RUFORUM Working Document Series (ISSN 1607-9345), 2021, No. 19 (1):218-228.
Available from http://repository.ruforum.org

Research Application Summary

Influence of different harvesting regimes on the biomass yield and nutritive quality of moringa (*Moringa oleifera*) in the guinea savannah zone of Ghana

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Abstract

The study was conducted to evaluate mass yield and nutrient composition of *Moringa oleifera* response to different cutting regimes in the savanna zone of Ghana. Three harvesting regimes were imposed on the initial establishment in a randomized complete block design which included harvesting at 12, 16 and harvesting at 20 weeks after planting. Cutting regimes were repeated in the regrowth phase. Sub-samples of the harvests were separated into leaves, stems and whole fractions for chemical analysis. Plant height and stem diameter were significantly (P< 0.05) influenced by harvesting regimes in both the initial establishment and regrowth phase. Number of branches and biomass yield were also significantly (P< 0.05) affected by harvesting regimes in the initial establishment but not at regrowth. All chemical components analyzed were influenced significantly (P< 0.05) by harvesting regimes, fraction and their interactions except for the interaction for dry matter (DM) in the initial establishment. Crude protein (CP) differed (P<0.05) in both establishments. Harvesting *M. oleifera* at 16 weeks in the initial establishment recorded the highest biomass yield (568kg DM/ha) whilst the harvest at 20 weeks recorded the highest bimass yield (400kg DM/ha) in the regrowth.

Key words: Biomass yield, chemical composition, fraction, Ghana, harvesting regimes, *Moringa oleifera*

Résumé

L'étude a été menée pour évaluer le rendement massique et la composition en éléments nutritifs de la réponse de Moringa oleifera à différents régimes de coupe dans la zone de savane du Ghana. Trois régimes de récolte ont été imposés à l'établissement initial dans une conception en bloc complet randomisé qui comprenait la récolte à 12, 16 et la récolte à 20 semaines après la plantation. Les régimes de coupe ont été répétés dans la phase de repousse. Des sous-échantillons des récoltes ont été séparés en feuilles, tiges et fractions entières pour analyse chimique. La hauteur de la plante et le diamètre de la tige ont été significativement (P < 0,05) influencés par les régimes de récolte à la fois dans la phase d'établissement initial et dans la phase de repousse. Le nombre de branches et le rendement en biomasse ont également été significativement (P < 0,05) affectés par les régimes de récolte dans l'établissement initial mais pas lors de la repousse. Tous les composants chimiques analysés ont été influencés de manière significative (P < 0,05) par les régimes de récolte, la fraction et leurs interactions, à l'exception de l'interaction pour la matière sèche (MS) dans l'établissement initial. La protéine brute (CP) différait (P<0,05) dans les deux établissements. La récolte de M. oleifera à 16 semaines dans l'établissement initial a enregistré le rendement de biomasse le plus élevé (568 kg MS/ha) tandis que la récolte à 20 semaines a enregistré le rendement de bimasse le plus élevé (400 kg MS/ha) dans la repousse.

Mots clés: Rendement en biomasse, composition chimique, fraction, Ghana, régimes de récolte, *Moringa oleifera*

Introduction

Ruminants derive a large proportion of their nutrients from growing natural pasture in most developing countries. The yields of these pastures are not adequate to meet ruminants' nutritional requirements especially in the dry season. This has called for the exploitation of other sources of feed. Trees and browse species such as *Albizia lebbeck, Leaucaena lecocephala, Entada Africana, Pterocarpus erinaceus,* and *Securinega virosa* have been used as feed in Ghana (Ziblim, 2015; Ansah, 2015).

Asaolu *et al*. (2012) stated that, multipurpose trees can also be used as cheap protein supplements which can increase digestibility, voluntary intake and overall performance of animals fed low quality feeds. *Moringa oleifera* is one of the most important trees in the world, as almost every part of the tree can be used as food, medication and industrial purposes (Khalafalla *et al*., 2010). The yield potential of Moringa makes it ideal for forage production. Further, Moringa possesses minor amount of anti-nutritional elements, has high crude protein content and contains substantial quantities of vitamins A, B, and C in the foliage (Nouman *et al*., 2014). The crude protein and organic matter are freely digestible in the rumen and/or in the intestine (Worku, 2016). However, the harvesting of Moringa forages at different stages of their growth, their regrowth, the nutritional composition and how the stage at which they are harvested affect the growth performances of the plants and animals have not been well studied in savannah zone of Ghana. Hence the rationale of this study.

Materials and Methods

Study area. This study was conducted at the Horticultural experimental field, Nyankpala Campus of the University for Development Studies. The study area has mean annual rainfall of 1043 mm distributed fairly from April to late November. Temperatures generally fluctuate between 15˚C (minimum) and 42˚C (maximum).

Experimental set-up and data collection . The field was first ploughed with tractor and later poultry manure was applied to the field at a rate of 0.4 kg/m^2. *Moringa oleifera* seeds were nursed in nursery bags and then transplanted onto the experimental plots two weeks after nursing.The seeds were slected from the local varieties in the savanna zone of Ghana. The selection was based on visual appearance of the seeds (seed coat, seed size, seed weight, colour and other physical purity).

The field was divided into 18 plots in a randomized complete block design with each plot measuring 5m×3m. Three harvesting regimes (12, 16 and 20 weeks) were assigned to the plants and replicated three times in each block. The plants were harvested at a stubble height of 50 cm.

Five (5) plants were randomly selected on each plot excluding those on the borders for the estimation of plant height, number of branches and stem girth diameter. Measurements commenced at four (4) weeks after planting to ensure plants were firmly rooted.

Plant height was measured from the base of the plant to the tip of the plant with a measuring tape whiles stem girth diameter was taken from the circumference of the base of the selected plant using veneer caliper. Number of branches was measured by simple arithmetic counting. The agronomic data were collected also in the regrowth phases of each treatment.

Herbage yield (Dry Matter). The plants were harvested at 12, 16 and 20 weeks using a machete at a height of 50 cm above ground and the total harvest per plot was weighed. Sub-samples (200g) were taken from each plot and chopped into short lengths (2-5cm) for dry matter determination using the AOAC (1990) procedure. Biomass yield of each plot was calculated on dry matter basis by multiplying the percentage dry weight of the sub-samples from the whole fraction to the fresh weight of the harvest from each plot.

Chemical analysis. Sub samples of the harvest from each plot was divided into whole plant, stem and leaf fractions. The chopped samples were milled using a Hammer mill (Brabender, Germany) to pass through a 2 mm and then 1 mm sieve screens sequentially for laboratory analysis as outlined by Goering and Van Soest (1970) and AOAC (1990). Determination of ash and crude protein were done according to AOAC (2000) method. Neutral detergent fibre and ADF were determined from residual ash through sodium sulfite and - amylase using the procedure of Van Soest *et al.* (1991) and this was done using Ankom200 fibre analyser (Method 5 for ADF and method 6 for NDF).

Data analysis. The one-way analysis of variance (ANOVA) from Genstat 18th edition was used for analysing the agronomic data in the field experiment. Chemical composition were analysed as two- way ANOVA. F-test means which were significant were separated at 5 % significance level using Tukey.

Results

Growth and yield of *Moringa oleifera*. Figure 1 shows the plant height of *Moringa oleifera* at three harvesting regimes. Harvesting at 16 weeks recorded the highest plant height whereas harvesting at 12 weeks had the least plant height in the initial establishment. In the regrowth, harvest at 20 weeks recorded the highest plant height with no significant difference between plants harvested at 12 and 16 weeks.

Number of branches. The number of branches of *Moringa oleifera* at different harvesting regime is shown in Figure 2. From the initial establishment, plants harvested at 16 weeks recorded the highest number of branches followed by plants harvested at 12 weeks with plants harvested at 20 weeks recording the least number of branches. There were no significant differences in number of branches between different harvesting regimes in the regrowth.

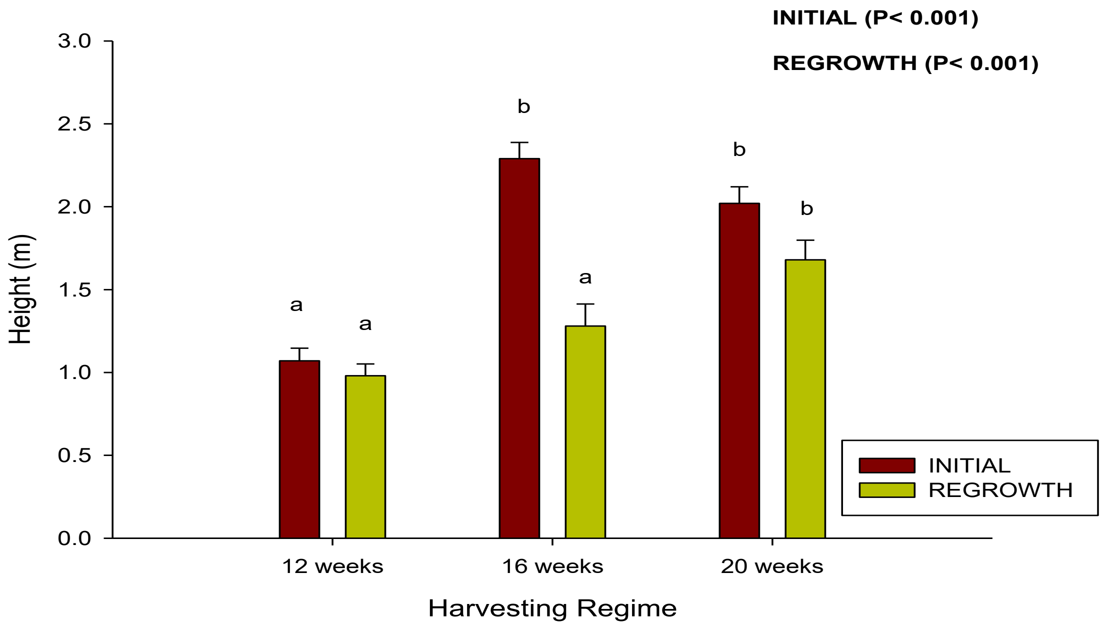

Figure 1. Plant height of *Moringa oleifera* at harvest

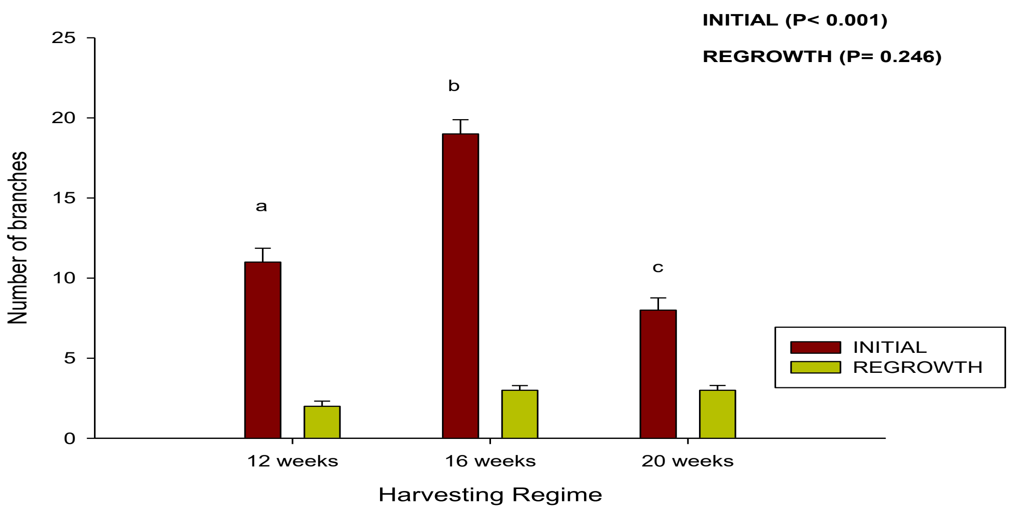

Figure 2. Number of branches of *Moringa oleifera* at harvest

Figure 3 shows the stem diameter of *Moringa oleifera* at three harvesting regimes. Harvesting at 16 weeks recorded the highest stem diameter with 12 weeks recording the least stem diameter. There was no significant difference between plants harvested at 16 weeks and 20 Weeks in both the initial establishment and regrowth.

The biomass yield of *Moringa oleifera* is shown in Figure 4. The highest biomass yield was recorded in harvesting at 16 weeks followed by 20 weeks where the lowest was recorded in the harvest at 12 weeks in the initial establishment. At regrowth, the highest biomass yield was recorded in harvesting at 20 weeks with the least biomass yield observed in harvesting at 12 weeks. There was however no significant difference between the three harvesting regimes in the regrowth.

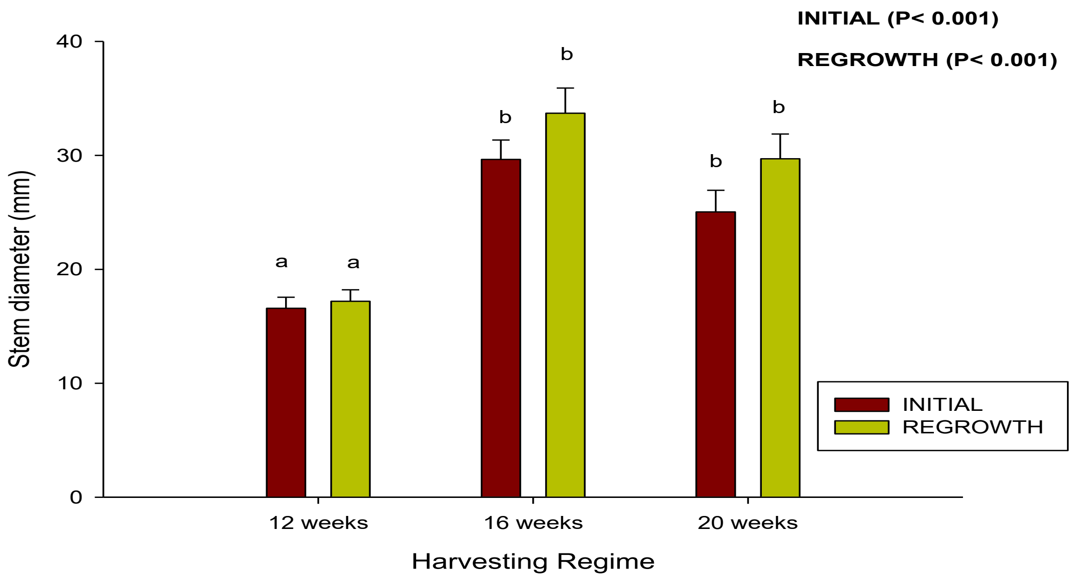

Figure 3. Stem diameter of *Moringa oleifera* at harvest

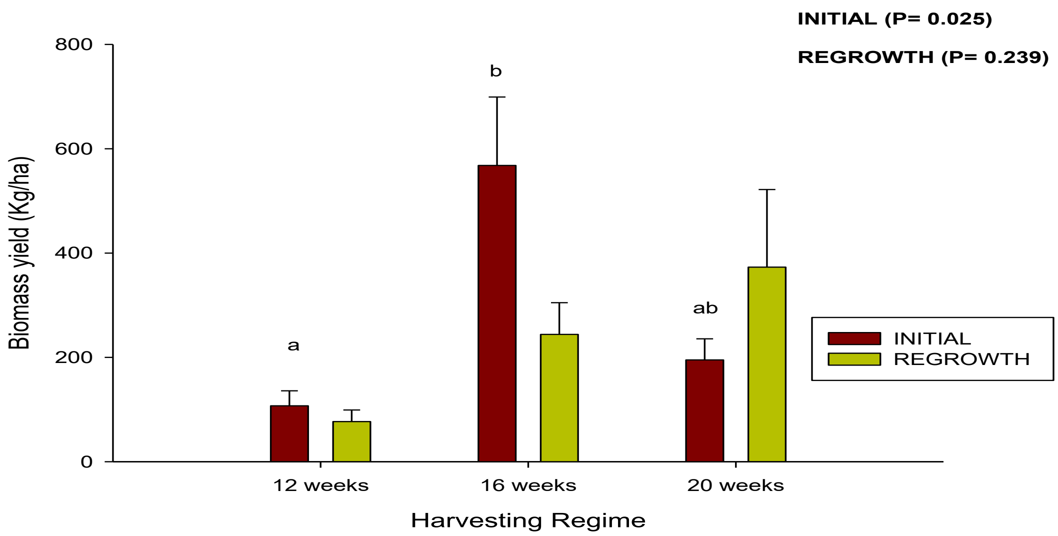

Figure 4. Biomass yield of *Moringa oleifera* at harvest

Table 1. Chemical composition of *Moringa oleifera* as influenced by harvesting regime on dry matter basis (g/kgDM) at initial establishment

Harvesting regime	Botanical Fraction	Parameters (g/kgDM) DM	CP	NDF	ADF	HEM	ASH
12 Weeks	Leaf	262.8	312.5^{h}	377.4^{c}	113.2^{b}	264.2^{g}	70.3^{d}
	Stem	213.6	112.2^{b}	460.5^{f}	280.3^{e}	180.5^{d}	51^{b}
	Whole	238.3	257.2^{g}	415.1^{d}	132.1^{c}	283.1^{h}	74.7^{e}
16 Weeks	Leaf	273.7	232.7^{e}	280.5^{a}	80.5^{a}	200.5^{f}	85^{f}
	Stem	234.7	94.3^{a}	627.5^{i}	431.4^{h}	196.1^{e}	30.3^{a}
	Whole	242.8	163.5^{d}	450.9^{e}	294.2^{f}	156.9^{b}	70.3^{d}
20 Weeks	Leaf	272.1	234.3^{f}	320.5^{b}	140.5^{d}	180.5^{d}	100.3^{g}
	Stem	250.5	114.0^{c}	604.1^{h}	437.8^{i}	166.7^{c}	50.3^{b}
	Whole	260.0	113.6^{c}	489.4^{g}	361.8^{g}	127.7^{a}	60.3^{c}
S. e. d		10.29	0.37	0.22	0.22	0.19	0.55
P value	Harvesting regime	0.006	< .001	< .001	< .001	< .001	< .001
	Fraction	< .001	< .001	< .001	< .001	< .001	< .001
	Age x Fraction	0.36	< .001	< .001	< .001	< .001	< .001

CP= Crude Protein, DM= Dry Matter, NDF= Neutral Detergent Fibre, ADF= Acid Detergent Fibre, HEM= Hemicellulose, P value = 0.05

Table 2. Chemical composition of *Moringa oleifera* as influenced by harvesting regime on dry matter basis (g/kgDM) at regrowth

Harvesting Regime	Botanical Fraction	Parameters (g/kgDM) DM	CP	NDF	ADF	HEM	ASH
12 Weeks	Leaf	264.0	308.8^{i}	244.9^{a}	122.5^{d}	122.5^{a}	84.7^{c}
	Stem	187.0	83.2^{b}	489.4^{g}	319.2^{i}	170.3^{b}	60.3^{b}
	Whole	228.0	271.2^{h}	313.7^{c}	137.3^{f}	176.4^{c}	100.3^{d}
16 Weeks	Leaf	272.0	211.0^{f}	319.2^{d}	106.4^{b}	212.7^{e}	81.0^{c}
	Stem	262.0	67.2^{a}	612.3^{i}	306.2^{h}	306.3^{h}	45.3^{a}
	Whole	262.0	170.4^{d}	375.3^{e}	125.4^{e}	250.5^{f}	53.7^{ab}
20 Weeks	Leaf	576.0	268.4^{g}	411.7^{f}	78.5^{a}	333.4^{i}	80.3^{c}
	Stem	206.0	122.5^{c}	547.2^{h}	283.1^{g}	264.2^{g}	60.7^{b}
	Whole	228.0	200.5^{e}	296.2^{b}	111.2^{c}	185.2^{d}	80.3^{c}
S. e. d		58.3	0.27	0.07	0.08	0.14	3.96
P value	Harvesting regime	0.015	< .001	< .001	< .001	< .001	< .001
	Fraction	< .001	< .001	< .001	< .001	< .001	< .001
	Age x Fraction	0.002	< .001	< .001	< .001	< .001	< .001

CP= Crude Protein, DM= Dry Matter, NDF= Neutral Detergent Fibre, ADF= Acid Detergent Fibre, HEM= Hemicellulose, P value = 0.05

Chemical composition. Table 1 shows the results of the chemical composition of *Moringa oleifera* harvested at three regimes for initial establishment. Two-way interaction effect was observed in all chemical parameters analyzed except DM. The leaf fraction of harvesting at 12 weeks recorded the highest CP (312.5g/KgDM) whereas the highest NDF (627.5g/KgDM) and ADF (437.8g/KgDM) were recorded in the stem fractions of harvest at 16 and 20 weeks, respectively.

The chemical composition of *Moringa oleifera* under different harvesting regime in the regrowth is presented in table 2. There were two-way significant interaction between harvesting regime and fraction in all chemical parameters measured.

The leaves at 12 weeks recorded the highest CP (308.8g/KgDM) whereas the lowest CP (67.2g/KgDM) was observed in the stems at 16 weeks. The highest NDF and ADF were respectively recorded in the stems at 16 and 12 weeks.

Discussions

Growth and yield of *Moringa oleifera*. The result on plant height, stem diameter, number of branches and biomass yield can be attributed to the period of harvest. Shoaib *et al*. (2013) stated that the growth and physiology in plants are mostly influenced by the period and stage of harvesting. This is consistent with the agronomic results obtained in this study. Higher plant height, number of branches and stem diameter obtained as the harvesting regime increases also agree with reports from Molla *et al*. (2018) that as plants continue to grow, there is possibility of the development of new tillers and increase in the height of the already formed tillers. The biomass yield recorded in the initial harvest at 12 weeks is similar to values reported by Sanchez *et al*. (2006) when harvesting was done 75 days after planting. However, higher biomass yield at16 weeks in this research contradicts that obtained by Amaglo (2006) who reported that higher biomass yield of Moringa can be obtained at a harvesting regime of 35 – 40 days. The difference could be attributed to the planting densities.

The results obtained in the regrowth as regards to plant height, number of branches and stem diameter can be attributed to both environmental and physiological factors. Higher plant height, number of branches and stem diameter obtained at regrowth 16 and 20 weeks explains the phenomenon of organic reserves in forages. Vast quantities of carbon (C) and nitrogen (N) reserves accumulate in specialized storage organs located near or below the soil surface as stated by Tainton (2000). Higher biomass yield recorded in regrowth at 20 weeks agrees with the findings of Amaglo (2006) who also experienced higher biomass yield of moringa in longer harvesting regime in the regrowth.

Chemical composition of *Moringa oleifera*. The significant differences observed with respect to growth and fraction in dry matter could be attributed to the differences in nutrient contribution for biomass allocation in the plant organs. Leaf size, area and number are major attributes altering leaf and stem fraction of forages. Again differences in leaf to stem ratio may also contribute to the plants adaptability with climatic condition, growth and canopy structures under the growing condition at the various stages of their maturity. Coleman and Moore (2003) stated that as forages mature, the leaf to stem ratio declines causing changes in the chemical composition and a concomitant reduction in feed value.

Hence, it is not only the length of the growing period (harvesting regime) but also the season in a particular year which may have affected dry matter yield. However, the dry matter yield of the leaf fractions reported in this study is higher than the dry matter yield reported by Nouman *et al.* (2014) in both the initial establishment and the regrowth.

The CP values obtained in this study are comparable to those reported by Mendieta-Araica *et al.* (2013) in both the initial establishment and regrowth stage. Significant differences obtained in the CP in relation to age and fraction interaction conforms to reports from Adesogan *et al.* (2002) about stage of maturity and botanical fractions influence on the nutritional quality of forages especially on CP. The highest CP concentration recorded in the leaf fraction at regrowth 12 weeks may be attributed to the high supply of nutrients to the shoots of the plant at the early stages of development where growth is accompanied with high mitotic activity and there is strong demand for nutrients particularly nitrogen (Hodge *et al.*, 2009).

The NDF and ADF values of Moringa obtained in this study is higher than that reported by Nouman *et al.* (2014) but compares favorably with what has been reported in other tropical forages (Heuzé *et al.*, 2015). The high NDF obtained in the stem fraction is an indication of the fibrous nature of the fodder which enhances rumination and rumen microbial fermentation. Significant difference observed between the interaction of harvesting regime and fraction agrees with what was reported by Lounglawan *et al.* (2014).

According to Lounglawan *et al.* (2014) increasing the harvesting interval increases dry matter and the crude fiber, acid detergent fiber (ADF), neutral detergent fiber (NDF) and acid detergent lignin (ADL) level in the plant. But this phenomenon was true only for the stem and whole fractions but not the leaf fractions. Lower levels of NDF and ADF in the leaf fraction are in line with what was reported by Debela *et al.* (2011) in *Sesbania sesban* which is also a tree legume. Bakshi and Wadhwa (2007) indicated that the content and type of cell wall fractions in plants will influence dry matter intake and digestibility of the forage.

The trend of hemicellulose obtained in this study shows a similar trend to that reported by Kakengi *et al.* (2005). Thomas and Chamberlain (1990) stated that legumes contain a lower cell wall content, lower hemicellulose to cellulose ratio and a higher lignin content within the cell wall compared to grass species and this has been observed in Moringa which is a legume. Significant difference observed in the ash content agrees with findings of Sanchez *et al.* (2006) who also observed difference in ash concentration in moringa at different harvesting regimes. Many factors can iinfluence the concentration of mineral elements (ash) in plants, notably minerals in the soil and their availability to the plant, soil type and soil pH and stage of growth (Lukhele and Van Ryssen, 2003).

Conclusion

Harvesting *Moringa oleifera* at 12 weeks and 16 weeks gives better nutrient composition in initial and regrowth establishment, respectively. In terms of biomass yield, initial harvesting should be at 16 weeks whiles at regrowth should be done at 20 weeks.

Acknowledgement

This paper is a contribution to the Seventh Africa Higher Education Week and RUFORUM Triennial Conference held 6-10 December 2021 in Cotonou, Benin.

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