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Full Length Research Paper

Production, characterization and nutritional quality of Napier grass [*Pennisetum purpureum* (Schum.)] cultivars in Western Kenya

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Napier grass [*Pennisetum purpureum* (Schum.)] is the most popular perennial fodder recommended for smallholder crop-livestock farming systems in Kenya, where 80% of the national milk output is produced. The emergence of new diseases resulting in DM yield losses signals the need to develop alternatives to currently grown cultivars. Eight new cultivars (Kakamega 1, Kakamega 3, Machakos hairless, Uganda L14, Soghor Nandi L13, Kitui L7, Ex-Mariakani and Kakamega 8) were compared to four currently grown cultivars (Bana, French Cameroon, Clone 13 and Pakistan Hybrid) in the sub-humid highlands of northwestern Kenya for two growing seasons. Agronomic measurements were made on DM yield, tiller number, length, diameter and angle, leaf length, width, hairiness and colour and disease incidence. Nutritional measurements were made on leaf to stem ratio, intake, milk yields and body condition of Friesian cows. Kakamega 1, and Kakamega 3 yielded similar ($p > 0.05$) DM yield as Clone 13, Bana and French Cameroon, which yielded more than 16 t ha-1 and greater ($p < 0.05$) than soghor Nandi L13, Kitui L7, Ex-Mariakani, Kakamega 8 and Pakistan hybrid. The tallest cultivars were Kakamega 1, Clone 13, and Kakamega 3 with 70, 69 and 61 cm, respectively. There was positive correlation ($r = 0.65$; $p < 0.001$) between tiller thickness and tiller length. There were no differences ($p > 0.05$) in DM intake between Bana, Kakamega 1, Kakamega 3 and Machakos hairless. Cows feeding on Kakamega 3 and Kakamega 1 Napier grass cultivars yielded similar ($p > 0.05$) milk as those fed Bana grass, but more ($p < 0.05$) than those fed Machackos hairless. Kakamega 1 and Kakamega 3 could be used as alternatives to the currently grown Bana grass in Kenya.

Key words: Napier grass, cultivars, DM, tillers, leaf, intake, milk.

INTRODUCTION

Napier grass [*Pennisetum purpureum* (Schum.)], also known as elephant grass, is a deep-rooted high yielding perennial bunch grass that is native to eastern and central Africa (Boonman, 1993). It grows in tropical and sub-tropical regions with a wide range of annual moisture from 750 to 2,500 mm rainfall and in altitudes ranging from sea level to altitudes of over 2100 m, but frost appears to limit its cultivation above this altitude (Skerman and Riveros, 1990). It is the most popular perennial fodder recommended for the intensively managed smallholder crop-livestock farming systems in Kenya, where 80% of the national milk output is produced. This is because it can withstand considerable periods of drought (Butt et al., 1993), produces greater dry matter (DM) yields than other tropical grasses (Skerman and Riveros, 1990; Boonman, 1997), and is of high nutritive value for dairy cattle particularly when supplemented with high quality feeds such as legumes (Nyambati et al., 2003). There are both giant (tall) and dwarf types. The tall Napier grass is robust, growing to 4 m in height and having up to 20 nodes (Henderson and Preston, 1977). This type resembles sugarcane in habit and adaptation and forms bamboo-like stems when mature. The dwarf 'Mott' Napier grass bred at the Coastal Plains Research Station in Tifton, Georgia, has maximum

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height of 1.5 m (Hanna and Monson, 1988). Unlike the tall Napier grass, the dwarf type is very leafy and non-flowering.

In East Africa and particularly in Kenya, several of tall cultivars have been selected and tested over a wide range of environments (Goldson, 1977). The common cultivars are Bana, French Cameroon, Clone 13 and Pakistan hybrid (Goldson, 1977). Bana is the most popular and is characterized by short succulent stems with broad leaves and has the least tendency to be stemy at maturity. French Cameroon which grows up to 3 m is stemy and hairy. The hairy nature of some Napier grass varieties traps moisture thus creating a suitable micro-catchment for a fungal infestation (white mold, *Spharaedea beniwoskia*). In Kenya, the average dry matter yields vary between 10 and 40 t DM ha^{-1} yr^{-1} depending on soil fertility, climate, and management (Schreuder et al., 1993). Napier grass on average contains 20% DM, 7 to 10% CP, 70% NDF, 45% ADF (Gwayumba et al., 2002; Islam et al., 2003).

Napier grass is propagated vegetatively from cuttings and grown throughout Kenya without incorporating new cultivars. This has resulted in the narrowing of genetic diversity as shown by the outbreak of new diseases such as head smut in central Kenya caused by a fungus *Ustilago kamerunensis* (Farrell et al., 2001) and stunting disease in western Kenya caused by phytoplasma (Jones et al., 2004) resulting in severe biomass losses (Farrell et al., 2001; Jones et al., 2004). This signals the need to develop other alternative Napier grass cultivars that are resistant to diseases. Some varieties such as Kakamega I and Clone 13 have shown resistance to head smut (Mwendia et al., 2006; 2008). Varietal differences in morphological characteristics such as tillering ability were observed by Mwendia et al. (2006) who reported that French Cameroon and Clone 13 produced greater tiller number compared to Bana, Kakamega I, Ex-Githunguri and Kakamega II. There are varietal differences in the proportions of different botanical fractions and chemical composition (Islam et al., 2003; Mwendia et al., 2008). The proportion of leaf fractions is positively correlated to the concentration of plant CP and digestible energy (Islam et al., 2003) and in turn determines the intake and animal performance (Gwayumba et al., 2002; Islam et al., 2003). Some varieties such as bana and Uganda hairless can be used as trap plants in the management of African stem borer *Busseola fusca* Fuller through the push-pull strategy (Khan et al., 2007). The performance of 8 new cultivars at NARC-Kitale in northwestern Kenya and their morphological characteristics were evaluated compared to four cultivars currently recommended in the region to identify the most promising cultivars that could be adapted for the “cut and carry” smallholder dairy farming system. The specific objectives of the study were to 1) determine herbage DM yields of the most promising cultivars, 2) identify characteristics that could be used to identify differences between the cultivars and 3) determine the fodder quality of the high yielding new cultivars in terms of leaf: stem ratio, intake, digestibility, and milk yields compared to the current recommended bana Napier grass.

MATERIALS AND METHODS

Agronomic experiment

Experimental site

The experiment was conducted in the sub-humid highlands of western Kenya at KARI Kitale Centre (1˚ N and 35˚ E, altitude 1860 m) in agro-ecological zone UM4 (Jaetzold et al., 2005), during the 2000 and 2001 growing seasons. The mean rainfall during the experimental period was 1100 mm (monomodal) while the mean monthly minimum and maximum temperatures were 12 and 24˚C, respectively. The soils are classified as humic Ferrolsols based on the FAO/UNESCO system (FAO-UNESCO, 1994). The top soil (0 to 20 cm) had the following properties; pH (1:2.5 H_2O), 5.4; organic C, 14.2 g kg^{-1}; total N, 1.3 g kg^{-1}; extractable P (modified Olsen), 9.7 mg kg^{-1}; and is clay loam with 39% clay, 41% sand, and 20% silt.

Experimental procedure

Twelve accessions/cultivars of Napier grass consisting of local collections, and introductions from various sites in Kenya and from International Livestock Research Institute (ILRI) were planted in a split plot design in which the main plot was cultivar and fertilization (with and without) was sub-plot treatment and replicated three times. The 8 new cultivars/accessions were Kakamega 1, Kakamega 3, Uganda L 14, Machakos hairless, Soghor Nandi L 13, Kitui L 7, Ex-Mariakani and Kakamega 8 and the four recommended cultivars were Bana, French Cameroon, Clone 13 and Pakistan hybrid. Experimental plots dimensions were 2 m × 3 m with a 1 m border between plots and 2 m path between replicates. Napier grass was planted using root splits at an inter- and intra-row spacing of 100 and 100 cm, respectively, giving a total of 12 stools per plot. The fertilizer treatments were planted using recommended fertilizer rate (26 kg P ha^{-1} yr^{-1} at planting and 60 kg N ha^{-1} as annual top-dress. The experiment was conducted for two growing seasons in 2001 and 2002. After establishment, Napier grass was cut back 3 months after planting and there after it was cut after every 8 weeks for data collection. During the establishment year in 2001 there were three cuts, whereas in 2002 there were six cuts.

Measurements

All the measurements were taken at eight weeks of re-growth, the recommended period for feeding the Napier grass. Measurements of DM yields were taken from whole plots. Morphological characterization was determined by measuring plant growth habit and leaf characteristics from representative stools/tillers. Plant growth habit was determined by measuring tiller number/stool, tiller height and thickness and from average angle of growth. Leaf length and width were determined from three representative plants in each plot. Leaf colour, hairiness and roughness were also assessed using scores from the same plants. The scores for hairiness were 0 = no hair, 1 = sparse and 2 = dense and those for roughness were 0 = smooth, 1 = rough and 2 = very rough. The

Table 1. Mean dry matter (DM) yields (t ha^{-1}) ‡ of Napier grass cultivars at Kitale, Kenya.

	Growing season		
Cultivar	**2001**	**2002**	**Mean**
Clone 13	12.2	25.0	18.6
Kakamega 1	13.2	23.5	18.3
French Cameroon	12.4	20.0	16.2
Bana	10.3	22.1	16.2
Kakamega 3	12.5	19.4	16.0
Uganda L 14	11.8	16.8	14.7
Machakos hairless	8.6	17.4	14.6
Soghor Nandi L 13	8.6	16.6	12.6
Kitui L 7	6.9	13.9	10.4
Ex-Mariakani	8.2	11.9	10.0
Kakamega 8	7.7	8.0	7.5
Pakistan hybrid	7.1	7.5	7.5
Mean	10.0	16.8	13.5
LSD	4.31	7.33	3.25
CV	24.8	25.7	20.1

‡ Yields are means of three cuts for 2001 season and 6 cuts for 2002.

general colour of the plant was assessed using visual scores as 0 = yellow, 1 = pale green, 2 = green and 3 = dark green. The disease resistance was assessed using the scores; 0 = resistant, 1 = susceptible and 2 = very susceptible. The pest resistance scores were 0 = not attacked, 1 = mildly attacked and 2 = very susceptible.

Feeding experiment

Three of the most promising cultivars in terms of DM yields (Kakamega 1, Kakamega 3 and Machakos hairless) were compared in terms of nutritive quality to cultivar Bana that is popularly grown by farmers. The cultivars were established and bulked at KARI Kitale. After establishment, they were cut back in sequential blocks to enable uniformity of the fodder during the feeding experiment. Eight dairy cows selected from a dairy herd at KARI Kitale were used in a 4 × 4 latin square change over design replicated twice. The adjustment and collection periods lasted for 14 and 7 days, respectively. The cows were fed with the Napier grass *ad libitum*. Feed intake and milk yield were measured for each cow. Leaf: stem ratio of the feeds were determined on representative samples taken from the bulked fodders. The data was analyzed using the GLM of SAS (SAS, 2001).

RESULTS AND DISCUSSION

Dry matter yields

The DM yields during the first growing season of establishment were lower ($p < 0.001$) than the second season (Table 1). The cultivar by fertilization interaction was not significant; therefore the means were averaged across the fertilization regimes. The interaction of cultivar by year was significant ($p < 0.001$); therefore the means are presented by year. During the 2001 season, three new cultivars (Kakamega 1, Kakamega 3 and Uganda L 14 in addition to the currently grown French Cameroon and Clone 13 were the five best yielding cultivars that yielded more than 12 t ha^{-1}. In the second season, Kakamega 1, Kakamega 3 and the three recommended cultivars were the five best performing with more than 19 t ha^{-1}. Mean DM yields across the two years showed that Kakamega 1, and Kakamega 3 yielded similar ($p > 0.05$) DM yield as Clone 13, Bana and French Cameroon, which yielded more than 16 t ha^{-1} and greater ($p < 0.05$) than Soghor Nandi L13, Kitui L7, Ex-Mariakani, Kakamega 8 and Pakistan hybrid. The superior DM yields of Kakamega I was similarly reported from Central Kenya (Mwendia et al., 2008) where three varieties (Kakamega I, Kakamega II and Muguga bana) were evaluated. The dry matter yields of the most promising cultivars are within the range (15 to 22 t ha^{-1}) reported for Napier grass in eastern Africa (Mugerwa and Ogwang, 1976; Muia et al., 2001). Clone 13 which yielded the highest mean DM was developed from French Cameroon and is resistant to fungal mould disease, (*Beniowiskia sphaeroidea*) (Goldson, 1977).

Morphological characteristics

Fertilization regime increased tiller number ($p = 0.05$), tiller length ($p = 0.001$), tiller diameter ($p = 0.01$) and leaf length ($p = 0.01$). But the fertilization by cultivar interaction was only significant for tiller length ($p = 0.04$). Since Napier grass performance of each cultivar is

Table 2. Plant growth habit characteristics of Napier grass cultivars at Kitale, Kenya.

Cultivar	Characteristic			
	Tiller number	Tiller height (cm)	Tiller diameter (cm)	Tiller angle
Clone 13	61	68.9	5.29	82.5
Kakamega 1	63	69.8	5.98	82.5
French Cameroon	60	58.4	5.07	75.0
Bana	63	55.3	5.52	80.0
Kakamega 3	63	60.8	5.96	82.5
Uganda L 14	49	48.4	4.82	75.0
Machakos hairless	49	57.4	6.84	90.0
Soghor Nandi L 13	82	49.8	5.97	82.5
Kitui L 7	63	57.2	6.23	75.0
Ex-Mariakani	48	38.5	5.12	75.0
Kakamega 8	61	51.4	4.00	82.5
Pakistan hybrid	59	41.6	4.54	67.5
LSD	18.6	15.2	0.98	15.7
CV	24.1	22.0	14.1	13.9

affected by more than one factor, data was analyzed across the two fertilization regimes. There was little variation in tiller number between cultivars except for Soghor Nandi L13 which had greater ($p < 0.05$) tiller number than Pakistan hybrid, Uganda L14, Machakos hairless and Ex-Mariakani (Table 2). The tiller number ranged from 48 in Ex-Mariakani to 82 in Soghor Nandi L 13. The variation in tiller number between different varieties was also observed by Mwendia et al. (2006) in Central Kenya who reported that French Cameroon and Clone 13 produced greater tiller number compared to Farmers Bana, Kakamega I, Ex-Githunguri, Kakamega II and Muguga bana which had similar tiller number. A similar study in Central Kenya (Mwendia et al., 2008) showed that Kakamega 1, Muguga Bana and Kakamega II produced similar ($p > 0.05$) number of tillers. There were varietal differences ($p < 0.05$) in tiller length (Table 2). The tallest cultivars were Kakamega 1, Clone 13, and Kakamega 3 with 70, 69 and 61 cm, respectively, and whose heights were similar ($p > 0.05$) to French Cameroon, Machakos hairless, Kitui L 7 and Bana. The taller varieties were the ones with greater tiller numbers and DM yields, concurring with Boonman (1993); Tessema et al. (2003) who reported that increasing foliage height increased biomass yield. The taller tillers are also associated with greater number of leaves per tiller and per plant, but less leaf: stem ratio (Tessema et al., 2003).

The varieties differed ($p < 0.05$) in tiller diameter. The cultivars with the greatest tiller thickness were Machakos hairless, Kitui L7, Kakamega 1, Soghor Nandi L 13 and Kakamega 3 with a diameter ranging from 6.0 to 6.8 cm. There was positive correlation ($r = 0.65$; $p < 0.001$) between tiller thickness and tiller length. This could probably because varieties with thick stems establish faster (Boonman, 1993). The growth form of the new cultivars assessed using the average angle of the tiller stems to the ground was upright (60 to 90˚) for all the new cultivars and was similar ($p > 0.05$) to the recommended cultivars.

Leaf characteristics

Most of the high yielding cultivars had longer leaf length (Table 3). The five cultivars with the longest leaf length were in the order of Kakamega 3 > Bana > Machakoes hairless > Kitui L 7 > Clone 13. Leaf length was the morphological characteristic best correlated ($r = 0.23$; $p < 0.08$) with DM yield. The cultivars with the widest leaves were Machakos hairless (2.7 cm), Bana (2.7 cm), Kakamega 3 (2.3 cm) and clone 13 (2.3 cm). Leaf hairiness was assessed on both the top and bottom parts of the leaf. On top of the leaves, the most hairy cultivars were Machakos hairless = Kitui L 7 = Songoh Nandi L 13 > Kakamega 3. On the bottom part of the leaf which may affect the comfort of handling by smallholder farmers, Machakos hairless and Songoh Nandi L 13 were the most hairy. Pakistan hybrid, Uganda L 14 and Ex-Mariakani had no leaf hair whereas most species had sparse hairs on their leaves. The hairiness of Kakamega 3 which is a promising alternative to Bana was similar to that of Bana. Pakistan hybrid, Kakamega 1, and Ex-Mariakani had the smoothest leaves. Most species had sparse sheath hair except Kakamega 1 that had dense sheath hair and also most of the cultivars had green leaf colour, except Machakos hairless and French Cameroon which tended to be pale green.

Disease and pest resistance

The most common diseases were leaf rust and fungal

Table 3. Leaf characteristics and disease incidence of Napier grass cultivars at Kitale, Kenya.

Cultivar	Characteristic									
	Leaf length	Leaf width	Top leaf Hair[1]	Bottom leaf hair[1]	Sheath hair[1]	Top leaf roughness[1]	Bottom Leaf roughness[1]	Leaf colour[1]	Sheath colour[1]	Disease
Clone 13	67.8	2.27	0.8	0.2	1.0	0.8	1.2	2.2	0.8	0.8
Kakamega 1	59.8	1.85	1.4	0.8	2.0	0.2	0.6	1.8	0	1.0
French Cameroon	61.8	1.91	1.4	0.8	1.2	0.8	1.2	1.8	0.2	1.0
Bana	71.5	2.71	1.6	1.0	1.4	0.4	0.8	2.0	0	0.4
Kakamega 3	74.5	2.28	1.8	1.0	1.0	0.8	0.8	2.0	0	0.4
Uganda L 14	54.0	1.90	1.0	0.4	1.4	0.6	0.8	2.0	0.2	1.0
Machakos hairless	70.2	2.72	2.0	1.6	1.2	0.6	1.2	1.2	0	0.8
Soghor Nandi L 13	67.0	1.89	2.0	1.3	1.0	0.7	1.0	2.7	0.5	0.8
Kitui L 7	67.9	2.08	2.0	1.0	1.2	0.8	1.2	1.8	0.8	1.2
Ex-Mariakani	51.5	1.65	0.4	0.2	1.0	0.4	0.4	2.6	0.2	0.8
Kakamega 8	42.8	1.49	1.6	0.8	1.4	0.4	1.2	2.6	0.4	1.2
Pakstan hybrid	45.3	1.51	0.2	0.2	0.8	0.2	0	2.4	0.2	1.0
LSD	11.1	0.48	0.7	0.6	0.7	0.7	0.7	0.6	0.7	0.6
CV	14.4	18.8	42.5	64.2	45.7	95.0	63.1	20.9	20.2	51.0

Scores were: Leaf hairiness 0 = no hair, 1 = sparse and 2 = dense; roughness 0 = smooth, 1 = rough and 2 = very rough; colour 0 = yellow, 1 = pale green, 2 = green and 3 = dark green and disease resistance 0 = resistant, 1 = susceptible and 2 = very susceptible. The pest resistance scores were 0 = not attacked, 1 = mildly attacked and 2 = very susceptible.

snow mould disease, *B. sphaeroidea*) which is in agreement with (Goldson, 1977). The fungal disease attacks leaves of the fodder turning them purple with white spores at the base of the leaves, thus reducing both the quantity and quality of the fodder. Most of the cultivars were susceptible (score = 1) to diseases except Kakamega 3 and Bana that were more resistant (score = 0.4). These results were in contrast to those from central Kenya (Mwendia, 2006; 2008) where Kakamega I and Clone 13 were the ones resistant to head smut, the major Napier disease in central Kenya. Based on field observations, the major pest was cereal stem borer, but its infestation was mild only affecting Clone 13 and Machackos hairless.

Nutritional quality

The leaf: stem ratio of the four cultivars (Bana, Machakos hairless, Kakamega 3, and Kakamega 1) evaluated for their nutritional quality are shown in Table 4. There was no difference ($p > 0.05$) in leaf: stem ratio between the four Napier varieties, and the ratios ranging from 1.7 to 3.1 were similar to the range reported for Napier grass from Thailand (Tudsri et al., 2002) and were also within the range (1.65 to 6.1) reported for similar varieties in Kenya (Mwendia et al., 2006). The lowest leaf: stem ratio was obtained from Kakamega 1 which was the tallest cultivar concurring with Tudsri et al. (2002) who showed that the highest leaf: stem ration is obtained from short cultivars. Leaf: stem ration is associated with high nutritive value of the forage because leaf is generally of higher nutritive value (Tudsri et al., 2002) and the performance of animals is closely related to the amount of leaf in the diet. The similarity in nutritive value between the cultivars was reflected in the dry matter intake. There was no difference ($p > 0.05$) in DM intake between the different varieties and on average the cows consumed 9.0 kg DM (109.4 g kg^{-1} BW0.75) day^{-1}. The DM intake was greater compared to 87 g kg-1 BW0.75 obtained by Irungu et al. (2006) for Bana, Kakamega I, Kakamega 2 and Kakamega 3 using sheep probably because they used Napier grass at more advanced and taller stage (162 to 180 cm) compared to 60 to 110 cm used in this study.

Table 4. Intake and milk yield of Friesian cows fed various Napier grass cultivars.

Constituents†	Cultivar				
	A-Bana	B-MH	C-KK3	D-KK1	CV
Leaf: stem ratio	3.1[a]	2.6[a]	2.4[a]	1.7[a]	37.5
NDMI (Kg)	8.9[a]	8.7[a]	9.3[a]	9.0[a]	18.8
NDMI (g kg^{-1} $BW^{0.75}$)	108.6[a]	106.1[a]	113.6[a]	109.7[a]	18.9
Milk (Kg)	6.2[a]	5.8[b]	6.3[a]	6.1[a]	11.4
Mean BCS	5.4[a]	5.2[a]	5.4[a]	5.7[a]	6.8

† NDMI = Napier grass dry matter intake; BW = body weight, MH = Machakos hairless, KK3 = Kakamega 3, KK1 = Kakamega 1. [ab] Treatment means followed by the same letter superscript in the same row do not differ significantly ($P < 0.05$).

Cows feeding on Kakamega 3 and Kakamega 1 Napier grass cultivars yielded similar ($p > 0.05$) milk as those consuming bana (Table 4). Cows that were fed Machackos hairless yielded less ($p < 0.05$) milk than the rest of the cultivars. However, there was no cultivar effect ($p > 0.05$) on cow body condition. The similarity in fodder quality of Kakamega 3, Kakamega 1 and Bana cultivars are in agreement with Gwayumba et al. (2002) who found no differences between Bana and French Cameroon grass cultivars in terms of DM intake and milk yields. The low milk yield (5.8 to 6.3 kg day^{-1}) reflected the combined effect of low DM intake of 8.7 to 9.3 kg day^{-1} compared to 10.4 kg day^{-1} recommended by NRC (1989) for cows producing at least 8 kg day^{-1} and the quality of Napier grass fed alone. To improve the efficient utilization of Napier grass, a supplement of high CP such as legumes (Tessema and Baars, 2004) is required.

Conclusion

Among the new Napier grass cultivars evaluated, Kakamega 1 and Kakamega 3, Uganda L14 and Machakos hairless yielded highest and could be used as alternatives to commonly planted Bana grass, French Cameroon and clone 13. Milk yields of cows feed on Kakamega 3 and Kakamega 1 Napier grass cultivars were similar to those given by Bana grass, suggesting that they have similar nutritional quality. Future research should focus on screening the performance and the optimal stages of feeding of the high yielding cultivars in different agro-ecological zones of western Kenya. Further research is also required to determine the chemical composition and digestibility in relation to intake and animal performance of the most promising cultivars.

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