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Morpho-ecological characteristics of forage grasses used to rehabilitate degraded African rangelands

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Livestock production remains a key source of livelihood to millions of pastoral communities inhabiting African rangeland environments. However, land degradation and scarcity of livestock feed in terms of quantity and quality continues to pose a great challenge. The use of multiple indigenous grass species for reseeding is an innovative strategy to combat degradation and provide a continuous supply of livestock feed especially during the lean dry season.

Abstract

African rangelands are a key source forage for pastoral livestock herds. However, increased degradation and land-use pressure has resulted to shrinkage of the forage resources. Feed shortages constitute the greatest challenge to livestock production in African rangelands. Seeding using native grasses has been identified as a viable option for increased pasture production and rehabilitation of degraded lands. Morpho-ecological characteristics of *Cenchrus ciliaris* L. (African foxtail grass), *Eragrostis superba* Peyr. (Maasai love grass), *Enteropogon macrostachyus* (Hochst. Ex A. Rich.) Monro ex Benth. (Bush rye grass), *Chloris roxburghiana* Schult. (Horsetail grass) and *Chloris gayana* Kunth. cv Boma (Rhodes grass) were used to establish their suitability for forage and rehabilitation in a semi-arid landscape in Africa. *Chloris gayana* cv Boma and *E. superba* depicted significantly higher (P <0.05) leafy biomass demonstrating their suitability for forage. *Enteropogon macrostachyus* and *C. ciliaris* displayed significantly higher values (P <0.05) for rehabilitation indices. *Chloris roxburghiana* exhibited significantly low values for the indices tested. This suggests that ecotypes of *C. roxburghiana* from one ecological site may not establish well in other similar landscapes. In conclusion, desirable outcomes of increased forage production and rehabilitation of African rangelands can best be achieved through multiple species approach to maximise on the unique strengths of different plant species.

Additional key words: *Cenchrus ciliaris*, *Chloris gayana*, *Chloris roxburghiana*, *Enteropogon macrostachyus*, *Eragrostis superba*

Introduction

Arid and semi-arid rangelands of sub-Saharan Africa (SSA) cover about 41% of SSA landmass (Vohland and Barry 2009) and about one-third of the global drylands (Darkoh 2003). They are generally characterised by low erratic annual rainfall (300-600 mm) and nutrient poor soils (Sanchez 2002). Extensive utilisation of multiple grazing resources by different animal species (cattle, goats, sheep and camels) in rangelands remains an important way of life among pastoral communities. Livestock are the main assets in African rangelands, helping improve the nutritional status of the community, contributing to economic growth and sustainable livelihoods. This is because a significant feature of livestock in African rangelands is that they fulfil multiple beneficial roles, ranging from draught power, social and religious ceremonies, to providing milk, blood, meat, manure, hides and skins (Mganga *et al.* 2015a).

Livestock in Africa are well adapted to the indigenous pastures within their ecological range. Natural pasture species in African rangelands have evolved over many decades. Consequently, they have become tolerant to the harsh rangeland environments and can withstand pressure from grazing herbivores. Native or natural pastures make-up the bulk of the feed in most ruminant production systems in the developing world (Ngwa *et al.* 2000). Indigenous grasses have been cited in numerous previous studies to be among the most important sources of forage for grazing herbivores in Africa. Some notable examples include *Themeda triandra* and *Cynodon dactylon* (Mapinduzi *et al.* 2003), *Chloris roxburghiana, Cenchrus ciliaris, Enteropogon macrostachyus* and *Eragrostis superba* (Mnene *et al.* 2005), *Chloris gayana* and *Sorghum sudanense* (Koech *et al.* 2016), *Panicum maximum* and *Digitaria macroblephera* (Ludwig *et al.* 2008) and *Panicum maximum* and *Panicum coloratum* (Macandza *et al.* 2004).

However, despite the rich biodiversity of forage resources in African rangelands, livestock production in these landscapes is constrained by a variety of factors. Seasonal nature of forage supply due to changes in climatic patterns, slow intake by herbivores and poor digestibility of low-quality forages have been cited as some of the factors contributing to the low livestock productivity (Ngwa *et al.* 2000).

Changes in land-use systems in typical rangeland ecosystems have changed the land cover to more agro-ecosystems with diminishing natural vegetation (Mganga *et al.* 2015a). Furthermore, recurrent droughts, termite attacks, uncontrolled burning and overgrazing have led to the reduction or disappearance of populations of important forage species, especially grasses (Mnene *et al.* 2005). Indiscriminate grazing and overstocking modify plant composition and reduces primary productivity, particularly palatable species, thus decreasing the community resilience and instigating damaging positive feedbacks (Kinyua *et al.* 2010). Lack of enough year-round pastures remains the most important constraint. Feed shortages during the dry season constitute the greatest challenge in terms of quantity and quality.

Seeding of desirable indigenous forage species has been promoted as a viable intervention to restore denuded pastures in African rangelands (Kinyua *et al.* 2010; Koech *et al.* 2016; Mganga *et al.* 2015b; Mnene *et al.* 2005). Passive methods (e.g. fencing and livestock exclusion) alone are ineffective because degraded pastures in rangeland environments are relatively stable and resilient in their undesirable state. Therefore, seeding plays a pivotal role in detached arid and semi-arid landscapes (via seed dispersal or seedbanks) to existing populations of desirable forage species (Sheley *et al.* 2006). Seeding trials using indigenous grasses have been established to demonstrate their potential for reclaiming degraded pastures and providing a year-round source of forage for grazing livestock (Koech *et al.* 2016; Mganga, *et al.* 2015b). Previous seeding attempts in African rangeland landscapes have demonstrated a lot of potential and encouraging success (Jordan 1957; Mnene *et al.* 2005).

Interestingly, previous seeding programs have predominantly been conducted for a short-term. Continuous management and long-term monitoring of newly established pastures have been lacking. Seeding trials to establish morpho-ecological characteristics of numerous indigenous tropical grass forages under rainfed conditions remain deficient, especially in sub-Saharan Africa. Furthermore, studies to determine the proportion of leaf and stem biomass in total aboveground herbage yield of tropical Africa grasses are largely absent. Indigenous tropical Africa grasses namely: *Cenchrus ciliaris* (African Foxtail Grass), *E. superba* (Maasai Love Grass), *E. macrostachyus* (Bush Rye Grass), *Chloris* *roxburghiana* (Horsetail Grass) and *Chloris gayana* cv Boma (Rhodes Grass) were chosen for this seeding trial. Selection criteria was primarily based on their evolved adaptive mechanisms for survival in African rangelands, seed availability and their multipurpose uses to the pastoralists i.e. source of animal feed and income through the sale of seed and hay. This seeding trial was established to determine the suitability of the selected tropical grass species in terms of: (1) livestock feed (herbage biomass yields) and (2) rehabilitation of degraded natural pastures, in a typical semi-arid environment in Africa, for two growing seasons.

Materials and methods

Experimental site

Seed trial was established in an Agricultural Training Centre (ATC) Farm, Kitui County, Kenya (site GPS coordinates latitude S 1º 22′ 33.329″ and longitude E 38º 0′ 34.771″) under rainfed conditions. Main inhabitants of Kitui County are the Akamba agropastoralists. They primarily rear local breeds of livestock notably small East African shorthorn zebu, Red Maasai sheep and small East African goats and cultivate drought-tolerant varieties of maize, millet, sorghum, pigeon peas and beans (Mganga *et al.* 2015). Rainfall pattern is bimodal with the long rains in March-April-May and short rains in October-November-December. Annual average rainfall ranges between 300-800 mm. Mean annual temperatures range between 14-34 ºC with an average of 24 ºC (Schmitt *et al.* 2018). Soils are shallow, deficient in nitrogen and phosphorus, with little organic matter. The basic soil chemical and physical characteristics of the experiment site are; 0.08% Nitrogen, 0.8% Carbon, 165 mg kg^{-1} soil Phosphorus, texture (6% sand, 31% silt, 22% clay). Surface sealing properties and low infiltration rates make the soils vulnerable to erosion, particularly since intense rains come early in the growing season, when the ground is bare. Common tree and shrub species include *Lannea triphylla, Commiphora africana, Acacia mellifera, Acacia senegal, Acacia tortilis, Premma oligotricha, Hermannia oliveria, Solanum incanum* and *Grewia* sp. (Hayashi 1996). Herbaceous layer is dominated by grasses such as *C. roxburghiana, E. superba, C. ciliaris, E. macrostachyus, Digitaria scalarum* and *Rhynchelytrum repens* (Hayashi 1996; Mganga *et al.* 2015a).

Experimental layout, rainfall measurements and site preparation

Five (5) experimental blocks with an area of 150 m^2 (10 X 15 m) were laid horizontally next to each other with a 2 m buffer spacing in-between them. The experimental site was uniform. Each block was further sub-divided into three (3) experimental plots with an area of 50 m^2 (10 X 5 m) each. During the period of study, daily rainfall data was collected and measured using a standard rain gauge set-up on site.

Seeds for the study were obtained from Kenya Agricultural and Livestock Research Organisation (KALRO), Kiboko Station, in neighbouring Makueni County, Kenya. The grasses were entirely established under natural rain-fed conditions in early October, 2017 before the onset of the short rains. Seeds were hand-sown at a constant density as monocultures along shallow (20 cm deep) tractor-ploughed microcatchments at a depth of 2 cm and covered by a light amount of soil. Shallow microcatchments were created to trap sufficient rainwater to prolong moisture availability and promote better germination of seeds and subsequent growth and development of the seedlings (Mganga *et al.* 2015a; Visser *et al.* 2007). Kenya Agricultural and Livestock Research Organisation (KALRO) recommended seeding rates (5 kg ha^{-1}) for pasture grasses in semi-arid lands.

Measurement of plant indices and morphometric characteristics

Plant biomass was estimated (in January 2018 and June 2018) using the destructive sampling technique. A quadrat (0.5 X 0.5m) was used and clipping was done at a stubble height of 2 cm. Six quadrats were used per grass species. Freshly harvested grass was weighted to estimate wet biomass yields. Thereafter, the harvested biomass was placed in brown paper bags and oven dried at 60º C for 24 h to estimate dry matter yields, moisture content in the herbage and seed production. Stem and leaf biomass fractions were separated to estimate stem-to-leaf ratios. Seed production was estimated from the biomass harvested in June, 2018. Plant height was determined manually using a 2 m ruler. Briefly, the ruler was placed vertically on the ground and the height of the top leaf estimated to the nearest centimetre. Plant densities (plants m^{-2}), average tiller densities per species and frequencies (%) were estimated (in June

2018) in six 0.25 m^2 quadrats (0.5 X 0.5 m) within each plot (Cox 1990). Percentage basal cover was estimated (in June 2018) using the classical step-point method (Evans and Love 1957). Four line transects were used in each of the three plots in all the six blocks.

Statistical analysis

Statistical analyses were performed using Software STATISTICA 10.0, StatSoft Inc. One-way ANOVA was used to test for significant differences between treatments. Fischer's LSD *post hoc* test was used to separate significant differences between treatments at P<0.05 significant level. All displayed results represent arithmetic means of replicates.

Results

Rainfall data

Total amount of rainfall received during the study period i.e. October, 2017 to June, 2018 was 1586 mm. Short rains of October-December, 2017 and long rains of March-May, 2018 recorded total amounts of 607 and 979 mm, respectively (Fig. 1). Total number of rainy days received during the entire period were 58, with the short and long rains experiencing 24 and 34 rainy days, respectively. The wettest month was April, 2018 which received 665 mm of rainfall in 18 rainy days and May (2018) received the least amount of rainfall i.e. 19 mm in three (3) rainy days.

Plant morpho-ecological characteristics

Percent moisture content in plant biomass was significantly different ($P <0.05$) and highest in *C. gayana* 83 % and 73 % in the first and second sampling respectively. *C. roxburghiana* had the least moisture in plant biomass of 46 % and 40 % in the first and second sampling periods respectively (Table 1). Above-ground biomass yields were significantly different ($P <0.05$). *Chloris gayana* had the highest biomass yields of 207 kg DM ha^{-1} and 5413 kg DM ha^{-1} in first and second sampling respectively. *Eragrostis* *superba, E. macrostachyus, C. ciliaris* and *C. roxburghiana* were ranked second, third, fourth and fifth respectively (Fig. 2).

On average, the leaf to stem ratio of most of the grass species was 2:1 and remained constant throughout the growing period. However, a significant change ($P<0.05$) in the leaf to stem ratio occurred in *C. roxburghiana* with a ratios of 8:1 and 3:1 at first and second sampling periods respectively. On average, *E. superba* and *C. gayana* had the highest proportion of stem biomass and density. *Chloris gayana* had the highest (173 kg ha^{-1}) and significantly different ($P <0.05$) seed production while *C. roxburghiana* had the lowest (35 kg ha^{-1}). *Eragrostis superba*, *E. macrostachyus* and *C. ciliaris* were ranked second, third and fourth with 140 kg ha^{-1}, 108 kg ha^{-1} and 92 kg ha^{-1} respectively (Fig. 2).

Enteropogon macrostachyus had the highest plant density and frequency of 11 plants m^{-2} and 76% respectively. These was significantly higher and different ($P <0.05$) compared to *C. gayana* with 5 plants m^{-2} and 53% respectively, which was ranked the lowest. Plots under *E. macrostachyus* had the highest and significantly different ($P <0.05$) percent basal cover of 70%. *Chloris gayana* and *C. roxburghiana* had the lowest basal cover of 15 and 17% respectively (Table 1).

Number of tillers were significantly different ($P <0.05$). *C. gayana* (32 tillers per plant) had the highest tiller density among the five grasses. *Enteropogon macrostachyus* (27 tillers per plant), *C. ciliaris* (21 tillers per plant), *E. superba* (15 tillers per plant) and *C. roxburghiana* (11 tillers per plant) were ranked second, third, fourth and fifth respectively. Average plant height of *C. gayana* at first and second sampling i.e. 83 and 156 cm respectively, was highest and significantly different ($P<0.05$) compared to the other grasses. *Cenchrus ciliaris* had the lowest average plant height of 20 and 45 cm during the two sampling periods respectively. *Eragrostis superba, C. roxburghiana* and *E. macrostachyus* were ranked second, third and fourth respectively.

Discussion

Rainfall received during the entire period was received in a few rainy days of the entire rainy season. This rainfall pattern is characteristic of many rangeland environments in Africa (Vohland and Barry 2009). Therefore, reference to total annual amount of rainfall received rather than its spread in the entire rainy season might be misleading, especially in arid and semi-arid environments. Rainfall distribution in the African rangelands is very erratic including high intensity rainfall events with 30-40 % in coefficients of variation (Fox and Rockström 2000).

Moisture concentration of the grasses were comparable to other tropical grasses such as Guinea Grass (*Panicum maximum)*, Jaragua Grass (*Hyparrhenia rufa*) and Signal Grass (*Brachiaria decumbens*) (Costa and Gomide 1991). *Chloris gayana* and *E. superba* contained significantly higher moisture concentration throughout the growing period compared to *C. ciliaris, E. macrostachyus* and *C. roxburghiana*. This is attributed to their much larger and succulent stems that store more water. Moisture concentration in pastures is among the significant factors affecting voluntary DM feed intake and digestion kinetics in ruminants (Estrada *et al.* 2004; Pasha *et al.* 1994). Pasha *et al.* (1994) demonstrated that voluntary DM feed intake, neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude protein (CP) and coefficients for dry matter (DM), NDF and ADF digestibilities were greater for hay than for high moisture forages. Furthermore, the mean particulate retention times (MRT) were much shorter for high moisture forages (23.3 h) than for hay (30.7 h) diets. Similarly, Estrada *et al.* (2004) demonstrated that voluntary DM intake of dairy cows fed on fresh grass increases with decrease in grass moisture content. High moisture concentration pastures such as *C. gayana* and *E. superba* are therefore best suited fed as conserved forage (hay and silage).

Plant height is a crucial component of a plant species' ecological strategy and an important morphological determinant of its competitive ability (Wilson 1988). Taller *C. gayana* cv Boma culms, of up to 150 cm, is attributed to their faster seed germination, establishment and growth rates. *Chloris gayana* cv Boma is known to establish easily, grow very fast and mature early (Ponsens *et al.* 2010). These features demonstrate its aggressive nature and competitive strength especially for light. Early colonisation strategy suggest a possible advantage of biomass over the other grass species, consequently resulting to higher competitive effect. Conversely, during the same growing season, *C. ciliaris* exhibited much shorter culms, of up to 45 cm. This is within the average range (20-150 cm tall) dimension of *C. ciliaris* culms in other studies (Marshall *et al.* 2012). Shorter culms of *C. ciliaris* is attributed to its slow-growing nature which is also a coping mechanism against drought similar to other tropical forages like *E. superba, E. macrostachyus* and *C. roxburghiana*. Furthermore, seed dormancy in *C. ciliaris* often hinders successful establishment of a new pasture. The dormancy mechanism of *C. ciliaris* lies both within the caryopsis and in the associated structures of the fascicle (Mganga *et al.* 2015b). However, slower germination and longer induction time of *C. ciliaris* is beneficial later in the growing the season when rainfall is more reliable to give the seedlings an advantage in inter- and intraspecific competition.

Plant height is among the most important biomass yield components. However, significantly higher biomass yields of *Chloris gayana* and *E. superba* is attributed to the nature of their stems. *Chloris gayana* and *E. superba* have tough stems, larger stem diameters and high stem densities and proportions of stem biomass. Previous studies (e.g. Benvenutti *et al.* 2009) have shown that *C. gayana* to have higher stem diameter and densities compared to most tropical grasses. Studies comparing culm diameters have also shown that stems of *C. gayana* (3 mm) can be more than three times those of *C. ciliaris* (1 mm) (Marshall *et al.* 2012; Benvenutti *et al.* 2009). Higher proportion of stem biomass (0.43) in *E. superba* compared to e.g. *C. roxburghiana* (0.10) and *E. macrostachyus* (0.26) contributed significantly to higher total biomass yields. These results are comparable to previous studies (Mganga *et al.* 2015a) to establish the potential of the same tropical grasses for rehabilitation programs in African rangelands. Forage quality is generally higher in leaves than in stems and it is largely accepted that grazing animals select leaves and avoid stems. High proportion of stems in *E. superba* suggest it has a high fraction of less nutritious plant tissue compared to *C. ciliaris, E. macrostachyus, C. roxburghiana* and *C. gayana* which had higher proportions of leaf biomass.

Plant density (plants m^{-2}), tiller density (tillers m^{-2}), basal cover (%) and plant frequency (%) have been used as indices to estimate the potential of tropical forage grasses for rangeland restoration (Koech et al., 2016). Considering these indices, our results demonstrated that *E. macrostachyus* has the greatest potential for pastureland restoration. Previous studies have obtained similar outcomes using the same species in a typical semi-arid rangeland in Africa (Mganga *et al.* 2015). High plant density, frequency and basal cover exhibited by *E. macrostachyus* is attributed to its large caryopsis size. Larger seeds promote faster seedling establishment in rangeland ecosystems, allowing them to emerge from deeper soil depths, where moisture levels are favourable for germination and growth. Other studies using the same plant indices have contradicted our outcomes. Similar species established in another rangeland ecosystem in Africa characterised by heavy clay vertisols, demonstrated *C. ciliaris* to have the best potential for pastureland restoration (Koech *et al.* 2016). These differences are attributed to edaphic factors. Several *C. ciliaris* have been developed to withstand flooding conditions and are more likely to establish on heavier clay soils that become too water-logged in tropical Africa (Marshall *et al.* 2012). However, similar to our results, Koech *et al.* (2016) demonstrated that *C. roxburghiana* had the least potential for replenishing denuded pastures. Poor establishment of *C. roxburghiana* is attributed to the genetic differences between ecotypes occurring as a result of adaptation to unique environmental factors of specific sites (Mnene *et al.* 2005). Furthermore, *C. roxburghiana* has a very small caryopsis that hinders the ability of the seedling to emerge from soil. Larger grass seeds have a greater capacity to support the plant seedling to emerge from the soil.

Plant ecological indices and biomass are the main factors used for selecting grasses for pasture restoration and livestock production. However, seed yield is a trait of significant importance for forage grasses because seed multiplication is economically important for new grass cultivars to compete commercially. High seed production also plays a critical role in the long-term success of natural pasture rehabilitation and revegetation. Significantly high seed yields of *C. gayana* (173 kg ha^{-1}) highlight its prolific seeding nature. This yield is much lower that seed yields of cultivar Callide (407 kg ha^{-1}) but higher than cultivar Mbarara (110 kg ha^{-1}) reported in other studies (Hacker 1999). Similarly, *E. superba* produced significantly higher seed yields of 140 kg ha^{-1}. This is much higher compared yields of 40 kg ha^{-1} reported in previous studies established in vertisols under in an arid environment (Koech *et al.* 2014). Prolific seeding characteristic of *C. gayana* and *E. superba* under favourable eco-climatic domains demonstrate their great potential to replenish depleted seedbanks and facilitate colonisation of bare patches once established. *Chloris roxburghiana* produced the least amount of seed (35 kg ha^{-1}). Ecotypes of *C. roxburghiana* from different eco-climatic sites demonstrate poor establishment and seed production in other arid and semi-arid environments (Mnene *et al.* 2005).

Conclusions

Livestock feed shortage is among the greatest challenges facing pastoralists inhabiting African rangelands. Introducing new seeds of indigenous grasses in denuded pastures has been identified as a viable option for active rehabilitation of depleted grazing lands and degraded rangeland landscapes. Indigenous forage grasses used in this study demonstrated a variety of attributes suitable to address these challenges. Plant indices showed that *C. gayana* cv Boma and *E. superba* to be the best suited for provision of livestock feed while *E. macrostachyus* and *C. ciliaris* demonstrated their suitability for rehabilitating and rejuvenating denuded pasturelands. However, *C. roxburghiana* a close relative to *C. gayana* and an important grass in arid and semi-arid rangelands, demonstrated its limitation to improve natural pastures and rehabilitate degraded landscapes. This is attributed to differences between ecotypes arising from adaptations to very distinct environmental factors of specific ecological sites. Therefore, in order to achieve desirable long-term outcomes of increased biomass yields and restoration of depleted pastures in African rangelands, seeding programs using indigenous grasses should consider a multiple species approach to maximise on the unique strengths of different indigenous grass species.

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Conflicts of Interest

The authors declare no conflicts of interest

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Figure legends

Fig. 1 Rainfall amount and distribution pattern in the October-December, 2017 short rains and March-May, 2018 long rains, Kitui, Kenya.

Fig. 2 Stem and leaf biomass yields (DM kg ha^{-1}) of five different grass species harvested in January, 2018 and June, 2018. Error bars represent standard error of means. Means of stem and leaf biomass yields followed by different letters differ at the 5% level according to Fischer's LSD test.

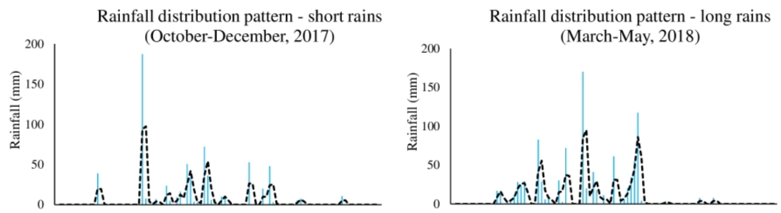
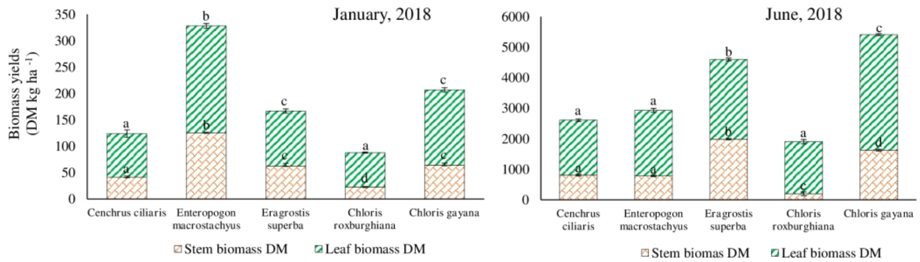


Fig. 1 Rainfall amount and distribution pattern in the October-December, 2017 short rains and March-May, 2018 long rains, Kitui, Kenya.

279x215mm (200 x 200 DPI)



Stem and leaf biomass yields (DM kg ha -1) of five different grass species harvested in January, 2018 and June, 2018. Error bars represent standard error of means. Means of stem and leaf biomass yields followed by different letters differ at the 5% level according to Fischer's LSD test.

279x215mm (200 x 200 DPI)

Table 1. Morpho-ecological characteristics of selected forage grasses in African rangelands

Column means with different superscripts are significantly different at $P < 0.05$ as determined using Fisher's LSD Mean comparison.

Grass Species	Moisture S1[A] (% wet wt.)	Moisture S2[B] (% wet wt.)	Height S1[A] (cm)	Height S2[B] (cm)	Plant density (plants m^{-2})	Tiller density (tillers m^{-2})	Basal cover (%)	Frequency (%)	Seed production (DM kg ha^{-1})
Cenchrus ciliaris	62 ± 0.7^{a}	44 ± 1.4^{a}	20 ± 2^{a}	45 ± 3^{a}	9 ± 0.5^{ab}	195 ± 7.5^{a}	55 ± 2.5^{a}	73 ± 3.0^{a}	92 ± 1.0^{a}
Enteropogon macrostachyus	57 ± 0.6^{b}	48 ± 2.3^{b}	35 ± 3^{b}	75 ± 3^{b}	11 ± 1.0^{a}	300 ± 0.9^{b}	70 ± 3.0^{b}	76 ± 1.4^{a}	108 ± 1.9^{b}
Eragrostis superba	75 ± 1.3^{c}	60 ± 0.1^{c}	75 ± 2^{c}	110 ± 5^{c}	8 ± 0.5^{b}	120 ± 13.6^{c}	40 ± 2.4^{c}	63 ± 2.5^{b}	140 ± 2.4^{c}
Chloris roxburghiana	46 ± 1.9^{d}	40 ± 3.4^{a}	42 ± 2^{b}	88 ± 4^{b}	7 ± 0.5^{bc}	77 ± 2.0^{d}	15 ± 2.5^{d}	56 ± 2.9^{bc}	35 ± 1.8^{d}
Chloris gayana	82 ± 0.3^{e}	73 ± 0.5^{d}	83 ± 3^{c}	156 ± 8^{d}	5 ± 0.3^{c}	170 ± 10.5^{e}	17 ± 1.3^{d}	53 ± 3.0^{c}	173 ± 2.0^{e}

A S1 = sampling time 1 (January, 2018).

B S2 = sampling time 2 (June, 2018).