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# Study of Different Harvesting Height on Annual Biomass Yield, Chemical Composition and in-Sacco Dry Matter Degradability of Moringa Fodder

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***Abstract* – An agronomical trial was carried out to evaluate the biomass yield, chemical composition and *In-sacco* dry matter (DM) degradability of different harvesting height of Moringa under on station condition. Twenty eight (28) plots each of 1x1 sq meter area having seven (7) replications for each harvesting height were assigned in a Randomized Block Design (RBD). Four different harvesting heights like 20cm, 40 cm, 60 cm and 80 cm above the ground level were imposed to fodder research field of the Bangladesh Livestock Research Institute (BLRI) having October, 2014 to December, 2015. The annual yield of biomass and its quality in term of chemical composition and *In-sacco* dry matter degradability of the four different harvesting height produced on a common dose of cow dung (2700Kg/hectare), chemical fertilizers (Urea, Tipple Super Phosphate (TSP) and Murat of Potash (MP) of 90:30:15 kg per hectare, respectively), and other agronomical practices (irrigation, weeding) were determined. The study revealed that, the survivability and the no. of prunes per plant did not differ significantly ($p<0.5$) on different harvesting heights of Moringa. The relative growth rate of 20 cm harvesting height was the highest (15.2 mg/day) followed that of 40 cm (10.9 mg/day), 60 cm (8.9 mg/day) and 80 cm (0.69 mg/day) and their differences were significant ($p<0.09$). The annual highest biomass yield in fresh and dry matter (DM) basis was obtained under 40 cm harvesting height compared to other harvesting height. The average leaf to stem ratio was significantly ($p<0.000$) increased with the increase of harvesting height of Moringa and varied from 0.5 to 0.74. Further, it was observed that, increasing harvesting height had a significant ($p<0.001$) effect on NDF content of all fractions but the ADF content was decreased with the increased of harvesting height. Their average value of EE was the highest in leaf (51.2 g $kg^{-1}$; $p<0.001$) associated to tops (37.4 g $kg^{-1}$) and stem (7.7 g $kg^{-1}$), respectively. It was shown that, hot & dry and hot & humid having Heat Index ranges of $25^0$ to $35^0$F and monthly total rainfall of 130 mm to 332 mm was suitable for 40 cm harvesting height of Moringa. It may be concluded that, 40 cm harvesting height of Moringa was suitable for higher biomass yield with the range of CP: ADF ratio 1.75 to 2.0 and effective DM degradability of tops above 60%.**

***Keywords* – Harvesting Height, Biomass, Season, Nutritional Values, Chemical Composition.**

## I. Introduction

Available crop residues like rice straw, green grass, tree foliage and leaves is failed to satisfy of farm animals for boosting milk and meat production in the country. The country required 34.5 million tons of fibrous residues [1] and meets only 17.5 million tons of their requirements. In contrast, concentrate feed, dietary level of which depends on animal production performance may support only 21.2 % of its total requirements [1]. Bran's and oilcakes may share bulk amount of concentrate feed that has limited formulation options for higher metabolizability including balancing of micronutrients essential for supporting nutritional planes of high yielding animals. Potential of plantation crops, in a tropical country like Bangladesh, as animal feeds is largely unknown, their exploration and use requires intensive efforts of science and technology. Moringa (*Moringa oleifera),* a plant fodder being researched and found responsive to increasing production and productivity of small [2] and large ruminants[3-4] was identified as one of the best options for Bangladesh [5] for supporting growing quality feed demands. Options for Moringa fodder production were tested [6] but locally, it is known as a source of drumsticks and, to a lesser extent, as leafy vegetable. It is one of the most useful, fast growing plants [7] throughout the tropics for human food, livestock forage, medicine, dye, and water purification. It may yield 580.0 ton fresh or 99.0 ton dry matter [6] and leaves contain 26.4 to 29.0% crude protein with an average rumen degradability of 48.6% and have post-rumen digestibility of 47% [8]. It contains all essential amino acids including lysine and methionine in adequate concentration [9] 0.63% calcium which is more than ten times higher than the level of phosphorus [10] and 5.0% saponin [8] that helps rumen degradation. Moringa foliage also containing 1.76: 1 leaf to stem ratio and 20.9 % crude protein is 52.79 % digestible in cattle [11] and may replace concentrate mixed feed. Asexual propagation of Moringa was established [12] but sexual propagation on the agronomical intervention like varietal response, density, harvesting height; fertilizer, irrigation and weeding are unidentified. Harvesting height of moringa is one of them. Impacts of harvesting height on the biomass and its response to ruminant animals are the burning question remains unaddressed. Moreover, Heat Index (HI) temperature and rainfall are also other climatic factors that affect the biomass production [13]. Considering the above factors, the present work was undertaken to investigate the effect of harvesting height on Moringa biomass and its quality with special orientation to weather condition.

## II. Materials and Methods

*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) during October, 2014 to December, 2015. The station was located at 23°42'0" N, 90°22'30" E at the 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 its classification belongs to the Madhupur Tract (Agro Ecological Zone 28) of Bangladesh. During the experimental period temperature ranged from $21^0$C to $35^0$C and humidity ranged from 50% to 75%.

*Preparation of Experimental Plots*

During the month of October, 2014 the seed of native black were propagated sexually with the moisture contain of 5 to 7%; and kept 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 were ploughed and fertilized with a basal dose of cattle dung (@ 3.0 tons/hectare) and 50% of required chemical fertilizers (a mix of Urea, Triple Super Phosphate (TSP) and Murat of Potash (MP) at a ratio of 90:30:15 kg per hector of N: P: K, and all other related agronomical practices e.g. weeding, irrigation etc were common.

*Experimental Layout Design and Treatment*

A uniformly plain land area of 63 $m^2$ was divided into four (4) blocks, each of 15.75 $m^2$ separated by 0.1 meter wide walking alleys. Each block was again divided into seven (7) experimental plots, each of 1.0 $m^2$ for planting of 9 saplings at a space of 0.3mx0.3m per sapling. In harvesting day, Black Seed Variety (BSV) were harvested at different harvesting height such as 20cm; 40cm; 60cm & 80cm respectively above the ground level at 60 days and arranged in a Randomized Block Design (RBD) to determine the production response.

*Yield Determination and Sample Collection*

After a post-transplantation growth period of 90 days, top plant parts with leaves (tops) were harvested at a 60 days interval from different harvesting height. The plants were allowed to grow after each cut and fertilized after each harvest with 60 kg Urea N/ha. The biomass yield of each of four harvesting height in different cuts of a year was added to determine annual yield of biomass production, and a total of six cuts were given. Survival rate (% of saplings grew after transplantation), number of prunes per plant and the relative 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 fresh yield per plot was recorded. Fresh yield (kg or ton) was converted to DM yield $plot^{-1}$ $ha^{-1}$ according to the equation: DM yield $plot^{-1}$ = Weight of fresh material × DM (%).

*Chemical Analysis*

The tops were manually separated into stem and leaves to determine stem to leaf ratio and weighed accordingly. Representative samples of tops, stem and leaves were taken to determine fresh dry matter, total ash, crude protein (CP) and ether extract (EE) according to AOAC [14] and neutral (NDF) or acid detergent Fiber (ADF) according to Van Soest [15]. 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 biomass of different harvests.

*Determination of Relative Growth Rate (RGR) and HI (Heat Index)*

During October, 2014 to 23 December, 2015, the data on rainfall, temperature, humidity were collected. The relative growth rate (RGR) of different cultivars was calculated using the equation $RGR = (l\text{n}W_2 - l\text{n}W_1) / (t_2 - t_1)$ described by Hoffmann and Poorter [16]. 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 in 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 [17].

*Rumen Kinetics 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 lib* and the roughages were supplemented with 1.0% of live weight of a locally mixed concentrate mix of wheat bran, sesame oil cake, Kheshari (*Lathyrus sativus*) bran, Di-calcium phosphate (DCP) and common salt. Having the animals adjusted to the diet for at least three weeks Dacron bags (7x16 cm, pore size 45 µm) containing the sample of three Moringa tops were incubated in the rumen following the method described by Ørskov *et al* [18]. Moringa tops were oven dried and milled using 1.0 mm sieves, and around 2.0 g of sample was taken in each bag. Considering animals and four periods as replication Samples of Moringa tops of different harvesting height were incubated at 0, 8, 16, 24, 48 and 72 hrs in the rumen. Each hour of incubation of a sample of each height was repeated in four animals in a period, and the incubations were repeated in four different periods. The degradation kinetics of DM were determined by fitting the disappearance values to the equation $P = a + b\ (1\text{-}e^{-ct})$ Ørskov and McDonald [19], 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 [20] where $ED = a + bc / (c + k)$, where 0.05 rate constant (k) was considered.

*Statistical Analysis*

Considering four different harvesting height of Moringa 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 or NDF) were analyzed in an ANOVA of a Randomized Block Design (RBD) using

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general linear model of SPSS-17.0 statistical software program in a computer. Any significant differences in the rate and extent of DM degradability *in- Sacco* of Moringa tops of different cultivars were analyzed using an ANOVA of 4x4 Latin Square Design.

## III. Results

The effect of different harvesting height of Moringa on survival rate (%), the number of prunes per plant and annual Relative Growth Rate (mg/day) are shown in table 1.The survivability was not significantly (p<0.78) effects on four harvesting height of Moringa. The survivability of 20 cm harvesting height was the highest (81.6%) where as the lowest survivability (75.2%) was found in 80 cm harvesting height. The average no of prunes of all harvesting height of Moringa varied from 1.9 to 2.04 and it did not differ significantly (p<0.61). The relative growth rate of 20 cm harvesting height was the highest (15.2 mg/day) followed that of 40 cm (10.9 mg/day), 60 cm (8.9 mg/day) and 80 cm (0.69 mg/day) and their differences were significant (p<0.09).

Table 1. Different harvesting height (cm) response on survival rate (%); number of prunes/plant & annual RGR (mg/day) (means; n = 7)

| Parameters | Harvesting height(cm) 20 | 40 | 60 | 80 | Significance Overall mean | Overall SE | Level |
|---|---|---|---|---|---|---|---|
| Survival rate (%) | 81.6 ± 4.4 | 80.0 ± 3.3 | 80.3 ± 5.4 | 75.2 ± 5.3 | 79.28 | 2.3 | P<0.78 |
| No of Prunes/plant | 1.9 ± 0.1 | 2.0 ± 0.1 | 2.04 ± 0.1 | 1.9 ± 0.2 | 1.94 | 0.05 | P<0.61 |
| Annual RGR (mg/day) | 15.3$^{a}$ ± 2.7 | 10.9$^{ab}$ ± 3.8 | 8.9$^{ab}$ ± 4.9 | 0.69$^{c}$ ± 5.0 | 8.92 | 2.13 | P<0.09 |

Figures with different superscript in the same row differ significantly at *= P<0.05 level; NS= Non significant

### *Biomass Yield*

The effect of four different harvesting heights on fresh or dry matter (DM) yield of tops, leaf and stem fractions of Moringa and their leaf to stem ratio are shown in Table 2. The annual fresh (92.5 tones/ha) and dry matter (19.5 ton/ha) yield of tops of 40 cm harvesting height were significantly (p<0.006) higher than that of 20 cm (85.0 ton/ha and 17.2 ton/ha), 60 cm (66.9 ton/ha and 14.4 ton/ha) and 80 cm (49.7 ton/ ha and 10.5 ton/ha), respectively. Similarly, the annual fresh or dry matter yield of stem (63.9 ton/ha and 12.6 ton/ha) was the highest (p<0.001) for 40 cm harvesting height followed by 20 cm (60.6 ton/ha and 11.1 ton/ha), 60 cm (44.4 ton/ha and 9.0 ton/ha) and 80 cm (32.1ton/ha) harvesting height, respectively. The response of different harvesting height was varied significantly (p<0.001). But the dry matter yield of leaves among the treatments were not differed significantly (p<0.240). Hence, the leaves of 40 cm harvesting height was produced the highest (p<0.109) biomass (28.5 ton/ha) compared to others. The average leaf to stem ratio was significantly (p<0.000) increased with the increase of harvesting height of Moringa. The ratio was varied from 0.5 to 0.74 for 20 cm and 80 cm harvesting height. The leaf to stem ratio of 40 cm harvesting height of Moringa was 0.54, it reflects that almost a half of the whole tops dry matter was shared by the leaves.

Table 2. Fresh biomass and DM (dry matter) yield of different botanical fractions and leaf stem ratio of *Moringa oleifera* at different harvesting height (means ± SE; n=7)

| Parameters | Harvesting height(cm) 20 | 40 | 60 | 80 | Significance Overall mean | Overall SE | Level |
|---|---|---|---|---|---|---|---|
| Fresh yield(t ha$^{-1}$year$^{-1}$) | | | | | | | |
| Tops | 85.0$^{ab}$ ± 6.1 | 92.5$^{a}$ ± 8.9 | 66.9$^{bc}$ ± 10.3 | 49.7$^{c}$ ± 7.0 | 73.5 | 5.03 | P<0.006 |
| Stem | 60.6$^{ab}$ ± 3.9 | 63.9$^{a}$ ± 5.8 | 44.4$^{bc}$ ± 6.9 | 32.1$^{c}$ ± 4.9 | 50.3 | 3.6 | P<0.001 |
| Leaf | 24.3$^{ab}$ ± 3.2 | 28.5$^{a}$ ± 3.2 | 22.5$^{ab}$ ± 3.4 | 17.6$^{b}$ ± 2.2 | 23.2 | 1.6 | P<0.109 |
| Dry matter yield(t ha$^{-1}$year$^{-1}$) | | | | | | | |
| Tops | 17.2$^{a}$ ± 1.3 | 19.5$^{a}$ ± 1.9 | 14.4$^{ab}$ ± 2.2 | 10.5$^{b}$ ± 1.5 | 15.4 | 1.04 | P<0.009 |
| Stem | 11.1$^{ab}$ ± 0.7 | 12.6$^{a}$ ± 1.1 | 9.0$^{bc}$ ± 1.4 | 6.4$^{c}$ ± 0.98 | 9.8 | 0.68 | P<0.004 |
| Leaf | 5.8 ± 0.8 | 6.9 ± 0.78 | 5.9 ± 0.88 | 4.63 ± 0.57 | 5.8 | 0.39 | P<0.240 |
| Leaf to stem | 0.5$^{b}$ ± 0.04 | 0.54$^{b}$ ± 0.01 | 0.70$^{a}$ ± 0.04 | 0.74$^{a}$ ± 0.05 | 0.62 | 0.02 | P<0.000 |

Figures with different superscript in the same row differ significantly at ***= P<0.001 or ** = P<0.01 or * = P<0.05 level; NS = Non- significant

### *Nutrient Composition*

Table 3 shows that the chemical composition of different botanical fractions of the four harvesting height of Moringa. The dry matter (DM) of tops, stem and leaf were significantly (p<0.001) differed among the treatments. The highest dry matter content of tops was observed at 60 cm harvesting height (217.6 g kg$^{-1}$) where as the lowest dry matter content of tops was found at 20 cm harvesting height (193.1 g kg$^{-1}$), respectively. The harvesting height of 40 cm had significantly higher DM of stem (193.7 g kg$^{-1}$) than 80 cm (187.4 g kg$^{-1}$) and 60 cm (188.9 g kg$^{-1}$) and then lower of 20 cm (194.49 g kg$^{-1}$), respectively. With the increase of harvesting height, the DM content of leaves was significantly (p<0.001) increased. The CP and ash content of tops stem and leaf were significantly (p<0.001) increased with the increased of harvesting height. Their average ash content of four harvesting heights was 49.5 g kg$^{-1}$ for tops, 37.5 g kg$^{-1}$ for stem and 73.2 g kg$^{-1}$ for leaf, respectively. The CP content of 80 cm harvesting height of tops, stem and leaves was the highest (211.4 g kg$^{-1}$, 90.96 g kg$^{-1}$and 284.5 g kg$^{-1}$) followed by 60 cm (206.7 g kg$^{-1}$, 88.8 g kg$^{-1}$and 282.7 g kg$^{-1}$), 40 cm (188.9 g kg$^{-1}$, 86.8 g kg$^{-1}$and 279.9 g kg$^{-1}$) and 20 cm (181.1 g kg$^{-1}$, 87.4 g kg$^{-1}$and 283.4 g kg$^{-1}$), respectively. The ADF content of tops and stem was significantly (p<0.001) decreased with the increase of harvesting height. It ranged from 280.3 to 410 g kg$^{-1}$ for tops and 288.5 to 342.8 g kg$^{-1}$ for stem. It was observed that 60 cm harvesting height of leaves obtained the highest ADF (56.1 g kg$^{-1}$) compared to others. Increasing the harvesting height had significant (P<0.001) effects on NDF content of all plant fractions. The mean of NDF content was higher in tops (532.6 g kg$^{-1}$) compared to stem

(528.4 g kg$^{-1}$) and leaf (138.3 g kg$^{-1}$), respectively. The EE content of tops, stem and leaf were significant ($p<0.001$) effect on different harvesting height of Moringa. Their average value of EE was the highest in leaf (51.2 g kg$^{-1}$) associated to tops (37.4 g kg$^{-1}$) and stem (7.7 g kg$^{-1}$), respectively.

Table 3. Chemical composition of different botanical fractions of *Moringa oleifera* at different harvesting height (means±SE; n=7)

| Parameters | Harvesting height(cm) 20 | 40 | 60 | 80 | Significance Overall mean | Overall SE | Level |
|---|---|---|---|---|---|---|---|
| | | | DM(g kg$^{-1}$) | | | | |
| Tops | 193.1$^{b}$ ± 1.1 | 197.0$^{b}$ ± 1.3 | 217.6$^{a}$ ± 2.3 | 216.7$^{a}$ ± 0.9 | 206.1 | 2.95 | P<0.001 |
| Stem | 194.49$^{a}$ ± 0.6 | 193.7$^{a}$ ± 0.7 | 188.9$^{b}$ ± 0.5 | 187.4$^{b}$ ± 0.7 | 191.1 | 0.83 | P<0.001 |
| Leaf | 233.3$^{d}$ ± 1.2 | 236.6$^{c}$ ± 0.5 | 250.49$^{b}$ ± 1.3 | 259.6$^{a}$ ± 0.8 | 245.0 | 2.13 | P<0.001 |
| | | | Ash(g kg$^{-1}$) | | | | |
| Tops | 43.3 ± 0.4 | 50.9 ± 0.4 | 49.1 ± 0.6 | 54.5 ± 0.5 | 49.5 | 1.07 | P<0.001 |
| Stem | 37.06$^{b}$ ± 0.7 | 36.7$^{b}$ ± 0.2 | 37.3$^{b}$ ± 0.4 | 38.8$^{a}$ ± 0.5 | 37.5 | 0.29 | P<0.04 |
| Leaf | 70.57$^{c}$ ± 0.3 | 70.05$^{c}$ ± 0.5 | 72.9$^{b}$ ± 0.4 | 79.4$^{a}$ ± 0.6 | 73.2 | 0.98 | P<0.001 |
| | | | CP(g kg$^{-1}$ DM) | | | | |
| Tops | 181.1$^{d}$ ± 0.5 | 188.9$^{c}$ ± 0.4 | 206.7$^{b}$ ± 0.4 | 211.5$^{a}$ ± 2.3 | 197.1 | 3.21 | P<0.001 |
| Stem | 87.4$^{c}$ ± 0.3 | 86.8$^{c}$ ± 0.4 | 88.8$^{b}$ ± 0.3 | 90.9$^{a}$ ± 0.4 | 88.5 | 0.44 | P<0.001 |
| Leaf | 283.4$^{ab}$ ± 0.2 | 279.9$^{c}$ ± 0.7 | 282.7$^{b}$ ± 0.5 | 284.5$^{a}$ ± 0.2 | 282.7 | 1.94 | P<0.001 |
| | | | ADF(g kg$^{-1}$ DM) | | | | |
| Tops | 410.2$^{a}$ ± 0.3 | 331.7$^{b}$ ± 0.5 | 314.4$^{c}$ ± 0.2 | 280.2$^{d}$ ± 0.6 | 334.2 | 12.31 | P<0.001 |
| Stem | 342.8$^{a}$ ± 0.9 | 324.2$^{b}$ ± 1.9 | 298.02$^{c}$ ±0.8 | 288.4$^{d}$ ± 1.0 | 313.4 | 5.57 | P<0.001 |
| Leaf | 44.9$^{b}$ ± 1.3 | 45.5$^{b}$ ± 1.1 | 56.1$^{a}$ ± 1.5 | 53.9$^{a}$ ± 0.7 | 50.1 | 1.39 | P<0.001 |
| | | | NDF(g kg$^{-1}$ DM) | | | | |
| Tops | 495.0$^{d}$ ± 1.3 | 517.9$^{c}$ ± 1.2 | 553.3$^{b}$ ± 3.1 | 563.9$^{a}$ ± 0.4 | 532.6 | 7.16 | P<0.001 |
| Stem | 437.2$^{d}$ ± 0.63 | 551.2$^{c}$ ±1.09 | 557.39$^{b}$ ± 0.4 | 567.61$^{a}$ ± 0.3 | 528.4 | 13.66 | P<0.001 |
| Leaf | 125.2$^{c}$ ± 0.8 | 135.5$^{b}$ ± 0.4 | 145.6$^{a}$ ± 0.9 | 146.6$^{a}$ ± 0.5 | 138.3 | 2.27 | P<0.001 |
| | | | EE(g kg$^{-1}$ DM) | | | | |
| Tops | 54.85$^{a}$ ± 0.85 | 28.0$^{c}$ ± 0.90 | 23.76$^{d}$ ± 1.46 | 42.96$^{b}$ ± 0.79 | 37.4 | 4.68 | P<0.001 |
| Stem | 9.67$^{a}$ ± 0.13 | 7.2$^{b}$ ± 0.21 | 7.4$^{b}$ ± 0.21 | 6.2$^{c}$ ± 0.35 | 7.7 | 0.47 | P<0.001 |
| Leaf | 40.92$^{b}$ ± 1.6 | 51.9$^{a}$ ± 0.7 | 57.12$^{a}$ ± 1.2 | 54.6$^{a}$ ± 1.8 | 51.2 | 2.38 | P<0.003 |

Figures with different superscript in the same row differ significantly at ***= P<0.001 or **= P<0.01 or *= P<0.05 level; NS= Non significant

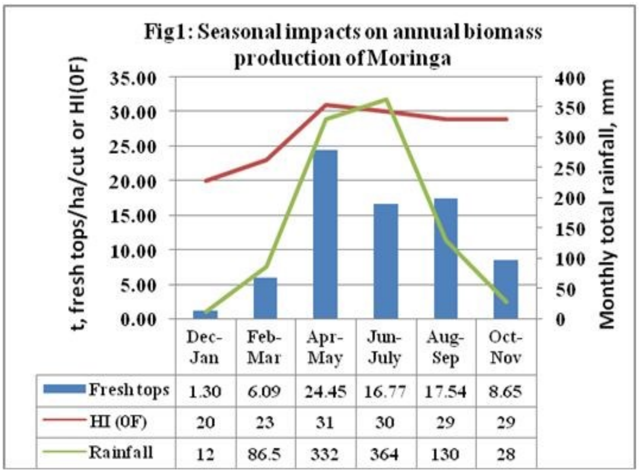
*Degradation Kinetics*

Estimates of ruminal degradation contents (a, b and c) fitted with rate of DM disappearance of tested Moringa tops of different harvesting height is presented in Table 4. It was observed that "a" washing loss of 80 cm harvesting height (40.0%) was significantly ($p<0.000$) higher than that of 60 cm (37.0 %), 20 cm (36.0 %) and 40 cm (34.8 %), respectively. The rate of rumen dry matter (DM) degradation of 80 cm harvesting height of moringa was the highest (0.26, $p<0.188$) followed by 0.20 of 40 cm, 0.18 of 20 cm and 0.15 of 40 cm , respectively. The potential or effective degradability of Moringa tops of four different harvesting height ranged from 29.5 to 40.6 % and 58.2 to 73.7 % at 5.0 % passage rate and their differences among the treatment was significant ($p<0.000$).

Table 4. Rumen degradation kinetics of DM of Moringa foliage of different harvesting height of Moringa (mean ± SE)

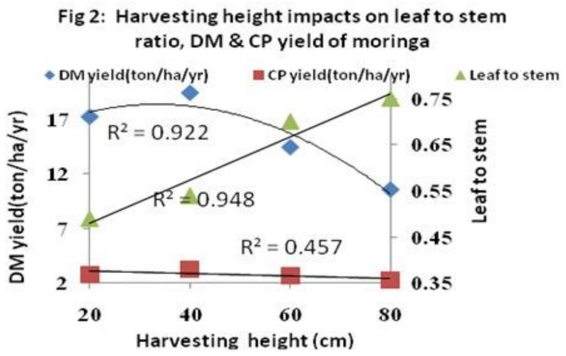
| Parameters | Cutting Height(cm) 20 | 40 | 60 | 80 | Significance Overall mean | Overall SE | Level |
|---|---|---|---|---|---|---|---|
| a | 36.0$^{b}$ ± 0.5 | 34.8$^{c}$ ± 0.4 | 37.0$^{b}$ ± 0.1 | 40.0$^{a}$ ± 0.3 | 37.0 | 0.52 | P<0.000 |
| b | 29.5$^{c}$ ± 0.9 | 37.3$^{b}$ ± 0.6 | 39.5$^{a}$ ± 1.2 | 40.6$^{a}$ ± 0.4 | 36.4 | 1.18 | P<0.000 |
| c | 0.18$^{a}$ ± 0.02 | 0.2$^{a}$ ± 0.05 | 0.15 ± 0.01 | 0.26 ± 0.04 | 0.26 | 0.02 | P<0.188 |
| Effective degradability | 58.2$^{d}$ ± 0.9 | 62.6$^{c}$ ± 1.7 | 66.5$^{b}$ ± 1.3 | 73.7$^{a}$ ± 0.8 | 64.92 | 1.57 | P<0.000 |
| RSD | 2.1 ± 0.3 | 3.2 ± 0.4 | 3.5 ± 0.8 | 1.6 ± 0.5 | 2.95 | 0.31 | P<0.019 |

Figures with different superscript in the same row differ significantly at ***= P<0.001 or **= P<0.01 or *= P<0.05 level; NS= Non significan




*Seasonal Effect on Moringa Production*

The average Heat Index (HI) Temperature was 20, 23, 31, 30, 29 and 29$^{0}$F and the monthly total rainfall was reported as 12, 86.5, 332, 364, 130 and 28 mm, respectively during the six harvesting period. The fresh tops yield (ton/ha/cut) varied according to the variation of HI and rainfall in a year. The lowest production (1.3 ton/ha/cut) was observed during the dry (monthly total rainfall 12.0, mm) and cool (HI, 20$^{0}$F) months (December to January). The yield of Moringa was raised in peak during the dry and hot period, from April to May with the increase of HI (31$^{0}$F) and rainfall (332 mm); it was 24.45 ton/ha/harvest. The heavy rainfall directly impact on raising biomass yield (16.77 to 17.54 ton/ha/cut) during the hot and humid period of the year.

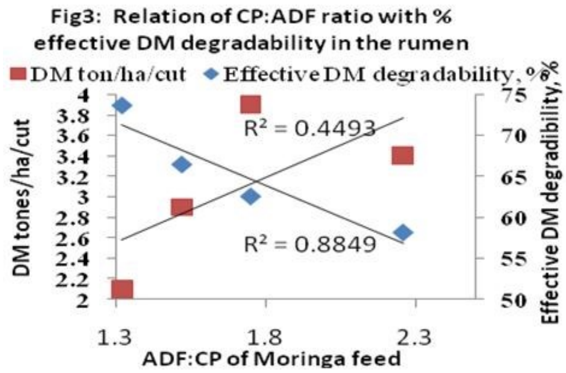



The relationship between the dry matter or CP yield and leaf to stem ratio with the different harvesting height of Moringa shown in Fig 2. It was observed that the increase of harvesting height is lower than that of increase of dry matter or CP yield (tones/ha). The leaf to stem ratio of Moringa was linearly ($R^2$=0.948) increased with the increase of harvesting height. It was also shows that the harvesting height of Moringa directly effects on biomass production and harvesting quality. Fig 2 shows that, 40 cm harvesting height is suitable for higher biomass and better quality.

The relationship between CP: ADF ratio and effective DM degradability in the rumen of four different harvesting height of Moringa is shown in Fig. 3. The effective DM degradability (%) was increased linearly ($R^2$=0.45) with the increase of harvesting height but the total dry matter production was linearly ($R^2$=0.88) decreased. It was observed that, the range of CP: ADF ratio 1.75 to 2.0 is appropriated for effective DM degradability (above 60%) and higher DM production that was indicated by 40 cm harvesting height of Moringa.

## IV. Discussion

Cutting of tops is a good practices, especially in hot & dry and hot & humid [21] except heavy rainfall to obtain maximum foliage production in the tropics [22]. In this experiment, the Moringa plants were cuts at different levels from the ground to evaluate the growth behavior, survivability, the no of prunes per plant, biomass yield and nutritional quality of Moringa plants. It was found that, the optimum biomass yield (92.5 tones/ha) was obtained in the hot rainy season (April to May & August to September) when the Moringa was harvested at 40 cm cutting level from the ground. Similar finding have also been reported by Nouman, *et al.* [13], at 30 cm cutting height. However, the present study was conducted in December – January when there was no rainfall and temperature is low but in April the temperature was extreme and the maximum rainfall occurred in July – August. Similar observation have been reported in the cases of Lucerne and mulberry [23,24] but Kadin and Kreil [25] reported high biomass yield at higher cutting levels and if the leaf stem ratio was higher, then thicker branches cannot be used as palatable foliage. Boschini [26] said that, the biomass yield depends on the relationship between leaf to stem ratio and the harvesting height. It has also been reported that higher cutting levels exhibit more dry matter compare to lower one [27,28]. The opposite observations were found in the present study. The effect of harvesting height on dry matter yield is still not clear, as Xavier and Carvalho [29] reported that the harvesting height does not affect on dry matter yield. In a few previous research reports [30-32] no significant effect of cutting levels was found on DM yield, but in all these cases the maximum cutting level was up to 50 cm.




Farmers produce moringa conventionally at their home steads for producing drumsticks without any use of foliage as livestock feed. For producing moringa as a livestock feed, its biomass is not only the required target; the quality of biomass is also important. The dry matter of all fraction of moringa was significantly ($p<0.001$) increased with the increased of harvesting height; its ranged from 193.1 g $kg^{-1}$ to 216 g $kg^{-1}$. The present study was similar to those obtained by Mendieta- Aracia *et al.* [33] and Aregheore, [34] and ranged from 110.4 g $kg^{-1}$ to 460.0 g $kg^{-1}$. The variations of DM can be explained by harvesting height, cutting frequency and stage of maturity, succulence of materials and the ratio of different fractions.

The effect of harvesting height on CP content of moringa tops, stem and leaves were significant ($p<0.001$). In the present investigation, the CP content of Moringa tops was within the ranges from 181.1 g $kg^{-1}$ to 211.5 g $kg^{-1}$. Some researchers said that Moringa is an excellent fodder with high CP concentrations [10, 34, 36-38] and it varying from 62.0 to 338.0 g $kg^{-1}$ DM [10,39]. The CP ranges from 279.9 to 284.5 g $kg^{-1}$ DM of Moringa leaves obtained in this study which was appeared to be lower than that reported by Soliva *et al.* [37] (320 g $kg^{-1}$ DM). The CP content of Moringa stem in comparatable to mature forages such as Napier grass (*Pennisetum purpureum*) (79.9 to 109.0 g kg-1 DM) or guinea grass (91.7 g $kg^{-1}$ DM) as informed by Ansah *et al.* [40] or Fadiyium *et al.* [35]. The mean CP value of Moringa tops (197.1 g kg-1 DM) and leaf (282.7 g kg-1 DM) was considerably higher than the mean CP content of forage legumes (170.0 g kg-1 DM) and grasses (115.0 g kg-1 DM) as reported by Minson, [41].

The harvesting height had a significant ($p<0.001$) effect on ADF, NDF & EE content of all fraction of Moringa during the year (Table 3). The ADF content of tops was increased with the decreased of harvesting height but the NDF content just reversed. The effect of harvesting height on fibre compounds was more in tops and stem fractions compared to leaf indicating that leaves have less structural

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materials than the stem. The young stems are generally of high quality but the quality decrease faster than in leaves, because epidermis and fibrous cells changes secondary cellular wall and lignin content increase with increased age of the plant. The ADF and NDF content of tops obtained in this study for the different harvesting height within the ranges of 280.2 to 410.2 g $kg^{-1}$ DM and 495.0 to 563.9 g $kg^{-1}$DM reported by other researchers [8,34,42,43]. The effective dry matter degradability of Moringa tops was significantly ($p<0.000$) increased with the increase of harvesting height. The IVDMD of Moringa was within the ranges of 582.0 to 737.0 g $kg^{-1}$. The similar finding (648.0 to 790 g $kg^{-1}$) was found of other researchers [8, 34, 39, 42-44].

## V. Conclusion

Considering the biomass yield, chemical composition, nutritional value, CP: ADF ratio, Heat Index and rainfall under different harvesting height, it can be concluded that 40 cm harvesting height of Moringa was suitable for higher biomass production in our country. Therefore farmer should be positive response to cultivate Moringa fodder following the above agronomical practices to feed their livestock.

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