0.93	*Feedipedia; http://www.feedipedia.org*

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Table.6: Rumen digestion kinetics of protein and amino acid composition of Moringa and other feed sources

Nutrients	*(Feedipedia; http://www.feedipedia.org)*			*Khalel et at (2014)*	
	Soybean meal	*Lleucocephala*	Alfalfa hay	Moringa feed	Berseem
In sacco degradability in the rumen		Nitrogen, %		Crude protein, %	
Soluble, a	15.3	18.5	55.8	22.1	25.9
Potential degradable, b	78.9	62.4	37	47.7	59.4
Effective degradability % at 0.06	65.0	45.0	79.0	55.1	67.7
		Amino acids, % CP			
Methionine	1.4	1.3	1.2	0.66	0.74
Lysine	6.3	5.5	4.7	7.69	4.92

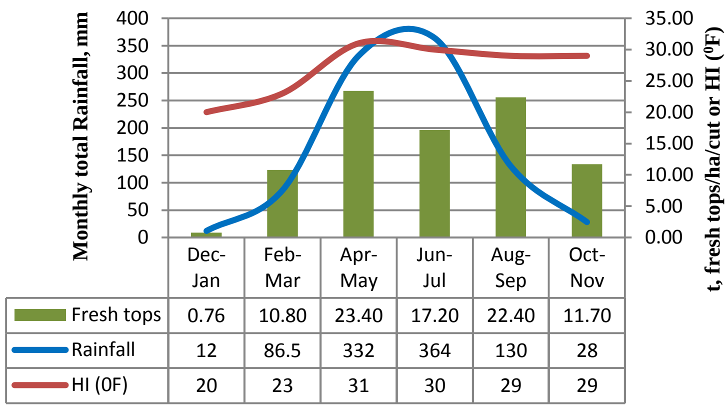

Fig.1: Seasonal impacts on annual Moringa production

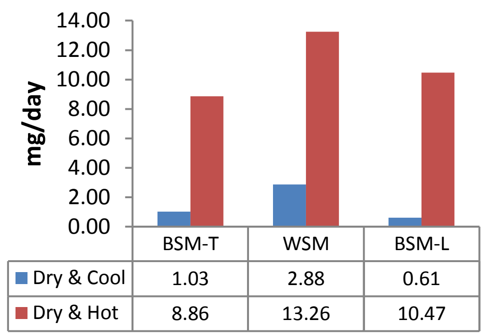

Fig.2: Seasonal impact on Relative Growth Rate of Moringa