Species and spatio-temporal variation in the yield, nutritive value and *in vitro* ruminal fermentation characteristics of selected grass species from two communal grazing lands of the Eastern Cape

By

Kwaza Ayanda

Thesis submitted in partial fulfilment of the requirements of the Degree of Master of Science in Agriculture (Pasture Science)

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Supervisor: Prof Solomon T Beyene

Co – supervisor: Prof V. Mlambo

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Approved as to style and content by:

________________________	________________________
Prof Solomon T. Beyene	**Prof V. Mlambo**
(Supervisor)	**(Co-supervisor)**

November 2013

DECLARATION

I, Ayanda Kwaza, vow that this dissertation has not been submitted to any University and that it is my original work conducted under the supervision of Prof Solomon T. Beyene and Prof. V. Mlambo. All assistance towards the production of this work and all the references contained herein have been duly acknowledged.

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Ayanda Kwaza

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ABSTRACT

Communal rangelands sustain a large proportion of the livestock in South Africa. A few dominant grass species contribute to the bulk of the livestock forage in these rangelands. Little is known on the chemical composition and *in vitro* ruminal fermentation characteristics of grass species grazed by ruminants in the communal grazing lands of Eastern Cape Province in South Africa. The objectives of this study were therefore to investigate seasonal and altitudinal variations in biomass yield, chemical composition, and *in vitro* ruminal degradability and cumulative gas production of selected (dominant) grass species. The grass species were collected over four seasons (summer, autumn, winter and spring) from three altitudes/landscape gradients (upland, gentle sloppy and bottomlands) across two communal areas (Hala in highland (Highveld) and Gqumashe in lowland (Lowveld)) of the Eastern Cape province, South Africa. In each altitude, three 50 m x 20 m plots, which served as replicates were marked to collect vegetation samples. A 5 x 4 x 3 factorial experiment in a randomised complete block design was used with season, altitude and grass species being the main factors, and with the plots within altitudes serving as blocks (replicates). Data analysis was done separately for the two communal study areas using the General Linear Models (GLM) procedure of SAS to test differences between species, seasons and altitudes. The common grass species in both grazing lands were *Cynodon dactylon*, *Eragrostis chloromelus*, *Eragrostis plana*, *Sporobolus africanus* and *Themeda triandra*. When the DM yield of all the grasses was combined, the results showed a generally low forage dry matter yield during the dry season. There was no significant ($P>0.05$) interaction between any of the main factors. Macro and micro mineral content of plant samples collected from the two communal grazing lands showed great variations ($P<0.05$) between species, seasons and altitude. In the Highveld, CP ranged from 3.9 to 6.5% DM being significantly highest (P<0.05) in *Cynodon dactylon* and lowest in *E. plana*. When all species were combined, higher CP was recorded for samples harvested in summer (5.5%) followed by spring and autumn, and lowest in winter (3.8%). In the Lowveld, *Eragrostis chloromelus* had higher (P<0.05) CP level followed by *C. dactylon* and *T. Triandra*. When all species were pooled, forage samples harvested in summer had a significantly higher (P<0.05) CP followed by spring, autumn and winter. In summary, CP content of all grasses was below the critical maintenance level for livestock especially during late dry seasons. In both areas, the highest NDF level was measured for *Eragrostis plana* and lowest for *Themeda triandra*. As for altitudinal differences, samples collected from the upland areas had generally the lowest (P<0.05) CP and highest ADF contents. For grasses harvested from the Highveld, *C. dactylon* produced the most (P<0.05) gas after 48 h of fermentation (794.6 ml/g DM) and also had the highest 48h DMD (415.1 g kg^{-1}). *Themeda triandra* produced least (P<0.05) gas (742 ml/g DM) 48h post-incubation. The least (P<0.05) degradable species after 48 h was *E. chloromelus* (372.9 g kg^{-1}). For grasses harvested from Lowveld, the 48h cumulative gas production was highest (822.7 ml/g DM) in *E. plana* and lowest (742.8 ml/g DM) in *E. chloromelus*, while *S. africanus* had least 48h DMD (327.9 kg^{-1}). In both the Highveld and Lowveld, gas production and DMD were highest in the autumn season. It was concluded most grasses were deficient in calcium, magnesium, phosphorus and potassium. Therefore, it is recommended that mineral supplements should be offered to animals to improve animal productivity throughout the year. Findings of this study suggested that addition of protein and energy sources may be desirable in both grazing areas to meet the maintenance/production requirements of the grazing ruminants throughout the year.

Key words: Forage yield, chemical composition, landscape gradient; seasonal variations; *in vitro* ruminal gas production; dry matter degradability.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ADF	Acid Detergent Fibre
Ca	Calcium
CP	Crude Protein
Cu	Copper
DM	Dry Matter
DMD	Dry Matter Degradability
Fe	Iron
GLM	General Linear Model
K	Potassium
Kg^{-1}	Kilograms per hector
Mg	Magnesium
Mn	Manganese
NDF	Neutral Detergent Fibre
P	Phosphorus
PF	Partitioning Factor
SAS	Statistical Analysis System
Zn	Zinc

CHAPTER 1. INTRODUCTION

1.1 Background

The nutritive value of forage for ruminants may be regarded as the product of the intake of the forage and its digestibility, with the intake of the forage being the most important of the two parameters (Marais, 2001; Kozloski *et al*., 2005). Minerals, proteins, fibre contents and *in vitro* ruminal fermentation are all determinates of forage nutritive value (Mirik *et al*., 2005). Effective rangeland management and monitoring programm should constitute the measurements of the biomass yield and nutritional characteristics of range forage as an indicator of range condition (Mirik *et al*., 2005). This is because the ability of a rangeland to sustain animal growth depends on its biomass production and herbage nutritive quality (Snyman, 2002), both of which are affected by season, topography and other environmental factors (Roukos *et al*., 2011). The nutritive value of rangeland forage is dependent on botanical composition of the vegetation (Arzani *et al*., 2006). As indicated by Mbatha and Ward (2010), grasses form the essential component of ruminant feed in semi-arid rangelands. Interactions between climate and topography create a temporal and spatial herbaceous mosaic of coexisting plant species, respectively, which are different in terms of palatability and nutritive values (Roukos *et al*., 2011).

One of the limitations of animal production in the savanna ecosystems is the seasonal variation in the quality and quantity of forages (Zewdu *et al*., 2002; Nyamukanza *et al*., 2010). The major production constraint during the dry season in many communal grazing areas of South Africa is the reduced forage yield and low nutritive values (Scogings *et al*., 1999; Nyamukanza *et al*., 2010). As reported by Nyamukanza *et al*. (2010), low-quality forages in the communal gazing areas have low crude protein and high neutral detergent fibre contents that limits the intake and digestibility of forage. Jingura *et al*. (2001) mentioned that CP concentration of the rangeland forages fluctuates with seasonal changes and can be as low as 1-2% during the dry season.

Forage yield is significantly controlled by variation in landscape attributes including aspect and elevation which influence the distribution of forage nutrients and vegetation by affecting soil nutrients (Rezaeia and Gilkes, 2005). Scholes (2009) mentioned that it is necessary to distinguish the loss of soil and its nutrients from its redistribution, because upland positions transports and deposit soils with its nutrients via gently sloppy areas to the bottomlands. In the communal grazing lands, it is important to identify the types of nutrients limiting livestock production (Mapiye *et al*., 2010) and the most crucial nutrients affecting livestock performance in the semi-arid are protein, energy and minerals. Several studies conducted in South African rangelands Grant *et al*. (2000) mentioned that P was the most common limiting mineral. Corona *et al*. (1998) concluded that the upper and middle zones had lower quality (low protein) and higher in the proportion of cell wall compounds as compared to lower zones.

The gas production technique has been confirmed as a good test to evaluate and rank forages. The *in vitro* degradability of forage can be easily estimated by the gas production method, because this method is based on the measurement of gas produced (Baba *et al*., 2002). For forage evaluation, *in vitro* method is reliable. To predict fermentation characteristics of forages, the *in vitro* gas production (IVGP) technique had been developed. The *in vitro* digestibility technique has been used to evaluate the nutritive value of plant materials (Ndagurwa and Dube, 2013). *In* *vitro* methods are less expensive, less time-consuming (Tilley and Terry, 1963). Measurement of *in vitro* fermentation is increasingly becoming popular for determining forage digestion characteristics and gas production is measured from the *in vitro* digestion of forage with bicarbonate-buffered rumen fluid (Davies *et al*., 2000). *In vitro* method is used to estimate the organic matter degradability of ruminant forages (Tilley and Terry, 1963; Groot *et al*., 1996) also this method involves the measurement of disappearance of substrate during incubation in the *in vitro* and are mostly end-points measurements.

1.2 Problem statement

For sustainable utilization of rangelands and optimum productivity of animals in communal areas, it is imperative that the seasonal and altitudinal variation in yield and nutritive value of the natural forage species be understood. A major challenge of livestock production in the communal grazing lands is low quantity and quality of forage characterised by temporal and spatial variations. Little is known about the yield and the nutritive value of dominant grass species grazed by ruminants in the communal grazing lands of the Eastern Cape Province. Ecological factors such as climate, soil and topography may affect the nutritive value and yield of forages. However, the effect of these factors (e.g. altitude and season) on the yield and nutritive values of grasses has not been extensively quantified and documented.

1.3 Justification

The ability of ruminants and non-ruminant herbivores to utilize forage plants improves food security for the growing human population. Optimum and sustainable utilization of these plant feed resources for animal feed reduces the competition between animals and humans for food.

The bulk of plants used as livestock feed on rangelands are native grass species, which are well adapted to the ecology of the semiarid and arid conditions. However, their nutritive value and yield are likely to vary considerably in response to soil and altitude. Investigations of such variations are vital for plant breeders to identify grasses which have higher nutritive value and yield for future use. Knowledge of topographic factors which affect forage yield and quality are desirable to plan communal range management and fodder flow programme. The current study was designed to provide information on the yield and nutritive value characteristics of common grass species along seasonal and landscape gradients in the Eastern Cape communal rangelands.

1.4 Objectives

The general objective is to improve the productivity of rangelands in the communal grazing areas.

The specific objectives are to determine the:

a. Biomass production of selected (dominant) grass species collected from different altitudes and seasons in two communal areas.
b. Macro and micro-mineral content of the selected (dominant) grass species.
c. Fibre and crude protein content of the selected (dominant) grass species.
d. *In vitro* ruminal fermentation of selected (dominant) grass species.

1.5 Hypothesis

Topography of the area and season does not have effect on the yield, nutritive value and *in vitro* ruminal fermentation characteristics of grass species.

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Livestock production is the major source of livelihoods to the resource poor farmers. South African rangelands support wildlife, game and livestock farming or crop production. The two main rangeland ecosystems in South Africa are savannas and grasslands which both account 60.4% of the total area (Rutherford and Mucina, 2006). The availability of quality forages is influenced by many factors including season, landscape and species. The three main types of livestock production systems in South Africa include communal livestock grazing, commercial ranching and game reserves (Tefera *et al*., 2008). However, livestock production in these systems is entirely dependent on natural rangelands. The major constraint to livestock production in South Africa is the limited availability of appropriate forages, especially during the dry season (April to August). The digestibility concentration of crude protein and palatability of rangeland grass species are very low (Simplice, 2004). The nutritive value of rangeland grass species in respect to livestock production is a function of voluntary intake and feed utilisation (Stone, 1994; Marais, 2001; Kozloski et al., 2005), and these two parameters are not independent because some plant traits have an effect on both intake and utilisation of nutrients. Management and time of the year can influence forage nutritive value and thus it is important to evaluate forage characteristics under grazing conditions (Moreira *et al*., 2004).

A study conducted in South African rangelands by Grant *et al.* (2000) reported that P was the most common limiting mineral in forages. Corona *et al*. (1998) concluded that the upper and gentle sloppy areas (7%) had lower quality (low protein) and higher in the proportion cellulose (30%) compounds as compared to bottomlands (19-20%).

2.2 Chemical composition, forage digestibility and palatability

Tainton (1999) defined digestibility as the difference between the amount of feed ingested and the amount excreted by the animal. Arzani *et al*. (2006) stated that digestibility is frequently considered to be the most valuable estimate of forage quality, since it is closely associated with animal productivity. Digestibility may be related to dry matter, energy, or to any component of the nutrient material available in the feed. There are two main methods developed to estimate digestibility, namely *in vivo* (in the body) and *in vitro* (in glass) methods. Tropical grasses usually have a lower dry matter digestibility (DMD) than temperate species due to higher fibre content associated with the climate in which they are grown (Tainton, 1999; Acosta *et al*., 2001). The stage of growth seems to be the most significant factor affecting the chemical composition and digestibility of range forage (Turk *et al*., 2007). Grant *et al*. (2000) indicated that palatability and digestibility of grasses are positively correlated with N concentrations during the growth season. Palatable species occur naturally in rangeland that is well managed, and decrease with poor management such as overgrazing (Lesoli, 2008). Moretto *et al.* (2001) highlighted that high-nutrient grasses tend to be palatable to livestock grazers, whereas low-nutrient grasses are unpalatable to livestock grazers (i.e. they are consumed either to a greater or to a lower degree than expected based on their abundance, respectively). Domestic livestock (cattle, sheep and goats) show a high degree of selection for palatable grasses and rejection of unpalatable grasses.

2.2.1 In vivo method

Adesogan (2005) mentioned that typical techniques (*in situ* incubation) to evaluate grass species need expensive facilities and large amounts of time and labour. Several methods are used to measure the fermentation of forage species in rumen fluid such as *in vivo* (in the body) and *in* *vitro* (in the glass). Gosselink *et al*. (2004) mentioned that a good measure of energy production of forages in the rumen is the *in vivo* fermentable organic matter (*in vivo* FOM) and it is an important factor for determining the potential synthesis of microbial protein in the rumen. Measurements of *in vivo* FOM with fistulated livestock ruminants are much expensive and affect animal welfare negatively (Gosselink *et al*., 2004). The *in vivo* measurements are laborious, expensive and difficult to standardize because forages are tested in total rations (Cone *et al*., 1996).

2.2.2 In vitro fermentation method.

The *in vitro* gas production technique is used as a method for determining the nutritive values of forage (Herrero *et al*., 1996). The *in vitro* ruminal gas production technique has been confirmed as a rapid and accurate test to evaluate and classify forages. The degradability of forage can also be easily estimated from the *in vitro* gas production method by quantifying recovered residues after fermentation (Baba *et al*., 2002). Data generated from the *in vitro* ruminal fermentation techniques can be used to help farmers make decisions on the stocking rate and feeding management. Tilley and Terry (1963) developed a two-stage technique to quantify *in vitro* digestion of forages and it has been widely used because of its convenience and high degree of correlation to *in vivo* digestibility and accuracy. Damiran *et al*. (2008) concluded that conventional *in vitro* techniques can be used to improve labor efficiency in estimating DM digestibility. Measurement of *in vitro* fermentation is increasingly becoming popular for determining forage digestion characteristics and gas production (Davies *et al*., 2000).

2.3 Factors affecting yield and the nutritive value of grasses

2.3.1 Landscape gradient

Stapelberg *et al*. (2008) stated that the mineral content of a grass plant is affected primarily by the mineral status of the soil in which it grows. Soil minerals on the other hand vary with topographic relief (Mbatha and Ward, 2006), and therefore the topographic gradient is a significant factor influencing the spatial availability in nutritional quality and forage mineral content (Vázquez-de-Aldana *et al*., 2000). Mbatha and Ward (2006) indicated that productivity of rangelands depends in large part on the amounts of nutrients stored in various parts such as vegetation and soil. Soil and topography can affect the growth yield and nutritive value of the grasses (Mbatha and Ward, 2006). Topography (altitude above sea level) influences microclimates such as precipitation and temperature which, in turn, influences soil properties and vegetation type (Roukos *et al*., 2011). Several factors can influence the ecological response of a species along an environmental gradient. Forage quantity and quality declines on steep slopes which lead to soil loss and declining soil fertility. Kagabo *et al*. (2013) reported that forage yield significantly vary between the uplands part and the bottomlands due to the movement of fertile topsoil from the uplands to the bottomlands.

2.3.2 Seasonal effects

Season plays a major role on the availability of forage. Ramirez *et al*. (2004) mentioned that there are few scientific studies to quantify seasonal nutritional changes of the most important grass species in the communal grazing lands. During different seasons the nutrient levels in grasses are not constant throughout the year but fluctuate (Stapelberg *et al*., 2008). During the summer there is an abundance of feed (Nyamukanza *et al*., 2010), CP and feed is of high digestibility and palatability, but this is obtained when there are good summer rains. In winter (dry season), the forge is dry and nutritional quality is low (Nyamukanza *et al.*, 2010) and hence digestibility is low. Dry season is the dormant season for plant growth as well as a critical time of year for ruminants because both the amount and nutritional status of the forage available declines drastically (Shrader *et al*., 2006). During this period, grass growth cease and the leaves change from green to brown and are eventually lost. This suggests that free grazing ruminants may encounter a decline in the nutritional quality of forage during the dry season (Henkin *et al*., 2011). The quantity and quality of rangeland grasses become more critical during the dry season imposing more serious constraints to the productivity of livestock (Abusuwar and Ahme, 2010) especially to the communal lands. Feed intake and therefore animal performance is low because protein levels of forages are low during dry seasons. Indeed, several studies found that there is a tremendous drop in the protein content of grasses during the dry season (Abusuwar and Ahme, 2010). Henkin *et al*. (2011) indicated that rainfall seasonality has a strong modifying effect on grass growth dynamics. In addition, Ramirez *et al*. (2004) concluded that CP and mineral contents of grass species were affected by climatic conditions.

2.3.3 Effect of grazing on yield and nutritive value

The dominant use of rangeland resources in the communal grazing lands of South Africa is grazing. The individual grass species, which make up the grassland communities, differ in their adaptive mechanisms and tolerance to grazing (Lesoli, 2008). Grazing for livestock production is the most widespread land use of vegetation in communal rangelands. In extensive communal grazing lands of South Africa, grass species are the major food source of grazers. The quantity and quality of forage yield in these rangelands are below the potential, owing to heavy, uncontrolled grazing for long periods of time. It is essential to evaluate forage characteristics under grazing conditions because soil, forage and animals are dynamic factors that affect native pastures (Moreira *et al*., 2004). Management and time of the year can easily influence forage nutritional status hence it is important to evaluate forage nutritive value under grazing in different seasons of the year (Moreira *et al.*, 2004). Grass species responses to grazing vary with habitat and resources and grazing stimulates recycling of nutrients to grasses, consequently leading to recycling of nutrients back to the herbivores (Wegener and Odasz, 1997). Overgrazing leads to excessive removal of the most palatable or preferred species, which are usually perennial grasses. This grants an opportunity for less palatable or less desirable and faster establishing annual grasses to take over the rangeland (Nsinamwa *et al*. 2005). Moreover, heavy grazing results in reduced plant vigor.

Lesoli (2008) mentioned that grass species differ in their tolerance and requirements from the environment hence the distribution varies along environmental gradient. Changes in grazing practice will cause a change in species composition. There are changes in vegetation structure, composition and productivity because of grazing pressure (Lesoli, 2008). Under such conditions (heavy grazing pressure), there is disappearance of decreaser species and replaced by increaser or invader species. An indicator of rangeland condition is species composition because species vary significantly in their acceptability and response to grazing herbivores (Abule *et al*. 2007; Lesoli, 2008). Rangelands consist of a mixture of uplands, gently sloping areas and bottom lands, the bottom and gently sloping lands are generally grazed approximately three times more intensely, than associated uplands because of easy access by the livestock (Lesoli, 2008). Grazing increases bare ground but reduces litter cover (Lesoli, 2008).

2.3.4. Characteristics of the plant

2.3.4.1 Species composition

Trollope *et al*. (1990) defined species composition as the relative proportion of different species occurring in a particular area or rangeland. Species composition, vegetation height, standing live biomass and sward structure are largely affected by grazing (Armstrong *et al*., 1997). As indicated by Abule *et al*. (2007), species composition is the well-known indicator of rangeland condition and has been widely used, as species may vary significantly in their acceptability to grazing animals due to differences in palatability. Production may also depend on the species present, their functional diversity or composition or the identity of individual species (O'Connor *et al*., 2001). Grazing for livestock production is the most widespread land use of vegetation in communal rangelands. In extensive communal grazing lands of South Africa, grass species are the major food source of grazers. The quantity and quality of forage yield in these rangelands are below the potential, owing to heavy, uncontrolled grazing for a very long time. Ecologically sensitive semi-arid areas in the communal grazing lands of South Africa are increasingly subjected to high grazing pressure and this causes changes of species composition from long-lived perennials to annuals or short-lived perennials (O'Connor *et al*., 2001; Snyman, 2009).

2.3.4.2 Species diversity

Corson *et al*. (2006), states that increased diversity of plant species or functional groups may increase the productivity, sustainability, and nutrient retention of temperate pastures. Management of forage species diversity to take advantage of variability in land and climate is an ecological approach to enhancing the multi-functionality, productivity, and sustainability of rangelands (Hector and Loreau, 2005). Fulfilling these functions probably will require good management of the rangeland. As stated by Sanderson *et al*. (2007), rangelands may appear homogeneous in plant species but closer examination of these natural pastures at different scales reveals a wide variety in composition. Though, diversity is often equated to species richness and other components of diversity have frequently been underestimated (Díaz and Cabido , 2001). The role of plant diversity in ecosystem performance has been the focus of high profile.

2.3.4.3 Dominant grass species description

Cynodon dactylon (Couch grass) is a warm season C_4 perennial grass which is used extensively as ruminant forage in tropical and subtropical regions (Xu *et al*., 2011). *Cynodon dactylon* grows in all types of soils, particularly in sandy and fertile soils. It is found in disturbed soil such as roadsides and trampled soils (van Oudtshoorn, 1999). This is a type of grass that can tolerate heavy grazing and offers palatable pasture. Under natural conditions, *C. dactylon* is an average to good pasture grass that remains green until late in winter. It is the most widespread grass that occur in all regions of the world with a moderate to warm climate (van Oudtshoorn, 1999). *Eragrostis chloromelas* grows only in southern Africa in open plains and in previously disturbed soils. It is a moderately palatable grass during early the growing season, but later becomes unpalatable due to rolled leaves. *Eragrostis plana* has strong smooth leaves, which are curly when mature. Often found in wet soils and where there is excessive trampling along footpaths (disturbed soils). It is dominant in sourveld areas and is an increaser II species. *Sporobolus africanus* is a tough perennial tussock grass that grows to a height of 50 cm. The stems are dark green, upright and slender. The leaves are dark green, mostly occurring around the base, and are slender and stiff. *Themeda triandra* (Red Grass) is a C_4 summer-growing and tufted perennial grass species that is native to South Africa, Australia and eastern Asia (Magawana, 2011) and it is dominant in a fire climax community that requires frequent burning to maintain grass productivity. *Themeda triandra* is common in undisturbed open grassland, savanna and bushveld and requires average to high rainfall. It is the most essential grazing grass in open grassland regions of southern and East Africa (van Oudtshoorn, 1999). It is palatable, and is often dominant in rangelands. It is resistant to fire and its presence indicates good rangeland healthy condition.

CHAPTER 3. MATERIALS AND METHODS

3.1 Description of the study area

Two communal areas of Eastern Cape, namely; Hala in the Highveld and Gqumashe in the Lowveld were selected for this study. Description of the geographical location of Hala is as follows: uplands (32^0 37’ 42’’ S and 26^0 54’ 38’’ E, Elevation 985m. a. s. l), gentle sloppy (32^0 37’37’’ S and 26^0 54’64’’ E, Elevation 857 m. a. s. l), and bottom lands (32^0 37’30’’ S and 26^0 54’ 79’’ E, Elevation 822 m. a. s. l). The average annual rainfall is 800 mm of which 70% falls between October and March. The mean temperature in summer is 20^0C and in winter is 8^0C (Mapiye, 2010). The vegetation is Amathole Montane Grassland (Mucina and Rutherford 2011). The dominant grass species in this area were *Cynodon dactylon*, *Digitaria eriantha*, *Eragrostis chloromelas*, *Eragrostis plana*, *Sporobolus africanus* and *Themeda triandra*. Soils are deep, freely drained and highly weathered also weakly developed lithosols (Mucina and Rutherford 2011). The topography is generally characterised by a hilly landscape and plain, bottom lands and top lands. The livestock kept in this area include cattle, sheep and goats.

Description of the geographical location of Gqumashe is as follows: uplands (32^0 46’ 10’’ S and 26^0 51’ 83’’ E, altitude 632 m. a. s. l), gently sloppy (32^0 46’ 25’’ S and 26^0 51’ 80’’ E, altitude 552 m. a. s. l) and bottomlands (32^0 46’ 34’’ S and 26^0 46’ 77’’ E, altitude 538 m. a. s. l). The mean annual rainfall is 480 mm of which 70% falls between October and March. The maximum and minimum temperatures range between 26 - 41°C in summer and between 5 - 11°C in winter (Mabuza, 2011), respectively. The vegetation type is Bisho Thornveld. The vegetation is composed of several grass species, woody plants and shrubs. The dominant grass species in this area were *Cynodon dactylon*, *Digitaria eriantha*, *Eragrostis chloromelas*, *Eragrostis plana*, *Sporobolus africanus* and *Themeda triandra*. *Acacia karroo* was the dominant woody plant.

Soils are heterogenous but are mainly sedimentary such as sandy and mudstones with some igneous rocks (doleritic dykes and sheets), which result in red soils occurring in this communal grazing lands. The topography is generally characterised by a hilly landscape and plain, bottom lands and top lands. The livestock kept in this area include cattle, sheep and goats.

3.2 Site selection and lay out

Three landscape positions, namely bottom lands, gentle sloppy and upland areas were selected in the two grazing areas. Three plots of 50 m x 20 m were marked in each landscape with the longest side of the plot laid perpendicular to the direction of the slope gradient.

3.3 Data collection

Initially, vegetation survey was conducted in both study areas using a step point method to identify grass species and select those with relatively high abundance as well as common occurrence. Biomass production for the selected species was determined by harvesting each species separately from six $0.25m^2$ quadrants per plot. The grass species were cut at a stubble height of 6 - 8 cm from the ground and placed in paper bags and dried in an oven at 75^0C for 48 hours. Weight of dried samples was measured immediately to determine dry matter yield. Plant samples were ground to pass through a 1 mm sieve pending chemical analysis. The samples were analysed for neutral detergent fibre (NDF), acid-detergent fibre (ADF), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn)) minerals. *In vitro* ruminal fermentation characteristics of plant samples were determined using the Reading Pressure Technique (Mauricio *et al*., 1999). Minerals and nitrogen were analysed in the Western Cape Department of Agriculture, Elsenburg, South Africa (ALASA, 1998). Fibre content analysis and *in vitro* ruminal fermentation were carried out in the Department of Food Production, Faculty of Science and Agriculture, University of the West Indies, St. Augustine, Trinidad and Tobago.

CHAPTER 4

ALTITUDINAL AND SEASONAL VARIATION IN THE ABUNDANCE, BIOMASS YIELD AND MINERAL CONTENT OF SELECTED GRASS SPECIES IN TWO COMMUNAL GRAZING LANDS

Abstract

Communal rangelands sustain a large proportion of the livestock of South Africa. A few dominant grass species contribute to the bulk of the livestock forage in these rangelands. The objectives of this study were to investigate the yield, macro and micro element contents of selected (dominant) grass species collected over four seasons from three altitudes in two communal areas (Gqumashe in the sweetveld and Hala in the sourveld) of the Eastern Cape province, South Africa. In each area, three experimental sites were selected along landscape gradients classified as upland, gentle sloppy and bottom lands. In each site, three 50 m x 20 m plots, which served as replicates (blocks) were marked to collect vegetation samples. A 5 (species) x 4 (seasons) x 3 (altitude) factorial experiment in a randomised complete block design was used with season, altitude and grass species being the main factors. Data analysis was done separately for the two study communal areas using the General Linear Models (GLM) procedure of SAS to test differences between seasons and altitudes. Standing herbaceous biomass significantly varied with season in both communal grazing lands. The dry matter (DM) yield of all the grasses, the results showed a generally low forage DM yield during the dry season. Macro and micro mineral content of plant samples collected from the two communal grazing lands showed great variations ($P<0.05$) between species, seasons and altitude. It was also concluded that most grasses were deficient in calcium, magnesium, phosphorus and potassium. Therefore, it is recommended that mineral supplements should be offered to animals to improve animal productivity especially during the dry seasons. This study concluded that ruminants may suffer from low total mineral intake during the dry season.

Key words: Forage yield, macro and microelements, landscape gradient, vegetation type

4.1 Introduction

Livestock production plays a significant role in the livelihood of farmers in the arid and semi-arid communal rangelands of southern Africa. The livestock production system is predominantly extensive, with virtually all cattle and small ruminants relying mainly on the natural rangelands with small proportion of crop residues supplemented from sideline small scale crop farming. On many rangelands, the bulk of the livestock feed is contributed by native grass species (Tefera *et al*., 2007). Native grasses remain the major source of minerals and other nutrients to grazing ruminants reared by resource poor communal farmers (Beyene and Mlambo, 2012a; Gizachew and Smit, 2012). It has been widely reported, however, that grasses hardly provide year round optimum nutrient intake to meet body requirements of the ruminants in arid and semi-arid African rangelands. For instance, Gizachew and Smit, (2012), Kennedy *et al.* (2002), and Beyene and Mlambo (2012b) reported low mineral concentrations and other nutrients in the arid and semi-arid rangelands. Nutrient deficiencies in turn contributes to general unthriftness, high infestation of parasites (Beyene and Mlambo, 2012b), low animal productivity as well as losses in terms of quality and quantity of animal products.

Both forage dry matter yield and mineral concentration of natural pasture is a function of season, soil and plant genotype (Gizachew *et al*., 2002). According to Zewdu *et al*. (2002) and Nyamukanza *et al*. (2010) livestock production in African rangelands is limited by seasonal fluctuations in the quantity and quality of available nutrients. This is because growth of native pastures follows a distinct seasonal pattern which is accompanied with marked changes in herbage forage yield and nutrient concentrations (Gizachew *et al*., 2012). Grass species may vary in terms of their forage dry matter and nutrient concentration (Beyene and Mlambo, 2012a). The proportion of grass species in a given vegetation community may thus influence the total nutrient available to grazers (Minson, 1990; Gizachew and Smit, 2008). Soil fertility and soil factors such as pH and drainage could also influence the yield patterns and mineral composition of forage plants (Reid and Horvath, 1980). These soil related factors are mainly influenced by soil types and landscape attributes including aspect and elevation (Saleem, 1998).

The Eastern Cape Province has the largest communally used grazing lands in South Africa. Livestock production system is characterised as agro-pastoral system because it is based on extensive rangelands and supplemented with crop residues. Reports on a livestock census of South Africa confirm that the country has 13.8 million cattle, 25 million sheep and 6.4 million goats (Gwelo, 2012), while the province of the Eastern Cape has about 3.1 million beef cattle (Mapiye *et al*., 2009) and 21% of the country's cattle, 28% sheep and 46% of goats. Continuous grazing is the common practice in both highlands (here after referred to as Highveld) and lowlands (hereafter referred to as Lowveld) parts of the province. This practice has induced overgrazing and selective grazing in many parts and led to the reduction of the climax (decreaser) grass species and their replacement by sub-climax (increaser) and pioneer grass species.

The studies of Lesoli (2008) and Gwelo (2012) indicated several parts of Eastern Cape communal grazing lands are dominated by such sub-climax grass species such as *Sporobolus africanus*, *Heteropogon contortus*, and *Eragrostis plana*. Nevertheless, there is no adequate documentation that describes the macro and micro elements concentrations of these grass species. Moreover, the change/dynamics of mineral concentration in relation to seasonal and landscape variations are unknown. This information would help to understand nutrient variations between grass species, season and altitude. The objectives of the study were to 1) determine species composition and abundance of grasses in two communal areas across three landscape gradients (bottom, sloppy and uplands) and seasons, 2) determine the dry matter yield and status of macro and micro mineral concentration of selected key grass species as influenced by season and landscape gradients.

4.2 Materials and methods

4.2.1 Description of the study area

Two communal grazing areas, namely; Hala (Highveld) and Gqumashe (Lowveld) were selected, respectively in the Eastern Cape province of South Africa. Description of the study areas is fully presented in section 3.1.

4.2.2 Site selection and lay out

Three landscape positions, namely bottom lands, gentle sloppy and upland areas were selected in the two grazing areas. Three plots of 50 m x 20 m were marked in each landscape with the longest side of the plot laid perpendicular to the direction of the slope gradient.

4.2.3 Data collection

4.2.3.1. Species composition

Based on the initial vegetation survey on species composition, the following grasses were selected as common or dominant in the two study areas: *C. dactylon*, *E. chloromelas, E. plana, S. africanus* and *T. triandra*. Biomass production for the selected species was determined by harvesting each species separately from six 0.25m^2 quadrants per plot. The grass species were cut at stubble height of 5 - 6 cm and placed in paper bags and dried in an oven at 75^{0}C for 48 hours. Weight of dried samples was measured immediately to determine the dry matter yield of each species.

Dried samples were then ground to pass through a 1 mm sieve pending chemical analysis. Grass samples were analysed for phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn). Calcium, Mg, Zn, Cu, Fe and Mn were determined using atomic absorption spectrophotometer (AAS). Phosphorous was analysed by using the Ultra-violet spectrophotometer, while K was determined using a flame photometer as described by AOAC (1995).

4.2.4 Statistical analysis

A 5 (grass species) x 3 (altitude) x 4 (seasons) factorial experiment in a randomised complete block design was used in this study with altitude and seasons being the main factors, and plots serving as replicates (blocks). Biomass production and mineral concentrations data for the selected grass species were analysed separately using the General Linear Models (GLM) procedure of SAS (2001) to test differences between altitudes and seasons. Means were separated using the Pdiff options of the least squares means statement of GLM procedure of SAS (2001). Data analysis was done separately for the two study areas. For species composition, average values for each landscape gradient of the two areas were calculated.

4.3 Results

4.3.1 Species composition

Table 4.1 presents the species composition of grasses in the two study areas. A total of 22 grass species were identified. Of these grass species, 4 species were classified as highly palatable, 7-moderately palatable, 7-less palatable and 4-poorly palatable species. *Cynodon dactylon* occurred as common or dominant species in the study areas. *Digitaria eriantha* dominated the bottom and sloppy areas of the Lowveld grazing lands. *Eragrostis chloromelas* showed presence in the bottom and sloppy areas and dominated the upland of the Lowveld, whereas it was common in the bottom and sloppy areas of the Highveld grazing lands. *Eragrostis plana* was common or present in the Lowveld, whereas it occurred abundantly, commonly or rarely in the Highveld grazing lands. *Sporobolas africanus* was common in the Lowveld and showed dominance in the Highveld grazing lands. *Themeda triandra* showed common occurrence in the Lowveld, while it showed either presence or common occurrence in the Highveld grazing lands.

Table 4.1 Palatability, life forms and distribution of grass species in the Lowveld and Highveld communal grazing lands.

Species	**Life forms (Palatability)** [a]	**Abundance** [b]					
		Lowveld [b]			Highveld		
		Bottom	**Slopy**	**Upland**	**Bottom**	**Slopy**	**Upland**
Aristida congesta	P (MP)	-	Pr	Pr	-	+	-
Cymbopogon plurinodis	P (LP)	Pr	Pr	-	-	-	-
Cymbopogon validus	P (LP)	-	-	-	-	C	C
Cynodon dactylon	P (MP)	C	C	C	D	C	C
Digitaria eriantha	P (HP)	D	D	+	+	+	+
Eragrostis capensis	P (LP)	-	-	+	-	Pr	+
Eragrostis chloromelas	P (MP)	Pr	Pr	D	C	C	Pr
Eragrostis obtuse	P (MP)	C	Pr	-	-	-	-
Eragrostis plana	P(PP)	C	Pr	Pr	D	C	Pr
Heteropogon contortus	P (LP)	-	-	-	+	Pr	Pr
Hyperrhenia hirta	P (LP)	-	-	-	+	Pr	-
Karochloa curva	A (LP)	Pr	-	Pr	-	-	-
Melinis repens	P (MP)	-	-	-	+	Pr	Pr
Microchloa caffra	P (PP)	-	-	Pr	-	+	-
Miscathus capens	P (PP)	-	-	-	-	Pr	Pr
Paspalum dilatatum	P (HP)	-	-	-	C	Pr	Pr
Pennisetumclandestinum	P (HP)	-	-	-	C	+	+
Panicum stafianum	P (MP)	Pr	Pr	-	-	-	-
Sporobolas africanus	P (PP)	C	C	C	D	D	C
Sporobolas fimbriatus	P (MP)	C	C	C	-	-	-
Themeda triandra	P (HP)	C	Pr	C	Pr	Pr	C
Trastachia leucotrix	P (LP)	-	-	-	+	Pr	Pr

[a] A = annual, P = perennial; HP = highly palatable, MP = moderately palatable, LP = less palatable; PP =poorly palatable; - = absent
[b] D= dominant (>15%), C = common (>5-15%), Pr = present (1-5%), + = rare ≤ 1

4.3.2. Dry matter production in the Highveld communal grazing lands

Table 4.2 presents seasonal variation in available DM yield (kg ha^{-1}) of selected grass species growing in three landscape gradients in the Highveld communal area. The yield of *C. dactylon* was significantly affected by seasons ($P < 0.05$) in the bottom lands (with the highest production in summer) and in the uplands (with highest production in winter). The yield of *C. dactylon* was affected by landscape gradient only in winter season with the upland biomass production found to be significantly greater than the sloppy and bottom lands. Results for *E. chloromelus* showed that yield did not respond to seasonal and landscape gradients. For *E. plana* seasonal effect ($P < 0.05$) on yield was noticed only at bottomland site with peak production records at the summer and winter seasons. Overall, the yield of *E. plana* at the bottom land was significantly greater than the sloppy and upland areas. DM yield of *S. africanus* fluctuated over seasons only at the bottomland grazing areas being highest in winter season. Overall dry matter yield of *S. africanus* at the bottomlands was significantly higher for the samples collected during summer and winter seasons. The dry matter yield of most of *T. triandra* forage samples did not fluctuate in response to seasonal and landscape gradients.

Table 4. 2 Variation in dry matter yield ($kgha^{-1}$) in relation to season and landscape gradient in the Highveld communal grazing land.

Species	Season	Bottom	Sloppy	Uplands
Cynodon dactylon	Summer	630.7^{Aa}	480.5^{Aa}	390^{ABa}
	Autumn	461.7^{ABa}	339.2^{Aa}	177.4^{Ba}
	Winter	494.6^{ABab}	303.8^{Ab}	517.8^{Aa}
	Spring	296.4^{Ba}	293.8^{Aa}	229.3^{ABa}
Eragrostis chloromelas	Summer	99.8^{Aa}	202.2^{Aa}	210.9^{Aa}
	Autumn	108.8^{Aa}	-	112.8^{Aa}
	Winter	-	70.1^{Aa}	169.6^{Aa}
	Spring	-	91.2^{Aa}	181.3^{Aa}
Eragrostis plana	Summer	1416.6^{Aa}	327.9^{Ab}	470.7^{Ab}
	Autumn	772.2^{Ca}	365.1^{Ab}	300^{Ab}
	Winter	1134.7^{Aba}	118.3^{Ac}	518.8^{Ab}
	Spring	1056.9^{BCa}	328.4^{Ab}	336.6^{Ab}
Sporobolus africanus	Summer	693.3^{Ba}	290.5^{Ab}	124.2^{Ab}
	Autumn	492.3^{BCa}	367^{Aa}	362.5^{Aa}
	Winter	1024.2^{Aa}	388.5^{Ab}	420.4^{Ab}
	Spring	389.2^{Ca}	359.5^{Aa}	413.3^{Aa}
Themeda triandra	Summer	222.6^{Ba}	471.8^{Aa}	250^{Aa}
	Autumn	429.2^{ABa}	406.2^{Aba}	366.5^{Aa}
	Winter	589.7^{Aa}	357.3^{Aa}	533.9^{Aa}
	Spring	480^{ABa}	431.8^{Aa}	299^{Aa}
SEM[1]		121.0	121.0	121.0

^{ABC}Within altitude and for each grass species, uppercase superscripts show significant difference ($P < 0.05$) between seasons.

^{ab}Within season and for each grass species lowercase superscripts show significant difference ($P < 0.05$) between altitudes.

[1]SEM: Standard error of means

4.3.3. Dry matter production in Lowveld communal grazing lands

Table 4.3 shows seasonal variation in the DM production (kg ha^{-1}) of five grass species across three landscape gradients in the Lowveld communal grazing area. *Cynodon dactylon* had the highest (P < 0.05) forage yield in the bottom and in winter. Landscape effects on the biomass production of *C. dactylon* were confined to autumn and winter seasons only, where lowest production was recorded in the uplands and sloppy grazing areas. Summer, autumn and winter yields of *E. plana* varied along landscape gradients. Autumn biomass production of *S. africanus* was significantly (P<0.05) greater than the other seasons at the bottom and sloppy sites. Similarly autumn and winter seasons had the highest (P < 0.05) biomass yields for *S. africanus*. As for the landscape gradients *T. triandra* had higher yield in the upland areas.

Table 4. 3 Variation in dry matter yield (kgha^{-1}) in relation to season and landscape gradient in the Lowveld communal grazing land.

Species	Season	Bottom	Sloppy	Uplands
Cynodon dactylon	Summer	521.3 ^{Ba}	509 ^{ABa}	325.3 ^{ABa}
	Autumn	726.5 ^{ABab}	760.9 ^{Aa}	607.1 ^{Ab}
	Winter	872.7 ^{Aa}	174.1 ^{Bb}	259.3 ^{Ba}
	Spring	661.5 ^{ABa}	407.7 ^{Ba}	556.9 ^{ABa}
Eragrostis chloromelas	Summer	149.3 ^{Aa}	337.8 ^{Aa}	378.4 ^{Aa}
	Autumn	442.8 ^{Aa}	341.1 ^{Aa}	424 ^{Aa}
	Winter	366.3 ^{Aa}	191.4 ^{Aa}	374 ^{Aa}
	Spring	126.3 ^{Aa}	380.2 ^{Aa}	416.3$^{A\ a}$
Eragrostis plana	Summer	811.6 ^{Ba}	564.8 ^{Aab}	235.9 ^{Ab}
	Autumn	1238.1 ^{Aa}	787.4 ^{Ab}	-
	Winter	-	121.7 ^{B}	-
	Spring	361.5 ^{Ca}	646.9 ^{Aa}	565.4 ^{Aa}
Sporobolus africanus	Summer	312 ^{Ca}	575.2 ^{Ba}	255.4 ^{Aa}
	Autumn	772.9 ^{Aab}	970.9 ^{Aa}	490.5 ^{Ab}
	Winter	735.9 ^{ABa}	459.6 ^{Bab}	357.2 ^{Ab}
	Spring	407.8 ^{BCa}	601 ^{Ba}	495A ^{Aa}
Themeda triandra	Summer	222.6 ^{ABb}	199.3 ^{Bb}	680.4 ^{Aa}
	Autumn	507.6 ^{Aab}	282.9 ^{ABb}	718.8 ^{Aa}
	Winter	316.7 ^{ABa}	615.5 ^{Aa}	508.8 ^{Aa}
	Spring	136.2 ^{Bb}	236 ^{Bab}	482.3 ^{Aa}
SEM		138.7	138.7	138.7

^{ABC}Within altitude and for each grass species, uppercase superscripts show significant difference ($P < 0.05$) between seasons.

^{ab}Within season and for each grass species lowercase superscripts show significant difference ($P < 0.05$) between altitudes.

[1]SEM: Standard error of means

4.3.1. Species variations in macro and micro element concentrations

The macro and mineral contents of grasses collected from Highveld and Lowveld grazing areas presented in Tables 4.3 and 4.4, respectively. Altitude, seasonal and species effects reported separately for minerals because there were no significant interactions.

4.3.1.1. Highveld grazing land

Results showed significant variations of all macro elements among the grass species. *Themeda triandra* (0.29%) had the highest (P<0.05) Ca level followed by C. *dactylon* (0.26%) and *E. chloromelus* (0.26%). *Themeda triandra* and *C. dactylon* had the highest levels of Mg (0.13%). The P level was highest in *C. dactylon* (0.11%) followed by *E. chloromelus*. *Sporobolus africanus* had exceptionally the highest K content. Micro-element concentrations showed marked variability among the grass species. With the exception of Mn which highest level in *S. africanus,* all micro-element levels were significantly (P <0.05) higher in *C. dactylon* followed by *T. triandra*.

4.3.1.2. Lowveld grazing land

Results showed significant variations in all macro elements among the grass species. *Eragrostis chloromelus* (0.37%) and *T. triandra* (0.37%) had the highest (P<0.05) Ca level followed by *C. dactylon* (0.34%). *Themeda triandra* and *C. dactylon* had the highest levels of Mg (0.12%), while *E. plana* (0.07%) had lowest levels of Mg. The P level was highest in *C. dactylon* (0.17%) followed by *E. chloromelus* (0.15%). *Eragrostis chloromelus* (0.79%) had the highest K content. Micro-element concentrations showed marked variability among the grass species. With the exception of Mn, which highest level in *T. triandra* (115.9 ppm). Iron concentrations were significantly (P < 0.05) higher in *E. chloromelus* (746.6 ppm), *C. dactylon* (724 ppm) and *T. triandra* (711.8 ppm). Copper and zinc were highest in *C. dactylon* followed by *T. triandra*.

Table 4. 4 Macro (%) and micro (ppm) mineral contents of selected grass species collected from the Highveld grazing lands.

Species	Ca	Mg	K	P	Fe	Cu	Zn	Mn
Cynodon dactylon	0.26[b]	0.131[a]	0.61[b]	0.11[a]	1262[a]	4.26[a]	32.59[a]	102.8[c]
Eragrostis chloromelas	0.26[b]	0.098[c]	0.60[b]	0.09[b]	541.8[bc]	2.15[bc]	11.91[c]	92.8[c]
Eragrostis plana	0.22[c]	0.066[d]	0.54[b]	0.07[c]	282.3[c]	1.57[cd]	12.49[c]	135.7[b]
Sporobolas africanus	0.20[c]	0.102[bc]	0.72[a]	0.08[bc]	274.3 [c]	1.39[d]	15.35[bc]	302.7[a]
Themeda triandra	0.29[a]	0.129[a]	0.54[b]	0.08[bc]	614.1[b]	2.59[b]	17.31[b]	149.8[b]
SEM[1]	0.01	0.004	0.03	0.01	120.9	0.25	1.5	9.9

[a,b,c,d]Within a column, means with different superscripts differ significantly ($P < 0.05$); [1]SEM: Standard error of mean

Table 4. 5 Macro (%) and micro (ppm) mineral contents of selected grass species collected from the Lowveld grazing lands.

Species	Ca	Mg	K	P	Fe	Cu	Zn	Mn
Cynodon dactylon	0.34[b]	0.12[a]	0.67[b]	0.17[a]	724[a]	3.04[a]	31.7[a]	67.6[bc]
Eragrostis chloromelas	0.37[a]	0.10[b]	0.79[a]	0.15[b]	746.6[a]	2.72[ab]	14.5[c]	58.9[c]
Eragrostis plana	0.28[c]	0.07[c]	0.70[b]	0.11[cd]	294.4[b]	1.87[c]	17.8[c]	49.8[c]
Sporobolas africanus	0.22[d]	0.11[b]	0.74[ab]	0.10[d]	351[b]	1.54[c]	17.2[c]	81.9[b]
Themeda triandra	0.37[a]	0.12[a]	0.72[b]	0.12[c]	711.8[a]	2.43[b]	24.5[b]	115.9[a]
SEM	0.01	0.003	0.03	0.01	58.8	0.15	1.2	6.5

[a,b,c,d]Within a column, means with different superscripts differ significantly ($P < 0.05$); SEM: Standard error of mean

4.3.2. Seasonal differences

4.3.2.1. Highveld grazing land

When all grass species were combined, results showed that there were marked variations in the macro-element levels among seasons (Table 4.6). Spring and summer had the peak Ca and Mg records. The levels of K (0.74%) and P (0.093%) were highest in summer and autumn (K, 0.42% and P, 0.071%) but lowest in winter. Results for micro-elements were variable in that Fe and Cu levels were not affected by seasons, while Zn was highest in spring (25.1 ppm) followed by summer (19.6 ppm) season. The highest and lowest level of Mn was recorded in summer (174.8 ppm) and winter (137.9 ppm), respectively.

4.3.2.2. Lowveld grazing land

When all grass species were combined, results showed that there were marked variations in the macro-element levels among seasons (Table 4.7). Spring had the peak Ca and Mg records while winter had lowest. The levels of P were highest in autumn (0.16%) and lowest in winter (0.09%), whereas K levels were highest in summer (0.95%) and lowest in winter (0.42%). Results for micro-elements are variable in that Mn levels were not affected by seasons, while Zn was highest in spring (30.1 ppm) followed by summer (23.5 ppm) season. Spring had the peak Cu records while autumn had lowest. The highest and lowest level of Fe was recorded in winter (845.7 ppm) and summer (370.7 ppm), respectively.

Table 4. 6 Mean macro (%) and micro (ppm) mineral content of grasses in relation to season in the Highveld communal grazing lands

Season	Ca	Mg	K	P	Fe	Cu	Zn	Mn
Autumn	0.23^{c}	0.10^{b}	0.69^{a}	0.097^{a}	549.6^{a}	2.3^{a}	12.1^{c}	152.3^{b}
Summer	0.26^{a}	0.12^{a}	0.74^{a}	0.093^{a}	500.2^{a}	2.2^{a}	19.6^{b}	174.8^{a}
Spring	0.27^{a}	0.11^{a}	0.56^{b}	0.083^{bc}	612.3^{a}	2.4^{a}	25.1^{a}	161.9^{ab}
Winter	0.24^{b}	0.09^{c}	0.42^{c}	0.071^{c}	717.5^{a}	2.7^{a}	14.9^{c}	137.9^{c}
SEM	0.01	0.003	0.03	0.005	108.2	0.2	1.3	8.7

^{a,b,c}Within a column, means with different superscripts differ significantly ($P < 0.05$); SEM: Standard error of mean

Table 4. 7 Mean macro (%) and micro (ppm) mineral content of grasses in relation to season in the Lowveld communal grazing lands

Season	Ca	Mg	P	K	Fe	Cu	Zn	Mn
Autumn	0.30^{b}	0.11^{a}	0.16^{a}	0.86^{b}	498.6^{bc}	1.9^{b}	14.9^{c}	77.7^{a}
Summer	0.31^{b}	0.11^{a}	0.13^{b}	0.95^{a}	370.7^{c}	2.1^{b}	23.5^{b}	70.2^{a}
Spring	0.33^{a}	0.11^{a}	0.14^{b}	0.76^{c}	547.1^{b}	2.9^{a}	30.1^{a}	81.4^{a}
Winter	0.31^{b}	0.09^{b}	0.09^{c}	0.42^{d}	845.7^{a}	2.4^{b}	16.1^{c}	70.1^{a}
SEM	0.01	0.003	0.005	0.03	52.5	0.13	1.1	6.0

^{a,b,c,d}Within a column, means with different superscripts differ significantly ($P < 0.05$); SEM: Standard error of mean

4.3.3 Altitudinal differences

Forage samples revealed major variations in the macro element content (%DM) in relation to landscape positions in both Highveld and Lowveld areas. In the Highveld areas (Table 4.8), most of these elements had highest values for forage samples collected from the bottom lands and lowest from the sloppy areas. The Fe (501.6 - 692.3 ppm) and Cu (2.26 – 2.50 ppm) levels of forages did not respond to differences in landscape positions, but forages from bottomlands showed significantly ($P < 0.05$) highest Zn (20.6 ppm) level, where the Mn level was lowest (Table 4.8). In the Lowveld (Table 4.9), the pattern of the variation in the above elements seemed to show different trends from the Highveld areas and is also inconsistent. Forage samples from the upland grazing lands had higher contents of Ca (0.34%) and Mg (0.11%) than the bottom lands, with significant ($P < 0.05$) variations in Mg content compared to the sloppy areas. Phosphorus and Potassium K concentrations were highest in the sloppy areas but lowest in the bottomlands. The Fe (841.4 ppm) and Cu (2.5 ppm) levels were highest in the uplands than bottomlands, but forages from bottomlands showed significantly ($P<0.05$) highest Mn (97.1 ppm) level than uplands (Table 4.9). The Zn (20.1 – 22.1 ppm) levels of forages did not respond to differences in landscape positions.

Table 4. 8 Mean macro (%) and micro (ppm) elements in relation to landscape gradients in the Highveld communal areas.

Altitude	Ca	Mg	P	K	Fe	Cu	Zn	Mn
Bottom	0.26^{a}	0.11^{a}	0.11^{a}	0.68^{a}	501.6^{a}	2.26^{a}	20.6^{a}	119.9^{b}
Sloppy	0.23^{b}	0.09^{b}	0.07^{c}	0.53^{c}	692.3^{a}	2.50^{a}	16.1^{b}	169.5^{a}
Uplands	0.25^{ab}	0.11^{a}	0.08^{b}	0.59^{b}	590.7^{a}	2.40^{a}	17.1^{b}	180.8^{a}
SEM	0.01	0.003	0.004	0.03	93.8	0.2	1.2	8.0

^{a,b,c}Within a column, means with different superscripts differ significantly ($P < 0.05$); SEM: Standard error of mean

Table 4. 9 Mean macro (%) and micro (ppm) elements in relation to landscape gradients in the Lowveld communal areas.

Altitude	Ca	Mg	P	K	Fe	Cu	Zn	Mn
Bottom	0.31^{b}	0.09^{b}	0.12^{b}	0.82^{a}	411.2^{b}	2.1^{b}	22.1^{a}	97.1^{a}
Sloppy	0.29^{b}	0.11^{a}	0.14^{a}	0.82^{a}	444.1^{b}	2.3^{ab}	21.2^{a}	59.6^{b}
Uplands	0.34^{a}	0.11^{a}	0.13^{b}	0.54^{b}	841.4^{a}	2.5^{a}	20.1^{a}	67.8^{b}
SEM	0.01	0.002	0.004	0.03	45.6	0.12	1.0	5.2

^{a,b}Within a column, means with different superscripts differ significantly ($P < 0.05$); SEM: Standard error of mean

4.4 Discussion

4.4.1 Species composition and biomass yield of grass species.

Cynodon dactylon, E. chloromelas, E. plana, S. africanus and *T. triandra* are the grass species found in common in the two studied communal grazing lands showing occurrence frequency rated from 'presence' to 'dominance'. These forage species are adapted to the ecology of these two communal grazing lands and to the environmental factors that affect these areas. Although many grass species have been identified in these study areas, only few of them made up the bulk of the species composition concurring with the findings of Beyene and Mlambo, (2012b) in semi-arid rangelands of Swaziland. Of the selected species in this study, all but *T. triandra* are increaser species, and may together contribute to the largest proportion of the total dry matter production available for the grazing animals.

The significant statistical difference in dry matter yield between grass species between the site may be because of difference in species abundance (Moyo *et al*., 2010), which in turn is influenced by selective grazing. The possible reason for these differences between the sites could be partly due to differences in grazing pressure/intensity as well as animal and edaphic factors in the two communal grazing lands. Indeed, grasses differ in their acceptability and response to grazing herbivore, due to differences in palatability (Teklu *et al*., 2010). Also, grass species yields were different because of their variation in the inherent production ability. Nonetheless, this variation in dry matter yield might have been the impact of edaphic conditions, grazing and climatic variables as described by Teklu *et al*. (2010).

The yield of all grass species harvested from both communal grazing lands responded to temporal variation. Seasonal variations in forage yield production among grazing lands can be partly explained by variability in soil type and fertility, and these results compared well with the finding of (Rubanza *et al.*, 2006) documented in Tanzania. In contrast, variation in the amount of precipitation across seasons is the main reason for the observed forage yield differences. Therefore, yield of arid and semiarid systems is strongly related with mean annual precipitation (Moyo *et al*., 2010).

Similarly, grass dry matter yield is significantly affected by landscape gradients. There was a reduced dry matter yield of decreasers (*Themeda triandra*) in the bottom lands and gently sloppy areas than uplands due to grazing pressure and easy access by animals. Bottom lands are grazed approximately three times more intensely than uplands due to easy access by animals (Lesoli, 2008; Lesoli *et al*., 2010). But increaser (*Cynodon dactylon*, *Eragrostis plana* and *Sporobolas africanus*) species had higher dry matter yield in the bottom lands than uplands because they are usually found in disturbed and trampled soils and areas.

Both types of environment found in the two study sites promote low forage yield. This low forage yield and predominance of increaser grass species in these two communal grazing lands mainly indicate over utilization of the rangelands ecosystem. The observed grass species in the study areas reflect typical Eastern Cape semi-arid forage species (Lesoli, 2008), indicating poor and disturbed soils in these semi-arid areas of South Africa. Generally, frequent and intense defoliations lead to low forage yield. In both communal grazing lands incorporating high grazing frequencies is likely to be associated with low vigor in grass species under such management. Grytnes *et al*. (2002) have reported the effects of seasons and altitudes on species biomass yield.

Moreover, Armstrong *et al*. (1997) mentioned that grazing can have great effects on the species differences as well as on standing live biomass and sward structure.

4.4.2. Species difference in macro and micro elements

Macro and micro elements variations among grass species found in the two study confirms the studies of Nsinamwa *et al*. (2005) in Botswana, Zafar *et al*. (2007) and Javed *et al*. (2008) in Pakistan, Tefera *et al*., (2009) and Solomon and Mlambo (2012) in Swaziland rangelands. Differences may be genotypic which influence nutrient uptake, growth form and leaf to stem ratio. Also grazing preference, which leaves some species to experience high biting rate (grazing) and others less. Though not statistically compared, all the grass species show differences in most of these elements between the Highveld and Lowveld areas concurring the findings of Lemma *et al*. (2002) and Solomon and Mlambo (2012). These variations among and within grass species reflect differences in soil nutrient status (Zafar *et al*., 2007; Beyene and Mlambo, 2012). However, differences in the content of Mg in this study could be partly explained proportion of leaf and stem fractions collected for mineral analysis.

Water logging and low temperatures depresses grass species Mg uptake, however, the continuous grazing rangeland comprised almost exclusively (>85%) of unpalatable and less nutritious grass species, where the palatability is judged based on the preferences of the grazing ruminants (Gezachew and Smit, 2012). All the grass species in both the Highveld and Lowveld areas have Ca (0.20 – 0.29% and 0.22 – 0.37%) and K (0.54 – 0.72% and 0.70 – 0.79%) levels, and the values are within the body requirements for ruminants as described by McDowell (1997) ranged (Ca: 0.19 – 0.82 %; K: 0.5 –1 %). This finding agrees and contrasts with the findings of Tefera *et al.* (2009) and Solomon and Mlambo (2012) who found adequate, low or high levels of these elements depending on grass species. Similar to the report of Solomon and Mlambo (2012) from Swaziland, all grasses collected from both ecologies have Fe levels beyond the need of ruminants as set out by National Research Council (1996) and summarized by McDowell (1997).

All grass species harvested from the Highveld had P and Cu levels lower than the requirements for ruminants as described by McDowell (1997). In the Lowveld areas, however only *Eragrostis plana* and *Sporobolus africanus* had lower P levels than the requirements indicated by National Research Council (1996) and summarized by McDowell (1997), but all grass species have still lower levels of Cu. These findings are in agreement with Beyene and Mlambo (2012) who indicated that micro-element concentrations are either within or above the dietary requirements for ruminants. It is therefore expected that ruminants grazing on these communal lands may encounter problems associated with mineral imbalances (Beyene and Mlambo, 2012b), and high K intake would depress the absorption of Mg from the alimentary tracts of the ruminants (Gezachew and Smit, 2012). With the exception of *C. dactylon* in the Highveld and *T. triandra* species in the Lowveld, grasses had lower Zn content than the level that fulfils the requirement of ruminants. All grasses harvested from the Highveld and Lowveld areas had Mn level within the dietary requirement of ruminants. Mean Mn concentrations (range: 92.8 – 149.8 ppm and 49.8 – 115.9 ppm) found in this study.

4.4.3. Seasonal difference

Both the macro and micro-elements of all grasses responded greatly to changes in seasons. The finding of this study is similar to the study reported by Gizachew *et al*. (2002).

In the Highveld areas, forage P and Cu levels of all seasons were lower than the P and Cu requirements for ruminants (cattle, sheep and goats). The consistent low phosphorus content across the seasons might be due to low P content in the soil. These results also supported the findings of Sultain *et al*. (2008, 2009) in Pakistan who reported that P was widely deficient in soils of rangelands in semi-arid and consequently in the forage growing in these areas. These results revealed that P concentration was below the minimum requirement (0.082%) of livestock (Anon, 1975).

Copper content in all grasses were lower than the livestock requirements 6-12 ppm of diet DM (Anon. 1975). The findings of this study were lower and disagree with findings of Sultain *et al*. (2008, 2009) in Pakistan, who mentioned that all grasses were higher than the livestock requirements. Forage Cu concentrations were found to be low in these grazing lands to meet the demand of ruminants during the various seasons. Therefore, monitoring metabolite concentrations across the seasons may assist in planning proper interventions such as the need for dietary supplementation (Safari *et al*., 2011). Provision of mineral licks can ensure that P and Cu requirements of ruminants are met. The level of Fe starts declining from summer to winter and levels were above minimum requirement for grazing ruminants. Seasonal Zn levels were below the livestock requirement of 30 ppm established by NRC (1996). Therefore, supplementation may be required to correct the imbalances. Magnesium and K in particular were deficient in winter forages hence supplementation may be required.

In the Lowveld areas, forages collected from all seasons had lower Cu than the dietary requirements for ruminants. Copper content in all grasses were lower than the livestock requirements 6-12 ppm of diet DM (Anon. 1975).). The findings of this study were lower and disagree with findings of Sultain *et al*. (2008, 2009) in Pakistan, who mentioned that all grasses were higher than the livestock requirements, also disagree with Beyene and Mlambo (2012). There is a need for dietary supplementation. But winter season in particular had Mg, K, P and Zn levels below the animal requirements described by McDowell (1997). The current study agrees with Ramirez *et al*. (2004) in north eastern Mexico who evaluated seasonally the mineral contents. However, mineral contents were insufficient to meet nutrient requirements of range animals during winter season and with most grasses, thus supplementation is required in the form of licks.

4.4.4. Altitudinal variations

In the Highveld areas, mean concentrations of most mineral elements in native pasture forage tend to be higher for bottomlands than uplands because of transportation of minerals from uplands to the bottomlands. Except for Mg in gently sloppy, mineral elements of Ca, K and Mn were within the dietary requirement of ruminants as described by National Research Council (1996) and summarized by McDowell (1997). Moreover, these findings are in agreement with Gezachew *et al*. (2002). High forage mineral concentrations in bottomland locations are considered a reflection of the soil mineral status (Gezachew *et al*., 2002). Native pasture forage P, Cu and Zn concentrations were below the critical level for the dietary requirements for grazing ruminants as suggested by McDowell (1997), hence supplementation was required in the form of licks. Mean concentrations of native pastures from both bottomlands, gently sloppy and upland sites contained Fe in excess of livestock requirement described by NRC (1996). Gezachew *et al*. (2002) confirmed that Fe at a level of 250ppm to 500ppm causes Cu depletion in cattle, hence in the current study Cu was below dietary requirement.

In the Lowveld areas, except for Mg in the bottomlands, mineral elements of Ca, P, K, Zn and Mn were within the dietary requirement of ruminants as described by National Research Council (1996) and summarized by McDowell (1997). These findings are in agreement with Gezachew *et al*. (2002). Mean concentrations of Ca, Mg and Fe in native pasture forage tend to be higher for uplands than bottomlands. This indicates low rainfall in this particular area for mineral transportation from uplands to bottomlands. For K, Zn and Mn native pasture forage tend to be higher in the bottomlands than uplands. Loganathan *et al*. (1995) found that greater mineral concentrations in forages grown on lower slopes. The high mineral concentration of bottomland pasture species was attributed to high soil mineral and OM levels at lower slopes (Gezachew *et al*., 2002). Iron concentrations were above the critical level for the dietary requirements for grazing ruminants as suggested by McDowell (1997), and highest levels were found in the uplands than bottomlands and sloppy areas. Copper concentrations in native pasture were below the acceptable range for all tested elements as described by NRC (1996) and highest levels were found in the uplands than bottomlands hence supplementation is required.

4.5 Conclusion

Available biomass yield significantly varied with season in both communal grazing lands. The DM yield of all the grasses, the results showed a generally low forage dry matter yield during the dry season. Results presented herein showed that there were great variation in nutrient elements between species, seasons and altitude. Our study indicates that P, Cu and Zn however, were deficient in all forage species. Correcting P deficiencies by provision of mineral licks could ensure that P requirements of animals are met. Calcium, Mg, K, Fe and Mn would meet the nutrient requirements for grazing ruminants managed in the communal grazing lands. Animals have to be supplemented throughout the year, especially during the winter seasons, in order to cover the maintenance requirements of the grazing livestock. However, rational range management techniques are required to improve the quality and quantity of forage and maintain these landscapes. This study also highlights the need for further research by taking the blood serum of livestock feeding in the same area in order to provide information based on the levels of nutrients in the same area. In addition, future studies should also define the correlation between mineral content of the grass species, the soil and the blood serum of grazing animals.

CHAPTER 5

ALTITUDINAL AND SEASONAL VARIATION IN CRUDE PROTEIN AND FIBRE CONTENT OF SELECTED GRASS SPECIES IN TWO COMMUNAL GRAZING LANDS

Abstract

This study was conducted to evaluate the species, seasonal and altitudinal variations in CP and fibre contents of selected grass species in two communal areas, namely Hala in highland (Highveld) and Gqumashe in lowland (Lowveld) of the Eastern Cape Province, South Africa. Grass samples were harvested from three landscape gradients (upland, gentle sloppy and bottom lands) over four seasons (summer, autumn, winter and spring). In each landscape, three 50 m x 20 m plots, which served as replicates were marked to collect vegetation samples. A 5 x 4 x 3 factorial experiment in a randomised complete block design was used with season, altitude and grass species as the main factors. In both communal lands, crude protein (CP) and fibre contents of plant samples showed significant variations (P<0.05) between species, seasons and altitude. In the Highveld, CP ranged from 3.9 to 6.5% DM being significantly highest (P<0.05) in *C. dactylon* and lowest in *E. plana*. When all species were combined, higher CP was recorded for samples harvested in summer (5.5%) followed by spring and autumn, and lowest in winter (3.8%). In the Lowveld, *E. chloromelus* had higher (P<0.05) CP level followed by *C. dactylon* and *T. triandra*. When all species are pooled, forage samples harvested in summer had a significantly higher (P<0.05) CP followed by those harvested in spring, autumn and winter. Crude protein content of all grasses was below the critical maintenance requirement for livestock throughout the year. In both areas, the highest NDF level was measured for *E. plana* and lowest for *T. triandra*. Sloppy areas had significantly higher (P<0.05) NDF and ADF content than the bottomlands and uplands. As for altitudinal differences, samples collected from the upland areas had generally the lowest (P<0.05) CP and highest ADF contents. Findings of this study suggested that addition of protein and energy sources may be desirable in both grazing areas to meet the maintenance requirements of the grazing ruminants throughout the year.

Key words: Chemical composition; energy; grazing lands; seasonal variations; livestock.

5.1. Introduction

In the communal areas, of South Africa, native pastures are the major source of feed to many ruminant livestock species. Grasses make up the largest proportion of the native pastures, and therefore contribute to the bulk of livestock forage nutrients. Most communal rangelands in the Eastern Cape are covered predominately by perennial grasses. However, over the last few decades, shifts in the herbaceous vegetation composition have been reported as the result of continued overgrazing and rangeland degradation. The shifts involve mainly the replacement of strongly perennial grasses by weak perennial or annual grasses and/or forbs. Many grass species can be identified in vast grazing areas of semi-arid rangeland ecosystems, but few of them remain the sole sources of the bulk of the utilisable forage and livestock nutrients.

One of the biggest challenges in communally based livestock production system is the low quantity and poor quality of available forages. In particular, native pastures have been reported to have lower crude protein (CP) and higher fibre content than optimal required for sustaining adequate intake and digestibility (Mekasha *et al*., 2002) for some part of the grazing period. Several authors (Arzani *et al*., 2004; Gebremeskel, 2006; Safari *et al*., 2011) regarded CP and fibre contents as the primary measure of quality of grazing forages in arid and semi-arid areas. This is because CP and forage fibres determine availability of energy from the fibres. Marginal deficiencies of protein and other energy sources in native pastures cause general low livestock performance and productivity (Beyene and Mlambo, 2012a) including low milk, meat and wool production.

Several researchers reported that CP and fibre contents of native pastures varies according to grass species, (Aregheore, 2001), stage of maturity, soil fertility and landscape positions, livestock management and other seasonal and environmental conditions (Gebremeskel, 2006). During the growing season there is abundance of rapidly growing grasses of high quality, which both decline as the season advances (Mbwile and Uden, 1997). Jingura *et al*. (2001) reported that CP concentration of the rangeland forages fluctuates with season and can be as low as 1-2% during the dry season. During the dry season generally, grasses have high fibre and low protein content resulting in poor livestock performance. Mountousis *et al*. (2011) found that the NDF and ADF contents of forage were low in the early vegetative stages (spring), in all altitudinal zones. The lower fibre contents could be explained by the presence of more leaves in grasses. However, fibre contents increase during the growing period showing their peak value at the end of autumn (Mountousis *et al*., 2011).

Knowledge of the chemical composition and nutritive value of grasses from natural grazing lands is important in the planning and sustainable use of feed resources for animal production (Peacock *et al*. 2005). This is because both the quantity and quality of nutrients determine animal performance and productivity. Information on the nutritive value of grass species is also desirable for long-term monitoring and management of communal rangeland resources. Understanding the nutrient quality trends of rangeland forages over landscapes and seasons will assist to predict the dynamics of spatial and temporal livestock nutritional status and make corrective measures through supplementation programmes. Moreover, selection of appropriate indigenous forage species for improvement to enhance fodder flow systems for a particular site and purpose requires that their chemical composition and nutritive values be known. The objectives of the study was to investigate the effects of season and landscape gradients on CP and crude fibre content of grass species from two communal areas in the Eastern Cape Province.

5.2 Materials and methods

5.2.1 Study description

The study area is fully described in section 3.1. *Cynodon dactylon, Eragrostis chloromelus, Eragrostis plana, Sporobolus africanus* and *Themeda triandra* samples were harvested for crude protein and fibre analysis. The grass species were cut at stubble height and placed in paper bags and dried in an oven at 75^0C for 48 hours.

5.2.2 Crude protein and fibre analysis

Grass samples were analysed for CP, neutral detergent fibre (NDF), acid detergent fibre (ADF). Nitrogen content was determined by a Kjeldahl method (AOAC, 1999 method number 976.06) and converted to CP content by multiplying % N content by 6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by refluxing 0.45g samples with neutral detergent and acid detergent solutions, respectively, for 1 h using the ANKOM^{2000} Fibre Analyzer (ANKOM Technology, New York) according to Lewis, Robertson and van Soest (1991). Heat-stable α-amylase and sodium sulfite were used for NDF analysis. The fibre fractions were expressed exclusive of residual ash.

5.2.3 Statistical analysis

A 5 x 3 x 4 factorial experiment in a randomised complete block design was used in this study with altitude, seasons and grass species being the main factors. Chemical composition data for the selected grass species was analysed using the General Linear Models (GLM) procedure of SAS (2001) to test differences between species, seasons and altitudes. Means were separated using the pdiff options of the least squares means statement of GLM procedure of SAS (2001). Data analysis was done separately for the two study areas because the vegetation types of these two communal grazing lands are different.

5.3 Results

5.3.1 Highveld grazing land

Forage CP content of the harvested samples was significantly influenced by species, season and altitude (P<0.05). However, no significant interaction effects were found between factors. The CP and fibre contents of grass species is presented in Table 5.1. Crude protein content ranged from 3.9 to 6.5% being significantly highest in *C. dactylon* and lowest in *E. plana*. *Eragrostis plana* had the highest NDF (74.4%) and *T. triandra* had the lowest NDF (62.5%). *Both E. plana and S. africanus* had significantly the highest ADF levels followed by *E. chloromelus* and *T. triandra*.

Table 5.1 Crude protein and fibre (%) contents of selected grass species harvested from the Highveld grazing lands.

Species	CP	NDF	ADF
Cynodon dactylon	6.5^{a}	66.8^{c}	34.8^{c}
Eragrostis chloromelus	5.5^{b}	68.2^{c}	37.7^{b}
Eragrostis plana	3.9^{d}	74.4^{a}	40.0^{a}
Sporobolus africanus	4.0^{cd}	71.3^{b}	40.2^{a}
Themeda triandra	4.5^{c}	62.5^{d}	37.8^{b}
SEM	0.2	0.6	0.5

[abcd]: Different small superscripts show significant difference (P < 0.05) between species (row). SEM: Standard error of means.

When all species were combined, higher CP was recorded for samples harvested in summer (5.5%) followed by spring and autumn, and lowest in winter (3.8%) (Table 5.2). The NDF content of grass species combined was significantly higher (P<0.05) in the winter (71.6%) followed by autumn and summer, and lowest in spring (65.6%). The mean value of ADF was highest in spring (41.3%) followed by summer and winter, and lowest in autumn (34.3%). Considering the altitudes, grasses harvested from bottomlands and uplands had significantly higher (P<0.05) CP content than the sloppy areas (Table 5.3). Sloppy areas had significantly higher (P<0.05) NDF and ADF content than the bottomlands and uplands.

Table 5.2 Mean crude protein and fibre (%) of grasses in relation to season in the Highveld communal grazing lands.

Season	CP	NDF	ADF
Autumn	5.3^{ab}	69.2^{b}	34.3^{d}
Summer	5.5^{a}	68.2^{b}	40.1^{b}
Spring	4.9^{b}	65.6^{c}	41.3^{a}
Winter	3.8^{c}	71.6^{a}	36.7^{c}
SEM	0.2	0.5	0.4

^{abc}: Different small superscripts show significant difference (P < 0.05) between seasons (rows). SEM: Standard error of means.

Table 5.3 Mean crude protein and fibre (%) contents of grasses in relation to landscape gradients in the Highveld communal areas.

Altitude	CP	NDF	ADF
Bottom	5.2^{a}	68.9^{ab}	37.6^{b}
Sloppy	4.5^{b}	69.2^{a}	39.1^{a}
Uplands	5.1^{a}	67.8^{b}	37.6^{b}
SEM	0.2	0.5	0.4

^{ab}: Different small superscripts show significant difference (P < 0.05) between altitudes (rows). SEM: Standard Error of means.

5.3.2 Lowveld grazing land

The CP content of grasses harvested from the Lowveld area varied significantly in response to species, altitude and seasonal differences. *Eragrostis chloromelus* had higher (P<0.05) CP level followed by *C. dactylon* and *T. triandra*. *Sporobolus africanus* had the lowest level of CP. *Eragrostis plana* and *S. africanus* had significantly the highest (P<0.05) NDF level and *T. triandra* had the lowest. *Sporobolus africanus* had highest ADF content, and *C. dactylon* had the lowest (Table 5.4).

Table 5.4 Crude protein and fibre (%) contents of selected grass species harvested from the Lowveld grazing lands.

Species	CP	NDF	ADF
Cynodon dactylon	6.2^{b}	67.2^{c}	35.1^{d}
Eragrostis chloromelus	6.8^{a}	68.5^{b}	38.2^{b}
Eragrostis plana	4.6^{d}	71.9^{a}	37.5^{bc}
Sporobolus africanus	4.1^{e}	71.4^{a}	40.1^{a}
Themeda triandra	5.2^{c}	61.8^{d}	36.4^{c}
SEM	0.2	0.5	0.4

^{abcde}: Different small superscripts show significant difference (P < 0.05) between species (rows). SEM: Standard error of means.

When all species are pooled, forage samples harvested in summer had a significantly higher CP followed by spring, autumn and winter. The NDF content of forage samples was highest in winter and lowest in spring and summer. Forage samples harvested in spring had a significantly higher (P<0.05) ADF followed by summer, winter and spring. As for altitudinal differences, samples collected from the upland areas had the lowest CP and highest ADF contents. NDF did not differ (P>0.05) and ranged from 67.8% (uplands) to 68.4% (bottomlands).

Table 5.5 Mean crude protein and fibre (%) contents of grasses in relation to season in the Lowveld communal grazing lands.

Season	CP	NDF	ADF
Autumn	6.4^{a}	68.8^{b}	33.7^{d}
Summer	5.5^{b}	65.9^{c}	38.8^{b}
Spring	5.9^{b}	65.8^{c}	40.0^{a}
Winter	3.8^{d}	72.1^{a}	37.2^{c}
SEM	0.2	0.5	0.4

^{abcd}: Different small superscripts show significant difference ($P < 0.05$) between seasons (rows). SEM: Standard error of means.

Table 5.6 Mean crude protein and fibre (%) contents of grasses in relation to landscape gradients in the Lowveld communal areas.

Altitude	CP	NDF	ADF
Bottom	5.5^{a}	68.4^{a}	37.3^{b}
Sloppy	5.7^{a}	68.2^{a}	37.0^{b}
Uplands	4.9^{b}	67.8^{a}	37.9^{a}
SEM	0.13	0.4	0.3

^{ab}: Small superscripts within columns show significant difference ($P < 0.05$) between altitudes (rows). SEM: Standard Error of means.

5.4 Discussion

Several studies reported the spatio-temporal as well as species variations in the quality of forage plants in the arid and semi-arid grazing lands (Arzani *et al*., 2006; Tefera *et al*., 2009; Mountousis *et al*., 2011; Roukos *et al*., 2011). Crude protein and fibre contents are among the nutritional indicators that are used to measure forage quality differences between species, and changes over time and space (Arzani *et al*., 2004; Arzani *et al*., 2006; Yayneshet *et al*., 2009). The significant variations in CP contents in the current study were similarly reported by

Ramirez *et al*. (2004), and Yayneshet *et al*. (2009) though this was not consistent with the report of Nsinamwa *et al*. (2005) made in Botswana rangelands. Generally, CP levels are within the range reported in many arid and semi-arid grasslands (Ramirez *et al*., (2004; Beyene and Mlambo, 2012b) made in Swaziland. However, many other findings reported higher (Evitayani *et al*., 2005; Salem *et al*., 2005; Cerrillo *et al*., 2006; Roukos *et al*., 2011) and lower (El-Beheiry and El-Kady, 1998) CP content than the current study.

The presence of marked variations in the level of NDF between grass species concur with the reports of Gonzalez Ronquillo *et al*. (1998), Tefera *et al*. (2009), and Beyene and Mlambo (2012a), but disagrees with Nsinamwa *et al*. (2005) who did not report any significant difference. Several studies reported higher ADF content (Arzani *et al*., 2006; Yayneshet *et al*., 2009; Tessema *et al*., 2010; Beyene and Mlambo, 2012b) than what was investigated in the current study. Temporal and spatial variations observed in this study were reported similarly by the studies of Safari *et al*. (2011) conducted in Tanzania. However, few other studies observed the absence of seasonal and spatial differences in the CP and fibre contents of grass species. Species differences in CP and fibre contents may be related to genetic difference in the absorption of nutrients from the soil, their photosynthetic efficiency and utilisation of nutrients and storage in the body tissues (Arzani *et al*., 2006; Zafar *et al*., 2007). Variations between grass species in leaf to stem ratios at any growth stage are widely reported and this may cause differences in CP and fibre contents (Arzani *et al*., 2006). Grass species are also different in terms of their growth rate and at any one time this may influence the animal preference for diet causing one species to be grazed more severely than the other. This condition may ultimately change the leaf to stem ratio of grasses and hence the CP and fibre contents. Many studies concluded that marked sseasonal changes in the CP and fibre contents of grasses are related to the advancement in maturity and age of the grass species (Evitayani *et al*., 2005; Nsinamwa *et al*., 2005).

In this study, though the CP contents of grasses was significantly lower in the dry winter and fibre contents varied between seasons, apparent trends were not evident with advance in season. This may show that continuous grazing system practiced in the open communal grazing lands may mask the effect of age of the plant or growth stage (Nsinamwa *et al*. (2005). Therefore, repeated leaf removal leaving high proportion of stem over leaves might cause low CP content of the forage. This study suggests that both the Highveld (CP range: 3.8% to 6.5%) and Lowveld (CP range: 3.8% to 6.8%) grasses may not meet the protein requirement of grazing ruminants when they are either grazed selectively or together for most part of the grazing year. According to National Research Council (NRC) (1985, 1996) beef cattle and sheep require a minimum CP amount of 8.2% and 8.9%, respectively in their diet. These are the minimum threshold levels below which intake of forage could be limited (Minson, 1980; Safari *et al*., 2011).

Indeed, intake of CP may be further limited by the low biomass production of the grasses recorded in this study. The low protein and high fibre (NDF and ADF) content observed in the grass species is not only a characteristics of mature tropical grasses as reported by Gonzalez Ronquillo *et al*. (1998), Nogueira Filho *et al*. (2000) and Mlay *et al*. (2006), but also characteristics of some native pastures at all stages of growth. Therefore, low CP and higher fibre content of forage species could be associated with higher concentrations of fibrous tissues. Beyene and Mlambo, (2012b) reported that protein deficiency may reduce the cellulolytic activity of rumen microbes by causing the slow breakdown of fibre and low passage rate. In this study, regardless of the grazing site and season or the type of plant preferably grazed, the CP contents were low in the two study areas. Therefore, the additional source of protein needs to be supplied in order to cover the maintenance requirements of the grazing ruminants (Mountousis *et al*., 2011).

The low level of CP in *T. triandra* found in this study is not anticipated because this species is regarded by many as a highly palatable, and well grazed species by all livestock species. Therefore, its low CP content may be related to heavy defoliation that might have left less leaf material before plant samples were harvested. *Themeda triandra* and *Cynodon dactylon* had the least concentration of NDF and ADF, which would have made these species easier to digest, but also had low protein content especially in both grazing lands.

5.5 Conclusion

This study showed that there were great variation in CP and fibre contents between species, seasons and altitudinal. Among the grass species, *E. plana* and *S. africanus* had higher fibre and lower CP content, while *C. dactylon* and *E. chloromelus* had higher CP content than all other grass species in both grazing lands respectively. Crude protein content was relatively higher during the autumn, summer and spring season than in the winter season, while NDF were lowest during the summer and spring season. Nevertheless, forages in both communal grazing lands may not meet the protein needs of grazing animals for maintenance in most grazing sites and periods. Therefore, a fodder flow program to supply additional protein and energy sources should be established. Besides, rational range monitoring and management programme are desirable. Monitoring will help to follow up the forage composition, quality and quantity status and the later will serve to maintain or improve the nutritional needs of the animals by manipulating grazing systems. Therefore, correct stocking rate and reduction of grazing pressure will lead to growth of newly formed leaves increasing CP and decrease fibre content of forage for landscape maintenance.

CHAPTER 6

EFFECT OF ALTITUDE AND SEASON ON *IN VITRO* RUMINAL FERMENTATION CHARACTERISTICS OF SELECTED GRASS SPECIES

Abstract

Little is known about the *in vitro* ruminal fermentation characteristics of grass species grazed by ruminants in the communal grazing lands of Eastern Cape Province in South Africa. This study was therefore conducted to investigate the degradability and cumulative gas production of selected grass species collected from two communal areas, namely Hala (Highveld) and Gqumashe (Lowveld) grazing lands. The common grass species in both grazing lands were *Cynodon dactylon*, *Eragrostis chloromelus*, *Eragrostis plana*, *Sporobolus africanus* and *Themeda triandra*. For grasses harvested from the Highveld, *C. dactylon* produced the highest (P<0.05) gas after 48 h of fermentation (794.6 ml/g DM) and also had the highest 48h dry matter digestibility (DMD) (415.1 g kg^{-1}). *Themeda triandra* produced the least (P<0.05) gas (742 ml/g DM) 48h post-incubation. The least (P<0.05) degradable species after 48 h was *E. chloromelus* (372.9 g kg^{-1}). For grasses harvested from Lowveld, the 48h cumulative gas production was highest (822.7 ml/g DM) in *E. plana* and lowest (742.8 ml/g DM) in *E. chloromelus*, while *S. africanus* had the least 48h DMD (327.9 kg^{-1}). In both the Highveld and Lowveld, gas production and DMD was highest in the autumn season. However, further study is needed to evaluate livestock response to feeding of the highly fermentable grass species.

Keywords: *in vitro* gas production; dry matter degradability; grasses species; seasonal variation.

6.1 Introduction

The southern African savanna and grassland biomes are characterized by the dominance of grasses and scattered woody vegetation. This biome has been extensively used for livestock production in communally used areas. Grasses in the savanna biome form the bulk of the utilizable forage for grazing ruminant (Meissner, 1997), and are the main sources of energy and other nutrients. In this biome, perennial grasses are the dominant species compared to annual grass species. Although several perennial grass species can be identified in the rangeland ecosystem, only few of them contribute to the largest proportion of the grass layer as well as the bulk of the utilisable forage and animal nutrients. Both the quantity and quality of available forage are important factors that affect the productivity and health of animals in communal areas (Beyene and Mlambo, 2012a). Forage nutritional quality is determined by the product of voluntary intake, digestibility and efficiency of nutrient use by the animal (Reid, 1994). Under normal conditions, grass dry matter yield and its quality during is a function of many factors, most importantly plant species, rainfall, temperature and length of the growing period, land scape positions and soil types which determine the nutrient pool and supply dynamics to plant demands (Saleem, 1998). One of the limitations of animal production in the savanna ecosystems is the seasonal variation in the quality and quantity of forages (Zewdu *et al*., 2002; Nyamukanza *et al*., 2010). Seasonal availability is a vital factor that limits the productivity of communal rangelands in this region, because grasses grow rapidly during the wet season and decline in production and nutritive value as the season advance towards the dry season (Tefera *et al*., 2009). High temperatures can be one of the dominant seasonal factor affecting growth and quality of grasses because with advance in temperature, which occurs from spring to summer, the rate of plant growth increases, and this causes it a reduction in digestibility of cell wall by increasing amount of indigestible cell wall

(Kloppenburg *et al*. (1995). On the other hand the decline in temperature may reduce growth rate of grass species from autumn to winter.

The major production constraint during the dry season in many communal grazing areas of South Africa is the low production and nutritive values of forages (Scogings *et al*., 1999). Dry season is always a stressful period for grazing ruminants because it is characterized by insufficient available forage which is also highly fibrous (Abimbola, 2010). Tessema *et al*. (2010) mentioned that nutritional status of grasses in communal grazing lands is also influenced by soil fertility status of the rangelands. Soil fertility in turn shows variability with regard to landscape gradients, positions and altitudes. Rainfall regime is another important factor that alters both forage quantity and quality of grazeable forages (Snyman, 2005). Grazing livestock may also influence forage quantity and quality by changing the species composition of grasses because continuous grazing may result in the replacement of highly palatable species by less and poorly palatable species (Distel *et al*., 2005; Beyene and Mlambo, 2012b).

Understanding the chemical composition, nutritive value and digestibility of grasses and the factors that affect them is vital for grazing management programs (Tefera *et al*., 2009). Moreover, this understanding will aid in the selection of grass species suitable for fodder production to plug the nutritional gaps that occur during periods low forage production (Tefera *et al*., 2009). The *in vitro* ruminal gas production technique has been used extensively to evaluate the nutritive value of plant materials (Ndagurwa and Dube, 2013). The technique measures the amount of gas produced from the *in vitro* microbial digestion of forage with bicarbonate-buffered rumen fluid (Davies *et al*., 2000). *In vitro* ruminal fermentation methods can also be used to estimate the organic matter degradability of ruminant forages (Tilley and Terry, 1963; Groot *et al*., 1996) by measuring the disappearance of substrate at different time points during the course of the incubation. *In vitro* methods are less expensive, less time-consuming and are more precise than *in vivo* trials (Tilley and Terry, 1963). In the Eastern Cape rangelands of South Africa, there is inadequate information with respect to the *in vitro* ruminal fermentation characteristics of grasses as influenced by season, landscape position and altitude. Therefore, the objective of this study was to investigate the effect of season (autumn and winter) and landscape gradients (uplands, middle sloppy and bottomlands) on *in vitro* ruminal fermentation characteristics of selected grass species in two communal grazing lands.

6.2 Materials and methods

6.2.1. Description of the study areas

Two communal areas, namely; Hala and Gqumashe were selected in the Highveld and Lowveld regions of the Eastern Cape Province, respectively. Description of the study areas is fully presented in section 3.1.

6.2.2. Plant sampling

Cynodon dactylon, *Eragrostis chloromelus*, *Eragrostis plana*, *Sporobolus africanus* and *Themeda triandra* samples were harvested for chemical analysis. Details of plot layout and quadrat sampling are discussed in section 3.1. The grass species were cut to stubble height (6 cm) from the ground and placed in paper bags and dried in an oven at 75^0C for 48 hours. Plant samples were ground to pass through a 1 mm sieve pending *in vitro* ruminal fermentation using the Reading Pressure Technique (Mauricio *et al*., 1999).

6.2.3. *In vitro* ruminal fermentation

6.2.3.1. Rumen fluid source and processing

Rumen inoculum was collected in the morning prior to feeding from a crossbred Holstein cow, weighing approximately 430 kg. The animal had been fed mixed grass of poor quality and a commercial feed, dry cow and bull conditioner (Master Mix Feeds Ltd, Trinidad). Rumen digesta was sampled by hand from several sites within the rumen. The rumen fluid was squeezed into prewarmed thermos flasks. The thermos flasks with rumen fluid were transported to the laboratory, where the fluid was blended and strained through two layers of warm cheese cloth. Strained rumen fluid was held at 39 °C under a continuous stream of carbon dioxide until used for innoculating serum bottles.

6.2.3.2 Incubation procedure – The Reading Pressure Technique

About 1 g of sample was weighed into 125 ml serum bottles. Using an automatic dispenser (Jencons, Hemel Hemstead, England), 90 ml reduced RPT buffer (Mauricio *et al*., 1999) was added to each serum bottle. Serum bottles without samples (i.e., blanks) were also included to allow correction of 48 h degradability values for residual feed from rumen fluid. After addition of buffer, the flasks were sealed and stored at 20°C before being transferred into the incubators, set at 39°C, 8 h before inoculation with rumen fluid. The serum bottles were each inoculated with 10 ml fluid and incubated at 39°C for the 48 h duration of the experiment. Inoculation was complete within 60 minutes of fluid being prepared and, during this time, anaerobic conditions were maintained through constant flushing of rumen fluid containers and serum bottles with carbon dioxide gas. The time between rumen fluid collection and the start of inoculation was about 40 minutes. Fermentation flasks without samples (blanks) were included to allow correction residual dry matter from rumen fluid and any direct effect of PEG on fermentation gas release. Grass samples were incubated in quadriplicate.

6.2.3.3. Gas measurements

Headspace gas pressure was measured at 2, 4, 6, 8, 10, 12, 15, 19, 24, 30, 36 and 48 hours post inoculation using a pressure transducer interfaced with a computer. Gas pressure readings (psi) were converted to gas volume (ml) using the relationship between gas pressure and gas volume pre-determined for the St. Augustine (Trinidad and Tobago) site as:

$$Gp = 1.7675 + 2.1244P_t - 0.0022P_t^2$$

where, G_p = the predicted gas volume (ml) and P_t = the pressure transducer reading at time t (psi).

6.2.3.4. Estimation of degraded substrate

End-point (48 h) *in vitro* DM degradability (DMD) was determined by recovering the fermentation residues by filtration through sintered-glass crucibles (100-160µm porosity, Pyrex, Stone, UK) under vacuum. Fermentation residues were dried at 105°C overnight and incinerated in a muffle furnace at 550°C for 12 hours. Loss in weight after incineration was used as a measure of undegradable OM. The OMD was calculated as the difference between OM content of substrate and its undegradable OM. Partitioning factors (PF, used as a measure of fermentation efficiency) were calculated using 48 h OMD (mg)/cumulative gas production (ml/g DM) fermentation parameters.

6.2.4. Statistical analysis

A 5 (grass species) x 3 (altitude) x 2 (seasons) factorial experiment in a randomised complete block design was used in this study. *In vitro* ruminal fermentation parameters data for the selected grass species were analysed using the General Linear Models (GLM) procedure of SAS (2001) to test differences between species, seasons and altitudes. Means were separated using the pdiff options of the least squares means statement of (GLM) procedure of SAS (2001). Data analysis was done separately for the two study areas because these two communal grazing lands are located in different ecologies.

6.3 Results

Results showed that there was no significant effect of landscape gradients on the *in vitro* ruminal gas production and DMD of selected grass species. Therefore, values are not presented in tables.

6.3.1. Variation in *in vitro* ruminal fermentation parameters of grass species

6.3.1.1. Highveld grazing area

Table 6.1 presents the cumulative gas production (ml/g DM) and DMD (g/kg) of selected grass species in the Highveld grazing lands. End point (48h) gas production was highest (P <0.05) in *C. dactylon* (794.6 ml), *E. plana* (792.9 ml) and *S. africanus* (790 ml), and lowest in *T. triandra* (742 ml). A similar trend was observed at 36 h after incubation. At 24 h post incubation, *C. dactylon* had the highest (P < 0.05) cumulative gas production while *E. chloromelas, S. africanus* and *T. triandra* had the lowest. Dry matter degradability was highest (P < 0.05) in *C. dactylon* followed by *S. africanus* and lowest in *E. chloromelas*. Results on PF showed that *C. dactylon* and *T. triandra* had the highest (P <0.05) values and *E. chloromelas* and *E. plana* had the lowest (Table 6.1).

6.3.1.2. Lowveld grazing lands

Table 6.2 presents the *in vitro* ruminal fermentation characteristics of selected grass species in the Lowveld communal grazing lands. End point (48h) gas production was highest (P <0.05) in *E. plana* (822.7 ml), and *C. dactylon* (770.3 ml), and lowest in *E. chloromelus* (742.8 ml) and *T. triandra* (745.8 ml). This trend was the same at 24 and 36 h after incubation. Dry matter degradability was highest (P < 0.05) in *T. Triandra* (391.3 g/kg) and *C. dactylon* (376.7 g/kg) followed by *E. plana* (369.5 g/kg) and lowest in *S. africanus* (327.9 g/kg). Results on PF showed that *T. triandra* had the highest (P <0.05) values followed by *C. dactylon*, while *S. africanus* and *E. plana* had the lowest fermentation efficiency (Table 6.2).

Table 6. 1 Variations in *in vitro* cumulative gas production (ml/g DM), DMD (g kg^{-1}) and partitioning factor (g DMD ml^{-1} gas) among selected grass species in the Highveld communal area.

Species	24 h	36 h	48 h	DMD 48 h	PF
Cynodon dactylon	585^{a}	714.9^{a}	794.6^{a}	415.1^{a}	0.53^{a}
Eragrostis chloromelus	557.5^{b}	687.3^{ab}	770.9^{ab}	372.9^{c}	0.48^{b}
Eragrostis plana	562.4^{ab}	698.1^{a}	792.9^{a}	382.5^{bc}	0.48^{b}
Sporobolus africanus	553.3^{b}	693.1^{a}	790^{a}	401.5^{ab}	0.51^{ab}
Themeda triandra	546.8^{b}	662.9^{b}	742^{b}	393.3^{bc}	0.53^{a}
MSE	12.5	16.82	19.64	11.6	0.02

^{ab}In a column, means with different superscripts show significant difference ($P \leq 0.05$) between grass species.

Table 6. 2 Variations in *in vitro* cumulative gas production (ml/g DM), DMD (g kg^{-1}) and partitioning factor (g DMD ml^{-1} gas) among selected grass species in the Lowveld communal area.

Species	24 h	36 h	48 h	DMD 48 h	PF
Cynodon dactylon	580.7^{ab}	696.9^{ab}	770.3^{ab}	376.7^{a}	0.49^{ab}
Eragrostis chloromelus	546.5^{b}	662.4^{b}	742.8^{b}	355.5^{bc}	0.48^{b}
Eragrostis plana	600.5^{a}	729.7^{a}	822.7^{a}	369.5^{ab}	0.47^{bc}
Sporobolus africanus	553.4^{b}	666.7^{b}	750.1^{b}	327.9^{c}	0.44^{c}
Themeda triandra	557.9^{b}	665.1^{b}	745.8^{b}	391.3^{a}	0.52^{a}
MSE	19.4	23.4	25.8	16.1	0.02

^{ab}In a column, means with different superscripts show significant difference ($P \leq 0.05$) between grass species.

6.4.2. Seasonal variations in in vitro ruminal fermentation and degradability of grass species

Table 6.3 presents the *in vitro* ruminal fermentation and DMD of grass species across seasons in the Highveld grazing lands. The results show that except for *T. triandra*, which did not show seasonal differences ($P \leq 0.05$), all the other species had significantly high cumulative gas production (24, 36, and 48h) in the autumn than the winter. Similarly, DMD value of all grass species was higher in autumn than winter. Except for *C. dactylon*, whose PF values did not differ between seasons, the remaining species had higher ($P \leq 0.05$) PF values in autumn than in winter (Table 6.3).

Table 6.4. presents the *in vitro* ruminal fermentation and DMD of grass species across seasons in the Lowveld grazing lands. The results show that except for *E. plana* and *S. africanus*, which did not show seasonal differences ($P \geq 0.05$) at 48h, all the other species had significantly higher ($P \leq 0.05$) cumulative gas production in the autumn than the winter. Similarly, except for *E. plana* which did not show seasonal differences, DMD value of all grass species was higher in autumn than winter. Except for *E. plana* and *S. africanus*, which did not show any significant difference, the remaining species had higher ($P \leq 0.05$) PF values in autumn than in winter (Table 6.4).

Table 6. 3 *In vitro* cumulative gas production (ml/g DM) and DMD (g kg^{-1}) of grass species across seasons in the Highveld communal area.

	24h		36h		48h		DMD48h		PF	
Species	Autumn	Winter	Autumn	Winter	Autumn	Winter	Autumn	Winter	Autumn	Winter
C. dactylon	611.3^a	558.7^b	760.8^a	668.9^b	848.4^a	740.8^b	457.7^a	372.4^b	0.54^a	0.51^a
E.chloromelas	594^a	521^b	749.9^a	624.7^b	848.8^a	693.1^b	460.7^a	285.2^b	0.54^a	0.42^b
E. plana	603.4^a	521.5^b	757.4^a	640.2^b	864.1^a	721.7^b	458.5^a	306.4^b	0.53^a	0.43^b
S. africanus	596.3^a	510.3^b	754.3^a	632^b	863.3^a	716.8^b	467.5^a	335.5^b	0.55^a	0.47^b
T. triandra	564.5^a	529.2^a	685.5^a	640.3^a	765^a	719.1^a	443.7^a	355.3^b	0.58^a	0.49^b
MSE	16.9	18.2	22.8	24.6	26.6	28.8	15.6	17.4	0.02	0.02

^{ab}For each species, within incubation time, means with different superscripts show significant difference (P ≤ 0.05) between seasons.

Table 6. 4 ***In vitro* cumulative gas production (ml/g DM) and DMD (g/kg) of grass species across seasons in the Lowveld communal area.**

	24h		36h		48h		DMD48h		PF	
Species	Autumn	Winter	Autumn	Winter	Autumn	Winter	Autumn	Winter	Autumn	Winter
C. dactylon	628.6^a	532.8^b	751.2^a	642.8^b	826.4^a	714.2^b	429.4^a	324.1^b	0.52^a	0.46^b
E. chloromelas	587.4^a	505.5^b	706.6^a	618.3^b	785.4^a	700.1^b	397.9^a	313.2^b	0.51^a	0.45^b
E. plana	584.4^a	616.7^a	699.6^a	759.7^a	793.7^a	851.8^a	384.4^a	354.6^a	0.48^a	0.47^a
S. africanus	590.9^a	515.8^b	708^a	625.3^b	795.6^a	704.6^a	369.6^a	286.4^b	0.46^a	0.41^a
T. triandra	598.4^a	517.4^b	704^a	626.2^b	784.9^a	706.7^b	450.1^a	332.4^b	0.57^a	0.46^b
MSE	26.5	28.5	31.9	34.2	35.4	38	22.1	23.5	0.03	0.03

^{ab}For each species, within incubation time, means with different superscripts show significant difference (P ≤ 0.05) between seasons.

6.5 Discussion

6.5.1 Species differences

For grasses harvested in the Highveld, cumulative gas production values show large variations in the extent of fermentation for all grass species. The high cumulative gas production in *C. dactylon* (794.6 ml/g DM), *E. plana* (792.9 ml/g DM) and *S. africanus* (790 ml/g DM) suggests a higher extent of fermentation compared to *T. triandra* (742 ml/g DM) (Table 6.1), which had low gas production and indicated low degradability; these findings are in agreement with Mlambo *et al*. (2008), who concluded that normally, low gas production forage would indicate low degradability. The large differences among grass species in cumulative gas production and degradability may be partly attributed to the variations in chemical composition (Salem *et al*., 2007; Tefera *et al*., 2008) especially cell wall content and composition (Ammar *et al*., 2005).

Efficiency of fermentation as measured by PF values was lowest for *E. chloromelas* (0.48 g DMD ml^{-1} gas) and *E. plana* (0.48 g DMD ml^{-1} gas) suggesting that more gas (waste product) was produced per g DM degraded. Low fermentation efficiency is a characteristic of forages with high fibre content and low energy and nitrogen content for microbial biomass production. This results in low organic matter degradability accompanied by higher gas production values. In contrast, *C. dactylon* (0.53 g DMD ml^{-1} gas) and *T. triandra* (0.53 g DMD ml^{-1} gas) was fermented with the highest efficiency among the common grass species harvested in the Highveld. For grasses harvested in the Lowveld, variations in cumulative gas production among the forages may be associated to variations in their chemical components (Tefera *et al*., 2008). In the Lowveld, *C. dactylon* (770.3 ml/g DM) and *E. plana* (822.7 ml/g DM) were highly fermentable, as indicated by high end-point (48 h) cumulative gas production (Table 6.2). This could be due to their chemical composition relative to the other grass species. *Cynodon dactylon* (376.7 gkg^{-1}) and *Themeda triandra* (391.3 gkg^{-1}) were the most digestible, while *S. africanus* (327.9 gkg^{-1}) had lowest digestibility, similar trends were found by Sebata *et al*. (2011). Efficiency of fermentation as measured by PF values were lowest for *E. plana* (0.47 g DMD ml^{-1} gas) and *S. africanus* (0.44 g DMD ml^{-1} gas) suggesting that more gas (waste product) was produced per g DM degraded. In contrast, *T. triandra* was fermented with the highest efficiency (PF = 0.52 g DMD ml^{-1} gas) among the common grass species harvested in Lowveld, these findings are in agreement with Tefera *et al*. (2009) in Swaziland.

6.5.2 Seasonal differences

The native grass species harvested from the Highveld showed wide differences in cumulative gas production, DMD and partitioning factor between dry seasons as indicated by Yayneshet *et al*. (2009). In the Highveld, with the exception of *T. triandra*, all forages were least fermentable in winter, as indicated by low end-point (48 h) cumulative gas production (ml/g DM). The probable cause of poor fermentation could have been the high fibre content of these forages (Tefera *et al*., 2008) during the winter season. Variations in gas production among the seasons could be due to the proportion and nature of fibre contents of these forages as indicated by Salem *et al*. (2007). The overall low digestibility of grass species may be attributed to the relatively highly lignified nature of their stems. The results of DMD in our study are lower than the results obtained in the study conducted by Arzani *et al*. (2006) in Iran. The DMD of forage selected during dry seasons was low with values ranged from 443.4 – 467.5 g/kg in (autumn) and 285.2 – 372.4 g/kg winter (Table 6.3). Higher DM digestibility was recorded during the autumn and these findings are in agreement with Cerrillo *et al*. (2006) where DM digestibility was higher during the autumn (65.1%). Several authors cited by Cerrillo *et al*. (2006) reported that the poorly digestible compounds such as NDF, lignin and secondary compounds (condensed tannins) of selected forage negatively affect DM digestibility. Grasses harvested in the Highveld in the autumn season were fermented with higher efficiency compared to the grass species harvested in winter.

All the grasses harvested in the Lowveld in winter season, except for *E. plana*, were poorly fermented as indicated by low end-point (48 h) cumulative gas production (ml/g DM). The probable cause of poor fermentation might be the high fibre content contained by these forages (Tefera *et al*., 2008) during the winter season. As indicated by Salem *et al*. (2007) differences in gas production among the seasons could be due to the proportion and nature of fibre contents in these forages. Certainly the higher fibre levels in these forages are responsible for reduced gas production (Salem *et al*., 2007) in winter. The DMD of forage selected during dry seasons was low with values ranging from 369.6 – 450.1 g/kg in (autumn) and 286.4 – 354.6 g/kg winter (Table 6.4). These values were lower than those reported by Cerrilo *et al*. (2006) where DM digestibility in autumn was 65.1% (651 g/kg) and 51.3% (513 g/kg) in winter.

In the current study, DMD values of all forages were below requirements for animal maintenance (50%). According to Arzani *et al*. (2006), about 50% digestibility is sufficient for animal maintenance. The low digestibility of forages might be due to anatomical characteristics. *Cynodon dactylon* and *Themeda triandra* had higher DMD due to lower ADF content which confirms negative correlations obtained between DMD and ADF contents (Arzani *et al*., 2006). PF values were lowest in winter season suggesting that more gas (waste product) was produced per g DM degraded among the common grass species growing in winter in the Lowveld.

6.6 Conclusion

This study indicated that *T. triandra* from both Highveld and Lowveld produced less gas, while DMD was highest in *T. triandra* and *C. dactylon* in the Lowveld. Cumulative gas production, DMD and PF were affected by season where highest levels were found in autumn season. The results confirm commonly held view that the quality of veld grasses decline in winter as grasses mature and deposit higher levels of fibre and lignin. In the two sites that were investigated, *T triandra* emerged as the grass with the highest potential as ruminant feed.

CHAPTER 7

7.1 SUMMARY AND RECOMMENDATIONS

The DM yield of all the grasses showed a generally low forage dry matter yield. The yield of all grass species harvested from both communal grazing lands responded to seasonal effect. Both communal grazing lands are more subject to overgrazing because of continuous grazing. In Gqumashe lower rainfall affected the species composition and forage yield, and steeper slopes which affect soil cover. Both Highveld and Lowveld communal areas are affected by overgrazing because in these landscapes animals have easy access to the whole grazing area continuously; selective grazing has led to the reduction of decreaser species. However, at Gqumashe, the basal cover is affected by bush density, while aerial cover is affected by lower rainfall.

The current study indicated that P, Cu and Zn were deficient in all grass species. Therefore, animals feeding in the Highveld should be supplemented with P, Cu and Zn throughout the year, while in the Lowveld Mg, P, K and Zn should be supplemented during the winter season and Cu must be offered throughout the year. Grass species combined higher CP was recorded for samples harvested in summer followed by spring and autumn, and lowest in winter. In the Lowveld, *Eragrostis chloromelus* had higher CP level followed by *C. dactylon* and *T. Triandra*. Mean CP of all grasses was below the critical maintenance level for livestock especially throughout the year. In both areas, the highest NDF level was measured for *Eragrostis plana* and lowest for *Themeda triandra*. Sloppy areas showed higher NDF and ADF content than the bottomlands and uplands. As for altitudinal differences, samples collected from the upland areas had generally the lowest CP and highest ADF contents.

For grasses harvested from the Highveld, *C. dactylon* produced the most gas after 48 h of fermentation and also had the highest 48h DMD. *Themeda triandra* produced least gas 48h post-incubation. The least degradable species after 48 h was *E. chloromelas*. For grasses harvested from Lowveld, the 48h cumulative gas production was highest in *E. plana* and lowest in *E. chloromelas*, while *S. africanus* had least 48h DMD. In both the Highveld and Lowveld, gas production and DMD was highest in the autumn season respectively. *Themeda triandra* emerged as the grass with the highest potential as ruminant feed. Therefore, it is recommended that moving the herds from lowlands to uplands for proper grazing practice (management) for better utilization of studied communal grazing lands. Rational range management techniques are required to improve the quality and quantity of forage and maintain these landscapes. Addition of protein and energy sources may be desirable in both grazing areas to meet the maintenance requirements of the grazing ruminants throughout the year. However, further study is needed to evaluate livestock response to feeding of the highly fermentable grass species.

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Appendix 1 Effect of species, season and altitude on forage mineral, chemical and *in vitro* ruminal fermentation and interactions.

Table 1. Statistical significance (P values) of the effects of main factors (species, landscape, and season) and their interactions on chemical composition and *in vitro* ruminal fermentation of grasses in Highveld.

Parameter	Species (S)	Landscape (L)	Season (Sea)	S × L	S × Sea	L × Sea
Highveld						
CP (%)	<0.0001	0.0052	< 0.0001	0.3226	0.5222	0.6303
NDF (%)	<0.0001	0.0830	<0.0001	0.5660	0.0396	0.8241
ADF (%)	<0.0001	0.0032	<0.0001	0.6776	<0.0001	0.4667
Minerals						
Ca (%)	<0.0001	0.0190	0.0021	0.2944	0.2223	0.8306
Mg (%)	<0.0001	0.0042	<0.0001	0.0225	0.0869	0.2401
K (%)	0.0003	0.0003	<0.0001	0.7543	0.0033	0.6737
P (%)	<0.0001	<0.0001	0.0005	0.4612	0.3147	0.9247
Fe (%)	<0.0001	0.3692	0.5601	0.3179	0.9223	0.8923
Cu (%)	<0.0001	0.7004	0.5168	0.5085	0.5112	0.5376
Zn (%)	<0.0001	0.0202	<0.0001	0.5925	0.0597	0.1493
Mn (%)	<0.0001	<0.0001	0.0394	0.0117	<0.0001	0.8109
Gas production parameters						
24h (ml/g DM)	0.2133	0.1970	<0.0001	0.3128	0.5459	0.9022
36h (ml/g DM)	0.2597	0.3127	<0.0001	0.3401	0.4143	0.7980
48h (ml/g DM)	0.2637	0.4425	<0.0001	0.3814	0.2753	0.8354
DMD48h (gkg^{-1})	0.1106	0.6719	<0.0001	0.4369	0.0809	0.7351

Table 2. Effect of species, season and altitude on crude protein and fibre contents of selected grass species in the Highveld.

Species	Season	Landscape								
			CP		NDF			ADF		
		Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands
C. dactylon	Summer	6.3	6.3	7.1	67.9	68.1	67.1	36.4	37.9	36.5
	Autumn	5.9	7.3	7.6	67.4	65.7	67.1	30.2	33.7	29.2
	Winter	5.1	5.8	6.6	69.7	68	67.2	32.9	32.8	32.7
	Spring	7.4	5.4	7.5	64.4	63.7	64.9	36.9	40.2	37.4
E. chloromelus	Summer	8.2	5.4	6.2	68.2	69.6	66.9	39.6	40.6	39.9
	Autumn	5.4	5.2	7.2	71.1	71.6	68.6	34.7	35.7	32.9
	Winter	5.1	3.0	3.3	70.6	70.1	66.3	35.2	35.9	32.6
	Spring	5.5	5.3	6.3	66.5	64.6	64.5	39.9	44.2	41.5
E. plana	Summer	5.1	4.6	4.2	74.5	72.7	71.6	41.4	41.2	40.2
	Autumn	4.4	4.4	4.0	73.9	75.7	76.4	36.6	37.5	38
	Winter	2.8	2.4	2.8	79.1	82.2	76.7	40.4	42.6	39.5
	Spring	4.6	3.3	4.5	67.6	71.2	70.7	39.2	42.5	40.6
S. africanus	Summer	5.3	4.4	4.6	68.9	70.7	70.3	40.3	40.2	40.1
	Autumn	4.8	4.0	3.9	72.6	73.2	68.9	37.2	37.2	37.1
	Winter	4.2	3.4	3.3	74.5	80.6	74.7	38.9	44.2	38.9
	Spring	3.7	3.3	3.6	67.8	67.3	67.1	41.5	44.4	41.6
T. triandra	Summer	5.6	4.3	5.4	62.1	62.2	61.7	41.7	43.7	40.9
	Autumn	6.0	4.5	4.6	61.6	61.8	61.9	31.2	30.5	32.4
	Winter	3.1	3.1	3.5	67.7	62.5	63.6	36.6	32.5	34.2
	Spring	4.8	3.8	5.1	62.6	61.6	60.1	41.4	43.7	44.8

Table 3. Effect of species, season and altitude on macro and micro-elements of selected grasses in the Highveld.

Macro minerals						Landscape							
Species	Season		Ca			Mg			K			P	
		Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland
C. dactylon	Summer	0.28	0.24	0.28	0.12	0.12	0.18	0.70	0.51	0.67	0.12	0.08	0.11
	Autumn	0.27	0.20	0.24	0.12	0.12	0.11	0.67	0.48	0.72	0.14	0.09	0.12
	Winter	0.26	0.24	0.29	0.11	0.11	0.13	0.71	0.42	0.43	0.17	0.08	0.11
	Spring	0.30	0.28	0.28	0.15	0.13	0.13	0.68	0.56	0.68	0.11	0.09	0.10
E. chloromelus	Summer	0.30	0.25	0.25	0.13	0.09	0.10	0.94	0.74	0.92	0.12	0.07	0.11
	Autumn	0.28	0.23	0.25	0.11	0.08	0.11	0.63	0.70	0.70	0.12	0.08	0.08
	Winter	0.38	0.25	0.23	0.13	0.06	0.05	0.34	0.36	0.21	0.09	0.05	0.05
	Spring	0.27	0.23	0.25	0.11	0.09	0.08	0.53	0.45	0.67	0.08	0.07	0.09
E. plana	Summer	0.18	0.23	0.24	0.06	0.07	0.07	0.76	0.76	0.67	0.09	0.07	0.06
	Autumn	0.22	0.19	0.21	0.07	0.06	0.06	0.67	0.66	0.54	0.11	0.08	0.05
	Winter	0.23	0.21	0.19	0.05	0.06	0.05	0.48	0.34	0.30	0.06	0.03	0.03
	Spring	0.28	0.24	0.24	0.08	0.05	0.07	0.56	0.32	0.42	0.11	0.05	0.06
S. africanus	Summer	0.24	0.24	0.21	0.12	0.13	0.13	0.97	0.75	0.99	0.12	0.07	0.08
	Autumn	0.19	0.16	0.16	0.09	0.09	0.10	1.05	0.83	0.92	0.14	0.07	0.07
	Winter	0.17	0.16	0.15	0.07	0.07	0.07	0.56	0.40	0.46	0.08	0.05	0.04
	Spring	0.27	0.23	0.23	0.10	0.10	0.10	0.72	0.45	0.51	0.11	0.04	0.05
T. triandra	Summer	0.28	0.29	0.32	0.13	0.12	0.14	0.66	0.46	0.61	0.11	0.06	0.08
	Autumn	0.24	0.25	0.28	0.11	0.12	0.12	0.67	0.55	0.49	0.11	0.07	0.09
	Winter	0.29	0.24	0.30	0.13	0.10	0.13	0.47	0.35	0.41	0.07	0.05	0.06
	Spring	0.31	0.28	0.32	0.16	0.12	0.14	0.75	0.42	0.59	0.09	0.06	0.08
Micro minerals													
			Fe			Cu			Zn			Mn	
		Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland

C. dactylon	Summer	825.0	1066.7	922.8	2.8	4.8	3.6	37.6	31.9	31.9	90.9	97.6	109.3
	Autumn	548.8	1779.6	1012.5	2.4	5.9	3.2	20.9	20.1	14.6	79.3	80.7	140.2
	Winter	968.7	2023.7	2188.1	4.8	5.3	6.4	38.4	26.2	36.2	107.7	114.3	93.9
	Spring	700.9	2030.5	1076.7	3.9	3.9	3.9	56.1	39.3	37.9	109.7	111.8	98.9
E. chloromelus	Summer	640.0	353.0	372.0	2.1	2.3	1.4	21.4	12.4	11.3	82.7	75.2	86.1
	Autumn	534.9	838.9	441.7	2.0	2.2	1.9	13.0	7.2	6.7	57.9	132.8	101.6
	Winter	765.7	393.9	510.8	3.3	1.9	2.1	9.0	11.7	7.5	55.7	126.4	92.0
	Spring	727.6	450.8	472.0	2.0	2.5	2.1	13.1	15.5	14.1	69.8	79.6	153.9
E. plana	Summer	230.0	282.0	325.1	1.3	2.2	1.7	11.3	12.3	11.3	87.9	165.9	137.6
	Autumn	174.9	139.1	167.1	1.3	1.1	1.5	6.3	8.9	9.3	110.3	95.6	197.3
	Winter	440.6	203.6	311.3	1.5	0.9	1.7	12.5	7.9	9.1	109.5	125.4	154.8
	Spring	390.9	275.2	448.0	2.4	1.3	1.9	25.6	16.6	19.1	117.6	166.9	159.6
S. africanus	Summer	298.7	473.3	299.2	1.7	1.4	1.5	17.9	11.8	26.4	326.0	480.7	442.6
	Autumn	120.3	167.3	142.1	1.4	1.3	1.2	11.5	7.8	16.7	182.2	336.5	375.3
	Winter	279.4	323.9	246.0	1.1	1.3	1.0	9.5	9.5	6.5	142.9	218.5	274.7
	Spring	236.6	340.3	364.7	2.0	1.4	1.3	37.8	13.8	14.9	216.1	296.6	340.0
T. triandra	Summer	396.0	593.3	425.5	1.9	2.4	2.1	15.4	21.4	19.3	114.8	162.1	162.5
	Autumn	657.5	1041.5	478.5	2.3	3.1	3.8	11.6	12.5	14.3	98.9	167.4	128.5
	Winter	475.5	560.1	1070.9	2.6	2.5	3.8	12.6	12.6	15.5	120.5	176.4	156.5
	Spring	620.5	509.9	540.0	2.3	2.2	2.2	30.7	22.3	19.7	118.5	180.6	210.7

Table 4. Effect of species, season and altitude on *in vitro* fermentation characteristics of selected grass species in the Highveld.

		Landscape											
		24h			36h			48h			DMD48h		
Species	Season	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands
C. dactylon	Autumn	659.3	570.3	604.3	819.4	716.8	746.1	910.3	804.5	830.1	459.1	464.7	449.3
	Winter	538.6	538.2	599.5	640.2	648.3	718.4	706.7	721.7	794.1	369.4	374.4	373.6
E. chloromelus	Autumn	583.4	611.6	587.1	732.4	775.8	741.5	827.6	878.1	840.6	443.2	470.8	468.1
	Winter	568.7	515.9	478.5	677.9	609.9	586.4	747.6	676.7	654.9	311.9	253.1	290.7
E. plana	Autumn	598.2	608.7	603.2	731.6	769.9	770.7	822.2	878.1	892	415.9	480.9	478.6
	Winter	498.1	483.3	583.1	611.1	593.9	715.6	689.7	871.8	803.6	298.8	300.8	319.8
S. africanus	Autumn	592.1	590.6	606.1	755.9	740.2	766.7	862.7	847.4	879.8	496.2	468.8	437.5
	Winter	544.2	500.4	486.3	672.5	619.6	603.9	764.2	699.4	686.7	359.4	318.8	328.3
T. triandra	Autumn	607.8	538.7	546.9	755.3	651.8	649.6	847.8	724.3	722.9	482.2	408.6	382.8
	Winter	551.8	529.7	505.9	660.6	641.4	618.8	728.8	727	701.4	341.3	341.9	-

Table 5. Statistical significance (P values) of the effects of main factors (species, landscape, and season) and their interactions on chemical composition and *in vitro* ruminal fermentation of grasses in Lowveld.

Parameter	Species (S)	Landscape(L)	Season (Sea)	S × L	S × Sea	L × Sea
Lowveld						
CP (%)	<0.0001	0.0020	<0.0001	0.6134	0.0002	0.1749
NDF (%)	<0.0001	0.5590	<0.0001	0.9560	0.0260	0.8620
ADF (%)	<0.0001	0.1516	<0.0001	0.2027	0.0018	0.3285
Minerals						
Ca (%)	<0.0001	<0.0001	0.0147	0.3756	0.3277	0.0127
Mg (%)	<0.0001	<0.0001	<0.0001	0.5410	0.0022	0.0312
K (%)	0.0376	<0.0001	<0.0001	0.8150	<0.0001	0.0009
P (%)	<0.0001	0.0077	<0.0001	0.0019	0.0271	0.0112
Fe (%)	<0.0001	<0.0001	<0.0001	0.0320	0.1301	0.0246
Cu (%)	<0.0001	0.0492	<0.0001	0.0412	0.1138	0.0046
Zn (%)	<0.0001	0.3725	<0.0001	0.2144	0.0030	0.3117
Mn (%)	<0.0001	<0.0001	0.4479	0.0005	0.7538	0.0526
Gas production parameters						
24h (ml/g DM)	0.3181	0.1329	0.0010	0.5570	0.2000	0.6238
36h (ml/g DM)	0.2519	0.1027	0.0064	0.4681	0.1420	0.3589
48h (ml/g DM)	0.2375	0.0913	0.0104	0.4677	0.2218	0.2885
DMD48h(gkg^{-1})	0.0554	0.0661	<0.0001	0.7430	0.4376	0.1176

Table 6. Effect of species, season and altitude on crude protein and fibre contents of selected grass species in the Lowveld.

Species	Season	Landscape								
			CP		NDF			ADF		
		Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands
C. dactylon	Summer	6.2	6.3	6.0	69.5	66.3	62.9	37.8	34.7	36
	Autumn	8.5	7.9	6.4	66.9	66.9	68.1	31.4	30.8	31.1
	Winter	4.9	5.4	4.0	70.7	72.8	71.7	34.8	35.6	33.4
	Spring	6.5	6.2	5.9	61.6	65.1	62.9	39.3	37.9	37.9
E. chloromelus	Summer	6.3	6.8	6.3	68.1	66.1	66.9	38.5	41.2	40.3
	Autumn	8.3	9.4	7.9	68.2	68.3	69.7	33.5	33.2	34.3
	Winter	4.4	4.4	4.5	72	74.6	72.8	36.9	39	37.8
	Spring	7.6	9.3	6.4	65.5	64.9	64.9	39.4	37.9	45.5
E. plana	Summer	5.1	5.1	4.5	69.5	68.3	68.3	39.5	38.6	40.6
	Autumn	4.4	3.5	5.4	75.7	75.4	72.7	37.7	32.5	35.9
	Winter	3.3	3.2	4.1	74.1	72.3	74.4	36.9	36.4	38.9
	Spring	6.1	7.1	3.6	70	71.6	70.3	35.9	38.8	38.5
S. africanus	Summer	5.4	4.7	3.7	67.5	66.8	68.7	38.6	38.3	39.4
	Autumn	6.2	4.5	4.8	72.1	69.3	70.8	36.5	36.1	36.5
	Winter	2.4	3.0	2.8	76.4	77.9	75.3	40.9	43.4	39.9
	Spring	3.3	4.0	4.0	73.1	69.3	69.8	44.2	44.6	43.1
T. triandra	Summer	5.6	5.3	4.7	59.3	59.9	60.3	39.2	37.8	40.9
	Autumn	5.6	6.6	6.0	62.4	62.8	61.7	32.3	32.2	31.9
	Winter	3.8	3.6	2.9	65.9	65.9	64.8	34.2	34.8	35.8
	Spring	5.8	6.9	5.7	59.1	60.2	58.7	38.6	37.4	41.3

Table 7. Effect of species, season and altitude on macro and micro-elements of selected grasses in the Lowveld.

Species	Season	Landscape											
Macro minerals			Ca			Mg			K			P	
		Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland
C. dactylon	Summer	0.35	0.31	0.33	0.11	0.14	0.13	0.88	0.80	0.51	0.15	0.13	0.19
	Autumn	0.28	0.36	0.36	0.12	0.17	0.14	0.98	0.99	0.46	0.15	0.24	0.17
	Winter	0.33	0.28	0.42	0.09	0.09	0.11	0.53	0.47	0.42	0.10	0.10	0.17
	Spring	0.31	0.26	0.43	0.09	0.11	0.13	0.74	0.67	0.54	0.16	0.15	0.22
E. chloromelus	Summer	0.39	0.30	0.35	0.10	0.09	0.10	1.13	1.03	0.79	0.15	0.14	0.11
	Autumn	0.31	0.30	0.40	0.09	0.12	0.12	0.88	1.21	0.76	0.15	0.21	0.18
	Winter	0.35	0.35	0.41	0.07	0.09	0.09	0.40	0.40	0.31	0.11	0.10	0.08
	Spring	0.40	0.36	0.47	0.09	0.09	0.13	0.89	1.12	0.56	0.13	0.18	0.16
E. plana	Summer	0.29	0.25	0.23	0.07	0.07	0.06	1.18	1.08	0.75	0.12	0.11	0.11
	Autumn	0.25	0.26	0.31	0.05	0.06	0.08	0.91	0.56	0.59	0.09	0.15	0.12
	Winter	0.31	0.29	0.32	0.04	0.06	0.07	0.46	0.49	0.33	0.07	0.09	0.06
	Spring	0.28	0.32	0.28	0.07	0.08	0.07	0.74	0.88	0.37	0.14	0.16	0.11
S. africanus	Summer	0.26	0.22	0.23	0.13	0.13	0.13	1.40	1.18	0.70	0.16	0.12	0.09
	Autumn	0.19	0.18	0.22	0.10	0.12	0.12	1.13	1.26	0.76	0.14	0.13	0.14
	Winter	0.16	0.17	0.21	0.07	0.07	0.08	0.48	0.38	0.39	0.06	0.06	0.04
	Spring	0.20	0.25	0.33	0.08	0.10	0.13	0.35	0.51	0.36	0.06	0.09	0.09
T. triandra	Summer	0.37	0.32	0.36	0.12	0.11	0.11	1.13	1.02	0.57	0.13	0.14	0.09
	Autumn	0.33	0.39	0.37	0.12	0.14	0.13	0.81	0.82	0.67	0.12	0.17	0.13
	Winter	0.36	0.33	0.41	0.09	0.11	0.10	0.44	0.45	0.37	0.08	0.11	0.07
	Spring	0.41	0.38	0.42	0.11	0.13	0.14	0.84	0.92	0.55	0.11	0.16	0.12
Micro minerals			Fe			Cu			Zn			Mn	
		Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland	Bottom	Sloppy	Upland
C. dactylon	Summer	398.3	374.7	576	2.9	2.7	2.3	43.4	40.5	36.5	80.6	47.1	55.8

	Autumn	526.4	703.5	1060.1	2.5	2.5	3.5	25.9	18.5	20.3	78.4	66.0	66.8
	Winter	388.4	6945	1808	1.5	1.6	4.9	21.1	11.5	30.2	43.2	50.5	88.1
	Spring	319.2	435	1403.9	3.5	3.6	5.0	48.1	41.0	43.9	94.9	51.6	87.8
E. chloromelus	Summer	466.2	219.1	692.7	2.7	1.3	2.8	17.1	13.8	12.4	68.6	30.1	39.6
	Autumn	556.1	548.9	1198.9	1.5	2.7	2.4	8.8	17.1	9.9	58.9	64.5	77.5
	Winter	562.5	1173.6	1570	2.5	3.1	3.8	10.1	11.9	13.3	56.7	58.9	69.7
	Spring	412.7	430	1127.9	2.7	4.1	3.1	15.8	24.3	19.9	51.3	62.7	68.3
E. plana	Summer	216.4	143.8	199.4	2.1	2.2	1.7	20.5	17.1	13.2	60.5	35	20.6
	Autumn	145.8	150.1	241.9	1.4	1.1	1.2	16.7	5.5	122.6	77.3	34.2	33.2
	Winter	435.3	458.5	572.4	1.2	1.3	1.6	20.5	13.9	12.4	88.2	60.7	36.7
	Spring	282.6	288.7	397.6	2.2	3.9	1.7	25.2	20.1	26.7	60.6	60.7	30.2
S. africanus	Summer	231.3	179.8	480.7	1.6	1.4	1.2	24.7	18.3	15.1	167.9	60.2	54.7
	Autumn	117.1	182.7	413	1.4	1.7	1.3	12.2	22.5	10.6	111.2	57.8	97.5
	Winter	257.2	388.2	610	0.9	1.5	1.7	11.6	6.8	10.1	61.8	47.3	47.8
	Spring	196.4	256.2	899.6	1.5	2.1	2.3	26.9	25.8	22.1	67.9	102.9	106
T. triandra	Summer	637.1	174.9	570	2.5	1.7	1.7	27.2	27.2	25.6	196.5	55.1	79.8
	Autumn	715.8	271.8	647	1.8	1.6	2.1	13.2	15.9	13.5	165.1	60.7	116.6
	Winter	949.3	1298.6	1519.5	2.4	3	3.9	22	23.3	22.5	127.6	100.8	112.9
	Spring	409.3	509.3	838.5	2.8	2.7	2.7	31.5	39.5	32.1	224.6	84.4	67.3

Table 8. Effect of species, season and altitude on *in vitro* fermentation characteristics of selected grass species in the Lowveld.

		Landscape											
		24h			36h			48h			DMD48h		
Species	Season	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands	Bottom	Sloppy	Uplands
C. dactylon	Autumn	673.3	639.6	572.8	799.9	771.1	682.5	874	854.8	750.5	428.8	504.4	355.1
	Winter	580.3	529.7	488.6	698.4	630.1	599.9	772.1	699.9	670.7	333.7	308.4	330.1
E. chloromelus	Autumn	587.9	621	553.3	696.6	731.4	691.8	773.5	803.7	779.1	388.2	372.6	432.8
	Winter	477.8	492.7	545.9	608.7	610.3	635.7	697.8	700.1	702.4	341.7	341.2	256.6
E. plana	Autumn	572.9	603.3	576.9	694.3	732.9	671.8	791.1	830.2	759.9	395	414.4	343.7
	Winter	735.7	537.4	577.1	917.3	654.5	707.4	1030.8	730.7	793.8	361.2	331.8	370.9
S. africanus	Autumn	595	566.3	611.4	698.3	709.9	715.9	779	806.4	801.3	334.3	438.7	335.7
	Winter	558.8	537.5	451.1	680.3	637.8	557.5	763.8	720.3	629.6	275.3	278.6	305.3
T. triandra	Autumn	602.5	598.9	593.9	607.1	717.1	697.9	773.4	804.3	777.2	395.6	526.7	427.9
	Winter	496.1	588.6	467.4	595.4	717.3	565.9	677.9	807	635.2	321	361.9	314.4

Appendix 2: Forage mineral, chemical and *in vitro* ruminal fermentation ANOVA tables

Dependent Variable: Ca Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.16036907	0.04009227	15.79	<.0001
altitude	2	0.02090993	0.01045497	4.12	0.0190
season	3	0.03982461	0.01327487	5.23	0.0021
species*altitude	8	0.02478926	0.00309866	1.22	0.2944
species*season	12	0.03999233	0.00333269	1.31	0.2223
altitude*season	6	0.00713390	0.00118898	0.47	0.8306
specie*altitu*season	24	0.02604449	0.00108519	0.43	0.9905

Dependent Variable: Ca Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.57910359	0.14477590	44.60	<.0001
altitude	2	0.07058505	0.03529252	10.87	<.0001
season	3	0.03557615	0.01185872	3.65	0.0147
species*altitude	8	0.02828870	0.00353609	1.09	0.3756
species*season	12	0.04479694	0.00373308	1.15	0.3277
altitude*season	6	0.05546593	0.00924432	2.85	0.0127
specie*altitu*season	24	0.05421197	0.00225883	0.70	0.8468

Dependent Variable: Mg Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.08673875	0.02168469	48.95	<.0001
altitude	2	0.00510724	0.00255362	5.76	0.0042
season	3	0.01273595	0.00424532	9.58	<.0001
species*altitude	8	0.00835071	0.00104384	2.36	0.0225
species*season	12	0.00880760	0.00073397	1.66	0.0869
altitude*season	6	0.00359817	0.00059969	1.35	0.2401
specie*altitu*season	24	0.00999051	0.00041627	0.94	0.5497

Dependent Variable: Mg Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.05762997	0.01440749	43.24	<.0001
altitude	2	0.01139968	0.00569984	17.11	<.0001
season	3	0.01864505	0.00621502	18.65	<.0001
species*altitude	8	0.00232873	0.00029109	0.87	0.5410
species*season	12	0.01118404	0.00093200	2.80	0.0022
altitude*season	6	0.00482233	0.00080372	2.41	0.0312
specie*altitu*season	24	0.00521232	0.00021718	0.65	0.8869

Dependent Variable: K Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.75436199	0.18859050	5.80	0.0003
altitude	2	0.58211843	0.29105921	8.96	0.0003
season	3	2.32194871	0.77398290	23.82	<.0001
species*altitude	8	0.16274282	0.02034285	0.63	0.7543
species*season	12	1.05122974	0.08760248	2.70	0.0033
altitude*season	6	0.13069920	0.02178320	0.67	0.6737
specie*altitu*season	24	0.29438834	0.01226618	0.38	0.9961

Dependent Variable: K Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.30112486	0.07528121	2.64	0.0376
altitude	2	2.77552079	1.38776039	48.60	<.0001
season	3	6.66478763	2.22159588	77.80	<.0001
species*altitude	8	0.12607264	0.01575908	0.55	0.8150
species*season	12	2.16860445	0.18071704	6.33	<.0001

altitude*season	6	0.70513626	0.11752271	4.12	0.0009
specie*altitu*season	24	0.86090571	0.03587107	1.26	0.2112

Dependent Variable: Pho Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.03288183	0.00822046	10.01	<.0001
altitude	2	0.04504688	0.02252344	27.42	<.0001
season	3	0.01581035	0.00527012	6.42	0.0005
species*altitude	8	0.00639230	0.00079904	0.97	0.4612
species*season	12	0.01152126	0.00096010	1.17	0.3147
altitude*season	6	0.00156425	0.00026071	0.32	0.9267
specie*altitu*season	24	0.01054542	0.00043939	0.53	0.9602

Dependent Variable: Pho Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	0.08974368	0.02243592	23.23	<.0001
altitude	2	0.00981680	0.00490840	5.08	0.0077
season	3	0.09413773	0.03137924	32.50	<.0001
species*altitude	8	0.02568959	0.00321120	3.33	0.0019
species*season	12	0.02357410	0.00196451	2.03	0.0271
altitude*season	6	0.01686195	0.00281032	2.91	0.0112
specie*altitu*season	24	0.02916398	0.00121517	1.26	0.2095

Dependent Variable: Fe Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	21960735.74	5490183.93	11.86	<.0001
altitude	2	931067.58	465533.79	1.01	0.3692
season	3	957952.88	319317.63	0.69	0.5601
species*altitude	8	4369013.33	546126.67	1.18	0.3179
species*season	12	2668745.38	222395.45	0.48	0.9223
altitude*season	6	1046825.29	174470.88	0.38	0.8923
specie*altitu*season	24	2478097.55	103254.06	0.22	1.0000

Dependent Variable: Fe Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	6574177.662	1643544.416	13.94	<.0001
altitude	2	6316305.697	3158152.848	26.79	<.0001
season	3	5024555.227	1674851.742	14.21	<.0001
species*altitude	8	2077942.470	259742.809	2.20	0.0320
species*season	12	2136645.465	178053.789	1.51	0.1301
altitude*season	6	1787787.601	297964.600	2.53	0.0246
specie*altitu*season	24	1591758.333	66323.264	0.56	0.9476

Dependent Variable: Cu Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	178.9853404	44.7463351	22.30	<.0001
altitude	2	1.4335866	0.7167933	0.36	0.7004
season	3	4.5967842	1.5322614	0.76	0.5168
species*altitude	8	14.6587881	1.8323485	0.91	0.5085
species*season	12	22.6118382	1.8843198	0.94	0.5112
altitude*season	6	10.1783409	1.6963901	0.85	0.5376
specie*altitu*season	24	16.5487719	0.6895322	0.34	0.9981

Dependent Variable: Cu Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	51.51231981	12.87807995	16.80	<.0001
altitude	2	4.74075227	2.37037614	3.09	0.0492
season	3	26.43047758	8.81015919	11.50	<.0001
species*altitude	8	12.87530975	1.60941372	2.10	0.0412
species*season	12	14.33068230	1.19422353	1.56	0.1138

altitude*season	6	15.33125069	2.55520845	3.33	0.0046
specie*altitu*season	24	19.59996708	0.81666529	1.07	0.3935

Dependent Variable: Zn Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	9448.319405	2362.079851	33.39	<.0001
altitude	2	572.976357	286.488179	4.05	0.0202
season	3	4022.153654	1340.717885	18.95	<.0001
species*altitude	8	460.163965	57.520496	0.81	0.5925
species*season	12	1515.126884	126.260574	1.78	0.0597
altitude*season	6	686.441202	114.406867	1.62	0.1493
specie*altitu*season	24	1251.729841	52.155410	0.74	0.8027

Dependent Variable: Zn Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	6728.121960	1682.030490	30.32	<.0001
altitude	2	110.508866	55.254433	1.00	0.3725
season	3	6367.696551	2122.565517	38.27	<.0001
species*altitude	8	610.521123	76.315140	1.38	0.2144
species*season	12	1803.321595	150.276800	2.71	0.0030
altitude*season	6	399.136849	66.522808	1.20	0.3117
specie*altitu*season	24	762.896247	31.787344	0.57	0.9420

Dependent Variable: Mn Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	983870.2046	245967.5511	79.10	<.0001
altitude	2	108242.7266	54121.3633	17.41	<.0001
season	3	26855.1693	8951.7231	2.88	0.0394
species*altitude	8	65155.1540	8144.3942	2.62	0.0117
species*season	12	165900.4414	13825.0368	4.45	<.0001
altitude*season	6	9235.2227	1539.2038	0.50	0.8109
specie*altitu*season	24	46435.9046	1934.8294	0.62	0.9093

Dependent Variable: Mn Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	91478.19187	22869.54797	15.01	<.0001
altitude	2	45651.79522	22825.89761	14.98	<.0001
season	3	4076.35838	1358.78613	0.89	0.4479
species*altitude	8	47040.14045	5880.01756	3.86	0.0005
species*season	12	12704.14264	1058.67855	0.69	0.7538
altitude*season	6	19691.36224	3281.89371	2.15	0.0526
specie*altitu*season	24	37129.14409	1547.04767	1.02	0.4536

Dependent Variable: CPs Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	162.2312517	40.5578129	29.45	<.0001
altitude	2	15.2500468	7.6250234	5.54	0.0052
season	3	60.0810033	20.0270011	14.54	<.0001
species*altitude	8	12.9151236	1.6143904	1.17	0.3226
species*season	12	15.3355161	1.2779597	0.93	0.5222
altitude*season	6	5.9890021	0.9981670	0.72	0.6306
specie*altitu*season	24	23.9914917	0.9996455	0.73	0.8151

Dependent Variable: CP Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	175.6835990	43.9208998	42.57	<.0001
altitude	2	13.5418031	6.7709015	6.56	0.0020
season	3	153.9665723	51.3221908	49.75	<.0001
species*altitude	8	6.5115529	0.8139441	0.79	0.6134
species*season	12	43.4327401	3.6193950	3.51	0.0002
altitude*season	6	9.4630958	1.5771826	1.53	0.1749
specie*altitu*season	24	35.7266591	1.4886108	1.44	0.1030

Dependent Variable: NDF Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	2853.381896	713.345474	63.49	<.0001
altitude	2	57.218987	28.609493	2.55	0.0830
season	3	700.789567	233.596522	20.79	<.0001
species*altitude	8	75.879977	9.484997	0.84	0.5660
species*season	12	258.672805	21.556067	1.92	0.0396
altitude*season	6	32.166359	5.361060	0.48	0.8241
specie*altitu*season	24	155.026492	6.459437	0.57	0.9404

Dependent Variable: NDF Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	2284.785539	571.196385	65.73	<.0001
altitude	2	10.158369	5.079184	0.58	0.5590
season	3	1083.769043	361.256348	41.57	<.0001
species*altitude	8	22.420028	2.802503	0.32	0.9560
species*season	12	213.487652	17.790638	2.05	0.0260
altitude*season	6	22.085665	3.680944	0.42	0.8620
specie*altitu*season	24	143.015441	5.958977	0.69	0.8566

Dependent Variable: ADF Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	662.626243	165.656561	25.03	<.0001
altitude	2	80.119829	40.059914	6.05	0.0032
season	3	1314.260689	438.086896	66.18	<.0001
species*altitude	8	37.877946	4.734743	0.72	0.6776
species*season	12	405.663671	33.805306	5.11	<.0001
altitude*season	6	37.496705	6.249451	0.94	0.4667
specie*altitu*season	24	116.059073	4.835795	0.73	0.810

Dependent Variable: ADF Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	523.3050857	130.8262714	20.55	<.0001
altitude	2	24.4190923	12.2095462	1.92	0.1516
season	3	973.9794711	324.6598237	50.99	<.0001
species*altitude	8	71.4484375	8.9310547	1.40	0.2027
species*season	12	218.1394573	18.1782881	2.86	0.0018
altitude*season	6	44.6039543	7.4339924	1.17	0.3285
specie*altitu*season	24	137.6152170	5.7339674	0.90	0.6006

Dependent Variable: DMD Highveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	17345.2078	4336.3020	1.98	0.1106
altitude	2	1751.7461	875.8730	0.40	0.6719
season	1	314880.2785	314880.2785	144.06	<.0001
species*altitude	8	17738.8937	2217.3617	1.01	0.4369
species*season	4	19300.9318	4825.2329	2.21	0.0809
altitude*season	2	1353.2172	676.6086	0.31	0.7351
specie*altitu*season	7	11081.5070	1583.0724	0.72	0.6520

Dependent Variable: DMD Lowveld

Source	DF	Type III SS	Mean Square	F Value	Pr > F
species	4	43076.0013	10769.0003	2.45	0.0554
altitude	2	24956.7151	12478.3575	2.84	0.0661
season	1	148111.8447	148111.8447	33.74	<.0001
species*altitude	8	22386.8241	2798.3530	0.64	0.7430
species*season	4	16805.2908	4201.3227	0.96	0.4376
altitude*season	2	19479.2633	9739.6317	2.22	0.1176
specie*altitu*season	8	48443.2892	6055.4111	1.38	0.2239