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Original Research Article

On-farm evaluation of growth performance and nutritional values of *Brachiaria* hybrid and *Pennisetum purpureum* cultivars in Southern Highlands, Tanzania

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Abstract

Improved cultivars (cvs.) of *Brachiaria* hybrid and *Pennisetum purpureum* forages have been studied extensively in research settings but still there is a paucity of information about their on-farm performance. This study was therefore set to evaluate the on-farm performance of *Brachiaria* hybrid cvs. Cayman and Cobra, and *Pennisetum purpureum* cvs. ILRI 16835 and Ouma in the Southern Highlands of Tanzania. A total of 30 smallholder dairy farmers who cultivated these improved forage grasses were involved in this study. A 2 m × 2 m sub-plot was marked in established pasture plots and a standardised cut at a 5–7 cm stubble height was done at the beginning of this study. The forage growth performance was conducted from April–July, 2021 (dry period) in two phases of 6 weeks each. These cultivars were evaluated for their above-ground growth performance and nutritional values at the end of each phase. Plant height, leaf length, leaf widths, and number of tillers per plant among cultivars varied significantly ($p < 0.05$) while above-ground forage biomass did not vary among cultivars ($p > 0.05$). Crude protein values did not vary significantly among cultivars ($p > 0.05$), they were 131–141 g kg^{-1} dry matter (DM). These values were not able to meet the nutritional requirements of the lactating dairy cow. *Brachiaria* hybrid cv. Cayman had the lowest ($p < 0.05$) neutral detergent fibre (NDF, 539 g kg^{-1} DM) compared to other cultivars (545–571 g kg^{-1} DM), hence high digestibility. It was concluded that Cayman was the best cultivar for forage production in the Southern Highlands, Tanzania due to its low NDF content. However, lower biomass warrants mixing of Cayman with other feeds to meet the daily requirements of a lactating dairy cow.

Keywords: Smallholder dairy farmers; dairy cattle; nutrition; improved forage varieties; forage production; cultivation period; forage; biomass

INTRODUCTION

Brachiaria hybrids and *Pennisetum purpureum* are important grass species used as forage for livestock in many parts of the world. These grasses are preferred due to their high above-ground biomass yields from on-station reports of up to 11 tonnes of dry matter (DM) ha^{-1} $year^{-1}$ and 13 t DM ha^{-1} $year^{-1}$ for *P. purpureum* and *Brachiaria* hybrid, respectively (Zewdu, 2005; Jørgensen et al., 2010; Hare et al., 2015; Maleko et al., 2019). Additionally, they have good nutritional values with protein contents ranging from 100–139 g kg^{-1} DM for *P. purpureum* and 50–157 g kg^{-1} DM for *Brachiaria* hybrid, and their energy content was reported to be up to 10 MJ kg^{-1} DM (Zewdu, 2005; Hare et al., 2015; Mutimura et al., 2018; Maleko et al., 2019). Moreover, *Brachiaria* hybrids and *P. purpureum* are resilient to drought and some tropical diseases such as leaf rust, smut, and ergot. Both grass species perform well in poor soil conditions and have fast growth rates (Jørgensen et al., 2010; Kamidi et al., 2016; Kariuki et al., 2016; Nyambati et al., 2016; Ohmstedt and Mwendia, 2018). These qualities make them ideal for intensive small-scale dairy production in the tropics and sub-tropics (Maass et al., 2015; Mutimura et al., 2018).

International Centre for Tropical Agriculture (CIAT) has been promoting the adoption of these grass species among smallholder dairy farmers. They provided dairy farmers in the Southern Highlands of Tanzania with different *Brachiaria* hybrid and *P. purpureum* cultivars (cv.) namely *Brachiaria* hybrid cv. Cayman, *Brachiaria* hybrid cv. Cobra, *P. purpureum* cv. ILRI 16835 and *P. purpureum* cv. Ouma (CIAT, 2017). It was expected that the adoption of these cultivars will address seasonal feed shortages and reduce feeding costs among smallholder dairy farmers. These in return would improve dairy production, increase dairy household income, improve food security and reduce farm greenhouse gases emission (Maass et al., 2015; Mutimura et al., 2018; Hawkins et al., 2021). Although these cultivars have been studied extensively under research settings (Zewdu, 2005; Hare et al., 2015; Kamidi et al., 2016; Nyambati et al., 2016; Maleko et al., 2019) to warrant their adoption but little is known about their on-farm performance in Tanzania. Smallholder farmers rarely have the same resources or agronomic practices needed to ensure similar yields or growth performance as on-station (Twine et al., 2017; Hailemariam et al., 2022). It is therefore imperative to study these cultivars under smallholder dairy farm management and condition to establish which one performs better so as to enable sustainable and profitable dairy production.

Therefore, this study aimed to evaluate on-farm growth performance and nutritional values of *Brachiaria* hybrid and *P. purpureum* cultivars namely Cayman, Cobra, ILRI 16835, and Ouma in Southern Highlands, Tanzania. It was hypothesised that there would be no difference in growth and nutritional values among cultivars. Findings from this study could help farmers to select the best cultivars under farm conditions in Tanzanian Southern Highlands.

MATERIALS AND METHODS

Description of the study area

The field study was conducted in Southern Highlands, Tanzania which is located at latitude 6°–12° S and longitude 29°–38° E. This research covered six wards: Igowole and Mtwango in Mufindi district, Ikuna and Kichiwa in Njombe district, and Kiwira and Lufingo in Rungwe district.

The wards selection was motivated by the adoption and cultivation of improved forage cultivars in the area. The highlands receive 823–2850 mm annual rainfall which falls from November to April and mean

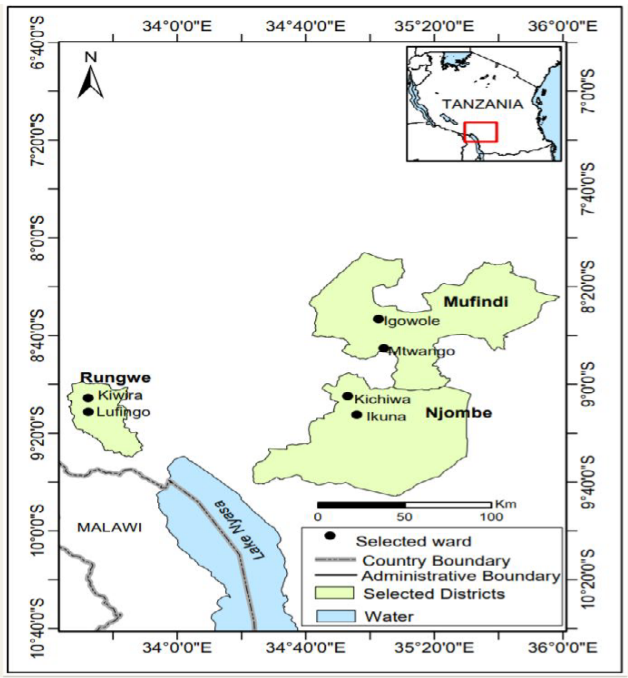

Figure 1. A map showing selected wards where pasture evaluation study was conducted in the Southern Highlands of Tanzania

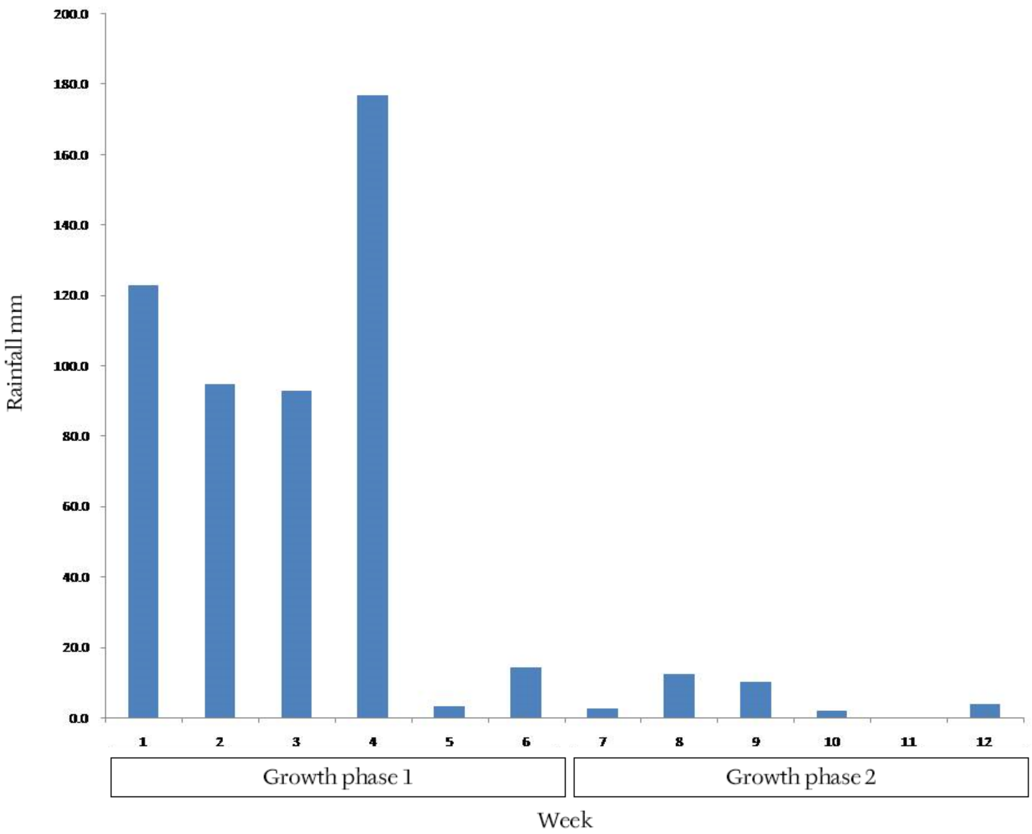

Figure 2. Weekly rainfall (mm) pattern in Southern Highlands, Tanzania during the experimental period

annual temperature between 13 °C and 19 °C with mist between May and August which are dry months (Mbululo and Nyihirani, 2012). The rainfall trend from April–July, 2021 when the study was conducted is shown in Figure 2.

Topsoil (0–20 cm) had 0.2–0.3 % total nitrogen (adequate), 0.03–8.7 mg kg^{-1} available phosphorus (low), 0.2–0.6 ppm exchangeable potassium (low) and acidic soil (pH < 5.6) in cultivated plots before study commencement (Mteta et al., 2022).

Study design

Purposive sampling was used to select farmers who were cultivating *Brachiaria* hybrid cvs. Cayman and Cobra, and *P. purpureum* cvs. ILRI 16835 and Ouma grasses. The planting materials were supplied by CIAT-Climate Smart Dairy Project on different occasions from early 2018 to late 2019. Thirty farmers were selected to participate in this study, whereby five farmers were serving as replicate per ward. Sampled farmers were cultivating all four cultivars and had a plot exceeding 256 m^2 for each cultivar. Forages were planted 50 cm apart between and within rows. Brachiaria hybrid was established using seeds or splits while Pennisetum purpureum was established solely from splits. A 2 m × 2 m subplot was marked at the centre of the selected pasture plot and demarcated using manila rope. Sub-plots were standardised by cutting fully established grasses to 5 cm and 7 cm height above ground for *Brachiaria* hybrid and *P. purpureum* cultivars, respectively. The two cut heights were selected because of their successful regeneration rate (Jørgensen et al., 2010; Nyambati et al., 2016). The forage performance study was conducted in two phases of 6 weeks each (same cultivation period as farmers' plots). Farmers were instructed to maintain similar management practices in sub-plot as those on the rest of the pasture plots. The plots were weeded manually with a hoe. Thereafter, Urea (184 kg N/ha) and cattle manure (26 kg N/ha) were applied 3 weeks after cutback and after first harvesting (week 6), respectively. Individual cultivars were evaluated for growth performance and nutritional values at the end of each cultivation phase.

Data collection

Six plants were selected randomly from the centre of the respective sub-plot and used to determine forage growth performance. Plant height, leaf length and width measurements were taken on all of the selected plants using a tape measure. The height was taken by holding a tape measure from the ground to the tip of the plant (inflorescence ignored). Leaf length and width were measured on the third leaf from the top of the sampled plants. Leaf length was measured from a leaf collar to the tip and its width was measured in the middle where a leaf was widest. Individual cultivars' tiller numbers were determined by counting live and/or sprouting tillers from the shoot of each of the selected plants in the respective sub-plot. Cultivar biomass was measured by clear cutting the established pasture in sub-plots to their respective regenerating heights. The cut forage in the respective plot was weighed using a digital scale and a sample of about 300 g was taken and sent to the laboratory for analysis. Above-ground forage biomass was calculated based on dry matter content (DM, see details below) and amount of harvested pasture per unit of land.

Sampled forage cultivars were analysed for nutritional values at the animal nutrition laboratory of the Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture. Individual samples were air-dried at 65 °C for 48 hours to obtain partial DM and ground thereafter to pass a 1-mm sieve. The Association of Official Analytical Chemists (AOAC, 1997) standard methods were used to analyse full DM (ID 930.15) and ash (ID 942.05) contents. The complete DM contents used to calculate above-ground forage biomass was a product of partial and full DM. Crude protein (CP) content was determined using the Kjeldahl method (ID 954.01) while neutral detergent fibre (NDF) and acid detergent fibre (ADF) fractions were analysed using the Van Soest et al. (1991) methods.

Data analysis

Statistical program R (version 4.0.1) was used to analyse data which were checked for normality and homogeneity using the Shapiro-Wilk's and Levene's tests, respectively. Kruskal-Wallis H test was used to analyse and compare median plant height, leaf length and width, tiller number per plant and forage biomass among cultivars. Pasture nutritional parameters (DM, ash, CP, NDF and ADF contents) were analysed using ANOVA mixed effect model: $Y = \text{Cultivar}_{(\text{Fixed})} + \text{Growth phase}_{(\text{Random})} + \text{Ward}_{(\text{Random})} + \text{Residual error}$. The growth phase and ward were set as random effects so as to generalise results over the entire experimental period and study area. Tukey's method was used for mean nutritional parameter comparison among cultivars and was declared significantly different at $p < 0.05$. Results were presented as mean and median for nutritional and growth parameters, respectively.

RESULTS

Pasture growth performance

Median plant height, leaf length and width, and number of tillers per plant varied significantly ($p < 0.05$, Table 1) among cultivars. *Brachiaria* hybrid cvs had a shorter median plant height and lower leaf length compared to *P. puerperium* cvs. Alternatively, *Brachiaria* hybrid cvs had a higher median tiller number per plant than *P. puerperium* cvs. In addition, median leaf width was highest in Cayman (2.1 cm) and lowest in Ouma (1.7 cm) while Cobra and ILRI 16835 were intermediate (1.9 cm). Generally, there were no significant differences ($p > 0.05$) in median forage biomass among cultivars as shown in Table 1.

Forage nutritional values

Mean nutritional values are shown in Table 2 and there were significant differences ($p < 0.001$) in NDF and ADF fractions among the cultivars. *Brachiaria* hybrid cv. Cayman had the lowest NDF (539 g kg^{-1} DM) compared to other cultivars (545–571 g kg^{-1} DM) while ADF was lower in Cayman (256 g kg^{-1} DM) and Cobra

Table 1. Growth performance of selected forage cultivars during the study period in Southern Highlands, Tanzania

Variables		*Brachiaria* **hybrid cultivars**		*Pennisetum purpureum* **cultivars**	
		Cayman	**Cobra**	**ILRI 16835**	**Ouma**
Plant height (cm)	**Median**	28.8^b	26.6^b	50.7^a	56.4^a
	Min–Max	13.0–55.7	12.7–57.3	13.7–108.2	12.7–131.8
Leaf length (cm)	**Median**	21.0^b	21.0^b	46.7^a	47.6^a
	Min–Max	12.7–39.2	12.2–38.2	13.3–77.4	16–77.3
Leaf width (cm)	**Median**	2.1^a	1.9^b	1.9^b	1.7^c
	Min–Max	1.7–5	1.5–2.2	1.5–2.5	1.3–2.3
Tiller numbers per plant	**Median**	64.0^a	67.0^a	22.5^b	21.0^b
	Min–Max	17–222	13–162	10–42	10–67
Biomass (kg DM ha^{-1})	**Median**	465.3^a	466.9^a	374.8^a	466.9^a
	Min–Max	93.6–1841.1	92.6–1667	91.7–2010.1	92.8–1565.7

Medians in the same raw with different letters were statistically significantly different

Table 2. Nutritional values of cultivated forage cultivars in Southern Highlands, Tanzania

Variables	*Brachiaria* hybrid cultivars		*Pennisetum purpureum* cultivars	
	Cayman	Cobra	ILRI 16835	Ouma
DM (g kg^{-1})	174.7 ± 40.3^{a}	178.3 ± 40.3^{a}	166.7 ± 40.3^{a}	172.6 ± 40.3^{a}
Ash (g kg^{-1} DM)	157.8 ± 10.7^{a}	159.4 ± 10.7^{a}	158.0 ± 10.7^{a}	142.0 ± 10.7^{a}
CP (g kg^{-1} DM)	131.5 ± 12.0^{a}	131.1 ± 12.0^{a}	132.3 ± 12.0^{a}	140.8 ± 12.0^{a}
NDF (g kg^{-1} DM)	539.1 ± 13.0^{b}	545.4 ± 13.0^{a}	571.9 ± 13.0^{a}	571.0 ± 13.0^{a}
ADF (g kg^{-1} DM)	255.5 ± 23.0^{b}	264.3 ± 23.0^{b}	291.7 ± 23.0^{a}	286.7 ± 23.0^{a}

DM = Dry matter; CP = Crude Protein; NDF = Neutral Detergent Fibre; ADF = Acid Detergent Fibre
Means in the same row with different letters were statistically significantly different ($p < 0.05$) and vice versa.

(264 g kg^{-1} DM) than ILRI 16835 (292 g kg^{-1} DM) and Ouma (287 g kg^{-1} DM). The CP, DM and ash contents were similar ($p > 0.05$) for all the cultivars.

DISCUSSION

There were no significant differences in median forage biomass among cultivars in the current study despite ILRI 16835 and Ouma having longer plant height and leaf length compared to Cayman and Cobra. Lack of biomass differences among cultivars was due to a higher tiller number per plant for *Brachiaria* hybrid than *P. purpureum* cultivars. The median tiller numbers per plant for *Brachiaria* hybrid in this study were within the 53–126 range reported by Kamidi et al. (2016) in Kenyan highlands. On the other hand, tiller numbers of the *P. purpureum* cultivars were below 29–123 per plant reported by Zewdu (2005), Kariuki et al. (2016) and Maleko et al. (2019) in other African highlands. The differences in tiller number per plant among cultivars was due to regular cuttings as was described above hence *Brachiaria* hybrid developed more tillers in response to cutting while *P. purpureum* reduced number of tillers per plant during the dry period when this study was conducted (Jørgensen et al. 2010). It was observed that *Brachiaria* hybrid cv. Cayman was the best cultivar due to its lower NDF contents hence we reject the stated hypothesis.

The CP values of cultivars in the current study (131–141 g kg^{-1} DM) were within the amount required for dairy cattle's maintenance and/or growth (Salah et al., 2014; Erickson and Kalscheur, 2020). However, CP content was lower than the amount required for milk production by improved dairy cattle e.g. Friesian and Jersey which are reared by farmers in the studied area (NRC, 2001; Mutimura et al., 2018; Mteta et al., 2022). It is therefore important that lactating dairy cows are fed these evaluated cultivars as basal diet and supplemented with concentrates during the early and mid-lactating stages to meet their protein requirements. Nonetheless, CP content in the current study was below 170 g kg^{-1} DM for Cayman and Cobra cultivars as was reported by Ohmstedt and Mwendia (2018) but was within 99.8–139 g kg^{-1} DM for ILRI 16835 and Ouma (Zewdu, 2005; Maleko et al., 2019). The CP variations in Cayman and Cobra between the current and former studies are due to differences in essential soil nutrients e.g. phosphorus and potassium which affects plant growth as was also noted by Nyambati et al. (2016). There were no differences ($p = 0.11$) in CP values among cultivars, which could be due to *Brachiaria* hybrid not reaching their full growth potential due to low rainfall and the possibility that *P. purpureum* is more resilient to poor soil condition. However, *P. purpureum* resilience to poor soil cannot be fully substantiated in this study; therefore it is desirable for farmers to improve soil fertility for better performance of the cultivars.

Brachiaria hybrid cv. Cayman had the lowest structural carbohydrate among evaluated cultivars which could make it an ideal feed for dairy cattle due to possible higher digestibility (Nyambati et al., 2016; Na et al., 2017). In addition, NDF content in this study was lower than 625–705 g kg^{-1} DM range recorded among the same cultivars in the tropics (Zewdu, 2005; Hare et al., 2015; Maleko et al., 2019). The variations in NDF between current and former studies could be due to differences in cultivation period and stage of maturity at harvest which can also explain the lower median forage biomass compared to 1400–12600 kg DM ha^{-1} in the same cultivars (Zewdu, 2005; Hare et al., 2015; Maleko et al., 2019; Karimi et al., 2021). Extremely low median biomass (375–467 kg DM ha^{-1}) in the current study was attributed to poor soil nutrients and lack of sufficient rainfall during growth phase 2. Additionally, differences in growth period between current and former studies contributed to variations since we estimated yield over a short period (6 weeks) while others estimated over entire growth period to determine per annum yield (Hare et al., 2015; Nyambati et al., 2016; Maleko et al., 2019). The short cultivation period by farmers was due to rainy season recommendations given by CIAT in the study area (Ohmstedt and Mwendia, 2018). It is also likely that farmers harvested forage at this stage when they have a high concentration of easily digestible water-soluble carbohydrates which provide high energy required for milk synthesis (Calvache et al., 2020). It seems farmers forego quantity for quality which necessitates the need to supplement cattle with other diets so as to increase the quantity of available feedstuffs.

CONCLUSION

The CP content was similar among cultivars but it was insufficient to meet the daily requirements of a lactating improved dairy cow. *Brachiaria* hybrid cv. Cayman had the lowest NDF content which made it an ideal cultivar due to its potential high digestibility. Above-ground forage biomass did not vary among cultivars, however, it was extremely low due to short cultivation period. It can be concluded that *Brachiaria* hybrid cv. Cayman was the best cultivar in Southern Highlands in terms of nutritional values, however, it had low biomass hence needs to be supplemented with other feeds, e.g. concentrates so as to meet daily requirements of lactating dairy cow.

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CONFLICT OF INTEREST

The author declared no conflicts of interest with respect to research, authorship and publication of this article.

ETHICAL COMPLIANCE

The authors have followed the ethical standards in conducting the research and preparing the manuscript.

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