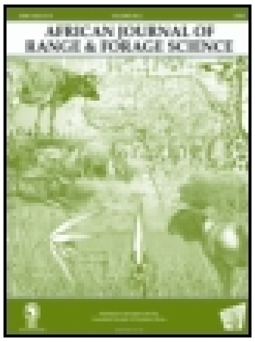

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Research Note

A comparative analysis of the morphology and nutritive value of five South African native grass species grown under controlled conditions

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The comparative growth habits and nutritive value of native grass species of South Africa are largely unknown despite the utility of this information in rangeland restoration efforts. This article presents a comparative characterisation of the morphology, chemical composition and *in vitro* ruminal fermentation of *Urochloa mosambicensis*, *Cymbopogon pospischilii*, *Eragrostis superba*, *Fingerhuthia africana* and *Eragrostis bicolor* when grown under controlled conditions. Species were analysed for height, number of leaves, number of tillers, stem diameter and leaf width at different growth stages, whereas chemical composition and *in vitro* ruminal dry matter degradability (DMD) were assessed at maturity stage. Grass species and growth stages significantly influenced morphological characteristics. *Eragrostis superba* and *U. mosambicensis* had the highest number of leaves at the reproductive stage. *Urochloa mosambicensis* ranked highest in terms of rangeland restoration potential when all morphological parameters were considered, followed by *E. superba* and *C. pospischilii*. With the highest crude protein, low acid-detergent lignin and higher DMD at 48 h, *F. africana* and *C. pospischilii* have the highest potential feed value. Across the three most suitable native grass species, *U. mosambicensis*, *E. superba* and *C. pospischilii*, there is sufficient genetic diversity that suggests that these plants may play different and complementary ecological roles in the communal rangeland ecosystem.

Keywords: communal areas, ecological niche, morphology, restoration, semi-arid

Sustainable pasture production and restoration of degraded rangelands are the two most important components of rangeland management and utilisation. Research on strategies to restore degraded rangelands has recently become prominent. In communal rangelands, major emphasis could be placed on the adoption of best management practices and land restoration using indigenous plant species that are adapted to the local environment (Smith et al. 2008). This, in turn, requires empirical data on the germination, phenology and nutritional value of available native plants (Kwesiga et al. 2003). Grass growth, as defined by vegetative, elongation and reproductive stages, determines the density, plant community composition (Fay and Schultz 2009) and carbon biomass accumulation. Disturbances during any of these stages may alter plant community composition. In South Africa, propagation of indigenous grass species from seed and vegetative parts could be an inexpensive and effective means to restore degraded rangelands. Although numerous studies have addressed germination characteristics of perennial herbaceous plants elsewhere, little is known about morphological characteristics and relative nutritional value of important native grass species in South African rangelands. Comparative assessment of chemical composition and ruminal fermentation of native grass species and varieties is also essential because, ideally, highly nutritive grasses should be preferred for rangeland restoration. In addition, the nutritive value of grasses is known to be influenced by climate, soil type, water and nutrient availability (Särkijärvi et al. 2012). This study, therefore, sought to determine the morphology, relative growth rates, chemical composition and *in vitro* ruminal fermentation parameters of selected native grass species when grown under controlled environmental conditions. The selected grass species were those found to be more common in target communal rangelands in the North West province.

The study was carried out in a controlled environment at Molelwane University Farm (25°48′00″ S, 25°38′21″ E). The controlled environment had light-reflective roofing, which maintained temperatures between 20 and 30 °C. Grass seeds used in the growth trial were harvested at two villages (Six-hundred: 25°43.133′ S, 25°38.597′ E; and Tsetse: 25°44.776′ S, 25°40.533′ E) from *Cymbopogon pospischilii*, *Eragrostis bicolor*, *Eragrostis superba*, *Fingerthuhia africana* and *Urochloa mosambicensis*. The villages are located in a semi-arid area, receiving 300–450 mm rainfall per annum with temperatures ranging between 2 and 34 °C. Harvesting of seed from each grass species was done by hand in mid-January. The seeds were allowed to dry at room temperature for three weeks and were sown in February 2016. Seeds were randomly allocated to each of 20 pots (experimental units) such that each grass species was replicated four times in the growth trial. A minimum of 20 seeds were sown in each 12 L plastic pot (36 cm diameter and 29 cm depth). Clay loamy soil was collected from the two villages, combined and homogenised, then sieved and 10 kg placed in each pot. Samples of the homogenised soil were analysed for chemical constituents prior to the start of the experiment. Upon germination, seedlings were thinned to 10 plants per pot. Morphological characteristics (plant height, leaf width, tiller number, tiller diameter and number of leaves) were recorded for each grass species at the vegetative, elongation and maturity stages from the end of February to the end of April 2016. However, the plants were allowed to continue growing until October 2016 to allow for tiller development.

At all growth stages, each grass species was scored on the basis of morphological traits with the tallest plants composed of broad leaves, thick stem diameters, high tiller number and high number of leaves being ranked high on a 1–5 scale. Based on the combination of morphological traits, grass species were ranked according to their potential for restoring degraded rangeland (1 = unsuitable, 2 = severe limitations, 3 = moderate limitations, 4 = suitable, and 5 = highly suitable). Chemical composition (crude protein [CP], fibre and lignin contents) and *in vitro* ruminal dry matter degradability (DMD) was determined at the maturity stage. Crude protein (AOAC 1999: method number 984.13), neutral and acid detergent fibre, and acid detergent lignin contents (van Soest et al. 1991) were determined. *In vitro* ruminal DMD of grass samples was determined by anaerobically incubating grass samples in heat-sealed ANMKOM F57 filter bags with rumen fluid in an ANKOM Daisy[II] incubator in accordance with the method described by ANKOM Technology, New York, USA. Ethical approval (NWU-00126-13-A9) for this study was obtained from North-West University Animal Research Ethics Committee.

Data on morphological characteristics were analysed using two-way analysis of variance to determine the significance of variation due to plant species and growth stage using SAS 10 (SAS Institute, Cary, NC, USA). Chemical composition and *in vitro* ruminal DMD data were analysed using one-way analysis of variance to determine the significance of variation due to species only. Least significant differences were used to separate treatment means.

The soil used as a potting medium showed the following properties: pH 4.32, 1.8% nitrogen, 1.5 mg kg^{-1} phosphorus, 169 mg kg^{-1} potassium, 328 mg kg^{-1} calcium, 86 mg kg^{-1} magnesium, 0.002 mg kg^{-1} sodium, 4 mg kg^{-1} iron, 0.6 mg kg^{-1} copper, 0.38 mg kg^{-1} zinc, 14.9 mg kg^{-1} manganese and 0.7 mg kg^{-1} carbon.

The germination status for each grass species, in increasing order, was 69% for *E. superba*, 78% for *C. pospischilii*, 80% for *F. africana*, 90% for *U. mosambicensis* and 98% for *E. bicolor*. Seed size might have affected the high germination percentage of *E. bicolor* (Hendrix 1984). Small seeds, such as those of *E. bicolor*, normally require a shorter time to germinate and for initial development of seedlings (Souza and Fagundes 2014). Species, growth stage and their interaction significantly ($p < 0.05$) influenced morphological characteristics of the grasses. Plant height, leaf width, tiller number, stem diameter and number of leaves of the grass species at different developmental stages are presented in Table 1. The use of local plant genetic resources to restore rangelands in semi-arid areas exposed to uncontrolled heavy grazing is a potentially sustainable strategy for improving grass species composition, carrying capacity and other environmental functions (Shono et al. 2007). Of all morphological characteristics measured, the number

Table 1: Effect of species and growth stage on plant height, leaf width, average number of tillers, stem diameter and number of leaves in five selected grass species grown under controlled conditions. Shared upper-case superscript letters within a column indicate a non-significant difference among growth stages ($p > 0.05$). Shared lower-case superscript letters within a column indicate a non-significant difference among grass species ($p > 0.05$)

Parameter	Growth stage	*U. mosambicensis*	*C. pospischilii*	*E. superba*	*F. africana*	*E. bicolor*
Plant height (cm)	Vegetative	29.2^{aC}	24.2^{bC}	19.0^{cC}	15.4^{dC}	14.7^{dC}
	Elongated	44.8^{aB}	42.5^{abB}	39.0^{bB}	25.8^{cB}	26.5^{cB}
	Reproductive	57.9^{cA}	71.0^{bA}	78.2^{aA}	50.5^{dA}	67.7^{bA}
Leaves width (mm)	Vegetative	3.6^{aC}	1.5^{cB}	2.0^{bC}	1.4^{cC}	1.2^{cB}
	Elongated	5.9^{aB}	1.9^{cdB}	3.3^{bB}	2.2^{cB}	1.6^{dB}
	Reproductive	7.3^{aA}	2.7^{dA}	5.1^{bA}	4.2^{cA}	3.0^{dA}
Average tiller number	0–3 months	1.0^{aB}	1.0^{aB}	1.0^{aB}	1.0^{aB}	1.0^{aB}
	>3–6 months	1.4^{abB}	2.0^{aB}	1.0^{bB}	1.0^{bB}	1.3^{bB}
	>6–9 months	3.0^{cA}	9.3^{abA}	7.4^{bA}	7.0^{bA}	11.1^{aA}
Stem diameter (mm)	Vegetative	1.2^{aB}	0.7^{cC}	0.7^{cC}	0.9^{bB}	0.6^{dB}
	Elongated	1.5^{aA}	1.2^{bcB}	1.3^{abB}	1.1^{cdB}	1.0^{dB}
	Reproductive	1.8^{aA}	1.5^{bA}	1.8^{aA}	1.9^{aA}	1.3^{cA}
Number of leaves	Vegetative	4.3^{aB}	3.9^{aC}	3.05^{bC}	3.3^{bC}	3.2^{bC}
	Elongated	5.9^{aA}	6.3^{aA}	5.2^{bB}	5.1^{bA}	5.0^{bB}
	Reproductive	6.3^{aA}	5.2^{bB}	6.3^{aA}	4.5^{cB}	5.5^{bA}

of tillers per shoot plays an overriding role because it is positively associated with biomass production, soil erosion reduction, weed suppression, resistance to trampling and prevention of bush encroachment (Sun and Liddle 1993).

Urochloa mosambicensis plants have the highest potential to restore degraded rangelands because they were the tallest plants, had the thickest stems (vegetative and elongation growth stages) and produced the greatest number of broad leaves at all growth stages (Tables 1 and 2). Broad-leaved plants prevent moisture evaporation from the soil by creating shade on the soil surface. In addition, broad leaves ensure higher rates of photosynthesis to stimulate rapid regrowth after defoliation or drought, which may contribute to the high nutritive value of grass species when harvested at the elongation stage. *Urochloa mosambicensis* can be preferably used if rangeland is to be restored using both replanting and exclusion of restored areas from grazing. This is because the species is mostly preferred by animals (van Oudtshoorn 2014) because of its high number of leaf blades, a quintessential morphological component of pastures with high nutritive value (Santos et al. 2008).

Cymbopogon pospischilii plants were the tallest ($p < 0.05$) at the elongated stage, had the highest tiller number at all growth stages, and the highest number of leaves at the vegetative and elongated stages. Indeed, Shackleton (1990) observed that *Cymbopogon* species accumulate many tillers and become part of the moribund material if left ungrazed, a finding that is in contrast to that of Smit and Rethman (1990). In addition, no loss of tillers was recorded in *C. pospischilii*. Despite these attributes, *C. pospischilii* is known to be a poor-quality forage species (van Oudtshoorn 2014) because of the presence of essential oils that give the grass a bitter taste. The number of leaves must be adequate if photosynthesis is to continue after grazing in order to generate significant regrowth. As such, species such as *U. mosambicensis* and *C. pospischilii* are suitable for the restoration of degraded areas owing to their high number of leaves (Tables 1 and 2). The high number of leaves in these species can also increase organic matter accumulation following natural defoliation.

Eragrostis superba had the highest ($p < 0.05$) tiller height and number of leaves at the reproductive stage, the highest stem diameter at the elongated and reproductive stages, and the broadest leaves after those of *U. mosambicensis* at all stages of growth. The high tiller value of *E. superba* recorded in the present study is comparable to that reported by van Oudtshoorn (2014). Within the limits set by genotype, Laude (1972) stressed that tiller growth is responsive to the environment. Taller species such as *E. superba* can be used to control grazing pressure as it is easily accessible by large herbivores. Indeed, Santos et al. (2013) reported that cattle preferentially grazed on the taller plants as opposed to shorter plants when put out to pasture composed of layers of plants of different heights. Bransby (1980) also observed that herbage height and amount of herbage grazed were linearly correlated.

Fingerhuthia africana had the highest ($p < 0.05$) CP content (102 g kg^{-1}) (Table 3), a value higher than that (40 g kg^{-1} dry matter [DM]) reported by Fourie et al. (1985). This difference could be due to differences in soil fertility or growth medium. *Urochloa mosambicensis* had the lowest CP content (42 g kg^{-1}). This value is lower than that reported by Beyene and Mlambo (2012), who reported an average CP content of 63.7 g kg^{-1} DM for this grass species. Although all species had higher neutral detergent fibre concentrations due to the stage of growth when harvested, species with high protein content and low lignin content, such as *F. africana*, are considered to be of high

Table 2: Rangeland restoration potential rankings of the selected native grass species based on morphological attributes measured at different growth stages

Species	Growth stage			Average rank
	Vegetative	Elongated	Reproductive	
U. mosambicensis	4	5	3	4
C. pospischilii	3	4	3	3.3
E. bicolor	1	2	3	2
E. superba	2	3	4	3
F. africana	2	2	3	2.3

Table 3: Chemical composition (g kg^{-1} dry matter, unless otherwise stated) and *in vitro* ruminal dry matter degradability of five selected grass species grown under controlled conditions. Shared superscript letters within a row indicate a non-significant difference among grass species ($p > 0.05$). DM = dry matter, OM = organic matter, CP = crude protein, NDF = neutral detergent fibre, ADF = acid detergent fibre, ADL = acid detergent lignin, DMD24 = *in vitro* ruminal dry matter degradability at 24 h, DMD36 = *in vitro* ruminal dry matter degradability at 36 h, DMD48 = *in vitro* ruminal dry matter degradability at 48 h

Component	*F. africana*	*E. superba*	*E. bicolor*	*C. pospischilii*	*U. mosambicensis*
DM (g kg^{-1})	956.1^{c}	983.6^{a}	967.7^{bc}	964.6^{bc}	971.8^{ab}
OM	847.5^{b}	890.7^{a}	872.8^{a}	690.9^{c}	709.1^{c}
CP	102^{a}	50^{d}	61^{c}	71^{b}	42^{e}
NDF	797.0^{a}	801.0^{a}	681.7^{b}	690.9^{b}	709.1^{b}
ADF	419.7^{a}	433.7^{a}	436.1^{a}	378.3^{b}	416.2^{a}
ADL	67.7^{c}	82.9^{b}	96.7^{a}	95.5^{a}	86.2^{ab}
DMD24	208.7^{b}	212.1^{b}	183.9^{b}	240.1^{a}	238.5^{a}
DMD36	403.9^{ab}	441.3^{a}	341.0^{b}	425.6^{ab}	377.0^{ab}
DMD48	562.7^{a}	407.4^{b}	424.2^{b}	526.6^{a}	474.4^{ab}

nutritive value. All other grass species that had a low CP content also had a high lignin content. Neutral detergent fibre is regarded as a necessary part of the diet in ruminant animals, being critical for optimal rumen function. Neutral detergent fibre values of all grass species in this experiment are similar to those reported by Mandebvu et al. (1999) and Aregheore (2001) for a variety of grass species.

Fingerhuthia africana and *C. pospischilii* had the highest DMD values at 48 h compared with those of the other grass species (Table 3). Lignin limits the achievable degradation of cellulose and hemicellulose and limits the digestible energy available to ruminants (Jung and Allen 1995), but the opposite was true with *C. pospischilii*. The high degradability of *C. pospischilii* might have been contributed by the number of leaves accumulated in tillers. Plants with greater numbers of leaves owing to production of many tillers tend to have higher CP contents and lower fibre proportions and therefore higher rumen degradability. The CP concentration (71 g kg^{-1} DM) of *C. pospischilii* also might have contributed to the high degradability of this grass species. The availability of nitrogen for the breakdown of lignocellulose in the rumen is affected by both feed and physiological factors. High absolute quantities of ruminally soluble and degradable nitrogen may increase microbial protein synthesis in herbivores exposed to this grass species.

The native grass species in the present study showed different morphological and nutritional characteristics. *Urochloa mosambicensis* ranked highest in terms of rangeland restoration potential when all morphological parameters were considered, followed by *E. superba* and *C. pospischilii*. Based on the morphological qualities of grasses that are critical for restoration of degraded rangelands, the above three grass species were ranked as the most suitable species, whereas *E. bicolor* and *F. africana* were judged to be the least suitable species. With the highest CP content, low acid-detergent lignin and higher DMD at 48 h, *F. africana* is a highly nutritive grass species that could increase productivity of grazing animals. Given the different morphological and nutritional characteristics, *U. mosambicensis*, *E. superba* and *C. pospischilii* can complement each other in rehabilitating communal areas affected by heavy grazing.

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References

AOAC (Association of Official Analytical Chemists). 1999. *Official methods of analysis of AOAC International* (16th edn). Arlington, VA: AOAC.

Aregheore EM. 2001. Nutritive value and utilization of three grass species by cross Anglo-Nubian goats in Samoa. *Asian-Australasian Journal of Animal Sciences* 14: 1389–1393.

Beyene ST, Mlambo V. 2012. Botanical and chemical composition of common grass species around dip-tank areas in semi-arid communal rangelands of Swaziland. *Tropical and Subtropical Agroecosystems* 15: 143–152.

Bransby DI. 1980. Herbage height as a determinant of the preference of steers grazing three pasture species. *Proceedings of the Annual Congresses of the Grassland Society of Southern Africa* 15: 153–155.

Fay PA, Schultz MJ. 2009. Germination, survival, and growth of grass and forb seedlings as affected by soil moisture variability. *Acta Oecologica* 35: 679–684.

Fourie JH, Opperman DPJ, Roberts BR. 1985. Evaluation of the grazing potential of grass species in *Tarchonanthus* veld of the Northern Cape. *Journal of the Grassland Society of Southern Africa* 2: 13–17.

Hendrix SD. 1984. Variation in seed weight and its effect on germination in *Pastinaca sativa* L. (Umbelliferae). *American Journal of Botany* 71: 795–802.

Jung HG, Allen MS. 1995. Characteristics of plant cell walls affecting intake and digestibility of forages by ruminants. *Journal of Animal Science* 73: 2774–2790.

Kwesiga F, Akinnifesi FK, Mafongoya PL, McDermott HH, Agumya A. 2003. Agroforestry research and development in southern Africa during the 1990s: review and challenges ahead. *Agroforestry Systems* 59: 173–186.

Laude HM. 1972. *External factors affecting tiller development*. In: Youngner VB, McKell CM (eds), *The biology and utilization of grasses*. New York: Academic Press. pp 146–154.

Mandebvu P, West JW, Hill GM, Gates RN, Hatfield RD, Mullinix BG, Parks AH, Caudle AB. 1999. Comparison of Tifton 85 and Coastal bermudagrasses for yield, nutrient traits, intake, and digestion by growing beef steers. *Journal of Animal Science* 77: 1572–1586.

Santos MER, Fonseca DM, Euclides VPB, Ribeiro Júnior JI, Balbino EM, Casagrande DR. 2008 Nutritive value of forage and its morphological components in pastures of *Brachiaria decumbens. Animal Industry Bulletin* 65: 301–311.

Santos MER, Fonseca DM, Silva GP, Braz TGS, Gomes VM, Silva SP. 2013. Defoliation patterns in signal grass tillers with varying heights in the same pasture. *Acta Scientiarum, Animal Sciences* 35: 259–265.

Särkijärvi S, Sormunen-Cristian R, Heikkilä T, Rinne M, Saastamoinen M. 2012. Effect of grass species and cutting time on *in vivo* digestibility of silage by horses and sheep. *Livestock Science* 144: 230–239.

Shackleton SE. 1990. Socio-economic importance of *Cymbopogon validus* in Mkambati game reserve, Transkei. *South African Journal of Botany* 56: 675–682.

Shono K, Cadaweng EA, Durst PB. 2007. Application of assisted natural regeneration to restore degraded tropical forestlands. *Restoration Ecology* 15: 620–626.

Smit GN, Rethman NFG. 1990. Association of *Cymbopogon plurinodis* with the clay content of soil in the Sourish Mixed Bushveld. *Journal of the Grassland Society of Southern Africa* 7: 64–66.

Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl P, Ogle S, O'Mara F, Rice C et al. 2008. Greenhouse gas mitigation in agriculture. *Philosophical Transactions of the Royal Society B* 363: 789–813.

Souza ML, Fagundes M. 2014. Seed size as key factor in germination and seedling development of *Copaifera langsdorffii* (Fabaceae). *American Journal of Plant Sciences* 5: 2566–2573.

Sun D, Liddle MJ. 1993. The morphological responses of some Australian tussock grasses and the importance of tiller number in their resistance to trampling. *Biological Conservation* 65: 43–49.

van Oudtshoorn FP. 2014. *Guide to grasses of southern Africa'* Pretoria: Briza Publications.

van Soest PJ, Robertson JD, Lewis BA. 1991. Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharide in relation to animal nutrition. *Journal of Dairy Science* 74: 3583–3597.

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