

Does harvesting *Urochloa* and *Megathyrus* forages at short intervals confer an advantage on cumulative dry matter yields and quality?

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Abstract

BACKGROUND: Due to increasing demand for livestock products in sub-Saharan Africa, increasing livestock productivity is a priority. The core constraint is limited availability of feed of good quality. We assessed optimal harvesting time of three improved grasses, two *Urochloa* lines (Basilisk a selection from wild population, Cayman – a hybrid, a product of breeding) plus Mombasa, a *Megathyrus* selection. All are released in Latin America and Kenya or in the registration in other regional countries. We assessed dry matter (DM) yields and quality at 4, 6, 8 and 12 weeks of age in two sites.

RESULTS: DM yields (in t ha⁻¹) were of the order Cayman (9.6–14.3) > Mombasa (8.0–11.3) > Basilisk (5.5–10.2) in one site, and Cayman (6.4–9.7) > Basilisk (4.9–7.6) > Mombasa (3.3–5.9) at site two. The harvesting regimes produced DM largely similar for weeks 4 and 6, 6 and 8, 8 and 12. Across the sites quality was of the order Cayman > Mombasa > Basilisk for neutral detergent fiber (NDF), metabolizable energy (ME) and crude protein (CP). With increasing harvesting interval, MJ ME ha⁻¹ and kg CP ha⁻¹ were inconsistent across both sites, but significant differences returned for MJ ME ha⁻¹ unlike kg CP ha⁻¹.

CONCLUSIONS: Harvesting at either 8 or 12 weeks is not recommendable as quality drops without an increase in DM yield that can compensate despite doubling and tripling time respectively, compared to 4 weeks. We recommend harvesting at 4 through 6 weeks for any of the three grasses based on yield against time, and demand at the intensified cut-and-carry smallholder systems.

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Keywords: forage quality; dry matter yield; harvesting interval

INTRODUCTION

Forage quality and quantity is key for success in livestock agriculture, especially in dairy production. Forage grasses constitute the bulk of the feeding providing nutrients, especially energy, for milk production. A wide range of forage options exists either as accessions for example from genebanks and, more recently, hybrids developed or bred to support livestock productivity. Ideally, these grasses should accumulate great forage biomass of acceptable quality, within a short growth period possible, thereby increasing forage resource and use efficiency, as in the case of perennials reducing establishment costs and shortening use intervals over time. With livestock intensification, forage technologies akin with the earlier characteristics are desirable to contribute to livestock roughages demand. By 2050, projections show that the demand for animal source foods¹ will double. An increase in demand for roughages matching the increase in milk and meat production is equally inevitable. Largely, and especially where smallholder dairy is practiced, for example under intensified cut-and-carry systems, forage demand is usually unmet.² In eastern Africa, the livestock annual feeds demand to the tune of 1.1 million tons to cater

for over 173 million heads of cattle,³ continues to grow as cattle numbers increase.⁴

Currently, there are efforts from national and international research organizations on validating and promoting the use of selected and improved forages to bolster forage production for improving livestock productivity. Forage species with realistic potential to increase feed resource base, in humid to semi-arid areas include species of *Urochloa* (syn. *Brachiaria*) and *Megathyrus maximus* (syn. *Panicum maximum*).^{5,6} While the agronomic and crop husbandry measures for the commonly used Napier grass under intensified production systems are well described,⁷ this is not the case for optimal harvesting stage, in view of dry matter (DM) and quality yields, for the improved forages in sub-Saharan Africa. Usually, as forage grows over time, biomass increases as quality declines; yet both quality and quantity are

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of importance.⁷ Optimal harvesting stage, defined by growth period, biomass yield and quality, present the most realistic argument for reaping benefits of cultivated forages. Usually, high fibers depress DM intake and further undesirably associated with low digestibility especially neutral detergent fiber (NDF).^{8,9} Most forage research does not take into consideration the three attributes simultaneously. Often DM yields and quality evaluations are without indication of growth-time competitiveness.¹⁰⁻¹² Of importance also is the agricultural context whereby most small-holder dairy farmers especially in east Africa practice cut-and-carry, harvesting forage and availing to confined cattle. As such, forages that can fit under such a context are desirable, for adoption and wide-scale use.

Therefore, taking into consideration the harvesting stage, with corresponding yield and quality over time, becomes critical to identify how various forages perform under a given production environment and context. This allows an informed choice by livestock producers. We therefore assessed two grass genus – *Urochloa* and *Megathyrus*. More specifically, we assessed two *Urochloa* lines, a cultivar and a hybrid, and one *Megathyrus* cultivar. We hypothesized that harvesting at short intervals accumulates similar biomass yields as long intervals, but presents better forage quality under a cut-and-carry context.

MATERIALS AND METHODS

Sites description

Two sites in central Meru county in Kenya, one linked to an Agricultural Training Center – Kaguru and the other to a farmers' dairy cooperative – Chure, were used for the current study. Kaguru site attains average annual precipitation of 1891 mm according to 15 years of data. Elevation is 1500 m above sea level. The closest weather station to Chure site is Wathine Kithurine located 1829 m above sea level and 1940 mm rainfall from 15 years of records. While both sites lie on the leeward side of mount Kenya, their marked abrupt differences are in altitude, being higher at Chure, and similarly for mean temperatures at 17.6–19.2 °C for Chure lower than 18.2–20.6 °C at Kaguru. Chure is located in coffee–tea zone unlike the main coffee zone for Kaguru. Soils in both sites are largely fertile volcanic, but very erodible.¹³ Small-holder dairy is important in the areas and animals are kept in sheds where they are provided with cut-and-carry forages.

Trial design, treatments, and management

At planting in March 2018, land preparation involved manually digging with hoe to depths of about 0.2 m. Because of small seed sizes, shallow furrows of about 0.02 m spaced at 0.03 m row-to-row done with wooden pegs applied. Within each plot of 6 m × 5 m, inorganic MEA fertiliser® (NPK fertiliser 23:23:0) was applied at the rate of 50 kg N ha⁻¹ followed by spreading forage seed at 8 kg ha⁻¹ for *Urochloa* species (described later) and at 3 kg ha⁻¹ for *Megathyrus*. Using the already established *Urochloa* and *Megathyrus* demonstration plots planted in the sites described earlier, we marked out plots of 3 m × 5 m for every treatment and every harvesting interval (4, 6, 8, and 12 weeks). Each treatment had three replicates, leading to 72 plots across the two sites, laid out in a randomized complete block design. Forage treatments were Basilisk, Cayman, Mombasa that is, an *Urochloa* selection, an *Urochloa* hybrid (*Brachiaria ruziziensis* × *B. decumbens* × *B. brizantha*) and a *Megathyrus* selection, respectively. We uniformed all the plots by cutting back to a stubble height of about 10 cm on January 28, 2019 at Kaguru and February 14, 2019 at

Chure. We prepared harvesting scheduling for both sites from the standardization dates, for the next 6 months (24 weeks). As such, the number of cuts/harvestings were 6, 4, 3 and 2 for the harvesting intervals of 4, 6, 8 and 12 weeks respectively. Because 24 is a multiple of all the harvesting intervals, the last harvesting date for all harvesting regimes per site converged to the same date, July 15, 2019 for Kaguru and August 1, 2019 for Chure. Throughout the trial period, we kept all the plots weed-free by manually weeding the plots. We top dressed once at the beginning of the 24 weeks with calcium ammonium nitrate fertilizer (26% nitrogen) at a rate of 300 g per plot equivalent to 200 kg ha⁻¹. At no time did we observe disease or pest challenge.

Dry matter yield determination

Harvesting for DM yield determination followed the scheduled dates as per the harvesting treatments of 4, 6, 8 and 12 weeks. Harvesting was maintained at 10 cm stubble height. All forage biomass was harvested and fresh weight determined with a digital weighing balance (KERN CH 50 K50 with 10 g precision) and recorded. Samples of about 450 g from every plot were put on paper sample bags after recording weight. We later dried the samples to constant weight at 65 °C for 48 h to determine DM content. We then ground the samples to pass 1 mm sieve and kept for quality analysis.

Forage quality analysis

Near-infrared spectroscopy (NIRS) at Crop Nutrition Laboratory Services Ltd, Limuru, Kenya, did quality analysis (<https://croppnuts.com/service/animal-feed-analysis/>). Key attributes analyzed include metabolizable energy (ME), crude protein (CP), NDF, acid detergent fiber (ADF), fat (%) and ash (%). From DM yield, ME and CP, we derived two metrics that is metabolizable yield per hectare (MJ ME ha⁻¹) and CP yield per hectare (kg CP ha⁻¹).

Data analyses

We managed all data in Microsoft Excel and performed one-way analysis of variance (ANOVA) and general linear regression in GenStat version 18 statistical. Further, we generated where applicable orthogonal contrasts and polynomials for biomass yields. The fixed variable were site, forage type and harvesting regime of which they were at two, three and four levels respectively. Random variable was biomass yield, with repeated measures taken from the plots coinciding with the harvesting intervals. The single factor ANOVA model followed as: $y_{ij} = \mu_j + \epsilon_{ij}$.

Where y is a key attribute of a forage type measured in site i under harvesting regime j . While μ is the mean of a key attribute for the j th harvesting regime.

Tukey HSD (honestly significant difference) test was applied as a *post hoc* pairwise comparison test to assess significant differences between harvesting regimes. For all the statistical analyses performed, differences were considered significant at $P < 0.05$.

RESULTS

The forage grasses accumulated variable DM over the growth period of 6 months (Fig. 1). At 4 weeks interval (six harvests), the biomass production order was Cayman > Basilisk > Mombasa at Chure site (Fig. 1(a)). The order at Kaguru was slightly different Cayman ≈ Mombasa > Basilisk (Fig. 1(b)). While Basilisk produced similar biomass at both sites at 4 weeks interval, Cayman and Mombasa produced more at Kaguru than Chure.

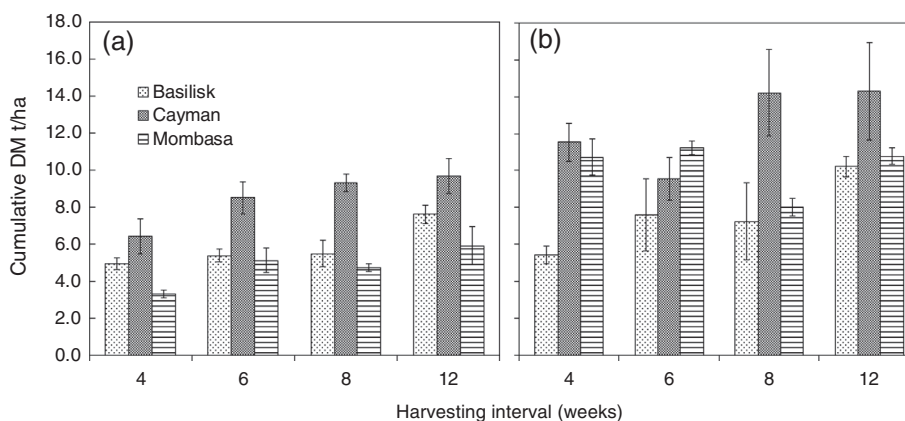


Figure 1. Means (\pm standard error) for forages (Basilisk, Cayman and Mombasa) cumulative dry matter (DM) yields ($t\ ha^{-1}$) from Chure (a) and (b) Kaguru trial sites, at 4, 6, 8 and 12 weeks harvesting intervals in 2018.

Table 1. Quality attributes for Basilisk, Cayman and Mombasa forage grasses from Chure and Kaguru trials sites from pooled data at 4, 6, 8 and 12 weeks harvesting regimes

Parameter	Basilisk	Cayman	Mombasa	P Value	lsd
<i>Chure</i>					
Energy ($MJ\ kg^{-1}$)	8.6 \pm 0.1	8.5 \pm 0.1	8.5 \pm 0.1	0.94	0.42
DM ($g\ kg^{-1}$)	865 \pm 2.0	863 \pm 3.0	868 \pm 3.0	0.74	11.13
Protein ($g\ kg^{-1}$)	204.6 \pm 2.5	202.2 \pm 4.6	217.3 \pm 4.2	0.24	19.28
ADF ($g\ kg^{-1}$)	351 \pm 2.0	352 \pm 3.0	393 \pm 3.0	<0.001	11.66
NDF ($g\ kg^{-1}$)	440 \pm 7.0	441 \pm 12.0	477 \pm 7.0	0.16	44
Fat (%)	4.5 \pm 0.1	4.4 \pm 0.1	4.6 \pm 0.1	0.52	0.4
Ash (%)	16.1 \pm 0.3	15.3 \pm 0.5	16.4 \pm 0.1	0.38	1.66
ME ($MJ\ ha^{-1}$)	50 222.4 \pm 1729	71 610.1 \pm 2162	40 472.9 \pm 1691	<0.001	9334.5
kg CP ha^{-1}	1190.2 \pm 37.7	1684.7 \pm 49.1	1020.6 \pm 39.4	<0.001	211.3
kg fat ha^{-1}	262.2 \pm 10.2	364.4 \pm 11.3	217.3 \pm 9.0	<0.001	50.9
<i>Kaguru</i>					
Energy ($MJ\ kg^{-1}$)	7.2 \pm 0.1	7.9 \pm 0.1	7.1 \pm 0.03	<0.001	0.4
DM ($g\ kg^{-1}$)	882 \pm 10.0	871 \pm 10.0	885 \pm 10.0	<0.001	5.59
Protein ($g\ kg^{-1}$)	151.0 \pm 4.0	169.3 \pm 3.8	142.7 \pm 3.2	0.02	18.34
ADF ($g\ kg^{-1}$)	372 \pm 30.0	366 \pm 30.0	407 \pm 10.0	<0.001	11.61
NDF ($g\ kg^{-1}$)	535 \pm 50.0	479 \pm 80.0	566 \pm 30.0	<0.001	29.28
Fat (%)	3.3 \pm 0.1	4.0 \pm 0.1	3.3 \pm 0.04	0.00	0.39
Ash (%)	13.1 \pm 0.2	14.1 \pm 0.3	15.0 \pm 0.2	0.01	1.14
ME ($MJ\ ha^{-1}$)	54 467.3 \pm 3146	95 969.5 \pm 3704	72 175.8 \pm 1870	<0.001	14 981.4
kg CP ha^{-1}	1134.3 \pm 68.1	2057.5 \pm 76.5	1460.5 \pm 56.5	<0.001	336.5
kg fat ha^{-1}	250.5 \pm 14.6	477.4 \pm 15.2	331.7 \pm 8.8	<0.001	65.7

Means followed by \pm standard error.
DM, dry matter; ADF, acid detergent fiber; NDF, neutral detergent fiber; ME, metabolizable energy; CP, crude protein.

At 6 weeks interval (four harvests), the order at Chure was maintained except Basilisk and Mombasa accumulated similar biomass. The trend reversed at Kaguru with Mombasa producing most biomass while Basilisk and Cayman had similar biomass (Fig. 1(b)). However, Cayman had a drop at 6 weeks compared to accumulation at 4 weeks though not significant. Although we did not measure tillering, senescence and rainfall, this could have coincided with reduced soil moisture affecting Cayman biomass more than the other grasses. Comparing 6 weeks intervals at Chure and Kaguru, Mombasa produced significantly more at Kaguru, while the other two produced similar DM yields. At 8 weeks intervals, the biomass production trend at Chure was

similar to that of 6 weeks intervals in same site. Comparing 8 weeks intervals at both sites, Basilisk produced similar biomass, while Cayman and Mombasa at Kaguru produced significantly more DM than at Chure. At 12 weeks intervals, trend at Chure was maintained as Cayman > Basilisk > Mombasa while that at Kaguru was Cayman > Mombasa \approx Basilisk. Across the four harvesting regimes/intervals, Basilisk produced similar DM at both sites except at week 12 interval that had more DM yields than the rest. For Cayman, similar biomass at Chure was at 6, 8 and 12-weeks intervals, all of which had more biomass than the 4 weeks interval (Fig. 1(a)). At Kaguru, was low for Cayman in the 6 weeks category and similar yields at 4, 8 or 12-weeks categories (Fig. 1(b)).

Table 2. Quality attributes including metabolizable energy, crude protein, fat and fibers for Basilisk, Cayman and Mombasa forage grasses grown at Chure and Kaguru trial sites when harvested at 4, 6, 8 and 12 weeks intervals

Site	Harvesting age (weeks)	Basilisk	Cayman	Mombasa	P Value	lsd
ME MJ kg⁻¹ (MJ ME ha⁻¹)[†]						
Chure	4	8.6 (42367) ^{ab}	9.3 (59618) ^a	8.8 (29338) ^b	0.022 (0.337)	0.45 (23065)
	6	8.6 (46454) ^b	8.9 (75670) ^a	8.9 (45417) ^b		
	8	8.4 (48944) ^b	8.9 (77949) ^a	8.6 (40833) ^b		
	12	7.6 (63124) ^{ab}	8.3 (73204) ^a	7.9 (46304) ^b		
Kaguru	4	7.6 (41240) ^b	8.5 (97271) ^a	7.3 (77485) ^a		
	6	7.5 (56814) ^a	8.4 (80302) ^a	7.1 (79642) ^a		
	8	7.1 (51248) ^b	7.6 (107830) ^a	7.0 (56261) ^{ab}		
	12	6.7 (68567) ^a	6.9 (98474) ^a	7.0 (75315) ^a		
CP g kg⁻¹ (kg CP ha⁻¹)[†]						
Chure	4	210 (1040) ^{ab}	234 (1503) ^a	243 (815) ^b	0.66 (0.312)	22.3 (543.2)
	6	201 (1091) ^a	216 (1835) ^{ab}	228 (1170) ^b		
	8	194 (1200) ^b	219 (1802) ^a	215 (1016) ^b		
	12	165 (1429) ^a	188 (1599) ^a	184 (1080) ^a		
Kaguru	4	168 (919) ^b	183 (2090) ^a	169 (1804) ^a		
	6	167 (1272) ^a	193 (1855) ^a	149 (1676) ^a		
	8	145 (1079) ^a	158 (2237) ^a	130 (1041) ^a		
	12	124 (1267) ^a	143 (2048) ^a	123 (1321) ^a		
Fat percentage (kg fat ha⁻¹)[†]						
Chure	4	4.2 (208.8) ^{ab}	5.0 (320.1) ^a	4.8 (159.1) ^b	0.009 (0.44)	0.40 (108.6)
	6	4.4 (236.5) ^b	4.8 (404.5) ^a	4.7 (240.7) ^b		
	8	4.3 (277.4) ^b	5.0 (402.2) ^a	4.9 (229.8) ^b		
	12	3.4 (326.0) ^a	4.3 (330.6) ^a	4.1 (239.7) ^a		
Kaguru	4	3.6 (197.4) ^c	4.5 (515.0) ^a	3.2 (337.2) ^b		
	6	3.6 (276.1) ^a	4.6 (439.6) ^a	3.5 (397.7) ^a		
	8	3.1 (228.6) ^b	3.7 (512.1) ^a	3.3 (264.5) ^b		
	12	2.9 (300.0) ^a	3.1 (442.8) ^a	3.0 (327.3) ^a		
NDF (%)						
Chure	4	43.0 ^a	37.1 ^b	45.2 ^{ac}	0.462	3.948
	6	44.2 ^{ac}	38.5 ^b	45.1 ^{ac}		
	8	46.8 ^{ac}	40.6 ^a	47.8 ^c		
	12	53.9 ^{de}	48.1 ^c	52.8 ^{de}		
Kaguru	4	51.8 ^d	44.2 ^{ac}	54.0 ^{de}		
	6	50.4 ^d	43.2 ^a	56.8 ^e		
	8	55.0 ^e	49.9 ^d	57.5 ^e		
	12	56.7 ^e	54.2 ^d	58.1 ^e		
ADF (%)						
Chure	4	35.0 ^a	33.8 ^a	38.6 ^{bc}	0.067	1.887
	6	35.4 ^a	37.0 ^b	38.9 ^{bc}		
	8	34.2 ^a	34.7 ^a	39.3 ^c		
	12	36.0 ^b	35.3 ^a	40.7 ^c		
Kaguru	4	36.2 ^b	35.2 ^a	40.6 ^c		
	6	36.6 ^b	36.2 ^b	40.7 ^c		
	8	37.3 ^b	36.4 ^b	40.8 ^c		
	12	38.8 ^{bc}	38.8 ^{bc}	40.7 ^c		

[†] Yield per hectare attributes (in brackets) for metabolizable energy (ME), crude protein (CP) and fat correspond to values in brackets along the rows. Means followed by different superscript lowercase letters with an attribute differ significantly at $P < 0.05$. NDF, neutral detergent fiber; ADF, acid detergent fiber.

For Mombasa, similar biomass production at Chure was observed for 6, 8 and 12-weeks categories, with the 4-weeks interval producing lower than the three categories. We observed similar trend at Kaguru except for the 8-weeks category that produced lower than either 6 or 8-weeks intervals. (Fig. 1(b)). We did not identify significant interactions between cutting regime, forage types and/or sites.

Quality attributes differed ($P < 0.05$) amongst the three forage types (Table 1). Cayman performed better than either Basilisk or Mombasa ranging from having low fibers, high ME, protein and fat, and subsequent high yield metrics for energy, protein and fat especially at Kaguru site. However, at Chure site, the same trend as at Kaguru except for similar values

Table 3. Contrast comparisons for cumulative dry matter for test forages and harvesting regime, and polynomials associated with harvesting regime

Comparison		Contrast	Significance
<i>Chure</i>			
Harvesting regime	4 and 6 weeks	-1.44 (0.93)	NS
	4 and 8 weeks	-1.61 (0.93)	NS
	4 and (6 and 8 weeks)	-3.1 (1.61)	NS
	4 and (6, 8 and 12 weeks)	-5.9 (2.28)	**
Cultivars/hybrids	Cayman versus Mombasa	3.7 (0.612)	***
	Cayman versus Basilisk	2.62 (0.612)	***
	Cayman versus (Basilisk and Mombasa)	6.3 (1.06)	***
Polynomials	Linear	-0.22 (0.94)	NS
	Quadratic	0.75 (0.329)	*
	Cubic	-0.92 (0.49)	NS
<i>Kaguru</i>			
Harvesting regime	4 and 6 weeks	-0.2 (1.56)	NS
	4 and 8 weeks	-0.6 (1.56)	NS
	4 and (6 and 8 weeks)	-0.8 (2.71)	NS
	4 and (6, 8 and 12 weeks)	-3.4 (3.83)	NS
Cultivars/hybrid	Cayman versus Mombasa	2.2 (1.13)	*
	Cayman versus Basilisk	4.8 (1.13)	***
	Cayman versus (Basilisk and Mombasa)	7.0 (1.96)	***
Polynomials	Linear	-0.56 (0.495)	NS
	Quadratic	0.73 (0.553)	NS
	Cubic	-0.43 (0.825)	NS

NS, not significant. Numbers in brackets in parentheses denote standard error.

* $P < 0.05$.

** $P < 0.01$.

*** $P < 0.001$.

between Cayman and Basilisk for energy, protein, fibers and fat contents.

When compared between Chure and Kaguru trial sites and across the four harvesting regimes (Table 2), Cayman had most ME content and yield per hectare at 4 weeks for either of the sites while Basilisk had the least. ME content dropped progressively from 4 weeks to 12 weeks intervals going as low as an average of 6.7 MJ ME kg⁻¹ at Kaguru for Basilisk at the 12 weeks' interval, and a yield of 29 338 MJ ME ha⁻¹ for 4 weeks interval Mombasa at Chure. CP content was largest for Mombasa (243 CP g kg⁻¹) at 4 weeks in Chure, and the yield 2237 kg CP ha⁻¹ for 6 weeks intervals for Cayman at Kaguru. For both sites, generally fat content was high in early harvesting intervals of 4 to 6 weeks before dropping by week 12 across the three grasses. We observed most fat content and yield in the order Cayman > Mombasa > Basilisk and higher values at Chure than Kaguru. Desirably, least fibers NDF and ADF were in the order Cayman < Basilisk < Mombasa while at site level Chure < Kaguru. Younger grasses at 4 weeks intervals accumulated least fibers that increased progressively by 12 weeks intervals. However, there was a drop in ADF for Cayman and Basilisk at Chure at week 8 possibly due to leaf ontogeny, and going up again at week 12 as leaves grew accumulating more fiber (Table 2).

Contrast comparisons for cumulative DM yields against cutting intervals, site, forage grasses and associated polynomials returned significance for forage cultivars/hybrid and 4-week harvest compared to other regimes only at Chure (Table 3). The cultivar/hybrid to a large extent therefore had influence on the DM yields obtained but not the harvesting regime.

Yields of ME and CP had a strong positive correlation at either four (i), six, (ii), eight (iii) or twelve (iv) weeks harvesting intervals (Fig. 2). At any of the cutting intervals, Cayman tended to have greater values than either Basilisk or Mombasa as visible from the symbols in the plots. Values for Basilisk compared to the other grasses tended to cluster at close to the plot origin at 4 weeks and slightly away from the origin under 12 weeks treatment. This was unlike at 6 and 8 weeks treatment for this grass where points were spread-out. For Mombasa, the values spread-out at all cutting time regimes except at 6-weeks treatment. At any of the cutting treatment, there was no clear shift of the value positions from the origin to further away suggesting age had little influence. Across all cutting regimes, the relations returned strong and positive R^2 explaining at least 85.8% at 12-week regime (Fig. 2).

DISCUSSION

The overall objective of comparing cumulative DM yields and quality from the three forage grasses harvested at either 4, 6, 8 or 12-weeks intervals was met. Our hypothesis of shorter cutting intervals producing similar biomass and quality was partially confirmed. There was a mix of responses. In some cases, the biomass was similar for some forage types especially at four, six and eight cutting intervals, similar to quality attributes. The differences among the grasses notwithstanding, cutting at either 4, 6 or 8 weeks produced comparable cumulative DM yields within both sites (Fig. 1(a,b)) and similar observation on contrast comparisons (Table 3). With exception of Mombasa at Chure, cutting Cayman

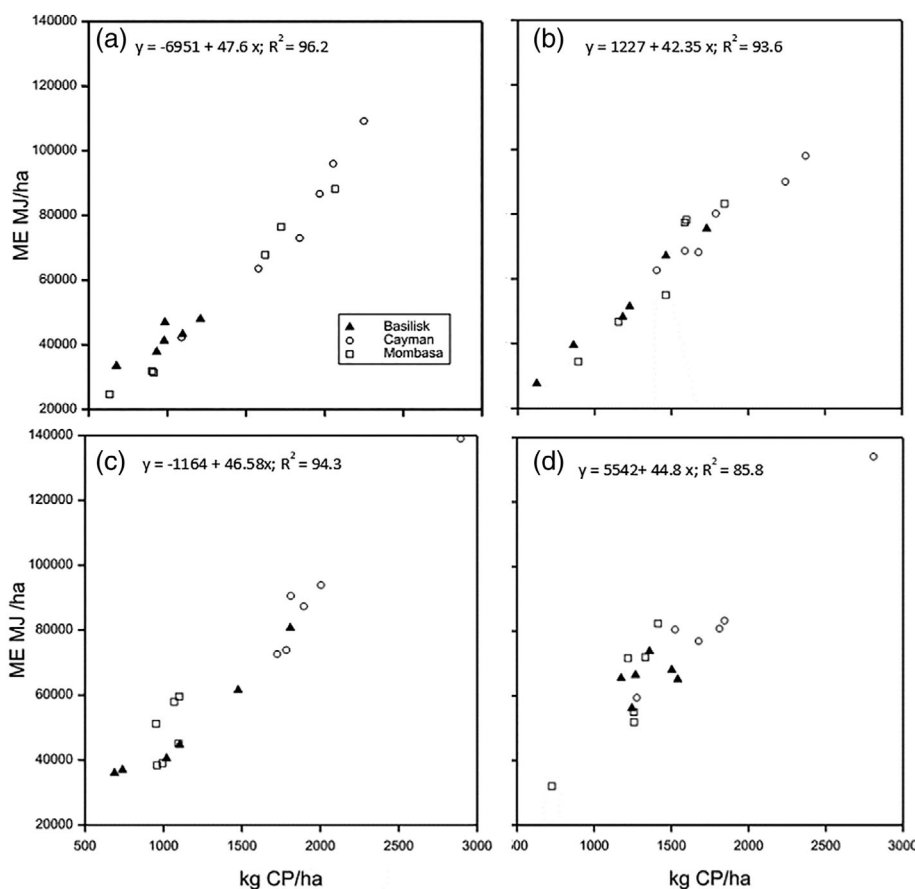


Figure 2. Regression between metabolizable energy (MJ ME ha⁻¹) and crude protein (CP) yields (kg CP ha⁻¹) for Basilisk, Mombasa and Cayman forage grasses. Data pooled for Chure and Kaguru trial sites for harvesting at 4 weeks (a), 6 weeks (b) 8 weeks (c) and 12 weeks (d).

or Basilisk at 4 or 6 weeks interval accumulated similar DM yields. As such, cutting at 6 or 8 weeks intervals did not confer appreciable cumulative yield gain compared to 4 weeks interval. Therefore, harvesting at the shorter 4-weeks interval would pragmatically help ameliorate frequent/daily forage demand at the farm level. Specifically, harvesting at 4 weeks allowed cutting six times, half the figure at 8 weeks. At 8 weeks intervals the average yields increase (%) between the two sites, compared to the 4-weeks interval, were by 22.5, 34 and 8.5 for Basilisk, Cayman and Mombasa respectively (Fig. 1), probably not warranting the lower harvesting frequency of three times, as opposed to six times in the 4-weeks interval, that favors seldom forage demand. Even further, at 12 weeks interval, only two cuttings would be possible in 6 months, exacerbating opportunities the livestock producer has to present forage to the animals. Therefore, harvesting at short intervals helps take advantage of the usually high growth rate in early age before later increasing at a decreasing rate. In intensified smallholder systems where forage cutting is based on daily demand, harvesting as early as possible is beneficial on two folds. First, it contributes to frequent forage supply for production, especially for lactating animals, second, paves the way for a much needed quality regrowth possible with perennial grasses as presented here.

Forage quality is key for utilization by livestock especially for the energy and protein that are vital for milk synthesis.¹⁴ The high yields per hectare of ME and CP (Fig. 2) makes Cayman hybrid a better choice amongst the three, boosted further by the high DM yield across the harvesting regimes and sites (Fig. 1), even when Cayman is compared to Basilisk and Mombasa in combination (Table 3).

Usually, increase in DM is inversely associated with quality,¹⁵ and therefore a forage that simultaneously sustains both quality and quantity without a serious compromise of either, is outstanding as portrayed by Cayman.

Considering forage biomass and quality, it is apparent that harvesting at either 8 or 12 weeks for any of the three grasses is not beneficial leaving harvesting at 4 or 6 weeks more feasible, or any time in between. Although DM yields at 6 or 8 weeks are comparable, the time lag of having to wait for the extra 2 weeks is undesirable in intensive dairy production where roughage demand is high. For the hybrid Cayman, the 14.2 t ha⁻¹ DM observed at Kaguru when harvested at 8 weeks intervals is comparable to 15.9 t ha⁻¹ DM reported by Mupenzi *et al.*⁵ for three cuts at similar growth interval for *Brachiaria* hybrid cv Mulato II. Given that the yields obtained in the current study are for a period of 6 months, doubling these figures could reliably give potential yields for a whole year. Utilizing Cayman at 4 weeks especially if it is under grazing would be appropriate, and when circumstances may not allow, getting up to 6 weeks is not profoundly punitive in quality. Given the agricultural context in the study area where manual cut-and-carry is the practice, harvesting at 6 weeks would probably offer better handling due to possible taller plants. Elsewhere under grazing system, foraging at 4–6 weeks for *Brachiaria* is recommended,¹⁶ falling within what we observe in this study. This is unlike for unimproved cultivars of the same species. For example, Enoch *et al.*¹⁷ recommended harvesting *Brachiaria ruziziensis* ecotype at 8 weeks following low quality at 12 weeks of growth. The increase in ME or CP yields in the current study are plausible

and similar observations have been reported. Wassie *et al.*¹⁸ recorded an increase in CP yield (44–67%) overtime (8 and 12 weeks of growth) at different highland altitudes in Ethiopia.

CONCLUSIONS

We partially proved our hypothesis where biomass was similar among four, six and eight cutting intervals except in some instances. The 12-weeks cutting produced higher biomass than either 4, 6 or 8-weeks regimes but not always, and depended on the forage type. Equally, cutting at 4, 6 or 8 weeks produced better quality than at 12 weeks. Our results therefore mean harvesting or grazing Basilisk, Cayman or Mombasa at 4 through 6 weeks in the area of study and by extension in other similar areas and ecologies is preferable, specifically due to more cuttings that come with better quality and contribute to addressing frequent forage demand characterized in smallholder dairy settings. Among the three forage types, Cayman presented greater yields and of better quality that would be preferable to Basilisk or Mombasa in the project sites. Further work would be worthwhile on longevity/persistency at the short harvesting interval, including how the grasses perform in other ecologies.

ACKNOWLEDGEMENTS

The authors would like to thank the managements of Chure Dairy Society and Kaguru Agricultural Training Center for allowing the field trial establishment on their land. The authors appreciate Frederick Muthomi who tirelessly helped with the data collection. Further, the team from SNV KMDP project namely Paul Mambo, Jansen Anton and Jos Creemers for suggestions that led to conception of this work deserve special complements. Finally, yet importantly, the authors express gratitude for the financial support from Livestock CRP of the CGIAR, through the Feeds and Forages Flagship that enabled them to accomplish this work.

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