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Comparative performance on plant morphology and biomass yield of two selected *Moringa oleifera* cultivars

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Abstract

Moringa (*Moringa oleifera*) could be one of the promising tree fodders to meet up the seasonal forage shortage in Bangladesh. Two cultivars of *Moringa oleifera* species namely Black Seed Moringa (BSM-L) Local and White Seed Moringa (WSM-L) Local were cultivated at fodder research field in Bangladesh Livestock Research Institute (BLRI), Savar, Dhaka, Bangladesh during the period from August 2015 to December 2017 to determine plant morphology and biomass yield in different seasons of two consecutive years under common agronomical practices. The production performances of two Moringa cultivars were analyzed in an ANOVA of a Randomized Block Design (RBD). The result revealed that BSM-L had significantly higher survivability (89.12%, $P<0.001$), number of prune $plant^{-1}$ (4.03, $P<0.001$) and lower defoliation rate (2.80%, $P<0.04$) than WSM-L(42.70%; 2.41 and 4.01%, respectively). On the other hand, leaf to stem ratio did not vary significantly ($P<0.30$) between cultivars (0.51 vs0.62). The annual fresh biomass yields ($t\ ha^{-1}$) of BSM-L foliage (leaf+stem), stem and leaf (120.88, 84.14 and 45.07, respectively) were significantly ($P<0.001$) higher than that of WSM-L(33.71, 20.65and 12.67, respectively). On the other hand, the annual dry biomass yields ($t\ ha^{-1}$) of BSM-L tops, stem and leaf (24.70, 14.49 and 09.85, respectively) were also significantly ($P<0.001$) higher than that of WSM-L (7.43, 3.93and 2.81, respectively). The seasonal effect of fresh foliage yield of Moringa showed that, dry& hot (March-June) (24.78 $t\ ha^{-1}$/cut for BSM-L and 8.93 $t\ ha^{-1}$/cut for WSM-L)and wet &hot(July-October) (31.48 $t\ ha^{-1}$/cut for BSM-L and 6.85 $t\ ha^{-1}$/cut for WSM-L)climates were found to be more suitable than dry & cool (November-February) (8.76 $t\ ha^{-1}$/cut for BSM-L and 1.97 $t\ ha^{-1}$/cut for WSM-L) climate. The initial growth of Moringa plants in the autumn or winter season was not satisfactory due to low temperature, humidity and rainfall. Results however, also showed that production of Moringa varied with variety and season. Finally, based on plant morphology and biomass yield, it may be concluded that, BSM-L may be cultivated as a potential tree fodder crop rather than WSM-L for ruminants in Bangladesh.

Keywords: plant morphology, biomass yield, seasonal variation, Moringa cultivars, Bangladesh

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Introduction

Forages provide adequate amount of nutritious feed for ruminants in the form of grasses which is preferred by the animals. Adequate and regular supply of quality fodder is essential for the development of livestock to meet the increasing demands of burgeoning population. However, in the dry season, there is feed constraint due to seasonal shortages in-terms of quantity and quality of forage from natural pastures, provides most of the feeds for animals which result into problems such as sickness and weight loss due to poor dietary profile for the animals and reduction in yield. To maintain reproductive performance and avoid nutritional stresses, adequate and spontaneous supply of nutritious fodder is essential during this crisis period (Benavides 1994; Raziq *et al,* 2008). With rapid population growth and increasing demand for food and other competing land uses, fellow periods are continually being reduced, with a resultant decline in soil fertility and productivity led to introduce the promising suitable tree fodders in fallow periods for present alternative feed resources of ruminants. Production of the potential nutritious tree fodders will help more scientific utilization of fodders as livestock feeds. The scarcity of fodder is seasonal, from October to May and during this long dry period, tree fodders and shrubs may be as an alternative sources of green fodders. Tree fodders are

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naturally grown on smallholder farms that might be an integral part of the farming system. Most of the tree fodder species are not primarily grown for fodder rather than other purposes.

The critical role of tree fodders and shrubs for livestock production in developing countries is now well recognized by the scientific community (Devendra, 1990; Swaminathan, 1989).Tree fodders provide a significant natural source of feed for grazing animals in many different parts of the world. Alternatively, tree fodders are often harvested by farmers to supplement low quality feeds offered to animals raised in housed or confined systems. Further, tree fodders and shrubs are quite essential in livestock farming, particularly in semi-arid environments where palatable grasses or browsers are scarce predominantly during drought times (Franzel *et al*., 2014).Their year round evergreen presentation and nutritional abundance provides for year round provision of fodder (Oji and Isilebo, 2000). It also enables standing feed reserve to be built so that herds can survive critical periods of shortfall, or even prolonged periods of drought, without remarkable losses (Odoh and Adamu-Noma, 2000). Tree fodders have high capacity to produce large quantity of leaves in range sites with prolonged dry periods because to have massive and deep root system and thus have good access to water that infiltrated into the sub-soil (Knoop and Walker, 1985). The tree fodders are gaining more attention due to low maintenance and less input requirements and their capability to provide good quality forage during the periods of food scarcity (Palada, 1996).

Moringa oleifera L. locally known as Moringa is one of the best nutritious trees, which can provide sufficient fodder for livestock during dry season. It is native to India but has been planted worldwide and naturalized in many countries with high growth rate and capacity to produce large quantities of biomass even in poor soils (Sanchez *et al*., 2006; Alhakman *et al.*, 2013; Hassan and Ibrahim, 2013).It is a fast growing tree with efficient capability of re-growth after pruning and capacity to produce good quality higher leaf biomass per unit area (Foidl *et al.,* 2001; Nouman *et al.,* 2014). Unlike other fodder plants, Moringa can grow in all types of soils preferable sandy loam, except waterlogged condition, and can tolerate long dry spells up to 6 months during dry season and grow well with annual rainfall between 250–1500 mm per year (HDRA, 2002; Karim*et al.,* 2007).Moringa has successfully been grown as field crop for biomass production and high dry matter yields of 4.2 to 8.3 t ha^{-1} harvested after every 40 days when planted at different spacing and cutting frequencies (Sanchez *et al.,* 2006).

Lots of varieties in Moringa species are available worldwide. However, Black Seed Moringa (BSM-L) and White Seed Moringa (WSM-L) are highly available throughout Bangladesh, which are relished by animals. But a very few information regarding agronomical cultivation, plant morphology, biomass yield and nutritional facts are available in Bangladesh. Further, there is no study on comparing the propagation of these two varieties in Bangladesh. The biomass production and cultivation practices have been discussed in other parts of the world as a fodder crop but a little emphasis was given in Bangladesh. The researchers have reported different yields of Moringa fodder under different climatic condition as affected by cutting height, cutting intervals, planting pattern and geometry (Sanchez *et al.,* 2006; Mendieta-Araica *et al.*, 2012), while no study is available under climatic conditions of Bangladesh. Therefore, the present study was conducted with a view to evaluate and compare plant morphology and biomass yield between two cultivars of *M. oleifera* mentioned earlier under same environment and agronomical practices in different seasons for sustainable production of this tree fodder plant which can minimize fodder shortages during dry season.

Materials and Methods

Location and agro-climatic condition of the experimental site

The agronomical trial was conducted at Pachutia fodder research field in Bangladesh Livestock Research Institute (BLRI) from 19 August 2015 to 23 December 2017. 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 (p^H 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 between 21^0-35^0C and relative humidity ranged from 50-77%. During the experimental periods, average temperature, relative humidity and rainfall were 19.6^0C, 69% and 3.0 mm in January, 23.8^0C, 61% and 15.5 mm in February, 28.1^0C, 53.5% and 43.5 mm in March, 29.6^0C, 68.5% and 96.0 mm in April, 29.6^0C, 71.5% and 200.0 mm in May, 30.1^0C, 74% and 292.5 mm in June, 29.1^0C, 81% and 514.5 mm in July, 29.9^0C, 77% and 282 mm in August, 29.6^0C, 79% and 242 mm in September, 28.8^0C, 72.5% and 63.5 mm in October, 25^0C, 68.5% and 12.5 mm in

November and 21.8^{0}C, 70% and 0.5 mm, in December, respectively.

Preparation of experimental plots

Two available Moringa cultivars namely Black Seed Moringa Local (BSM-L) and White Seed Moringa (WSM-L) Local collected from local sources were used in this experiment (Plate 1). The seeds of these two cultivars were tested for determining the rate of germination and it ranged from 65.0-75.0%. Two seeds in each polythene pouch containing were raised up to an age of five weeks. The baby plants were transplanted in pre-designed experimental plots. Before transplantation, the soil of the plots was ploughed and fertilized with a basal dose of cow 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 again repeated at each harvest. All other agronomical practices like weeding, irrigation etc. were common for all cultivars.

Local White Seed Moringa (WSM-L) Local Black Seed Moringa (BSM-L)

Plate 1: Moringa cultivars

Design and layout of the experiment

Preparing a uniformly plain land of 64.8m^2, and dividing it into four blocks each of 16.2m^{2}and then each block was divided into four equal plots of 4.05m^2, saplings of the two cultivars were randomly planted at a space of 0.3m x 0.3m for the planting of 90 saplings. The blocks and plots were arranged in a Randomized Block Design (RBD) to determine the production responses of two Moringa cultivars.

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 and it continued for two years. The plants were allowed to grow after each cut and fertilized accordingly. A total of twelve cuts were given for two consecutive years. The biomass yields of each of the cultivar in six (6) different cuts in a year as of Nov-Dec, Jan-Feb. Mar-April, May- June, July-Aug- Sep- Oct and Nov-Dec repeatedly 2nd year were added to determine the average annual biomass production (Plate 1). Survival rate (% of saplings grew after transplantation), the number of prunes per plant, defoliation rate (% of total leaf biomass defoliated), and biomass yields at different harvesting times were recorded. 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 was converted to DM yield plot^{-1} ha^{-1} according to the equation; DM yield plot^{-1} = Weight of fresh material × (%) DM.

Statistical analysis

Considering two cultivars of Moringa as treatment, responses for plant morphology and biomass production were analyzed in a one way ANOVA in a Randomized Block Design (RBD) using SPSS-20.0 statistical software.

Results and Discussion

Plant morphology

The effect of cultivar on survival rate (%), number of prunes, defoliation rate (%) and leaf to stem ratio from 12 harvests in 2 consecutive years are presented in Table 1.

Table 1: Morphological performances of two Moringa cultivars

Parameters	**Cultivar (n=12)**		**Overall SEM**	**Level of significance**
	BSM-L	WSM-L		
Survivability (%)	89.12	42.70	6.47	P<0.000
Number of prunes plant^{-1}	4.03	2.41	0.24	P<0.000
Defoliation rate (%)	2.80	4.01	0.30	P<0.040
Leaf : stem	0.51	0.62	0.03	P<0.300

BSM-L: Black Seed Moringa Local; WSM-L:White Seed Moringa Local

The survivability of BSM-L was found to be higher than WSM-L and the difference between cultivars were found to be highly significant (P<0.000). Amaglo (2006) reported 50.64-69.42% survivability of *Moringa oleifera* with varying plant densities which is in consistence with WSM-L of this study. However, they also observed large number of plant death during the period from 100 to 280 days after sowing associated with dry period. According to their observation, this could be attributed due to decrease in growth factors and the increased competition between individual plants leading to the death of many more plants from the higher plant densities relative to other densities. To minimize plant death as a consequence of competition between individual plants, it is obvious that plant should be provided good management practices (weeding, fertilizing, and watering) as to ensure optimum level of nutrients in the soil from which plant can uptake sufficient nutrients to reduce competition among the individual plants as had been reported by Amaglo *et al.* (2006).

BSM-L cultivar had significantly (P<0.001) higher numbers of prunes which made it bushier than WSM-L. Actually, plant growth begins after pruning. Growth depends on the interplay between external and internal factors, in a highly ordered and organized system (Amaglo, 2006). The external factors those may interplay for the growth and development of plant are plant density, availability of nutrients, water and sunlight (Amaglo *et al*., 2006). However, internal factor for pruning is fairly due to inherited from the mother plant and higher pruning could be obtained by selection by plant by applying the knowledge of plant breeding and genetics.

Defoliation is the premature removal of leaves from the trees. Defoliation could be happened by naturally or by cutting or grazing. Sometimes it is essential for trees and happened naturally. When leaves reach in to maturity then defoliation happens naturally. Defoliation is unexpected in fodder plant or tree fodders. The average defoliation rate between cultivars varied significantly (P<0.05) with higher defoliation rate investigated in WSM-L (4.01%). For maximum production, a forage plant must be able to regrow or continue to grow. Massive leaf defoliation removes the opportunity for photosynthesis and most plant functions decline. As the growing season ends, proper defoliation practices will allow the plant to produce tillers build up carbohydrate reserves to survive dormancy and initiate re-growth in the next season. The variation of defoliation between cultivars could be caused by internal factor of the plant or may be due to external factors.

The average leaf to stem ratio of both cultivars reflect that almost a half of the whole foliage dry matter was shared by leaves. The leaf to stem ratio is a feature that varies depending on the production of the fractions of leaves and stems and, for forage plants, it is important as it shows values greater than 1 (one), given that in this case there is always a larger amount of leaves than stems. These variations influence the nutritional value of the forage, since the chemical composition of each of the fractions may differ widely, because, generally, in leaves, the concentration of digestible nutrients is larger than in the stem. Nevertheless, the variation in the leaf to stem ratio among these two cultivars was not significant (P<0.30). According to Silva *et al,* (2010), the number of leaves present in a plant is related to the potential plant biomass accumulation, which is an important feature for recommending the use of forage species. In addition to the yield potential, forage plants that produce increased amounts of leaves tend to provide better-quality forage, considering that in the leaves there is a higher concentration of nutrients for the animal. The canopy dimensions interfere with the performance of physiological processes and in many cases are used as indicators of the capacity of a plant to compete for other resources (Nutto, 2001) explains that this variable is directly related to the growth and biomass yield of a plant. Therefore, it is possible that plants with larger canopy diameter, as well as an increased number of leaves on the branches, produce higher amounts of forage with better quality.

Fresh biomass yield

The annual fresh biomass yield of two cultivars according to botanical fraction is illustrated in Table 2. In this study, only the leaves and fragile shoots (<5 mm girth) were considered as fresh biomass. Table 2 showed that cultivar had highly significant (P<0.001) effect on biomass production of *Moringa oleifera*.

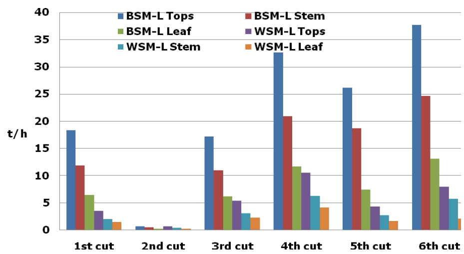

Figure 1: The fresh biomass yields (whole foliage, stem and leaf) of two Moringa cultivars in different harvests for the first year

as shown in Figure 1, the annual fresh biomass yield of BSM-L foliage, stems and leaves were significantly (P<0.001) higher than that of WSM-L values. The highest biomass yields of foliage, stem and leaf for both cultivars were obtained in 6th harvest, while lowest in 2nd cut. Figure 2 implies the fresh biomass yields (whole foliage, stem and leaf) of two Moringa cultivars in different harvests for second year. The highest biomass yields of foliage of BSM-L were obtained in 6th harvest, while lowest in 2nd cut. However, highest biomass yield of stem and leaves of BSM-L were observed in 4th cut (Figure 2) and lowest in 2nd cut.

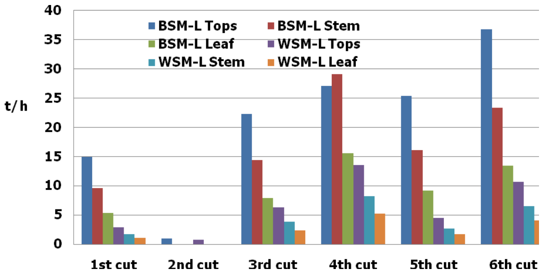

Figure 2: The fresh biomass yields (whole foliage, stem and leaf) of two Moringa cultivars in different harvests for the second year

The variations of biomass production in terms of foliage, leaf, and stem between cultivar could be attributed due to genetic variation of two cultivars. Actually, biomass yield depends on the age, growth and canopy diameter of the plant. This finding are in well agreement with the findings of Sun *et al.* (1999) and Karim and Fattah(2007) who showed that leaf area during flowering stage of plant is important factor for consideration of high yield. Indeed, productivity in leaves biomass of Moringa is low in the first year and it increases to stabilize in the second and third year. Sanchez *et al*. (2006) reported annual fresh biomass yield of Moringa to be 100.7, 75.3 and 71.4 t/ha for 5, 6 and 8 harvests, respectively in the first year, and 57.4, 39.4 and 26.7 t/ha for same harvests in the second which is lower than BSM-L, but higher than WSM-L as obtained in this study. Amaglo (2006) reported fresh shoot yield of Moringa from first harvest after 60 days of sowing to be varied from 38.47 to 101.52 ton ha^{-1} depending on plant spacing. In their same experiment, they obtained stem and leaf yields to be 52% and 30% of the entire shoot yields, respectively (20 to 52.8 and 11.5 to 30.5t ha^{-1}, respectively) which are lower than BSM-L, but agrees with WSM-L in this study. In another experiment, Foidl *et al,* (2001) reported a biomass yield up to 99 t ha^{-1} from 8 harvests in a year which is also lower than BSM-L in this study. The variations of fresh biomass production among different works might be due to the variations of agro-ecology, rainfall, soil fertility, cutting frequency or plant density. This is in agreement with the reports of Assefa (1998) and Nygren and Cruz (1998), who reported that longer cutting interval increases yields and as a consequence of frequent cutting, biomass yield decreases.

Dry biomass yield

The annual dry biomass yield of two cultivars according to botanical fraction is depicted in Table 3, which showed that cultivar had highly significant ($P<0.001$) source of variation for dry biomass yield. The annual dry matter yield of BSM-L foliage were significantly ($P<0.000$) higher than that of WSM-L. Dry matter yield depends on the amount of fresh biomass yield. The higher dry matter yield of BSM-L is due to higher biomass yield of this cultivar. Sanchez *et al*. (2006) reported annual dry matter yield of Moringa ranged from 13.5 to 24.7 t ha^{-1}in first year and 4.7 to 10.4 t ha^{-1} in second year depending on different cutting interval, which is in the line of this study. Amaglo (2006) reported dry shoot yield of Moringa from first harvest after 60 days of sowing to be varied from 11.71 to 31.32 ton ha^{-1} depending on plant densities which are slightly higher than this study. In another study, Palada (1996) investigated leaf, stem and tops dry matter yields as4.5, 6.8 and 11.2 t ha^{-1} in a year which is lower than BSM-L, but slightly higher than WSM-L of this study. These variations could be due to leaf stem ratio similar with the observation of Salerno and Seiffert (1990). However, climate, soil, harvest frequency and potentiality of Moringa cultivar could be possible reasons for variations among authors.

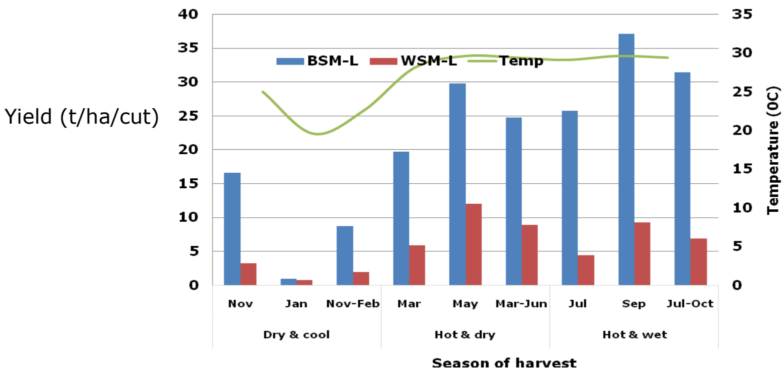

Figure 3: Seasonal variation of biomass yield in relation with temperature of two Moringa cultivars

Table 2: Average fresh biomass yield (2 years) of two cultivars according to botanical fraction of the Moringa plant

Botanical fraction	Fresh yield (t/ha; mean±SE)		Overall (mean±SE)	Level of significance
	BSM-L	WSM-L		
Tops	120.88±5.34	33.71±3.88	77.29±11.70	P<0.000
Stem	84.14±4.61	20.65±2.65	52.39±8.54	P<0.000
Leaf	45.07±2.91	12.67±1.21	28.87±4.45	P<0.000

BSM-L: Black Seed Moringa ; WSM-L: White Seed Moringa

Effect of climate on foliage production of Moringa cultivars

It was found that maximum fresh biomass was harvested in hot rainy season. Nouman *et al,*(2014) reported that fresh biomass is partially correlated with temperature and rainfall averaged over time, mostly per annum. Similar observation was also reported by Benavides (1986) and Baatar (2008) for Lucerne and mulberry. It was reported by many researchers that climate has a major role for vegetative growth leading to higher foliage yields in Moringa plants. The seasonal yields of fresh foliage of two cultivars of *M. oleifera* in relation with temperature, rainfall, humidity and heat index (HI) are shown in Figure 3 to Figure 6.

Fig 3 shows the relationship between temperature and fresh biomass yields of two cultivars of Moringa plant according to season. As shown in Fig 3 that the lowest temperature which was prevailing in this study was January, which greatly affected biomass yields for both cultivars (0.85 and 0.71 t ha^{-1} cut^{-1}, respectively for BSM-L and WSM-L). As temperature increased, biomass yield was increased up to September when highest production of 38.53 t ha^{-1} cut^{-1} was obtained for BSM-L. After the months of September, biomass yield was sharply declined up to January. Again after January, the production was increased up to May and again dropped in July. The reasons behind this trend could be due to heavy rainfall affected at that time as shown in Fig 4. Anyway, there were no published reports on Moringa cultivation under low temperature conditions. The younger the plant, the greater the damage to the leaves, stems and branches by frosts, due to the higher sensitivity of the vegetative material due to the proximity to the ground, where the temperature inversion is more pronounced (Caramori *et al.*, 2000). Based on results presented here, we infer that the Moringa cultivars used in this study is highly sensitive to low temperature conditions. Therefore, the Moringa cultivation on autumn/winter season should not be recommended because at low temperatures negatively affects the crop establishment. Nouman *et al.*(2014) reported a suitable ambient temperature range of 27^0C to 35 ^{0}C in Nicargua. Camargo *et al*. (1993) reported that susceptibility of the crop to low temperatures varies greatly according to the species and phonological stage of the plants. Maximum biomass productivity in the present study was obtained in the month of June to October with the temperature between 27^0C and 29^0C. Besides, the poor performance of WSM-L could probably be due to poor genetic adaptations influenced by climatic conditions in these areas.

Table 3: Comparison of annual dry biomass yield between two cultivars according to botanical fraction of the Moringa plant

Botanical fraction	Dry biomass yield (t/ha) (mean±SE)		Overall mean (±SE)	Level of significance
	BSM-L	WSM-L		
Tops	24.70±1.30	7.43±0.81	16.06±2.35	P<0.000
Stem	14.49±0.76	3.93±0.51	9.21±1.43	P<0.000
Leaf	9.85±0.62	2.81±0.28	6.33±0.97	P<0.000

BSM-L: Black Seed Moringa; WSM-L: White Seed Moringa

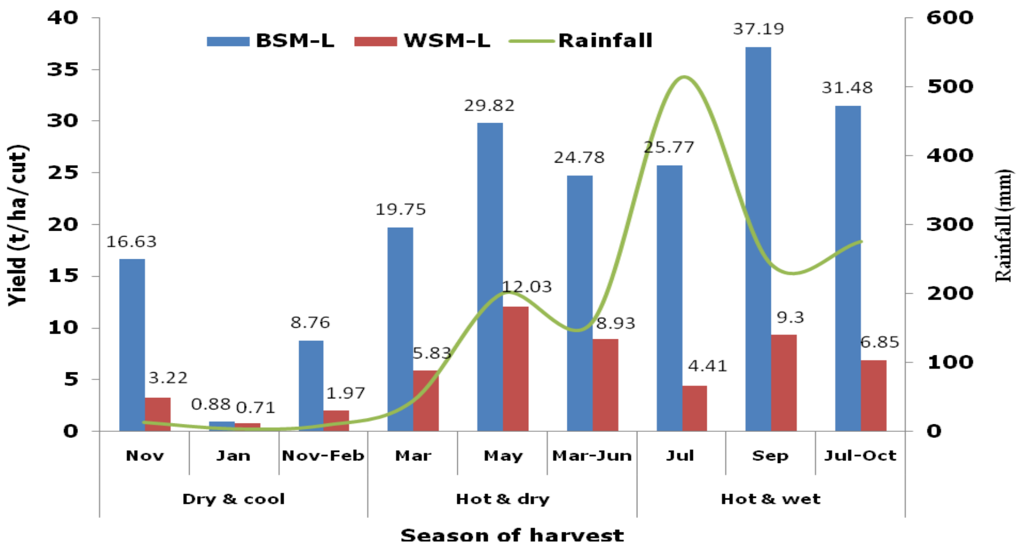

Figure 4: Seasonal variation of biomass yield in relation with rainfall of two Moringa cultivars

Fig 5 shows the trend of biomass yield of Moringa in relation with relative humidity. Though, relative humidity particularly depends on temperature and precipitation, there has possibly no effect on biomass production of Moringa for humidity of its own. Fig 5 however, implies that highest biomass production was obtained in the month of September, when relative humidity was remain around 80%. Earlier, Huda *et al*. (2016) also reported good foliage yield with humidity ranged from 70-79% RH for the same species in the same location. Their reports perfectly harmonize with this experiment.

Fig 6 shows the association of fresh foliage yield of Moringa with heat index. Fig 6 however, implies that highest biomass production was obtained in the month of September, when heat index (HI) was 36.5^{0}C. Huque *et al.* (2017) in their study obtained highest fresh foliage yield of Moringa in the month of April to May when heat index was 31^{0}C which is not agreed with our study. However, variation could be due to differences of temperature, rainfall, humidity, agronomical management or frequency and month of harvest.

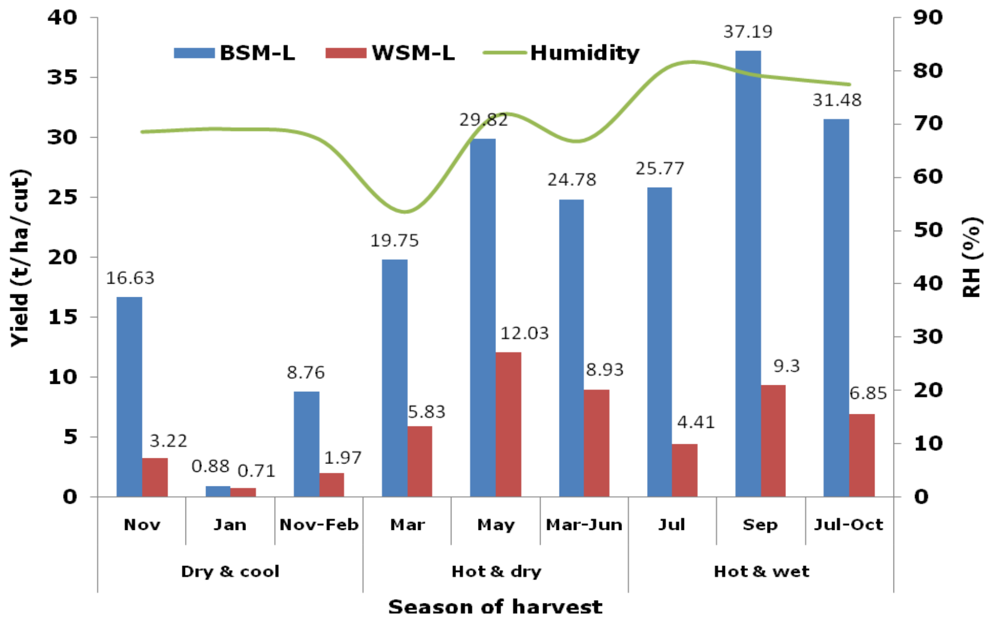

Figure 5: Seasonal variation of biomass yield in relation with humidity of two Moringa cultivars

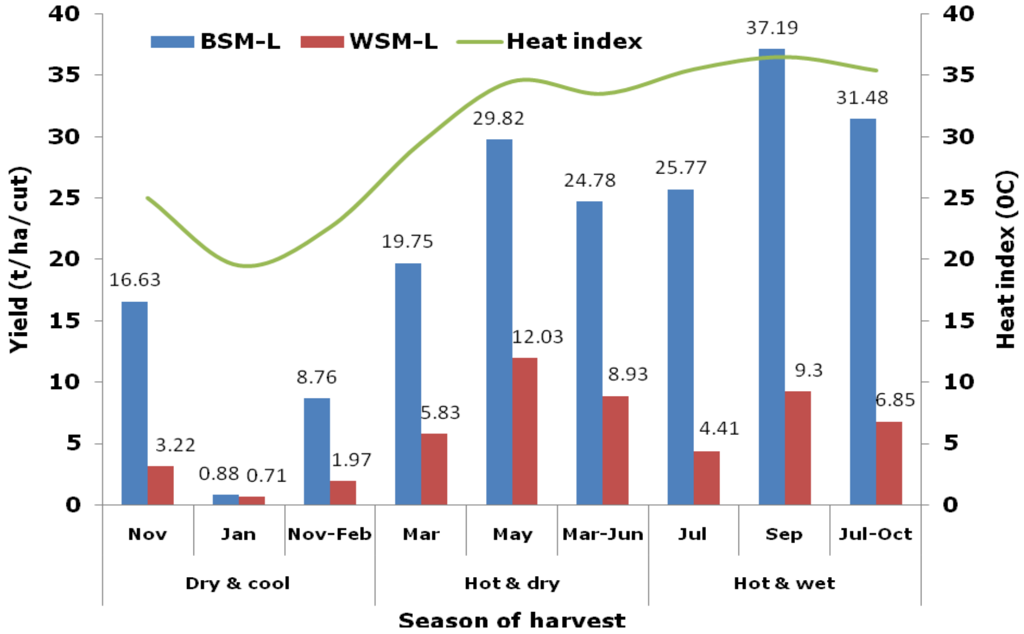

Figure 6: Seasonal variation of biomass yield in relation with heat index of two Moringa cultivars

Conclusion

Based on the morphological parameters of *M. oleifera* studied in this experiment, BSM-L was found to be better in terms of survivability, number of prunes, defoliation and biomass yield as compared to WSM-L. The study also revealed that dry & hot and wet & hot seasons as compare to dry & cool season were suitable for Moringa cultivation. The temperature between 27^0-29^0C, monthly total rainfall at a range of 66.5-326 mm and relative humidity around 80% favoured better growth and biomass production of *M. oleifera*.

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Conflict of interest

There is no conflict of interest among the authors.

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