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The choice of grass species to combat desertification in semi-arid Kenyan rangelands is greatly influenced by their forage value for livestock

K. Z. Mganga*, N. K. R. Musimba*, D. M. Nyariki*, M. M. Nyangito† and A. W. Mwang'ombe‡

*Department of Range and Wildlife Sciences, South Eastern Kenya University (SEKU), School of Agriculture and Veterinary Sciences, Kitui, Kenya, †Department of Land Resource Management and Agricultural Technology, University of Nairobi, College of Agriculture and Veterinary Sciences, Nairobi, Kenya, ‡Department of Plant Science and Crop Protection, University of Nairobi, College of Agriculture and Veterinary Sciences, Nairobi, Kenya

Abstract

Livestock production is the main source of livelihood in the arid and semi-arid lands in Africa. However, desertification characterized by vegetation degradation and soil erosion is a major threat to the sustainability of land-based production systems. Native rangeland forage species *Cenchrus ciliaris* L. (Buffel grass/African foxtail grass), *Eragrostis superba* Peyr. (Maasai love grass) and *Enteropogon macrostachyus* (Hochst. Ex A. Rich.) Monro ex Benth. (Bush rye grass) have been used to combat desertification. The objectives of the study were to identify the best-suited native grass species to combat desertification in a semi-arid environment in Kenya and to identify the preferred grass species among the agropastoralists in the area. Percentage basal cover, plant densities and frequencies of the three grasses in pure stands and mixtures were estimated. Grass species preferences were through household survey and focus group discussion. Results showed a significant difference ($P < 0{\cdot}05$) in plant densities and cover estimates: *E. macrostachyus* was ranked first; *C. ciliaris* and *E. superba* were ranked second and third respectively. The agropastoral farmers, however, preferred *E. superba* followed by *C. ciliaris* and *E. macrostachyus,* a reverse trend. These results suggest that the choice of grass species to combat desertification is influenced more by its contribution as a source of forage for livestock than its contribution for rehabilitation purposes.

Correspondence to: K. Z. Mganga, Department of Range and Wildlife Sciences, South Eastern Kenya University (SEKU), School of Agriculture and Veterinary Sciences, P.O. Box 170-90200, Kitui, Kenya.
E-mail: kmganga@seuco.ac.ke

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Introduction

Rangelands in Africa are largely inhabited by pastoral people and cover 60% of the continent's land area. Livestock are the main source of livelihood where over 1·9 and 0·6 tropical livestock units (1TLU is equal to an animal weighing 250 kg) per square kilometre are realized in the nomadic pastoral and sedentary agropastoral areas respectively (Nyangito *et al.*, 2008). Livestock also provide the main source of food among pastoral communities. The animals (cattle, camels, goats) provide milk and are also sold when cash is required to buy grains, pay school fees or meet other domestic requirements (Nyariki and Abeele Jan, 2004). Rangelands in Kenya constitute 88% of the land surface area and are home to a number of pastoral communities, which account for about 30% of the national human population, mostly pastoralists who depend directly on the natural resource base for their livelihoods (Opiyo *et al.*, 2011).

Agropastoralists, like pastoralists all over the world and especially in sub-Saharan Africa (SSA), are faced with problems of low livestock productivity. The low livestock productivity at the agropastoral level can be attributed to a number of factors. These include inadequate understanding of the ecology of semi-arid environments, particularly the temporal and spatial variability of rangeland production, range utilization and trophic interaction patterns, and the role of mobility in sustaining livestock production in these environments. However, inadequate supply of feeds, both in quantity and quality, is the main factor leading to low livestock productivity (Nyangito *et al.*, 2008). For example, in the semi-arid rangelands in Kenya, an important source of forage for both domestic and wild animals, the indigenous perennial grass species, notably *Cenchrus ciliaris* (African foxtail grass/ Buffel grass), *Eragrostis superba* (Maasai love grass) and *Enteropogon macrostachyus* (Bush rye grass), are disappearing at an alarming rate. The depletion of semi-arid pastures can partly be attributed to increased land-use pressure within the last 15 years, due to a number of factors, notably climate (recurrent droughts and low amount of rainfall), increase in livestock and human population, and the migration of populations from the high potential areas to marginalized areas and changes in land-use systems (Opiyo *et al.*, 2011).

Land-use systems in the savannah ecosystems have changed over time. For example, the expansion of cultivation (increased sedentarization) in many parts of East Africa has changed the land cover to more agro-ecosystems and less natural vegetation. These changes are fuelled by a growing demand for agricultural products that are necessary to improve food security and generate income, not only for the rural poor but also the large-scale investors in the commercial farming sector (Maitima *et al.*, 2009). Natural vegetation cover has given way not only to cropland but also to pasture (Lambin *et al.*, 2003).

Former ranches have also been subdivided, which has led to shrinkage of the pastoral-production resource base, thus confining pastoralists to the less productive areas. For example, the Maasai adapted to life in the arid and semi-arid rangelands by shifting between the wet- and dry-season grazing areas and by maintaining multiple species of livestock. This movement was undertaken to cope with forage availability as determined by spatially and temporally variable and unpredictable rainfall patterns and grazing pressure (Kioko and Okello, 2010). Now, reduced livestock mobility and an increase in livestock numbers have led to overstocking and the decline in the general health of the rangelands and the land's ability to recover from stochastic events, such as drought, making them more at risk and vulnerable to land degradation. Decline of productivity, the loss of biodiversity and the increasing rate of soil erosion are evidence of degradation in these environments (Visser *et al.*, 2007). This interaction of heavy grazing and climatic variability can cause dramatic ecological degradation in the semi-arid rangelands (Wessels *et al.*, 2007). Heavy grazing initially alters vegetation composition and decreases primary productivity, especially of palatable species, thus decreasing the community resilience and initiating damaging positive feedbacks (Kinyua *et al.*, 2010). Despite the extensive research on the causes and consequences of rangeland degradation, studies on rangeland restoration are less common (King and Hobbs, 2006).

Considering the ecological and socio-economic value of the semi-arid rangelands to the pastoral and agropastoral communities, improved management methods of rangeland resources are necessary. Reseeding is one procedure that is used to restore ecosystem functionality and productivity (Coronado *et al.*, 2005). *Cenchrus ciliaris, Chloris gayana, E. macrostachyus, E. superba, Cynodon dactylon* and *Chloris roxburghiana* have a high potential for reseeding degraded arid and semi-arid lands (Mganga *et al.*, 2010). Grasses selected for this study were *C. ciliaris, E. macrostachyus* and *E. superba*. The selection criteria of these three grasses were not only based on their evolved adaptive mechanisms for survival (Mganga *et al.*, 2010; Opiyo *et al.*, 2011) but also on the availability of the seeds through the Community Based Forage Seed System (a joint initiative between the Kenya Agricultural Research Institute (KARI) and the agropastoralists) and their multipurpose uses to the community, notably as a source of livestock feed, source of income (sale of seed and hay), thatching material and role in soil conservation.

The objectives of the study were to identify the best-suited native grass species to combat desertification in a semi-arid environment in Kenya and to identify the preferred grass species among the agropastoralists in the study area.

Materials and methods

Study site

This research was conducted in the semi-arid rangelands of Kibwezi District, Kenya, in 2008. The Akamba agropastoralists are the main inhabitants in the study area. Their main economic activity is raising livestock and cultivating drought-tolerant cereals and pulses. Livestock consist of local breeds, mainly small East African shorthorn zebu cattle, Red Maasai sheep and small East African goats. The crops grown include different drought-tolerant varieties of maize, sorghum, millet, pigeon peas and beans (Nyangito *et al.*, 2009). The average annual rainfall, evaporation and temperatures are 600 mm, 2000 mm and 23°C respectively (Mwang'ombe *et al.*, 2011). The lowlands in the south receive an annual rainfall of 500 mm, and the highlands in the north receive 1200 mm annually. Due to its proximate position along the equator, the rainfall is characterized by strong seasonal and bimodal distribution, with high temporal and spatial variability between seasons. Soils are Ferralsols, Cambisols and Luvisols characterized by strong surface-sealing properties that cause much run-off during heavy rains (Mganga *et al.*, 2010). The vegetation is dominated by *Commiphora, Acacia* and allied genera mainly of shrubby habitat. Perennial grasses such as *C. ciliaris, E. macrostachyus, E. superba* and *C. roxburghiana* dominate.

Methods

Seed viability tests as described by Tarawali *et al.* (1995) were conducted under controlled conditions (22°C, 14 d) before the field experiment was carried out. The grass seeds that germinated were counted daily and removed from the petri dishes. At the end of the 14 d, all seeds that had germinated were expressed as a percentage of the total number of seeds. The seeds used in this study were harvested in 2007 and acquired through the Community Based Forage Seed System.

Three blocks with an area of 150 m^2 (10 × 15 m) were laid horizontally next to each other with 2 m spacing between them. Each block was further subdivided into six experimental plots with an area of 25 m^2 (5 × 5 m) each. Briefly, the soil in the study site had the following characteristics: sandy clay loam texture, 0·92% carbon (C), 0·43% nitrogen (N), 13·72 mg kg^{-1} phosphorus (P), CEC 6·40 (me/100 g) and 1·92 me/100 g potassium (K) (Mganga *et al.*, 2011). The three grasses used in this study were as follows: *C. ciliaris*, (African Foxtail Grass), *E. superba* (Maasai Love Grass) and *E. macrostachyus* (Bush Rye Grass).

The grasses were hand-sown as pure stands (*C. ciliaris, E. superba* and *E. macrostachyus*) and as mixtures (*C. ciliaris- E. macrostachyus, C. ciliaris- E. superba* and *E. superba- E. macrostachyus*) along shallow ox-ploughed microcatchments (15 cm deep) at a depth of 1·5–2 cm and covered by a minimal amount of soil. The seeding rates were 5–6 kg ha^{-1} (Kenya Agricultural Research Institute (KARI) recommendations for pasture grasses in the semi-arid rangelands). The density was kept relatively constant in monocultures and mixtures. Microcatchments were created to trap water and thus promote better germination of seeds and subsequent establishment and development of the seedlings (Visser *et al.*, 2007). Sprinkler irrigation system (simulated rainfall) was occasionally used to maintain soil moisture sufficient for germination and seed development. A sprinkler irrigation system application rate was 0·638 cm^3 sec^{-1} (Mganga *et al.*, 2010).

The percentage basal cover in all blocks was estimated using the step-point method as described by Evans and Love (1957). Four line transects were used in each of the six plots in all three blocks. Plant densities (plants m^{-2}) and frequencies were estimated 4 months after establishment in six 0·25 m^2 quadrats (0·5 × 0·5 m) within each plot (Cox, 1990). Statistical analyses were performed using Statistical Package for Social Sciences (SPSS) (Einstein and Abernethy, 2000), and means were separated using Tukey's-B Mean comparison at $P < 0·05$ level.

Survey and focus group discussions

A household survey was conducted in 50 households among the agropastoral Akamba community using a semi-structured questionnaire. The households interviewed were among a larger group of farmers who had previously participated in the Dryland Husbandry Project. This had been initiated in response to the problems of severe drought, famine, deteriorating socio-economic conditions, land degradation and inappropriate pastoral development policies that contributed to declining standards of living among pastoralists and agropastoralists. These farmers had adopted some of the technologies introduced, notably reseeding to combat desertification, water harvesting, apiculture and agroforestry using multipurpose trees. The questions were dichotomous, multichoice and open-ended to allow ease of capture of the diverse issues being investigated.

A focus group discussion was also conducted involving a group of twenty people. The group chosen were farmers in the same area but they were not involved in the household exercise. This was aimed at validating the trends observed from the survey conducted. Simple descriptive statistics were used to establish which grasses the farmers used to rehabilitate their lands, the different mix of grasses sown and the criteria used in selecting the grass species.

Results

Seed viability tests showed that seeds of *E. macrostachyus* had the highest germination rate of 85%. *Cenchrus ciliaris* and *E. superba* were ranked second and third with 40% and 21% respectively (Figure 1). The first bunch of seeds for *E. superba* and *E. macrostachyus* germinated on the third day of the experiment, while those of *C. ciliaris* germinated on the fourth day. The plateaus observed in Figure 1 were a period during which minimal or no further germination was observed.

There was no significant difference ($P > 0·05$) in plant frequency of the grasses as pure stands and mixtures. Although plots under *E. macrostachyus* recorded the highest frequency (72%), they were not significantly different to those of *C. ciliaris* and *E. superba* which recorded 44 and 40% respectively. The *E. macrostachyus- E. superba* mixture was ranked second overall with 56% frequency and highest among plots

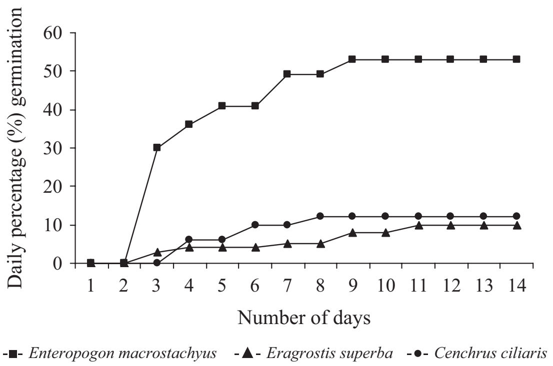

Figure 1 Daily percentage seed germination of *Enteropogon macrostachyus, Eragrostis superba* and *Cenchrus ciliaris* for a period of 14 d, under controlled laboratory conditions, 22°C.

under two grass mixture but was not significantly different than the *C. ciliaris- E. macrostachyus* and *C. ciliaris-E. superba* mixtures both with 39% plant frequency.

The percentage basal cover estimates, however, showed significant differences ($P < 0{\cdot}05$) both in pure stands and grass mixtures (Table 1). On average, the two grass mixture plots had a higher basal cover percentage of 42%, compared with plots under pure stands which had an average basal cover of 35%. The *E. macrostachyus-E. superba* mixture had the highest overall percentage of basal cover of 58% (Table 1). *Enteropogon macrostachyus* (54%) was ranked second overall and had the highest value among plots under pure stands.

Plant densities among the grasses showed a significant difference ($P < 0{\cdot}05$). On average, the grass mixtures had higher plant densities (22 plants m^{-2}) compared with pure stands (16 plants m^{-2}). Plant density was highest in plots under *E. macrostachyus* (36 plants m^{-2}). Plots under *C. ciliaris* and *E. macrostachyus* mixture were ranked second with 28 plants m^{-2} and highest among mixtures (Table 1).

Results from the household survey indicate that 38 of the fifty farmers interviewed (76%) adopted the introduced grass reseeding technology. Most farmers sowed the grasses as pure stands (42%), others sowed as mixtures (14%) or a combination of the two sowing patterns (20%). *Eragrostis superba* was the most preferred grass species among farmers practising grass reseeding. *Cenchrus ciliaris* and *E. macrostachyus* were ranked second and third respectively. *Cenchrus ciliaris -E. superba* and *C. ciliaris -E. macrostachyus* mixtures were popular among the farmers who sow the grasses in mixtures. *Eragrostis superba –E. macrostachyus* was the least preferred mixture combination used by the farmers (Table 2).

Table 1 Percentage basal cover and frequency and plant densities of *Cenchrus ciliaris*, *Enteropogon macrostachyus* and *Eragrostis superba* as monocultures and mixtures

Experimental plots	Frequency (%)	Basal cover (%)	Plant densities (plants m^{-2})
CC	44^{a}	30^{c}	7^{a}
EM	72^{a}	54^{ab}	36^{b}
ES	40^{a}	23^{c}	5^{a}
CC/EM	39^{a}	34^{bc}	28^{b}
CC/ES	39^{a}	33^{bc}	6^{a}
EM/ES	56^{a}	58^{a}	34^{b}

CC, *Cenchrus ciliaris*; EM, *Enteropogon macrostachyus*; ES, *Eragrostis superba*. Column means with different superscripts are significantly different at $P < 0{\cdot}05$ as determined using Tukey's-B Mean comparison.

Discussion

Percentage frequency, cover and plant densities are attributes which can be used to establish the rehabilitation success of denuded environments (Table 1). Results from this study strongly suggest that *E. macrostachyus* is the best grass among the three grasses used to rehabilitate denuded semi-arid lands, restore ecosystem functionality and reduce soil erosion. Similarly, previous studies by Nyangito *et al.* (2009) and Mganga *et al.* (2010) showed that *E. macrostachyus* improved soil hydrological properties by increasing infiltration capacity and reducing run-off compared with *E. superba*. This is attributed to the fact that *E. superba* has a high proportion of stem and thus is less effective in concentrating rainwater into its rhizospheres compared with *E. macrostachyus* which tends to be more leafy than stemmy, thus trapping more rainfall water, resulting in less soil disturbance and thus erosion.

Table 2 Preferences of native forage grass seeds and two grass mixture sowing patterns among the agropastoralists in the semi-arid Kibwezi District, Kenya

	Pure stands	Two grass mixture combination	
Grass species	Number of farmers (%)	Grass species	Number of farmers (%)
ES	74	CC/ES	8
CC	48	CC/EM	8
EM	28	ES/EM	4

CC, *Cenchrus ciliaris*; EM, *Enteropogon macrostachyus*; ES, *Eragrostis superba*.

Perennial grass cover is essential in protecting vulnerable lands against run-off and erosion. Perennial grass tufts improve water infiltration by channelling rainwater via the root base into their own rhizospheres, stimulating biological activity and decreasing bulk density, thereby increasing retention and availability of soil water (Nyangito *et al.*, 2009) and thus less surface run-off and higher rainwater-use efficiency. Reduced infiltration capacity results in low soil water recharge and low soil-water availability. This precipitates soil-water limitations on plant growth and thus negatively affects plant ecosystem regulatory services (Yates *et al.*, 2000).

Although *E. macrostachyus* and *C. ciliaris* showed better rehabilitation results compared with *E. superba, E. superba* remains the most popular and preferred grass species among farmers in the area (Table 2). Higher preference for *E. superba* can be attributed to its contribution to livestock production (fattening and milk production). *Eragrostis superba* has also been identified by agropastoralists in the area as their preferred forage species. This result compares well with a study conducted by Wasonga *et al.* (2003) among the East Pokot and Il Chamus pastoral communities inhabiting the semi-arid reaches of Baringo District, Kenya. The East Pokot and Il Chamus communities have identified *E. superba* as a forage species to fatten livestock and improve their body condition score.

The agropastoral farmers in the study area have also noted that free-ranging livestock have a higher preference for *E. superba* compared with *C. ciliaris* and *E. macrostachyus,* ranked second and third respectively. This preferential behaviour by the grazing animals to *E. superba* has also influenced its high preference among the pastoral and agropastoral communities. Its high nutritional value (approximately 12% crude protein in the dry matter at early flowering stage and 30–35% crude fibre) has made it popular as a basal diet in many livestock feed experiments (Nyambati *et al.*, 2006; Koech *et al.*, 2011). In addition, *E. superba* is also very resistant to high grazing intensities. Although *E. macrostachyus* achieves better rehabilitation results, it is the least preferred species because of its less leafy biomass, nutritive value and resistance to grazing compared with *C. ciliaris* and *E. superba.* Moreover, it is easily uprooted by the grazing animals especially during the rains when the soils are moist, compared with *C. ciliaris* plants which have strong fibrous root systems to more than 2 m deep. *Enteropogon macrostachyus* is also very susceptible to termite attacks.

Enteropogon macrostachyus- E. superba combination showed the best rehabilitation results among mixtures (Table 1). Good rehabilitation performance of the *E. macrostachyus- E. superba* mix can be attributed to the presence of *E. macrostachyus* in the mixture and presumably there is less inter-species competition between the two grass species. This result suggests that this combination best suits the farmers' needs as it combines grass species with good rehabilitation performance and the preferred grass species for livestock production. Interestingly, it remains the least preferred combination among farmers (Table 2). Farmers in the area prefer sowing grass seeds as pure stands rather than mixtures. This partly explains why *E. macrostachyus- E. superba* remains unpopular among the farmers. Pure stands also yield more biomass, presumably due to the absence of inter-species competition. Competitive ability of the individual grass species over the other grass species, weeds and pests, plays a critical role influencing biomass production and determining the rehabilitation success using that particular species. For example, *C. ciliaris* is reported to be allelopathic (Mganga *et al.*, 2010), and may suppress the other grass species when sown in mixtures.

Buffel grass, *C. ciliaris,* is highly valued as a pastoral species and more recently for rehabilitation and erosion control because of its high nutritional value for sheep and cattle, high tolerance to drought, an ability to withstand heavy grazing, a deep stabilizing root system and because it responds quickly to rainfall events (Marshall *et al.*, 2012). However, its allelopathic characteristic could have contributed to the consistent lower percentages in frequency and basal cover and plant densities in the *C. ciliaris- E. macrostachyus* and *C. ciliaris- E. superba* mixtures compared with the *E. macrostachyus- E. superba* mixture which had the second highest performance of all treatments.

Faster seed germination is highly desirable under field conditions as it gives the seedlings a head start in the normal plant competition. Differences in germination capacity among the three grass species in terms of percentages may have been influenced by many factors notably seed dormancy, integument hardness, morphology, harvesting method, storage conditions, conditions before seed harvest as well as seed drying. Higher percentage seed germination of *E. macrostachyus* compared with *E. superba* and *C. ciliaris* in this study can be explained by the seed harvesting method. Although all the three species are harvested manually, *E. macrostachyus* seed harvesting involves cutting the seed head with its stalk, whereas *E. superba* and *C. ciliaris* seed heads are stripped by hand. Cutting panicles with stem involves stacking in the field. The swath is then dried for a period of 2 weeks and then threshed manually on a threshing floor. Some of the advantages of this method of harvesting include high seed recovery, longer seed storage and high seed quality, which might have contributed to the higher germination percentages of *E. macrostachyus* compared with

C. ciliaris and *E. superba.* This characteristic is advantageous in arid and semi-arid ecosystems characterized by low, erratic and infrequent rainfall events and high evapotranspiration rates.

Higher germination capacity of *C. ciliaris* compared with *E. superba* can be attributed to the hairy bristle coat of the *C. ciliaris* seeds. The fascicles are likely to have also aided germination by maintaining high humidity within them and thereby helping to reduce water loss from the caryopsis, thus enhancing a higher germination (Sharif-Zadeh and Murdoch, 2001), as compared to that of *E. superba*. Additionally, these fascicles are known to contain more than one caryopsis as shown in earlier studies (Daehler and Georgen, 2005). Seed of buffel grass has been shown to germinate between 10 and 40°C with optimal germination rates at 30°C/20°C d/night temperatures. Preliminary germination tests by Voigt and Tischler (1996) indicated high levels of post-harvest dormancy in *E. superba.* Although seed dormancy can contribute to establishment and stand persistence when a reserve of dormant seed preserves the opportunity for plant establishment over time, excessive levels of dormancy can hinder successful stand establishment when rapid germination of large numbers of seed is desired.

Conclusion

Desertification is a central problem in the sustainable development of dryland ecosystems. Reseeding using native rangeland forage grass species notably *C. ciliaris, E. macrostachyus* and *E. superba* acclimatized to the local conditions is one method used to combat desertification in the arid and semi-arid environment in Kenya. Our study revealed that *E. macrostachyus* is best suited to rehabilitate semi-arid lands in Kenya, but is less preferred than *E. superba* among the agropastoralists. We conclude that the choice of grass species to combat desertification is much more influenced by their forage value for livestock than their contribution for rehabilitation purposes. Maximizing the contributions of *E. macrostachyus* and *E. superba* in mixtures is a feasible method which can be explored further and promoted among the agropastoralists in semi-arid Kenya.

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