DIET SELECTION OF CATTLE IN THE PIETERSBURG PLATEAU BUSHVELD OF THE LIMPOPO PROVINCE, SOUTH AFRICA

BY

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DECLARATION

I declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Pasture Science has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

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NTSOANE, T (Mr) Date

DEDICATION

I dedicate this work to my parents Mokgohloe Ntsoane and Moroasereme Ntsoane, my late fiancé Lefa Takalo, and my grandparents Ramoroaswi Mowa and Kuduku Mphahlele

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ABTRACT

An experiment was conducted at the University of Limpopo to determine the diet selection of cattle in the Petersburg Plateau Bushveld, the aim being to identify important and palatable grass species during four seasons of the year and to determine their above-ground biomass production. For diet selection data, five permanently marked transects were randomly laid out per camp, each 100 m long. On each transect, grass tufts were identified and permanently marked at 1 m intervals (100 tufts per transect). Turfs were surveyed on a weekly basis to determine frequency, intensity of utilization and tuft height. A palatability index was determined for each species. Diet selection data were analysed, using descriptive statistics.

For biomass production, five permanent 20 m x 20 m plots were randomly laid out per camp, in which biomass of grass were measured. Within each plot, five 1 x 1 m quadrates were randomly harvested. The biomass data was analysed using the General Linear Mixed Model. Means were compared, using a Tukey test at the 5% significance level.

Digitaria eriantha, Eragrostis rigidior and *Heteropogon contortus* were the dominant grass species. On average, *Brachiaria nigropedata, Panicum maximum* and *Digitaria eriantha* were utilized at higher frequencies and intensities. *Brachiaria nigropedata, P. maximum*, *Urochloa mosambicensis*, *Themeda triandra, D. eriantha, Schmidtia pappophoroides* and *H. contortus* were regarded as the most palatable species. The circumference of the tuft of *S. pappophoroides*, *E. rigidior* and *D. eriantha* decreased highly significantly ($P<0.01$). The height of utilizable leaves of *B. nigropedata, D. eriantha, P. maximum* and *S. pappophoroides* decreased highly significantly, while the height of highest leaves of *B. nigropedata, D. eriantha, P. maximum, S. pappophoroides*, *H. contortus* and *T. triandra* also decreased highly significantly. Total biomass production was significantly higher ($P<0.05$) during autumn, while total biomass production during winter was low, compared to other seasons. Total biomass production did not differ significantly between spring and summer. *Panicum maximum,*

B. nigropedata, *D. eriantha, T. triandra*, *H. contortus, S. pappophoroides* and *U. mosambicensis* were regarded as “key species” in the diet selected by cattle.

Farmers in the Pietersburg Plateau Bushveld should graze their camps to assure the maintenance or improvement of perennial palatable grasses with high biomass production, which will result in overall improvement of veld condition.

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LIST OF ABBREVIATIONS

Autumn camp = The camp grazed during autumn

FAOSTAT = Food and Agriculture Organization Statistics

Pi = palatability index

SAWS = South African Weather Service

SEF = Syferkuil Experimental Farm

Spring camp = The camp grazed during spring

Summer camp = The camp grazed during summer

Winter camp = The camp grazed during winter

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Research background

Cattle (*Bos taurus*) are domesticated bovine farm animals that are raised for their milk and meat (Hoon, 2010), and are reared under a wide range of climatic conditions (Mkhize *et al.,* 2014). FAOSTAT (2013) estimated global cattle numbers at 1.47 billion. As of 2003, Africa had about 231 million head of cattle, raised in both traditional and non-traditional systems. South Africa had approximately 14 million cattle owned by commercial and small-scale farmers (Hoon, 2010).

The culture of cattle farming in bushveld (savanna) areas of Limpopo Province has become increasingly concerning due to overgrazing (Macaskill, 2016). This phenomenon has a negative impact on forage availability (Roath and Krueger, 1982). Quantity and quality of forage increases as the rainfall season progresses (Mphinyane *et al.*, 2015) and decreases towards the end of growing season (Rooyen and Botha, 2016). Moreover, bushveld areas are characterized by variable and unpredictable rainfall, which largely determines the condition of the rangeland (veld), and forage availability (O'Connor, 1992).

The availability of forage is the main determining factor of diet selection of cattle in terms of quantity and quality (Mphinyane *et al.,* 2015). Diet selection can be defined as "the removal of some forage components or plant parts by cattle" (Mkhize, 2008; Newman *et al.,* 1995). Factors affecting diet selection of cattle in the semi-arid rangelands are diverse and complex. These factors include overgrazing, soil related factors, climate change and incorrect fire strategies (Magandana, 2016).

Overgrazing, as one of the factors that affect diet selection, has a direct negative influence on aboveground biomass production of the grass component (Magandana, 2016). The aboveground biomass production is an important ecosystem property that is affected by environmental variability (Byrne *et al.,* 2011). A thorough understanding is necessary to attribute its value in an ecosystem (Palmer *et al.,* 2016). The necessity to predict annual biomass production is an essential part of agricultural planning and models of livestock carrying capacity (Running et al. 2004; Palmer *et al.,* 2016).

1.2 Problem statement

In many arid and semi-arid areas, the availability of quality diet for herbivores is largely seasonal (Woodward and Coppock, 1995). The variable rainfall in such environments determines the availability of biomass (Ndlovu *et al.,* 2000). Forage resources decline in diversity, abundance and quality during dry seasons and droughts, thereby limiting diet choice. Hence, during the dry season and during droughts, cattle may expand their diet to include less palatable species (Owen-Smith, 1994). Quantity and quality of the grass layer are some of the most important factors in maximizing the production of cattle. Understanding grass species, their utilization and available biomass are critical to cattle farmers in terms of the number of livestock that their land can carry. This creates a challenge, especially when cattle farmers need to introduce supplementation for optimum production (Tainton, 1999).

1.3 Motivation for the study

Several authors (Kruger and Edwards, 1972; Gammon and Roberts 1976a; Gammon and Roberts 1976b, Gammon and Roberts 1976c, Daines, 1980; Jordaan, 1991; Jordaan *et al.,* 1996) have documented the diet selection of cattle in veld types with bushveld region in the 1970's, 1880's and 1990's. However, in the Pietersburg Plateau Bushveld, little work has been done in the past regarding the diet selection of cattle. This means that applied knowledge of grass species utilization by cattle is currently based on the results obtained from other areas or on subjective observations that are not scientifically confirmed (Jordaan *et al.,* 1996). To determine the impact of cattle grazing on veld, it is not only sufficient to know what plants are being grazed, but also when and how much specific grass species are being utilized. This study investigated the frequency and the intensity of utilization of grasses by cattle during four different seasons in the Pietersburg Plateau Bushveld, to determine which grasses are utilized during each season, the frequency and intensity at which they were utilized, and their above-ground biomass production.

1.4 Purpose of the study

1.4.1 Aims

The study had two aims, namely:

- To investigate the diet selection preference of cattle in the Pietersburg Plateau Bushveld.
- To investigative the availability of grass biomass for cattle in the Pietersburg Plateau Bushveld.

1.4.2 Objectives

The objectives of the study were as follows:

- To determine the frequency, intensity and palatability of different grass species utilized by cattle in the Pietersburg Plateau Bushveld.
- To determine the aboveground biomass production of grasses that occurs in the Pietersburg Plateau Bushveld.

1.5 The layout of the dissertation

The purpose of the study was to determine the utilization and the biomass availability of grass species in the Pietersburg Plateau Bushveld. Research background, the problem statement, motivation for the study, purpose (aim and objectives) and layout of the dissertation is given in Chapter 1.

In Chapter 2, the literature review is presented, which contains a review of the established literature relating to utilization studies, as well as the biomass production of grass species.

Chapter 3 presents a detailed discussion of the characterization of the study area, including vegetation description, soil forms and long-term average meteorological data of the area, as well as the study's methodology.

Chapter 4 contains results and discussion of the findings from the study in narrative format.

The conclusions and recommendations from the study as they were determined in accordance with the overall findings are presented in Chapter 5.

CHAPTER 2
LITERATURE REVIEW

2.1 Diet selection of cattle

2.1.1 Why do cattle select?

Diet selection is defined as the removal by cattle of plant parts rather than others (Newman *et al.,* 1995; Mkhize, 2008). This process determines both the quantity and the quality of food intake and hence the nutritional status of individual cattle, their time and activity budgets, their physiological condition, growth rates, and potential reproductive and survival rates (Hanley, 1997). In simpler terms, diet selection determines which plants are taken, where, when, and to what degree (Mkhize, 2008).

The diet selected by cattle is influenced by season and environment (e.g. soil, rainfall etc.) and consequently availability of aboveground biomass (Balph and Provenza, 1990). Through selective grazing ruminants can consume diets of a higher nutritive value than that on offer (Baumont *et al.,* 2000). There are variations in the magnitude of such selection because of differences in local climate, soil fertility, plant species and animal management factors (Balph and Provenza, 1990; Abate, 1998). Other factors that determine magnitude of selection include the species, age and quality of the herbage, species of animal and the stocking rates and, therefore, grazing pressure imposed upon the grazed plant communities (Abate, 1998).

Several authors around the world published theories that relate to reasons why animals select:

Euphagia

Animals possess nutritional wisdom or euphagia; they have the natural ability to sense, through taste and smell, the specific nutrients and toxins in plants (Tainton, 1999). Through such nutritional “wisdom”, animals select nutritious foods and avoid those containing harmful plant metabolites (Balph and Provenza, 1990).

Natural selection favour feeding behavior that minimizes the ingestion of compounds that interfere with digestive or metabolic processes, in such cases, the plant tissue provides a signal, presumed to be secondary metabolites, which herbivores recognize and avoid (Balph and Provenza, 1990)

Hedyphagia

Animals obtain a nutritious diet by selecting nutritious vegetation (Tainton, 1999). Plant compounds, which are nutritious, ultimately taste good and those that are toxic ultimately taste bad, all through natural selection (Rhoades, 1979).

Ruminants generally prefer plant parts that are young, green, and leavey, attributes generally associated with more nutritious vegetation, to those that are old, dead, and stemy (Balph and Provenza, 1990). Plants with spines and stinging hairs are avoided, as they are difficult to ingest (Gurevitch *et al.,*2002). In addition, many ruminants readily accept sweet and reject bitter taste which suggest that sweet and bitter may be stimuli signifying nutrients and toxins respectively. Although animals generally accept sweet and reject bitter taste, a number of exceptions are known to occur (Balph and Provenza, 1990).

Dietary learning

Animals may also learn to discriminate between nutritious and toxic foods by process called dietary learning (Tainton, 1999). A young animal first learns about which foods to eat and which to avoid by foraging with its mother (Galef and Laland, 2005). By the time the animal forage on its own, it is already familiar with several plants that are nutritious and safe to eat (Balph and Provenza, 1990).

Dietary selection

Dietary selection is based on allometric relations between both body size, and morphology and physiology (Balph and Provenza, 1990). Large animals because they require more food than small animals, have less time available, per nutrient required, for feeding selectively. Their metabolic requirements per unit of body mass are lower than in small animals, they can subsist on lower quality food items than small animals (Tainton, 1999).

2.2 Patterns of selection

Daines (1976, 1980) showed that cattle select the grasses on offer in a set sequence. The harvesting procedure is a continuous process during which a series of profile patterns appear in the grass sward due to the selection of plant material by the grazing animal. Four distinct patterns were identified during harvesting (Figure 2.1). These patterns are;

1. A creaming phase, where less than 50% leaf material are removed.
2. A notable area or species utilization pattern (50% of leaf material removed and 50% of leaf material remain).
3. An accentuated phase between grazed and ungrazed tufts, where all leaf material is removed.
4. Total utilization.

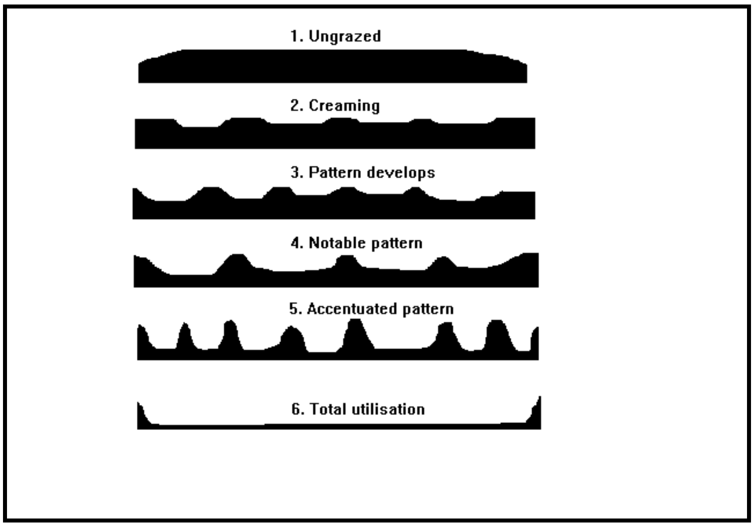

Figure 2.1: Different stages of veld utilization (Daines, 1980).

Tufts are defoliated as follows (Daines, 1980):

1. A first bite, which removes 50% of the leaves.
2. A second bite, which removes more than 50% of the leaves.
3. A third bite, which removes all other material.

The pattern of diet selection by ruminants is influenced by many factors, which includes; nutritional status of the animal, avoidance of toxic plants, secondary compounds, experience and learning, and physical and logistical constraints on daily intake (Murden and Risenhoover, 1993). Other factors such as animal species, and its basic anatomic and physiological adaptations, relative palatability of the plant species and available biomass, and physiological condition of the animal also play a role (Owen-Smith, 2013). The decision to consume certain grass species is determined by its value relative to other available grass species.

The patterns of grazing with respect to species, plant structure and size, and the position in the landscape are quantitative, where response of one variable depends on the level of other variables (O'Connor, 1992; Hooper, 2005). Patterns of selection vary with changes in the moribundness of tuft, population size structure, steminess resulting from grazing variability, spatial location, and compositional differences. Season is the main factor affecting herbage biomass availability and quality and consequently, diet selection of cattle. Diet selection is possibly, in part, a consequence of selection for plant structure that optimizes intake (O'Connor, 1992).

2.3 Intensity of utilization by cattle

The intensity of utilization is defined as the effects that grazing animals have on rangeland during the period of occupation (Holechek *et al.*, 1998a). It is often suggested that heavy utilization in periods when plants are dormant has little effect on their vigour. However, Holechek *et al.* (1998b) indicated that to maintain plant productivity, grazing intensity must be kept at moderate levels even in periods of plant dormancy.

Heavy utilization depletes plant residues, soil erosion increases, water infiltration decreases, and water overland flow increases (Holechek *et al.* 1998b). However, the adverse impacts of moderate grazing relative to light or no grazing have been small and unimportant. A heavily utilized plant would have a low residual amount of leaf thus a low photosynthetic activity (Booysen, 1966). Initial regrowth is thus dependent of stored reserves. The amount of stored reserves influences the rate of regrowth after utilization.

Cattle have a choice between different grass species, each in a different stage of development (Daines, 1980). Certain grass species are selectively utilized. As the grazing period progresses, the cattle are forced to utilize more tufts selectively (Gammon and Roberts 1976a, Gammon and Roberts 1976b, Gammon and Roberts 1976c). Heavy utilization of palatable species occurs. Thereafter cattle utilize less palatable, and later least palatable species (Gammon and Roberts 1976a; 1976b; 1976c). If grazing period is too long, unpalatable species are also grazed (Daines, 1980). Palatable species are repeatedly utilized in between. Certain species are utilized intensively, while others are not utilized (Daines, 1980).

2.4 Frequency of utilization by cattle

To reduce the impact of grazing, the critical growth periods for each key plant species should be determined. Frequency depend on the condition of the rangeland. If it is badly degraded, rest may be needed to kick start recovery. In general, depending on rangeland condition and the types of grass species present, rest periods of at least 30 to 60 days during active growing season will be needed to prevent overgrazing. When managing for pasture and range health, it is generally accepted that pastures should be grazed for short periods (three weeks or less) with adequate rest periods in between (Booysen, 1966).

Initial regrowth followed by lenient and frequent defoliation is more rapid than the initial regrowth followed by severe defoliation. More rapid regrowth follow after lenient defoliation, because more leaves will remain, which will keep on with its photosynthetic activities. The reserves are normally low in frequent severely grazed plants; thus slow regrowth (Booysen, 1966).

Fourie *et al.* (1985) did frequency studies in relation to stocking rates in *Tarchonanthus* veld of the Northern Cape and found that throughout the season the frequency of utilization of *Chrysopogon serrulatus* was exceptionally high, while *T. triandra* and *D. eriantha* were intermediate, followed by *Cymbopogon pospischilli* which was still well grazed. *Eragrostis lehmanniana* was poorly grazed. The utilization of species was influenced by stocking rate. At 10 ha LSU^{-1} the average frequency of utilization of the above species was 83%, 42%, 43%, 34%, 12%, 9% and 8% respectively, and at 4 ha LSU^{-1} the frequency of utilization of the species was 96%, 74%, 69%, 72%, 57%, 35%, and 31% respectively. The frequency of utilization increased in direct proportion to the stocking rate. Utilization also increased during periods of drought and during winter, regardless of stocking rate (Fourie *et al.,* 1985).

2.5 Palatability of grass species

In the Sourish Mixed Bushveld, Jordaan *et al.* (1996) indicated that during summer and winter, the frequencies of defoliation of different grass species differ. *Panicum maximum*, *B. nigropedata* and *S. pappophoroides* are utilized at the fastest rate during summer, while *B. nigropedata* and *Enneapogon scoparius* were frequently utilized during winter (Jordaan *et al*., 1996).

During summer, *P. maximum* and *B. nigropedata* are utilized at the highest degree. In the case of *B. nigropedata*, the species' growth form and low production led to a single bite being required to remove most of available material, while *P. maximum* was utilized by means of lighter defoliations at high frequencies. With regard to *T. triandra* and *H. contortus* , some tufts were utilized at a higher degree, while others were not utilised at all (Jordaan *et al*., 1996). This clearly illustrate the effect of occurrence of ecotypes, which differs in palatability. The general preference for *T. triandra* by cattle vary between geographic locations and is partly associated with the composition of the plant community (O'Connor, 1992).

Schmidtia pappophoroides was utilized repeatedly through relatively light defoliations that were followed by relatively long periods during which no defoliation occurred. *Digitaria eriantha* and *Eragrostis rigidior* were utilized at a lower degree than any dominant species (Jordaan *et al*., 1996). *Heteropogon contortus* and *D. eriantha* are considered palatable species in Gazankulu region (O'Connor, 1992) The only two dominant species that showed tendencies in the degree of utilization during winter in the Sourish Mixed Bushveld were *B. nigropedata*, which was highly utilized, and *E. rigidior*, which was poorly utilized (Jordaan *et al*., 1996). *Hyparrhenia hirta* is not high in palatability, but was well utilized when available (Roos *et al.*, 1973).

Factors that influence palatability include presence of lignin, phenolic, or tannin like compounds, energy requirements, nitrogen and/or crude protein and other nutrients present. Lignin in grasses increases as plants mature and reaches a peak after flowering. Ecotype differences will also influence the prevalence of lignin in grasses (Snyman *et al*., 2013).

2.6 Effect of season on diet selection

Season is the main factor affecting herbage biomass availability and quality (Mphinyane *et al.*, 2015). Grass quality decrease from wet to dry season with greater declines in grasses than browse. Similarly, quality also decreases, and dry season grasses are deficient in most nutrients that are needed to meet cattle's maintenance requirements (Mphinyane *et al.*, 2015).

The chemical composition of veld grasses undergoes seasonal changes that may affect the nutrition of grazing animals. Tainton (1999) pointed out that the nutritive value of grass influenced the preference of cattle to certain grass species. High fibre content and the presence of chemical substances like volatile oils may limit the acceptability of certain grass species to grazing cattle. In some grass species this acceptability may change with plant age as some species may be acceptable when young or after drying, while being avoided at other times (Trollope *et al*., 1990). In a diet selection study conducted with cattle, it was found that the time spent grazing grasses and forbs were closely correlated with their relative abundance. It was also observed that preferences changed through the seasons. The stage of growth of the plant and temperature influenced preferences. It was also noted that heavy utilization of grasses obtained an expression of preference by the cattle (Tainton, 1999).

Little can be done to change the seasonal decline in nutritional quality of grass. However, some commonly used approaches in cattle management systems include the supplementation of the deficient nutrients. Rangeland fertilization may also be practical and profitable considering the economic value of livestock. Bulk feeders, such as cattle, are more affected by poor diet quality during dry seasons, compared to selective feeders, such as goats, that predominantly utilize high-quality plant material throughout the year (Morris and Tainton, 1993).

Holechek *et al.* (1998) suggested that heavy utilization in periods when plants are dormant (during winter) has little effect on their vigour. However, studies have shown that to maintain plant productivity, grazing intensity must be kept at moderate levels, even in periods of plant dormancy (Holechek *et al*., 1998).

Some of the most comprehensive studies on the benefits of controlled timing of grazing in semi-arid and arid areas (Martin and Cable, 1974), found that perennial grass cover was higher on yearlong than seasonally grazed pastures. Perennial grass production was closely associated with degree of utilization and was highest where grazing intensity use was lowest. Winter-spring grazing with summer rest was inferior to yearlong grazing from the standpoint of productivity and density of desirable perennial grasses. Heady and Child (1994) reviewed the long-term (20-

year) results of various grazing management practices applied on rangeland management. All seasonally grazed pastures started with moderate grazing and had increased forage production over period of 20 years (Holechek *et al*., 1998). There was no evidence that rotational grazing had any advantages over season long grazing in terms of improving range condition or forage production. Holechek *et al.* (1998) indicated that stocking rate reductions have more potential to improve rangeland species composition than rotation grazing systems.

2.7 Factors that influence diet selection

2.7.1 Morphological characteristics of plants

Cattle consume an array of plants, but often prefer some and avoid others. These preferences are responses to certain physical and chemical senses of which touch, smell and taste are of greatest importance to cattle (Balph and Provenza, 1990). Diet selection is seldom a response to a single factor, but rather a combined response to several stimuli (Danckwerts and Stuart-Hill, 1987).

Sense of touch plays a role in the response of the cattle to the feed. The sense of touch is used in selective grazing to avoid thorny and sticky plants. Physical characteristics of the grass such as dry matter content, particle size and resistance to fracture or height and density of the sward are known to affect ease of prehension, and thus intake rate (Balph and Provenza, 1990).

2.7.2 Availability of forage

Forage quantity can be a problem, even when there appears to be plenty of standing grass (Lyons, 2009). Cattle have very definite food preferences. They instinctively look for green plant material (Lyons, 2009). Their first preference is new green leaves (Lyons and Machen, 2000). When new green leaves are not available, they will move to older green leaves, then to green stems, dry leaves and, last, to dry stems. When green plant material is scarce, cattle will spend more time looking for it and forage intake is likely to decrease as a result (Lyons, 2009).

Where there is an abundance of feed, the cattle can express their preferences freely (Heady, 1964). As the feed supply decreases, cattle must eat less acceptable plant material or starve. In effect, cattle appear to compromise so that whilst eating previously neglected species, a high proportion of its total grazing time will still be spent on favoured species of low accessibility (Zengeya *et al*., 2004).

Cattle farming depend on the natural vegetation as the main source of feed throughout the year (Mapiye *et al*., 2008). Therefore, fluctuations in both forage quantity and quality pose major challenges to cattle production. These variations in forage quantity and quality, in turn, can lead to over grazing of rangelands owing to lack of appropriate grazing management and over utilization of natural vegetation (Masafu, 2006; Fuhlendorf and Engle, 2001). Consequently, this amounts to a further reduction of both forage yield and quality (Mapiye *et al*., 2008).

Plant species also vary in palatability or attractiveness to cattle (Lyons and Machen, 2000; Lyons, 2009). Grazing animals are selective in what they eat. This implies that cattle do not find enough of what they would like to eat to meet nutritional requirements (Lyons and Machen, 2000). As much as 80% of the diet during a season may come from only 1% of the total forage available on rangeland (Lyons, 2009).

The availability of forage can be problematic during early spring green-up when forage quality is high but green plant material is scarce (Hulme, 2005). Not so obvious are problems associated with grazing distribution. Cattle cannot or do not graze in areas where there is no water, too much brush, or the land is rough and steep (Lyons, 2009).

Standing crop estimates are very useful for vegetation and watershed management. However, closely observing cattle and knowing what species they prefer will be more useful in distinguishing between forage quality and quantity problems (Hulme, 2005). For example, if green forage is available but cattle are losing condition, forage quantity is the most likely problem. If cattle spend an unusual amount of time comsuming browse (rather than the grass they prefer), forage quantity is probably limited (Lyons, 2009).

A lack of forage quantity might be alleviated by providing larger grazing areas, by reducing stocking density, by weaning young calves to reduce the nutrient requirements of the mothers, or a combination of these approaches (Hulme, 2005). Managing calving seasons to match forage production seasons can help reduce both forage quality and quantity problems (Tainton, 1999). Flexible stocking rates also are important when forage is scarce (Lyons, 2009).

2.7.3 Forage quality

Forage quality is defined as the capacity of forage to provide the required nutrients to livestock (Amary, 2016). Forage quality is a direct reflection of essential nutrient content and availability to the grazing cattle, and includes the nutritive value and forage intake (Newman *et al.,* 2009). Knowledge about the quality of forage in rangelands is important to determine the grazing capacity in the rangeland (Amary, 2016). It is significant because it is linked to growth performance of cattle (Amary, 2016). Furthermore, the quality of forage changes at local scales between different soil types, at larger scales from one region to another, and at temporal scales from season to season based on the type of vegetation cover (Godari *et al.,* 2013). Thus, understanding the spatial and temporal changes in forage quality in the rangeland is essential for cattle farmers (Amary, 2016).

To maximise diet quality, cattle need to feed on plants to gain nutrients and energy for maintenance, growth and reproduction requirements when foraging (Amary, 2016). According to Provenza and Launchbaugh (1999), herbivores distinguish between both toxins and nutrients in fodder, which can influence selection behaviour and their choice of which plants to utilize. Cattle generally consume forage that is higher in nutrients and lower in toxins, and tend to feed selectively among plant species, plant parts and foraging locations (Provenza and Launchbaugh, 1999). Therefore, variation in feed quality and quantity in rangelands lead to variation in performance of cattle (Amary, 2016).

The selection of forage by cattle is based on the plants' palatability (Amary, 2016). Palatability can be described as the hedonic response of an animal to its food in terms of flavour, texture and tasting (Provenza and Launchbaugh, 1999; Amary, 2016). Plant palatability can also be described as plants' attributes that change acceptability to animals, including chemical composition, growth stage and associated plants (Provenza and Launchbaugh, 1999). Mentis (1981) relates palatability to those factors of the feed itself that determine the in absolute attractiveness to the animal. Thus, palatability is much more than a matter of taste; it is the interrelationship between a flavour of forage (smell, taste and texture), and its nutrient and toxin content (Burritt and Provenza, 2011).

Most research on forage plants has found that animals tend to select a mixed diet of forage plant (Trollope *et al.*, 1990; Jordaan *et al*., 1996; Tainton, 1999; Rooyen and Botha, 2016). However, according to Samuels *et al.* (2007), the availability of the amount of palatable plant species in a grazing area does not indicate that the area is rich in forage quality for livestock to graze, as a high number of toxic plants can be present at the time in the same area.

The nutrient value of grass depends on its nutrient content and on the extent to which the grass is eaten by the animal (Minson and McLeod, 1970), which is characterized by chemical composition and digestibility. These factors are strongly affected by plant specie's age at utilization and soil fertility (Amary, 2016). Grasses are the most common sources of energy for ruminants, for they contain a high percentage of cellulose, lignin and hemicellulose. Forage contains a variety of chemical constituents, which serve as nutrients (Amary, 2016). Some nutrients are sources of energy while others satisfy specific requirements of the animal body (Tainton, 1999). It is fact that the chemical composition of veld grasses undergoes seasonal changes that may affect their nutritional value to cattle (Tainton, 1999). The chemical composition of veld grasses is determined by environmental factors such climate, soil type and growth stage. The chemical composition of veld grasses will consequently vary within species, as determined by a multitude of external factors. Despite this, grass species can be classified according to observed tendencies as good, intermediate or poor in chemical composition (Robison and Jordaan, 2000).

2.7.4 Animal characteristics

Animals select their diets based on forage availability and quality in addition to their body size, type of digestive system and anatomical characteristics of the animal itself, amongst other (Owen – Smith, 1999). These factors influence the performance of grazing animal in terms of weight gain, reproduction and other production parameters (Grunow, 1980).

Cattle primarily consume grasses (Grunow, 1980). The size of the mouth of cattle limits their ability to select individual parts (leaves, twigs) of plants (Owen-Smith 1979). The large rumen of cattle is well suited to consuming large quantities of low quality, fibrous forage like dormant grasses. They obtain the nutrients they need by consuming a large quantity of low-quality forage (Frost and Mosley, 2016).

Cattle age can also profoundly affect diet selection and tolerance to secondary compounds (Grunow, 1980). Metabolic requirements decline with age, so older cattle need less food and spend less time foraging (National Research Council, 2001). Compared with adults, young, growing animals need diets higher in protein and energy and lower in fibre (Frost and Mosley, 2016).

Animals choose their diets based on nutritional needs, which change during their various life stages. The greatest nutrient demands are for lactating females who need more energy and protein to support milk production (Frost and Mosley, 2016).

"Individuality" is a powerful force that influences dietary preference. Even animals of the same age, sex, breed, and experience will vary in their diet selection plant preferences. Some prefer plants high in energy, while others select those with medium or low energy concentrations. Animals have unique dental structure, physical abilities, organ size and function, and sensory abilities. Individual differences affect foraging abilities and how an animal metabolizes nutrients (Frost and Mosley, 2016).

2.7.5 Watering points

Water is a major determinant of livestock distribution (Van Rooyen *et al.,* 1994). Localised areas of animal concentration occurs around watering points (Owen-Smith, 2013). Many authors (Lange, 1969; Zumer, 1976; Perkins, 1991; Van Rooyen *et al.,* 1994; Thrash, 1998; Mphinyane, 2001) have reported changes in rangeland condition around water points. Lange (1969) used the term 'piosphere' to describe the pattern of change in grazing effects with increased/decreased distances from the water.

Vegetation of a potentially flat area is most effectively utilized when all grazing occurs within 1500 m of a watering point (Mphinyane, 2001). The implication of this is that a single watering point should serve a maximum area of 900 ha. However, other factors such as the size of the veld type and topography may reduce this area considerably. The amount of water needed per livestock unit is approximately 40 l per day (Mphinyane, 2001). The amount of water required depends on the physiological stage of the animal and the climate. Lactating animals require more water, and the amount of water-required increases as atmospheric temperature increases (Mphinyane, 2001).

2.7.6 Environmental conditions

Wind, rain and temperature influence the direction in which animal's travel when feeding. These environmental factors cause localised concentrations of animals, with corresponding localised defoliation, trampling and deposition of dung and urine (Owen-Smith, 2013). Cattle are mainly diurnal feeders, with concentrations in feeding activity during the twilight (crepuscular) times (Phillips, 2002). When intake requirements are high or when the day length is short, nocturnal feeding will take place. Feeding speed is reduced at night, probably because the cattle do not have necessary visual cues for fast herbage selection (Phillips, 2002). Wind and rain increase the feeling of cold in grazing cattle, forcing them to seek shelter in extreme conditions. According to Phillips (2002), rainfall has no effect on grass on grass utilization

2.8 Utilization height

The Society for Range Management definition of utilization is "the proportion of the current year's biomass production which is removed by grazing animals" (Glossary Revision Special Committee, 1989). Utilization is expressed as a percentage of the height of forage grasses, which has been removed by grazing cattle (Frost *et al.,* 1994; Holechek *et al.*, 1998). Utilization can also be expressed as the height of plant material remaining on forage plants after grazing (Frost *et al.,* 1994).

According to Heady (1994), the height measurement method is based on the premise that percentage utilization of grass is equal to the reduction in average leaf height because of grazing. Enclosures are necessary if grazing occurs for any considerable length of time during the period of rapid growth of the grasses. When grazing is completed, the difference in average leaf heights of the grazed and ungrazed areas is considered as the removed portion, and is used to calculate percentage utilization (Holechek *et al.*, 1998).

If the grasses are mature or growth is negligible, differences in leaf height before and after grazing, or of grazed and ungrazed plants may be used for the calculation of percentage utilization. Due regard must be given the different degrees of use of different species and the percentage composition of various species in the stand. Collecting the data may involve the use of either plots or transects (Holechek *et al.*, 1998).

Two variations of the height measurement method based on stubble height follow: Holechek *et al.* (1998) measured stubble heights and diameters along a 100 m line transect and then arranged the data according to species and stubble height classes. The measurements along the line were converted to percentages so that the final summary sheet shows the part of the stand contributed by each species, the proportion of each species in each stubble height class, and weighted mean-use by stubble height classes (Holechek *et al.*, 1998).

2.9 Aboveground biomass production

Biomass refers to the amount of aboveground dry matter herbaceous material that is available for animal consumption and is expressed in (kg ha^{-1}) (Abule *et al.,* 2007; Magandana, 2016). The amount of forage that will be available for animal consumption is measured using the biomass of the forage and this helps in determining the carrying capacity of the veld and its condition (Abule *et al.,* 2007). The quality and the biomass production of the rangeland may describe the forage yield (Peden, 2005). Factors such as nutrients, moisture percentage, fibre content, and chemical substances found, all these vary between species (Lesoli, 2008).

The available soil moisture and nutrients influence the biomass production of the rangeland (Noellemeyer *et al.,* 2006). Biomass production is higher in soils with high organic content and they are soils that are silt and clay dominated while the sand dominated soils have low organic matter (Magandana, 2016). The continuous removal of the leaves of the grass leads to the loss of vigour through the draining of the nutrient reserves (Malan and Van Niekerk, 2005).

2.10 The effect of defoliation on aboveground biomass production

The greatest stress factor affecting productivity of biomass in the arid ecosystems, however, is the grazing impact of large domestic animals which may consume up to 75 % of the total primary productivity (Tuffa *et al.,* 2017). Overgrazing by livestock is exceptionally severe in arid ecosystems because of the suite of environmental stress factors that limit vegetative and reproductive growth. Moreover, during prolonged droughts, livestock are forced to feed on plants that have not fully recovered from prior grazing, which often leads to irreversible damage (Tuffa *et al.,* 2017). Over-utilization of the arid ecosystem vegetation by livestock leads towards the creation of desert-like conditions.

Moderate defoliation significantly reduce above-ground biomass in mature tufts in contrast to young grasses (Tuffa *et al.,* 2017). Aboveground biomass significantly decline by up to 75% under high intensity and frequent defoliation in mature tufts. Defoliation, further, significantly enhance grass nutrients in grass tufts by up to 82 and 105% in *Cenchrus ciliaris* and *Chloris gayana*, respectively (Tuffa *et al.,* 2017). Hence, management should focus on balancing this trade-off in mature grasses for nutritious rangeland production by cutting and storing grass for later supplemental feeding when nutrients drop. Further, young pastures should be moderately defoliated/grazed for better establishment and biomass allocation (Tuffa *et al.,* 2017). The effects of defoliation on biomass production have been variously debated. Many findings indicate that herbage dry matter yield decreases with increasing intensity of defoliation (Gao *et al.,* 2008). Tainton (1981) observed that rotational, i.e., moderate grazing reduced aboveground biomass and increased belowground biomass, whereas Gao *et al.* (2008) observed a decrease of belowground biomass with increasing grazing intensity.

2.11 Effect of season on aboveground biomass production

The aboveground biomass production is affected by both biotic (herbivores and farmers cultural practices) and abiotic factors (environmental and climatic factors) (Monyedi *et al.,* 2017). Unreliable rainfall in semi-arid areas threatens grazing lands from recovering after grazing and lead to lower productivity (Tainton, 1981). In the grasslands of South Africa, mean annual rainfall is 600–1200 mm (Schulze and Lynch, 2007) and occurs predominantly in the spring and summer (October to March), when precipitation generally takes the form of thunderstorms and growth is most vigorous. Maintaining productivity of rangelands requires extensive knowledge on how vegetation responds to the dominant environmental factors such as grazing and climate variability. Rangelands across the world are facing increasing pressure due to overgrazing and climate change (Tuffa *et al*., 2017).

According to Magandana (2016), dry matter production is affected by season. Summer has higher biomass production in Eastern Cape, although overall dry matter production for both seasons was low. The higher biomass production in summer can be attributed to higher rainfall and temperatures. It is speculated that higher rainfall in summer contributes to the increased leaf production and leaf area of the grasses thereby promoting production per plant. The aboveground production of grasses is dependent on rain, increased rainfall enhances biomass allocation of grasses (Tuffa *et al*., 2017). Lower rainfall during spring, summer and autumn reduce the aboveground biomass production by 24% and 42% in *Cenchrus ciliaris* and in *Chloris gayana* respectively (Tuffa *et al*., 2017). The overall biomass production in the semi-arid savannas of Eastern Cape was low in both seasons (Magandana, 2016). Summer showed higher biomass production than winter (Magandana, 2016). Increasing frequencies of droughts and high herbivore pressure significantly affect individual aboveground biomass in semiarid regions (Tuffa *et al*., 2017).

2.12 Soil related factors that affect aboveground biomass production

Nutrients such as macro-minerals and micro-minerals are very important to the plant nutrition and can also act as the determining factors of vegetation productivity, structure and composition (Magandana, 2016; Smit, 2004). Grasses require the nitrogen for fast growth (Kraaij and Ward, 2006). It is predicted that the high levels of nitrogen in the soil enhances the growth of herbaceous plants which, will then suppress the establishment and the growth of tree seedlings of leguminous trees (Moshe *et al.,* 2000).

A high number of grasses in an area promote high fixation of soil particles, which has a good impact on the soil fertility and water holding capacity (Magandana, 2016). The higher nitrogen in the soil has promoted the higher biomass production on moderate and severe encroached sites. *Vachellia* and *Senegalia* are leguminous plants, therefore it increases the supply rate of nitrogen to the grasses that grow near it (Magandana, 2016).

According to Magandana (2016), the grass biomass production was high in highly encroached areas than open areas. *Acacias* has a positive effect on the occurrence of *T. triandra* due to the increased soil nitrogen content. The high grass biomass production under *Vachellia karroo* trees can be attributed the favourable influence of the micro-environment, which might have led to increases in moisture content and soil fertility (Smit, 2004).

CHAPTER 3
METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Experimental site

The experiment was conducted at the Syferkuil Experimental Farm (SEF) (23° 50' S; 29° 40' E) of the University of Limpopo, Polokwane, in the Limpopo Province, South Africa (Figure 3.1). The Syferkuil Experimental Farm (SEF) is situated 9 km north-west of the main campus. The SEF is 1 600 ha in size, accommodating 1300 ha grazing and 300 ha croplands.

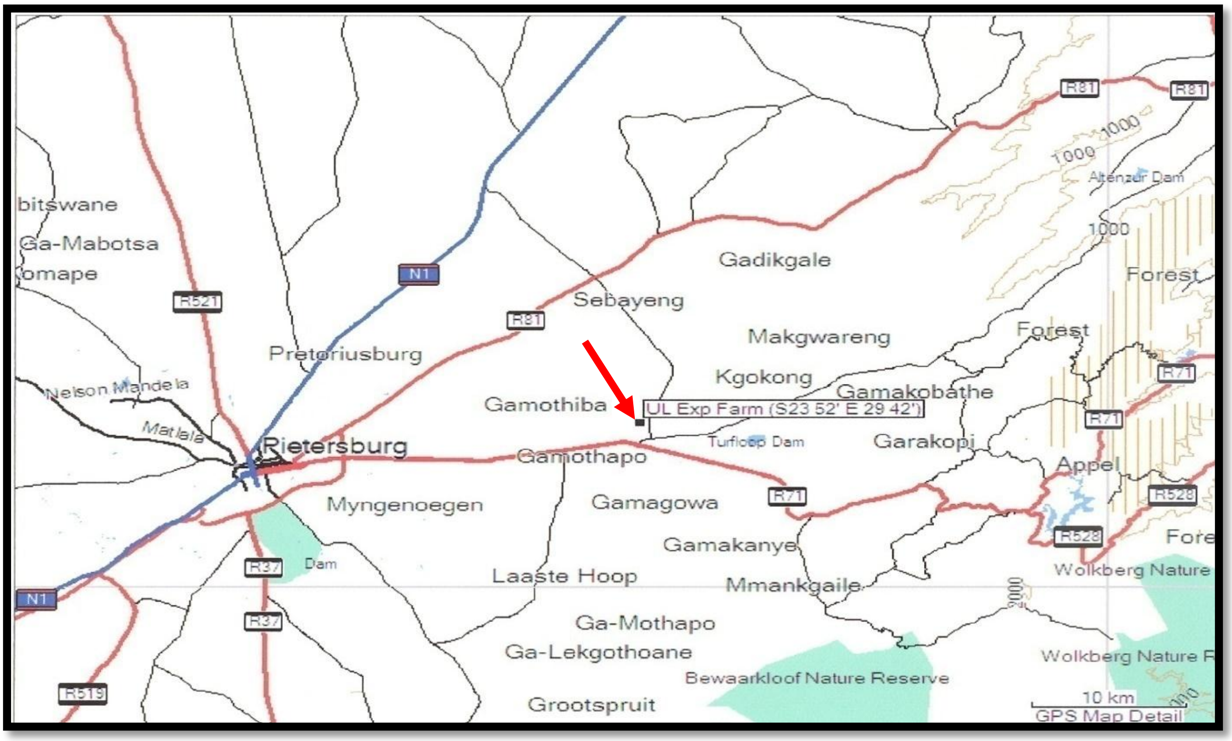

Figure 3.1: A map showing the location of the Syferkuil Experimental Farm.

3.1.1 Climate

The climate of the area is classified as semi-arid. The SEF is characterised by cool, dry winters and hot, arid summers. The mean annual rainfall varies between 400 mm and 600 mm (with a mean of 468.5 mm) (Table 3.1, Figure 3.2). Rainfall is erratic, with most rain occurring in the form of late afternoon thunderstorms. Summer minimum temperatures are relatively high (27.6°C - 27.5°C) and winter minimum temperatures can be cold (2.4°C - 2.5°C °C), with a mean summer temperature of 24.8º.C and a mean winter temperature of 10.2 ºC. Incidences of frost occur (on average 8 days per year). Mean annual potential evaporation is 2015 mm (SA Weather Service, 2006).

Table 3.1 The Long-Term Average (LTA) Meteorological data for the Syferkuil Experimental Farm (SA Weather Service, 2006).

Month	Evap	FD	Rain	RHn	RHx	Suns	Tmin	Tmax	Wind
Jan	201.4	0.00	72.6	36.8	89.0	7.8	16.1	27.6	139.0
Feb	188.2	0.00	66.0	35.1	88.9	7.8	15.8	27.5	138.8
Mar	170.1	0.00	58.6	35.6	90.2	7.4	14.4	26.8	114.7
Apr	137.4	0.80	30.8	31.2	90.1	7.8	10.5	25.0	104.7
May	124.9	5.70	11.3	25.8	88.7	8.5	5.7	22.9	90.8
Jun	112.6	8.80	7.5	24.3	85.1	8.5	2.5	20.7	98.5
Jul	116.8	3.50	7.5	25.3	85.3	8.6	2.4	20.3	105.9
Aug	156.0	0.10	4.1	25.3	81.9	8.9	4.6	22.4	126.7
Sep	191.1	0.00	8.6	27.8	78.5	8.8	9.0	25.4	155.5
Oct	223.2	0.00	41.7	32.3	80.4	8.3	12.4	26.2	181.0
Nov	195.0	0.00	88.4	36.0	83.0	7.6	14.2	26.4	163.1
Dec	199.2	0.00	71.2	36.7	85.8	7.4	15.5	27.1	141.0
Total	2015.	-	468.4	-	-	-	-	-	-
Mean	-	-	-	31.0	85.5	8.1	10.2	24.8	132.4

KEY NOTES

Average first frost: 10 June

Average last frost: 22 August

Average frost season: 74 days

Average frost day's year^{-1}: 20

Percentage years with frost: 100

Rain: Rainfall mm month^{-1}

FD days: Frost Days

Utot km day^{-1}: Wind run

Evap mm: A-Pan Evaporation

RHx %: Maximum Daily Relative Humidity

RHn %: Minimum Daily Relative Humidity

Suns hours: Sunshine hours

Tmax ^{o}C: Daily Maximum Temperature

Tmin ^{o}C: Daily Minimum Temperature

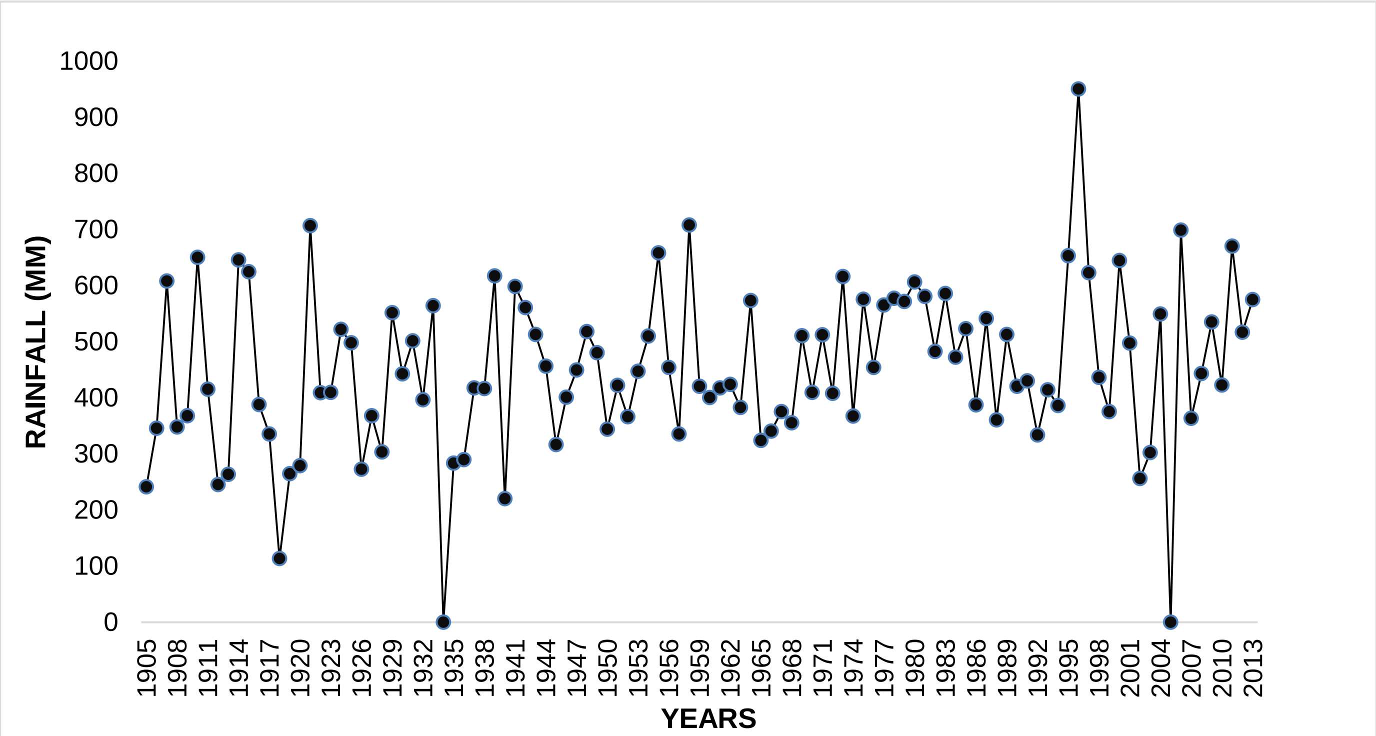

Figure 3.2: The long-term annual rainfall of the Syferkuil Experimental Farm (1905 – 2013).

3.1.2 Vegetation

The study area is situated in the Savanna Biome. According to Low and Rebelo (1996), the SEF falls broadly within the Sourish Mixed Bushveld, situated on the margin of the Polokwane Plateau Bushveld, previously known as Pietersburg Plateau Bushveld (Acocks, 1988). The SEF is composed of elements of two overlapping vegetation types. These include the Polokwane Plateau Bushveld (flatter areas) and the Mamabolo Mountain Bushveld (mountainous areas). The Polokwane Plateau Bushveld varies from a dense, short bushveld to an open tree savanna with a well-developed grass layer (Mucina and Rutherford, 2006). They distinguished the Mamabolo Mountain Bushveld as a subsection of the Polokwane Plateau Bushveld. The Mamabolo Mountain Bushveld consists of a combination of dense shrubby thickets and small trees of both *Vachellia* and *Senegalia* (*Acacia*) and broad-leaved species (Potgieter, 2018). Rock slabs or domes are sparsely vegetated, mostly with a mixture of xerophytes and several succulents (Low and Rebelo, 1996). The area where the study was conducted was confined to the Polokwane Plateau Bushveld areas at the SEF. The dominant grasses are typical bushveld grasses, such as *Aristida* species, *P. maximum* and *T. triandra*, while the woody component is dominated by *Vachellia* species, such as *Vachellia rehmanniana*, *Vachellia habeclada* and *Dichrostachys cinerea* (Acocks, 1988).

3.1.3 Soils

The SEF varies in geology, which includes basement granite and gneiss, clastic sediments of the Pretoria Group (Vaalian) and ultramafic and mafic metavolcanics of the Pietersburg Group (Swazian). Shallow and skeletal soils (including Mispah and Glenrosa soil forms) occur (Soil Classification Working Group 1991). Land types are mainly Ib and Fa (Low and Rebelo, 1996). According to Dlomu (1966), great diurnal variations of temperature have favoured the weathering of granite into large boulders associated with fine sandy materials. The grey ferruginous lateritic soils are shallow and spread over the old granitic rock. Colluvial soils are found around granitic outcrops, while alluvial soils are found in river valleys. These include soils of the Hutton form. Due to the size of the study area, it included various soil forms, namely Hutton, Glenrosa, Clovelly, Rocky, and Etosha (Soil Classification Working Group, 1991).

3.2 Experimental procedures

The study was conducted from March 2017 to February 2018. The experiment was conducted in four camps, each 36 ha in size. Each camp was stocked at a carrying capacity of nine ha LSU^{-1} $year^{-1}$, as recommended by the National Department of Agriculture (2008). Two-year-old Nguni steers was used in this study. To determine diet selection of different plant species during each season of the years [spring (September to November), summer (December to February), autumn (March to May) and winter (June to August)], animals rotated between four camps on a (three-monthly basis), representing grazing of a different camp during each respective season.

At the mentioned stocking at rate, the animals continuously remained in a relevant camp for a full three months' period. However, to ensure adequate grazing for the whole period of stay, the camp where animals were present was inspected on a weekly basis. It was not necessary to remove cattle from camps due to grazing shortages during the study. The cattle were not supplemented with commercially available phosphorus, molasses and dry veld concentrates or salts, but they relied solely on the naturally available forage.

3.3 Data collection

3.3.1 Diet selection of cattle

Five permanently marked transects were randomly laid out per camp, each 100 m long. On each transect, grass tufts were identified and permanently marked at 1 m intervals (100 tufts per transect). Turfs were surveyed on a weekly basis via datasheet.

3.3.1.1 Species composition

At the beginning of study, grass species composition data was collected in the four grazing camps. Five 100 m long transects were randomly laid in each camp. Grass species were recorded at 1 m interval along each transect.

3.3.1.2 Frequency of utilization

The tuft height of all the grass species (leaf height, excluding flowering stems) in each transect were measured using a tape measure. The actual tuft height (the height of the leaves occurring in the tuft itself, or utilizable leaves) was also measured. To estimate the frequency of utilization, all grass species from each transect were measured on the weekly basis for any change in the tuft heights during the grazing period.

The frequency of utilization was determined by counting the number of changes in actual tuft height (utilizable leaves) between surveys. The frequency of utilization was thus used to determine how many times each grass species defoliated during each grazing period.

The height of the highest leaf was used to determine if flowering stems influenced utilization [for example, in the case of *Hyperthelia dissoluta* and *Hyparrhenia* species, where utilization is severely influenced by hard flowering stems during mid- and late summer (Jordaan 2017)], and if flowering stems and inflorescences were utilized (Refer to 4.2.3.3., Page 55, Height of the highest leaves).

3.3.1.3 Intensity of utilization

To determine the intensity or the degree of utilization, grass species were subjectively allocated into utilization classes according to a method similar to that of Kruger and Edwards (1972). The following utilization classes were used:

- Class A: Ungrazed, 0% utilization (Average, 0%)
- Class B: Between 1% and 25% utilization (Average, 12.5%)
- Class C: Between 25% and 50% utilization (Average, 37.5%)
- Class D: Between 50% and 75% utilization (Average, 62.5%)
- Class E: More than 75% utilization (Average, 87.5%)

As an example, for clarification, utilization between 1 and 25% were regarded as 12.5% utilization, which was then recorded as utilization Class B. These classes represented changes in the intensity of utilization on a weekly basis. At the end of each grazing period, cumulative utilization was determined by adding the class averages to represent the total utilization of each grass species. However, during the active growing season, the determination of cumulative utilization had to be adapted to incorporate regrowth. This is illustrated, using the following scenarios:

1. Defoliation with regrowth - During Week 1, the tuft was defoliated to Class B. During week 2, regrowth occurred, and the tuft was recorded as being in Class A. During Week 3, the tuft was again defoliated, but to Class D. The cumulative utilization would thus be 12.5% (1st defoliation) + 12.5% (regrowth back to 0%) + 62.5% (2nd defoliation) = 90.5% [not 62.5% (which is either 12.5 + 50% (A to B to D) or 62.5% in total (A to D)]
2. Continuous defoliation - During Week 1, the tuft was recorded as defoliated to Class B, during Week 2 to Class C and during Week 3 to Class D. Cumulative defoliation would thus be 12.5% + 25% (the difference between Class B and C) + 25% (the difference between Class C and D) = 62.5%

3.3.1.4 Palatability of different grass species

The importance of a plant species in the diet of the cattle does not necessarily reflect the palatability thereof (Jordaan and Le Roux, 2015). Important grass species are those that have a high composition/occurrence and high frequency of utilization. They thus make up large proportions of animal's intake, irrespective of preference (Mentis, 1981). Palatability relates to traits of grass itself, which determine its attractiveness to the animal (Mentis, 1981). Important grass species are determined by circumstance (Meissner *et al.*, 2013). As an example, Species A might occur 100 times but might be defoliated 20 times, compared to Species B that occurs once but is defoliated 10 times. Based on the high occurrence and frequency of defoliation (20/100 = 0.5), Species A is then considered the more important in the diet, because it was more frequently utilized, but less palatable. Based on its lower occurrence together with a slightly lower frequency of defoliation (10/1 = 10) Species B would be more palatable but less important, because it was less frequently utilized (Kruger and Edwards, 1972; Jordaan and Le Roux, 2015).

Important grass species was thus denoted by the number of times that a species was utilized. To determine the palatability of different grass species, a palatability index was determined for each species, using the following formula (Jordaan, 1991; Jordaan and Le Roux, 2015; Seloana *et al.,* 2018):

$$\frac{\text{Number of times utilized}}{\text{Number of times present}} \times 100$$

The index was used to divide different grasses into five different palatability groups (A, B C, D and E), namely; highly palatable, palatable, less palatable, least palatable and avoided species, respectively. Categorising of species palatability groups was done as follows, on a subjective basis:

1. Palatability indices were determined.
2. The median was determined to obtain two groups: namely above and below the median. Indices thus represented a palatable (Group AB) and an unpalatable group (Group CD). The medians of the two groups were then separately determined and each again divided into groups, resulting in four groups: a highly palatable (Group A), palatable (Group B), less palatable

(Group C) and a least palatable group (Group D). A fifth (Group E) contained all species that were not utilized.

3.3.1.5 Tuft traits

On every tuft, along each 100 m transect, the following traits were measured using a tape measure; the circumference of the tuft, height of utilizable leaf and height of highest leaf. The tuft traits data was collected on weekly basis to monitor changes that occurs over each grazing period.

3.3.2 Aboveground biomass production

Five permanent (20 m x 20 m) plots were randomly laid out per camp, in which biomass of grass species and forbs were measured. Within each plot, five (1 x 1 m) quadrates were randomly placed (the aboveground biomass was thus determined monthly over a three months period, for each camp). Grass species or forbs occurring within each quadrate were identified and harvested, on a species basis, at a height of 3 cm above ground. Samples were oven dried for 48 hours at 60^0C and weighed immediately after drying to obtain the dry weight.

3.4 Data analyses

Being surveys, selection data were subjected to descriptive statistics analysis, using XLstat software (2017).. Tuft traits and biomass production data were analysed, using the statistical program GenStat® (VSN Int., 2015). Data were subjected to Analyses of Variance, Where biomass production data were concerned, a Gamma, distribution was indicated for positively-skewed data and with heterogeneous variances (Payne, 2015). Generalized Linear Mixed Model (GLMM) Analysis was thus applied to the biomass production data with the Gamma distribution and logarithmic link function, to test for differences between species. Means were compared, using the Tukey test at the 5% significance level (Snedecor and Cochran, 1980).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Grass species utilization

4.1.1.1 Species composition

Twenty-three grass species were identified in all the camps (Table 4.1). All the grass species were either weak perennial or perennial grass species, except *Eragrostis viscosa* and *Urochloa mosambicensis*, which are annuals, and *Cynodon dactylon,* which is a perennial creeper. Overall, *Digitaria eriantha*, *Heteropogon contortus, E. rigidior*, *Schmidtia pappophoroides, Panicum maximum* and *Brachiaria nigropedata* were dominant (Table 4.1). All four grazing camps were dominated by Increaser II grass species, which indicates that all four camps they were subjected to high stocking rates in the past (Van Oudtshoorn, 2012).

Cynodon dactylon and *Panicum natalense* occurred in the winter and summer camps. *Eragrostis gummiflua*, *E. racemosa*, *E. viscosa* and *Sporobolus festivus* were found in the summer camp only. *Hyparrhenia hirta* occurred exclusively in the spring, while *Trichoneura grandiglumis* occurred in all camps, except the summer camp. *Urochloa mosambicensis* was absent in spring camp. *Microchloa caffra* and *P. natalense* occurred in the summer grazing camp; the former also occurred in the spring camp and the latter in the winter camp. Fourteen species occurred in the autumn camp. All species were perennials, except *U. mosambicensis. Digitaria eriantha* (40.40%), *E. rigidior* (15.00%), *H. contortus* (10.80%) and *S. pappophoroides* (10.80%) were dominant in the autumn camp. Eighteen species occurred in the winter camp. All species, except *U. mosambicensis*, were perennial grasses. *Digitaria eriantha* (26.20%), *T. triandra* (11.00%), *S. pappophoroides* (9.00%), *E. rigidior* (8.80%) and *H. contortus* (8.4%) were dominant in the winter camp. Fifteen species occurred in the spring camp; All were perennials. *Digitaria eriantha* (47.00%), *H. contortus* (10.20%), *E. rigidior* (8.60%), *P. maximum* (6.60%) and *B. nigropedata* (4.80%) were dominant grass species in spring camp.

Twenty one species were identified in the summer camp. All species were perennial except two, namely *E. viscosa* and *U. mosambicensis. Digitaria eriantha* (22.40%), *E. rigidior* (21.40%), *T. triandra* (14.40%), *H. contortus* (6.60%), *S. pappophoroides* (6.40%) and *E. gummiflua* (4.40%) were dominant.

Table 4.1 Percentage grass species composition of different camps.

Grass species	Autumn camp	Winter camp	Spring camp	Summer camp	All camps
Aristida spp	2.80	6.20	2.40	3.20	3.70
Brachiaria nigropedata	4.80	5.80	4.80	2.00	4.40
Cynodon dactylon	0.00	1.80	0.00	2.40	1.10
Digitaria eriantha	40.40	26.20	47.00	22.40	34.00
Elionurus muticus	0.00	4.40	0.00	2.00	1.60
Eragrostis gummiflua	0.00	0.00	0.00	4.40	1.10
Eragrostis lehmanniana	1.20	0.40	0.80	1.40	1.00
Eragrostis racemosa	0.00	0.00	0.00	0.20	0.10
Eragrostis rigidior	15.00	8.80	8.60	21.40	13.50
Eragrostis superba	1.40	3.40	1.20	1.80	2.00
Eragrostis viscosa	0.00	0.00	0.00	0.40	0.10
Heteropogon contortus	10.80	8.40	10.20	6.60	9.00
Hyparrhenia hirta	0.00	0.00	3.40	0.00	0.90
Melinis repens	3.20	2.40	3.40	1.40	2.60
Microchloa caffra	0.00	0.00	2.60	0.80	0.90
Panicum maximum	5.80	4.80	6.60	4.00	5.30
Panicum natalense	0.00	0.20	0.00	0.60	0.20
Pogonarthria squarrosa	0.60	0.80	1.20	2.80	1.40
Schmidtia pappophoroides	10.80	9.00	4.20	6.40	7.60
Sporobolus festivus	0.00	0.00	0.00	0.60	0.20
Themeda triandra	1.80	11.00	3.40	14.40	7.70
Trichoneura grandiglumis	0.60	0.60	0.20	0.00	0.40
Urochloa mosambicensis	0.80	1.00	0.00	0.80	0.70

4.1.1.2 Frequency of utilization

Overall, according to Figure 4.1, *B. nigropedata* (19.96%) was utilized at the highest frequency, followed by *P. maximum* (18%), *U. mosambicensis* (18.19%), *D. eriantha* (16.35%), *T. triandra* (13.62%), *S. pappophoroides* (13.39%) and *H. contortus* (13.34%). The average frequency of utilization of *E. rigidior* (6.09%) and *Melenis repens* (4.86%) were lower, while *E. lehmanniana* (3.60%), *E. superba* (2.43%), *T. grandiglumis* (2.41%) and *Aristida* spp (0.31%) also had low frequencies of utilization. *Pogonarthria squarrosa* (0%) was not utilized.

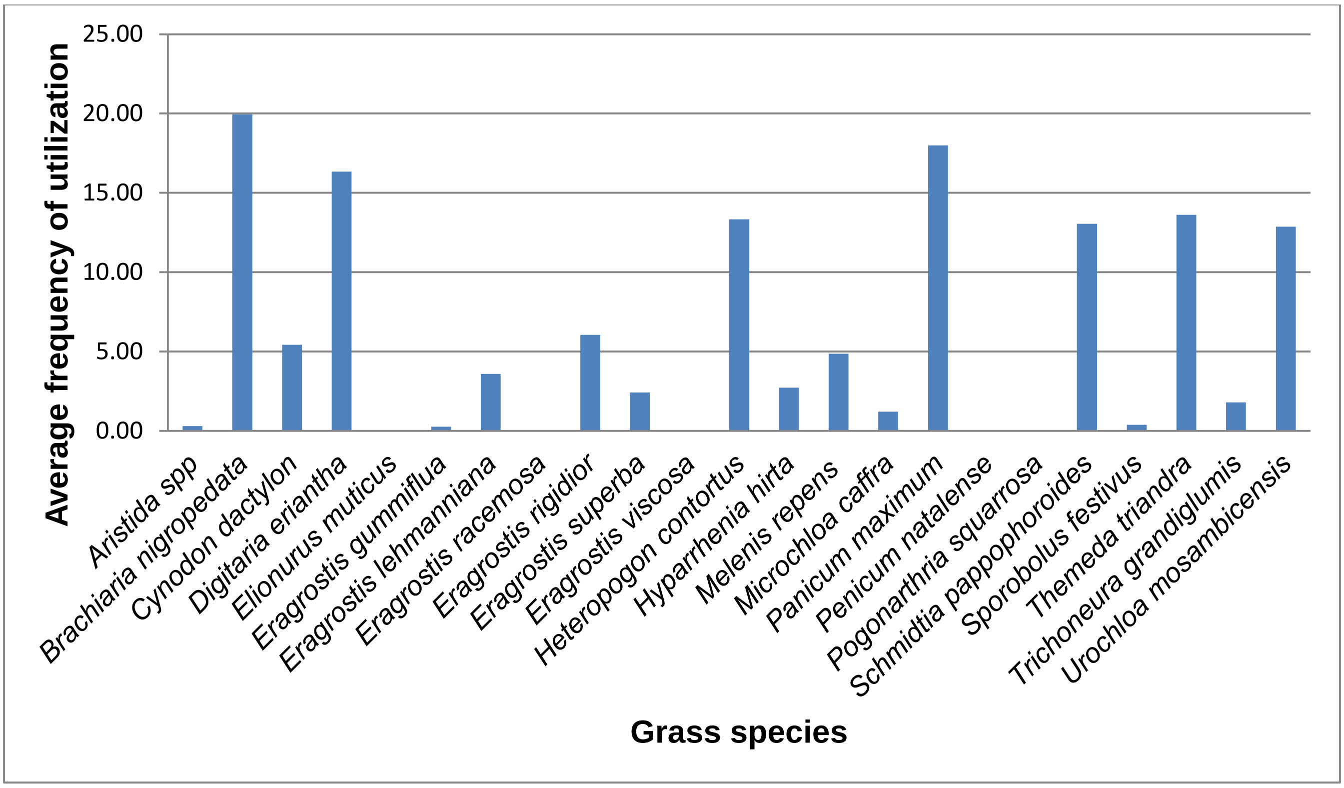

Figure 4.1 Average frequency of utilization of different grasses over all four seasons.

Table 4.2 indicates that, in autumn, *B. nigropedata* was utilized at the highest frequency, followed by *U. mosambicensis, D. eriantha, P. maximum* and *S. pappophoroides.* Similarly, during winter, the highest frequency of utilization involved the same grass species in the same order, namely *B. nigropedata, U. mosambicensis, D. eriantha*, *P. maximum* and *S. pappophoroides.*

During spring, *B. nigropedata, D. eriantha* and *P. maximum* were utilized at high frequencies, while *B. nigropedata, D. eriantha*, *P. maximum, U. mosambicensis* and *H. contortus* were utilized at the highest frequencies during summer. Other grasses that were utilized at high frequencies during the growing season were *H. contortus* and *S. pappophoroides.*

Panicum maximum had the second highest frequency of utilization after *B. nigropedata*. The frequency of utilization of *P. maximum* was low at the beginning of each season when cattle entered a new camp. However, it increased as the period of stay in the camp progressed. This trend was observed throughout the year.

Table 4.2 Frequency of utilization of different grass species over the study period.

Grass species	MAR	Autumn APR	MAY	JUN	Winter JUL	AUG	SEP	Spring OCT	NOV	DEC	Summer JAN	FEB
Aristida spp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08	1.67	0.00	0.00	0.00
Brachiaria nigropedata	21.67	29.17	25.83	12.93	16.38	13.10	12.50	21.88	18.33	20.45	20.00	27.27
Cynodon dactylon	0.00	0.00	0.00	2.78	5.56	8.89	0.00	0.00	0.00	12.50	16.67	18.75
Digitaria eriantha	18.53	21.69	21.18	6.11	12.02	12.67	8.72	19.36	20.60	13.84	18.04	23.43
Elionurus muticus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis gummiflua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	0.91	1.14
Eragrostis lehmanniana	6.67	4.17	0.00	0.00	0.00	0.00	6.25	12.50	10.00	0.00	0.00	3.57
Eragrostis racemosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis rigidior	8.65	5.67	4.59	0.57	3.98	5.45	2.91	9.30	11.63	5.84	5.42	8.64
Eragrostis superba	5.71	7.14	5.71	2.94	2.94	4.70	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis viscosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heteropogon contortus	15.92	18.06	15.56	9.52	14.28	12.86	5.88	13.73	14.9	10.94	11.25	17.19
Hyparrhenia hirta	0.00	0.00	0.00	0.00	0.00	0.00	8.82	13.24	10.59	0.00	0.00	0.00
Melenis repens	8.00	6.67	10.67	2.08	4.17	5.00	2.94	11.76	7.06	0.00	0.00	0.00
Microchloa caffra	0.00	0.00	0.00	0.00	0.00	0.00	1.92	3.85	1.54	0.00	0.00	0.00
Panicum maximum	20.00	25.86	19.31	6.25	17.71	20.00	1.52	24.24	32.12	6.25	19.00	23.75
Panicum natalense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pogonarthria squarrosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Schmidtia pappophoroides	16.29	18.98	18.52	6.11	12.78	15.11	3.57	14.29	18.09	7.03	9.38	16.41
Sporobolus festivus	0.00	0.00	0.00	1.04	2.08	1.67	0.00	0.00	0.00	0.00	0.00	0.00
Themeda triandra	17.78	16.67	15.56	8.64	13.64	12.00	7.35	13.24	15.29	11.11	11.39	20.83
Trichoneura grandiglumis	6.67	8.33	6.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urochloa mosambicensis	20.00	18.75	20.00	10.00	15.00	12.00	0.00	0.00	0.00	18.75	15.00	25.00

4.1.1.3 Intensity of utilization

Brachiaria nigropedata, D. eriantha, H. contortus, S. pappophoroides, T. triandra and *P. maximum* were utilized at the highest intensity throughout the year. *Brachiaria nigropedata* was utilized at the highest intensity at the beginning of summer than any other grass species, but the intensity of utilization dropped in the middle of summer (January) and increased again towards the end of summer (February). During winter, *B. nigropedata* and *P. maximum* were utilized at the highest intensities, followed by *T. triandra* and *H. contortus.*

The intensity of utilization of *P. maximum* increased constantly from 20% at the beginning of summer to 80% at the end of summer. At the beginning of each season, the intensity of utilization of *P. maximum* was low, but increased as the period of stay progressed. The lowest intensity occurred at the beginning of spring in September and the highest at the end of summer in February. *Digitaria eriantha* had the third highest intensity of utilization after *B. nigropedata* and *P. maximum*. The highest intensity of utilization for *D. eriantha* occurred at the end of summer. At the beginning of summer, *D. eriantha* (48%) was the second highest utilized grass species after *B. nigropedata.* Its lowest intensity of utilization occurred during winter. *Heteropogon contortus* (21%) was utilised at the beginning of autumn. Its utilization remained below 40% from autumn until late spring in November, while its highest intensity of utilization (56%) was in late summer.

At the beginning of autumn, *T. triandra'*s (31%) intensity of utilization was relatively low, but it increased, as the period of stay increased, to 49%. During winter, it declined to 22.50%. The highest intensity of utilization occurred in spring (64%) and summer (63%). *Schmidtia pappophoroides* was utilized throughout at intensities below 50%, the highest being 48% at the end of spring, and the lowest 8% at the beginning of spring.

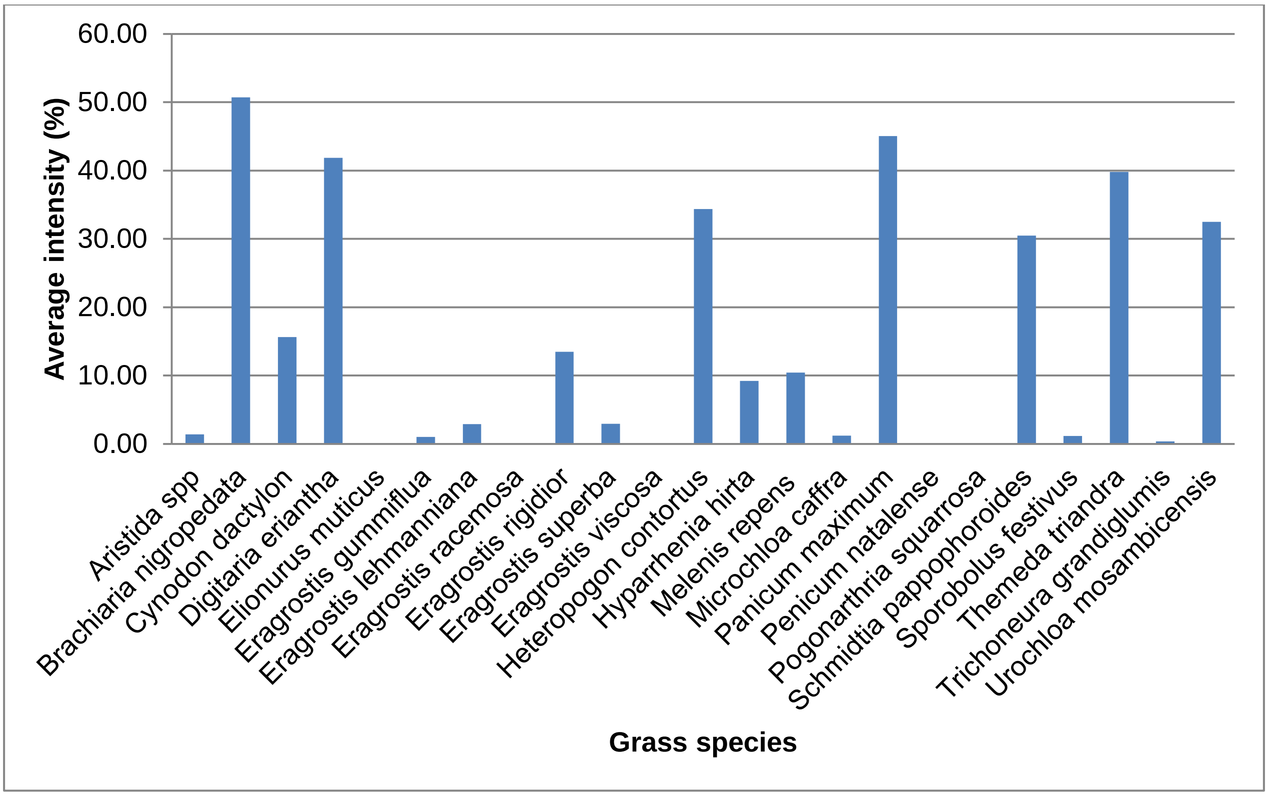

Figure 4.2 Average intensity of utilization of grasses over the study period.

Of the 23 grass species, four were utilised at low intensities, namely *Aristida* spp, *E. rigidior*, *M. repens* and *P. squarrosa* (Figure 4.2). *Aristida* spp were utilised at a low intensity (5%) between October and December (late spring and early summer), while *P. squarrosa* was the only grass species that was not utilized throughout the year. *Eragrostis rigidior* was well utilized in spring (31.98%) and summer (27%); but utilization was still low compared to other grass species. *Melenis repens* was utilized in spring (25%) and again at the end of autumn (27%).

Table 4.3 Intensity of utilization of grasses over the study period.

Grass species	MAR	Autumn APR	MAY	JUN	Winter JUL	AUG	SEP	Spring OCT	NOV	DEC	Summer JAN	FEB
Aristida spp	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.21	5.21	4.69	0.78	0.78
Brachiaria nigropedata	29.69	43.75	60.93	35.34	46.55	52.15	25.00	53.00	56.25	69.32	55.68	80.68
Cynodon dactylon	0.00	0.00	0.00	4.17	8.33	16.67	0.00	0.00	0.00	43.75	57.29	57.29
Digitaria eriantha	24.88	36.27	53.92	14.89	27.86	35.59	24.15	52.39	61.27	47.77	58.37	65.18
Elionurus muticus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis gummiflua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.98	3.98	3.98
Eragrostis lehmanniana	4.16	0.00	0.00	0.00	0.00	0.00	3.13	10.00	9.38	0.00	0.00	8.23
Eragrostis racemosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis rigidior	6.75	5.23	9.46	0.87	7.67	7.67	4.16	18.02	31.98	20.40	22.76	27.00
Eragrostis superba	3.57	3.57	3.57	5.88	8.09	10.29	0.00	0.00	0.00	0.00	0.00	0.00
Eragrostis viscosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heteropogon contortus	20.52	27.55	36.57	20.83	31.25	36.01	13.73	35.78	45.83	37.50	50.39	56.25
Hyparrhenia hirta	0.00	0.00	0.00	0.00	0.00	0.00	26.87	41.91	41.91	0.00	0.00	0.00
Melenis repens	10.83	10.00	27.50	5.21	6.25	11.46	2.94	25.74	25.00	0.00	0.00	0.00
Microchloa caffra	0.00	0.00	0.00	0.00	0.00	0.00	4.81	4.81	4.81	0.00	0.00	0.00
Panicum maximum	34.05	47.84	55.18	15.63	42.19	58.33	2.27	58.33	66.29	18.25	60.63	81.25
Panicum natalense	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pogonarthria squarrosa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Schmidtia pappophoroides	17.82	27.55	47.22	13.61	26.67	38.61	8.93	34.52	48.21	21.48	36.33	44.92
Sporobolus festivus	0.00	0.00	0.00	3.64	5.21	5.21	0.00	0.00	0.00	0.00	0.00	0.00
Themeda triandra	30.56	36.11	48.62	22.50	34.32	38.18	21.32	38.97	63.97	36.81	43.23	63.02
Trichoneura grandiglumis	0.00	0.00	4.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urochloa mosambicensis	21.87	15.63	62.50	15.00	37.50	37.50	0.00	0.00	0.00	65.63	59.37	75.00

4.1.1.4 Palatability

Palatable species are utilized at higher frequencies than they occur while important species are utilized the most. As an example, Species A might occur 100 times but might be defoliated 20 times, compared to Species B that occurs once but is defoliated 10 times. Based on the high occurrence and frequency of defoliation (20/100 = 0.5), Species A is then considered the more important in the diet, because it was more frequently utilized, but less palatable. Based on its lower occurrence together with a slightly lower frequency of defoliation (10/1 = 10), Species B would be more palatable but less important, because it was less frequently utilized.

4.1.1.4.1 Important grass species

The most important species in the diet of cattle during autumn was *D. eriantha* which was utilized 582 times, followed by *S. pappophoroides* (144 times). Other important grass species were *H. contortus* (123 times), *P. maximum* (87 times), *B. nigropedata* (85 times) and *E. rigidior* (66 times).

In winter, the most important species in the diet of cattle was *D. eriantha*, which was utilized 178 times followed by *T. triandra* (82 times). Other important grass species were *S. pappophoroides* (68 times), *H. contortus* (67 times), *B. nigropedata* (53 times) and *P. maximum* (47 times).

In spring, the most important species in the diet of cattle was *D. eriantha*, which was utilized 506 times, followed *P. maximum* (87 times). Other important grass species were *H. contortus* (78 times), *B. nigropedata* (55 times) and *E. rigidior* (46 times).

In summer, *D. eriantha* was utilized 268 times, whereas *T. triandra* was utilized (133 times). Other important grass species were *E. rigidior* (91 times), *H. contortus* (53 times), *S. pappophoroides* (45 times) and *P. maximum* (43 times).

4.1.1.4.2 Palatable grass species

Out of the 14-grass species that occurred in the autumn camp, eight were highly palatable (Table 4.4). In autumn, *B. nigropedata* had the highest palatability index (Pi = 351.17; Table 4.4), followed by *P. maximum* (Pi = 300), *D. eriantha* (Pi = 285.29), *U. mosambicensis* (Pi = 275.00), *S. pappophoroides* (Pi = 266.67), *T. triandra* (Pi = 233.33), *H. contortus* (Pi = 227.78) and *M. repens* (Pi = 120.00). *Eragrostis rigidior* was recorded as a palatable grass (Pi = 89.19), while *E. lehmanniana* (Pi = 50.00) and *Eragrostis superba* (Pi = 42.86) were less palatable. *Trichoneura grandiglumis* (Pi= 33.33) was recorded as least palatable grass. *Aristida* spp and *P. squarrosa* were avoided.

Table 4.4 Palatability indices of various grass species in autumn.

Grass species	Number of times present	Number of times utilized	Palatability index	Palatability group
Aristida spp	14.00	0.00	0.00	E
Brachiaria nigropedata	24.00	85.00	354.17	A
Digitaria eriantha	204.00	582.00	285.29	A
Eragrostis lehmanniana	6.00	3.00	50.00	C
Eragrostis rigidior	74.00	66.00	89.19	B
Eragrostis superba	7.00	3.00	42.86	C
Heteropogon contortus	54.00	123.00	227.78	A
Melenis repens	15.00	18.00	120.00	A
Panicum maximum	29.00	87.00	300.00	A
Pogonarthria squarrosa	3.00	0.00	0.00	E
Schmidtia pappophoroides	54.00	144.00	266.67	A
Themeda triandra	9.00	21.00	233.33	A
Trichoneura grandiglumis	3.00	1.00	33.33	D
Urochloa mosambicensis	4.00	11.00	275.00	A

Highly palatable = A. palatable = B. Less palatable = C. Least palatable = D. Avoided = E

In winter, *P. maximum* had the highest palatability index (195.83; Table 4.5). The other grass species that were also grouped as highly palatable were *B. nigropedata* (Pi = 182.76), *U. mosambicensis* (Pi = 160), *H. contortus* (Pi = 159.52), *S. pappophoroides* (Pi = 151.11), *T. triandra* (Pi = 149.09) and *D. eriantha* (Pi = 135.88). *Cynodon dactylon* was the only grass species that was classified as palatable (77.78). *Melenis repens* (Pi = 50), *E. superba* (Pi = 47.06) and *E. rigidior* (Pi = 45.45) were less palatable. *Sporobolus festivus* was recorded as least palatable (Pi = 20.83), while six grass species were avoided namely; *Aristida* spp*, Elionurus muticus, E. lehmanniana, P. natalense, P. squarrosa* and *T. grandiglumis.*

Table 4.5 Palatability indices of various grass species in winter.

Grass species	Number of times present	Number of times utilised	Palatability index	Palatability group
Aristida spp	31.00	0.00	0.00	E
Brachiaria nigropedata	29.00	53.00	182.76	A
Cynodon dactylon	9.00	7.00	77.78	B
Digitaria eriantha	131.00	178.00	135.88	A
Elionurus muticus	22.00	0.00	0.00	E
Eragrostis lehmanniana	2.00	0.00	0.00	E
Eragrostis rigidior	44.00	20.00	45.45	C
Eragrostis superba	17.00	8.00	47.06	C
Heteropogon contortus	42.00	67.00	159.52	A
Melenis repens	12.00	6.00	50.00	C
Panicum maximum	24.00	47.00	195.83	A
Panicum natalense	1.00	0.00	0.00	E
Pogonarthria squarrosa	4.00	0.00	0.00	E
Schmidtia pappophoroides	45.00	68.00	151.11	A
Sporobolus festivus	24.00	5.00	20.83	D
Themeda triandra	55.00	82.00	149.09	A
Trichoneura grandiglumis	3.00	0.00	0.00	E
Urochloa mosambicensis	5.00	8.00	160.00	A

Highly palatable = A. palatable = B. Less palatable = C. Least palatable = D. Avoided = E.

Out of a total of 15 grass species recorded in the spring camp, nine were classified as highly palatable (Table 4.6). *Panicum maximum* had highest palatability index (Pi = 263.64). The other eight grasses were *B. nigropedata* (Pi = 229.17), *D. eriantha* (Pi = 215.32), *S. pappophoroides* (Pi = 161.90), *T. triandra* (Pi = 158.82), *H. contortus* (Pi = 152.94), *H. hirta* (Pi = 141.18), *E. lehmanniana* (Pi = 125) and *E. rigidior* (Pi = 106.98).

Melenis repens was the only grass recorded as palatable (Pi = 94.12), while *Microchloa caffra* (Pi = 30.77) and *Aristida* spp (Pi = 16.67) were recorded as least palatable grasses. There were three grass species that were completely avoided, namely; *E. superba, P. squarrosa* and *T. grandiglumis*.

Table 4.6 Palatability indices of various grass species in spring.

Grass species	Number of times present	Number of times utilised	Palatability index	Palatability group
Aristida spp	12.00	2.00	16.67	D
Brachiaria nigropedata	24.00	55.00	229.17	A
Digitaria eriantha	235.00	506.00	215.32	A
Eragrostis lehmanniana	4.00	5.00	125.00	A
Eragrostis rigidior	43.00	46.00	106.98	A
Eragrostis superba	6.00	0.00	0.00	E
Heteropogon contortus	51.00	78.00	152.94	A
Hyparrhenia hirta	17.00	24.00	141.18	A
Melenis repens	17.00	16.00	94.12	B
Microchloa caffra	13.00	4.00	30.77	D
Panicum maximum	33.00	87.00	263.64	A
Pogonarthria squarrosa	6.00	0.00	0.00	E
Schmidtia pappophoroides	21.00	34.00	161.90	A
Themeda triandra	17.00	27.00	158.82	A
Trichoneura grandiglumis	1.00	0.00	0.00	E

Highly palatable = A. palatable = B. Less palatable = C. Least palatable = D. Avoided = E.

During summer, *B. nigropedata* had the highest palatability index (Pi = 290.91) (Table 4.7), followed by *U. mosambicensis* (Pi = 250.00). Other grass species that were highly palatable were *D. eriantha* (Pi = 239.29), *P. maximum* (Pi = 215.00), *C. dactylon* (Pi = 208.33), *T. triandra* (Pi = 184.72), *H. contortus* (Pi = 165.63) and *S. pappophoroides* (Pi = 140.63).

Eragrostis rigidior alone was classified as palatable (Pi = 85.05), while the least palatable group included *E. lehmanniana* (Pi =14.29) and *E. gummiflua* (Pi = 13.64). Ten out 21 of grasses recorded in the summer grazing camp were avoided, namely; *Aristida* spp*, E. muticus, E. racemosa, E. viscosa, M. repens, M. caffra, P. natalense, P. squarrosa* and *S. festivus.*

Table 4.7 Palatability indices of various grass species in summer.

Grass species	Number of times present	Number of times utilised	Palatability index	Palatability group
Aristida spp	16.00	0.00	0.00	E
Brachiaria nigropedata	11.00	32.00	290.91	A
Cynodon dactylon	12.00	25.00	208.33	A
Digitaria eriantha	112.00	268.00	239.29	A
Elionurus muticus	10.00	0.00	0.00	E
Eragrostis gummiflua	22.00	3.00	13.64	D
Eragrostis lehmanniana	7.00	1.00	14.29	D
Eragrostis racemosa	1.00	0.00	0.00	E
Eragrostis rigidior	107.00	91.00	85.05	B
Eragrostis superba	9.00	0.00	0.00	E
Eragrostis viscosa	2.00	0.00	0.00	E
Heteropogon contortus	32.00	53.00	165.63	A
Melenis repens	7.00	0.00	0.00	E
Microchloa caffra	4.00	0.00	0.00	E
Panicum maximum	20.00	43.00	215.00	A
Panicum natalense	3.00	0.00	0.00	E
Pogonarthria squarrosa	14.00	0.00	0.00	E
Sporobolus festivus	3.00	0.00	0.00	E
Schmidtia pappophoroides	32.00	45.00	140.63	A
Themeda triandra	72.00	133.00	184.72	A
Urochloa mosambicensis	4.00	10.00	250.00	A

Highly palatable = A. palatable = B. Less palatable = C. Least palatable = D. Avoided = E.

On average, over the whole study period, the highly palatable group included *B. nigropedata* (Pi = 264.25), *P. maximum* (Pi = 243.62), *U. mosambicensis* (Pi = 228.33), *D. eriantha* (Pi = 218.94), *T. triandra* (Pi = 181.49), *S. pappophoroides* (Pi = 180.08), *H. contortus* (Pi = 176.47), *C. dactylon* (Pi = 143.06) and *H. hirta* (Pi = 141.18). Nine grass species out of 23 were in the highly palatable group (Table 4.8). *Eragrostis rigidior* (Pi = 81.67) was the only grass to be recorded as palatable, while *M. repens* (Pi = 66.03) and *E. lehmanniana* (Pi = 47.32) were the only less palatable ones out of the 23-grass species that occurred.

Six grass species out of 23 was recorded as least palatable. They included *E. superba* (Pi = 22.48), *M. caffra* (Pi = 15.38), *E. gummiflua* (Pi = 13.64), *T. grandiglumis* (Pi =

11.11), *S. festivus* (Pi = 10.42) and *Aristida* spp (Pi = 4.17), respectively. Grass species that were avoided by cattle throughout the study; included *E. muticus, E. racemosa, E. viscosa, P. natalense* and *P. squarrosa.*

Table.4.8 Average palatability index and palatability grouping of grasses.

Grass species	Palatability index	Palatability group
Aristida spp.	4.17	D
Brachiaria nigropedata	264.25	A
Cynodon dactylon	143.06	A
Digitaria eriantha	218.94	A
Elionurus muticus	0.00	E
Eragrostis gummiflua	13.64	D
Eragrostis lehmanniana	47.32	C
Eragrostis racemosa	0.00	E
Eragrostis rigidior	81.67	B
Eragrostis superba	22.48	D
Eragrostis viscosa	0.00	E
Heteropogon contortus	176.47	A
Hyparrhenia hirta	141.18	A
Melenis repens	66.03	C
Microchloa caffra	15.38	D
Panicum maximum	243.62	A
Panicum natalense	0.00	E
Pogonarthria squarrosa	0.00	E
Schmidtia pappophoroides	180.08	A
Sporobolus festivus	10.42	D
Themeda triandra	181.49	A
Trichoneura grandiglumis	11.11	D
Urochloa mosambicensis	228.33	A

*Highly palatable = A. palatable = B. Less palatable = C. Least palatable = D. Avoided = E.

4.1.2 Difference in tuft traits before and after grazing

4.1.2.1 Tuft circumference

In autumn, the tuft circumference of only three grass species decreased highly significantly (P<0.01), namely; *Aristida* spp*, E. rigidior* and *S. pappophoroides,* while tuft circumference of *M. repens* and *T. grandiglumis* decreased significantly (P<0.05) (Table A1, Appendix A). No significant decreases occurred where other species were concerned.

In winter, the tuft circumference of six grass species decreased highly significantly (P<0.01), namely; *B. nigropedata, D. eriantha, H. contortus, P. maximum, S. pappophoroides* and *T. triandra*, while the tuft circumference of *E. rigidior* decreased significantly (P<0.05) (Table A1 and Table 4.9). No significant decreases occurred where other species were concerned.

In spring, the tuft circumference of three grass species decreased highly significantly (P<0.01) in *D. eriantha, H. contortus* and *P. maximum,* while the tuft circumference of *B. nigropedata* decreased significantly (P<0.05) (Table A1). No significant decreases occurred where other species were concerned.

In summer, the tuft circumference of four grass species decreased highly significantly (P<0.01) namely *D. eriantha, E. rigidior, S. pappophoroides* and *T. triandra,* while the tuft circumference of *B. nigropedata, H. contortus* and *P. maximum* decreased significantly (P<0.05) (Table A1 and Table 4.9). No significant decreases occurred where other species were concerned.

4.1.2.2 Tuft height (utilizable leaves) before and after grazing

In autumn, the height of utilizable leaves of four grass species decreased highly significantly (P<0.01) in *B. nigropedata, D. eriantha, P. maximum* and *S. pappophoroides,* while the height of utilizable leaves of *Aristida* spp, *E. superba, H. contortus* and *T. triandra* decreased significantly (P<0.05). No significant decreases occurred where other species were concerned (Table A2, Appendix A).

In winter, the height of utilizable leaves of six grass species decreased highly significantly (P<0.01) in *B. nigropedata, D. eriantha, H. contortus, P. maximum, S. pappophoroides* and *T. triandra,* while the height of utilizable leaves of *E. rigidior* decreased significantly (P<0.05) (Table A2, Appendix A). No significant decreases occurred where other species were concerned.

In spring, the height of utilizable leaves of five grass species decreased highly significantly (P<0.01) in *B. nigropedata, D. eriantha, H. hirta, P. maximum* and *S. pappophoroides,* while the height of utilizable leaves of *E. rigidior, H. contortus, M. caffra* and *T. triandra* decreased significantly (P<0.05) (Table A2, Appendix A). No significant decreases occurred where other species were concerned.

In summer, the height of utilizable leaves of eight grass species decreased highly significantly (P<0.01) in *D. eriantha, E. muticus, E. rigidior,* E. *superba, M. repens, P. squarrosa* and *T. triandra,* while the height of utilizable leaves of *C. dactylon, E. lehmanniana, P. natalense* and *S. festivus* decreased significantly (P<0.05) (Table A2, Appendix A). No significant decreases occurred where other species were concerned.

4.1.2.3 Tuft height (highest leaves) before and after grazing

In autumn, the height of highest leaves of six grass species decreased highly significantly (P<0.01), namely; *Aristida spp, B. nigropedata, D. eriantha, H. contortus, P. maximum* and *S. pappophoroides.* No significant decreases occurred where other species were concerned (Table A3, Appendix A).

In winter, the height of highest leaves of seven grass species decreased highly significantly (P<0.01), namely; *B. nigropedata, D. eriantha, E. rigidior, H. contortus, P. maximum, S. pappophoroides* and *T. triandra* (Table A3, Appendix A). No significant decreases occurred where other species were concerned.

In spring, the height of highest leaves of seven grass species decreased highly significantly (P<0.01), namely; *B. nigropedata*, *D. eriantha*, *E. rigidior*, *H. contortus*, *H. hirta*, *P. maximum*, *S. pappophoroides* and *T. triandra* (Table A3, Appendix A). No significant decreases occurred where other species were concerned.

In summer, the height of highest leaf of seven grass species decreased highly significantly (P<0.01), namely; *Aristida spp*, *B. nigropedata*, *C. dactylon*, *D. eriantha*, *E. muticus*, *E. superba*, *H. contortus*, *P. maximum*, *P. squarrosa* and *T. triandra* while the highest leaves of *M. repens*, *P. natalense*, *S. festivus* and *S. pappophoroides* decreased significantly (P<0.05) (Table A3, Appendix A). No significant decreases occurred where other species were concerned.

4.1.3 Availability of aboveground biomass

4.1.3.1 Seasonal availability of aboveground biomass

Total biomass production was significantly higher (P<0.05) during autumn (7527.68 kg ha^{-1}), while biomass production during winter (5434.4 kg ha^{-1}) was significantly (P<0.05) lower, compared to other seasons. Total biomass production did not differ significantly between spring (6638.05 kg ha^{-1}) and summer (6269.66 kg ha^{-1}) (Figure 4.3).

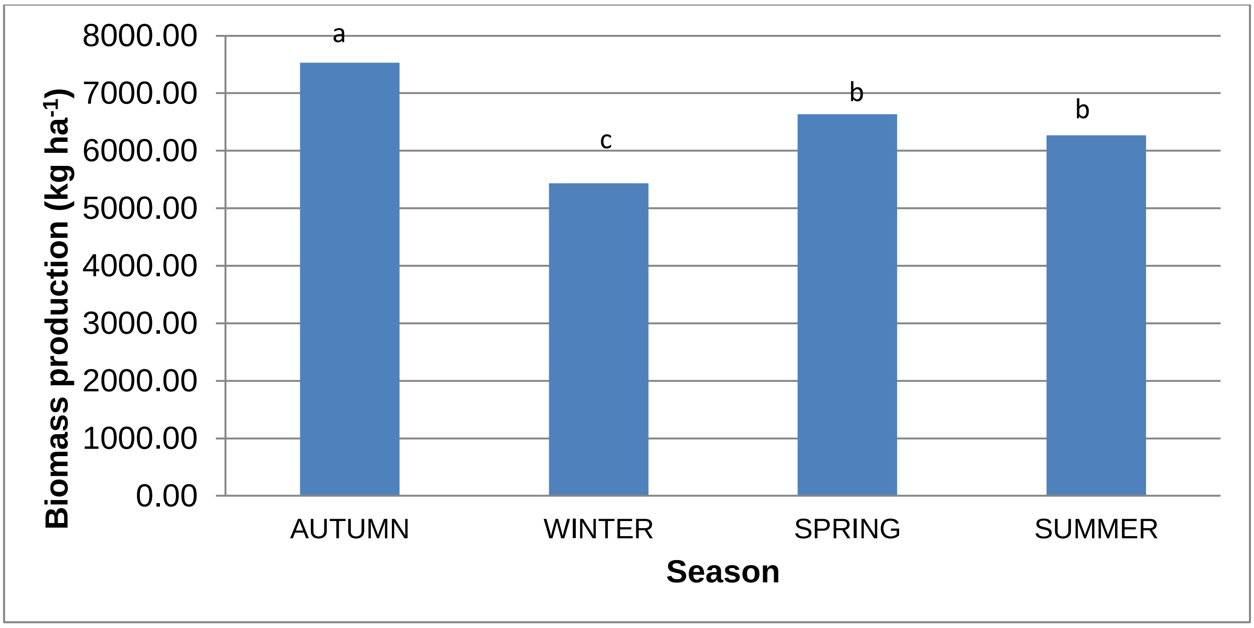

Figure 4.3 Seasonal biomass production during the study period.

Digitaria eriantha, E. rigidior and *H. contortus* were dominant at the study site (Table 4.1). Total percentage species composition of these grass species as a group was 56.45%, but they only produced 22.27% of the available biomass (1676.49 kg ha^{-1}) during autumn, 25.72% during winter (1397.99 kg ha^{-1}), 24.70% during spring (1640.17 kg ha^{-1}) and 26.68% during summer (1673.08 kg ha^{-1}), respectively (Table 4.1).

The grass species that produced the highest biomass were *P. maximum* (1236 kg ha^{-1}) in autumn, followed by *T. triandra* (1081.81 kg ha^{-1}), *H. contortus* (863.81 kg ha^{-1}), *D. eriantha* (669.98 kg ha^{-1}) and *B. nigropedata* (601 kg ha^{-1}), also in autumn. Biomass production from all other grass species and forbs were relatively low (Figure 4.4). From Figure 4.4, the biggest contribution to biomass production was made by six species, namely; *P. maximum, T. triandra, H. contortus*, *D. eriantha*, *B. nigropedata* and to a lesser extent, *S. pappophoroides.* These species contributed to 66.30% (4991.01 kg ha^{-1}), 66% (3586.71 kg ha^{-1}), 59.82% (3971.20 kg ha^{-1}) and 66.83% (4190.11 kg ha^{-1}) of the biomass production in autumn, winter, spring and summer, respectively.

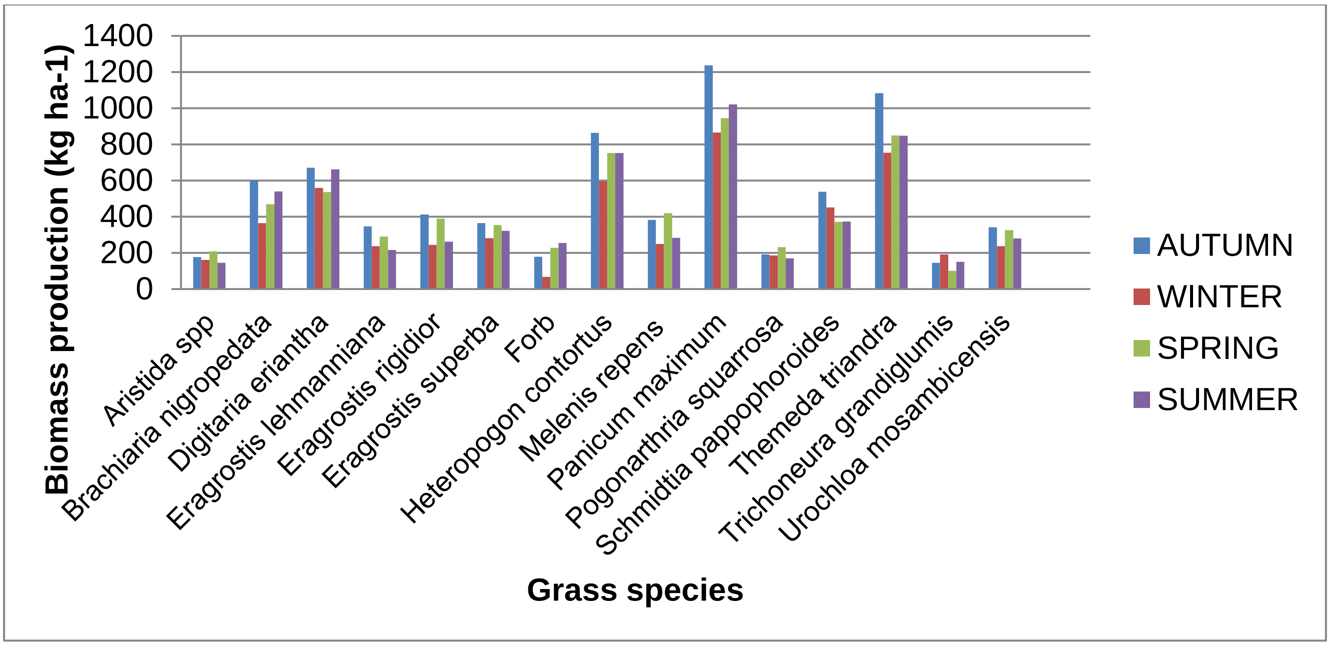

Figure 4.4 Seasonal biomass production (kg ha^{-1}) of different grass species per season.

4.1.3.2 Seasonal availability of biomass production within species

In autumn, the biomass production of the following grass species before and after defoliation decreased highly significantly (P<0.01) (Table A5, Appendix A and Table 4.9): *Aristida spp* (100%), *B. nigropedata* (75.89%), *D. eriantha* (74.18%), *E. rigidior* (81.61%), *E. superba* (71.71%), *H. contortus* (72.75%), *M. repens* (80.32%), *P. maximum* (79.36%), *S. pappophoroides* (72.09%) and *T. triandra* (72.30%). The decrease in biomass production before and after defoliation of *U. mosambicensis* (89.13%), *P. squarrosa* (100%), *S. festivus* (100%), *T. grandiglumis* (100%) and *E. lehmanniana* (85.42%) was significantly different (P<0.05). No significant decreases occurred where other species were concerned.

In winter, the biomass production of the following grass species before and after defoliation decreased highly significantly (P<0.01): *Aristida* spp (100%), *D. eriantha* (91.24%), *E. lehmanniana* (96.55%), *E. rigidior* (100%), *H. contortus* (88.26%), *M. repens* (100%), *S. festivus* (100%), *T. triandra* (92.99%) and *U. mosambicensis* (100%). *Brachiaria nigropedata* (97.75%), *P. maximum* (89.26%), *P. natalense* (100%) and *P. squarrosa* (100%) had significantly different (P<0.05) decrease in biomass production before and after defoliation, while no significant decreases occurred where other species were concerned (Table A5, Appendix A and Table 4.9).

In spring, the biomass production of the following grass species before and after defoliation decreased highly significantly ($P<0.01$): *Aristida* spp (100%), *D. eriantha* (76.36%), *E. rigidior* (71.92%), *H. contortus* (80.32%), *M. repens* (73.30%), *P. maximum* (69.56%), *P. squarrosa* (80.32%), *S. pappophoroides* (75.69%), *T. triandra* (76.35%) and *U. mosambicensis* (74.95%). The decrease in biomass production before and after defoliation of the following grass species was significantly different ($P<0.05$): *B. nigropedata* (76.36%) and *E. superba* (66.22%). No significant decreases occurred where other species were concerned (Table A5, Appendix A and Table 4.9).

In summer, the biomass production of the following grass species before and after defoliation decreased highly significantly ($P<0.01$), namely; *Aristida spp* (86.50%), *B. nigropedata* (69.95%), *D. eriantha* (69.53%), *E. lehmanniana* (64.85%), *E. rigidior* (63.75%), *E. superba* (63.26%), *H. contortus* (60.31%), *M. repens* (65.64%), *P. maximum* (61.24%), *P. squarrosa* (84.54%), *S. festivus* (82%), *S. pappophoroides* (72.89%), *T. triandra* (65.15%) and *U. mosambicensis* (63.23%). No significant decreases occurred where other species were concerned (Table A5, Appendix A and Table 4.9).

Table 4.9 showed that *H. contortus, T. triandra D. eriantha* and *P. maximum* where the biggest contributors to biomass. Species composition played an important role in the total biomass production. In general, the higher the species composition of a specific species, the higher its contribution to the total biomass production. However, there were a few exceptions. As an example, *P. maximum* had a lower species composition compared to *D. eriantha,* but it still managed to produce more biomass while decreases in biomass production of *T. triandra* was 597 kg ha^{-1} (1.8% species composition) compared to *D. eriantha*, which was 461 kg ha^{-1} (40% species composition) in autumn. The biomass production of the following species decreased the most: *H. contortus, T. triandra D. eriantha* and *P. maximum.* They were the biggest contributors of biomass throughout the seasons.

Table 4.9 The percentage decrease in available biomass within different grasses before and after defoliation.

Species	Autumn			Winter			Spring			Summer		
	First cut	Last cut	Total % decrease	First cut	Last cut	Total % decrease	First cut	Last cut	Total % decrease	First cut	Last cut	Total % decrease
Aristida spp	89.00	0.00	100.00	175.00	0.00	100.00	79.50	0.00	100.00	94.00	9.50	86.50
Brachiaria nigropedata	278.00	67.00	97.89	112.50	11.00	97.75	177.00	37.00	76.36	296.00	83.00	69.95
Digitaria eriantha	626.50	165.00	74.18	848.00	24.00	91.24	617.00	147.50	75.43	646.50	190.50	69.53
Eragrostis lehmanniana	79.00	15.00	85.42	112.50	15.00	96.55	32.00	10.50	67.26	65.00	22.00	64.85
Eragrostis rigidior	196.50	39.50	81.61	210.50	0.00	100.00	179.50	49.50	71.92	199.50	64.00	63.75
Eragrostis superba	100.50	21.50	71.71	74.00	0.00	100.00	79.00	25.00	66.22	86.00	30.50	63.26
Heteropogon contortus	810.50	213.00	72.75	558.00	23.00	88.26	287.00	56.00	80.32	536.50	251.00	60.31
Melenis repens	159.00	31.50	80.32	248.50	0.00	100.00	149.50	38.00	73.30	176.00	49.50	65.64
Microchloa caffra	60.00	12.00	86.67	0.00	0.00	0.00	0.00	0.00	0.00	29.00	9.00	70.03
Panicum maximum	387.00	75.50	79.36	267.00	4.00	98.26	372.00	112.00	69.56	339.00	95.50	61.24
Panicum natalense	0.00	0.00	0.00	36.00	0.00	100.00	31.00	5.00	88.10	41.00	11.50	70.20
Pogonarthria squarrosa	55.50	0.00	100.00	55.50	0.00	100.00	72.00	15.00	80.32	48.50	9.00	84.54
Schmidtia pappophoroides	343	83.50	72.09	414.50	16.00	96.14	231.00	53.00	75.69	221.00	59.00	72.89
Sporobolus festivus	25.00	0.00	100.00	39.50	0.00	100.00	46.00	9.50	81.94	48.50	13.00	82.00
Themeda triandra	667.00	183.00	72.30	248.00	35.00	92.99	482.00	105.00	76.35	331.00	105.50	65.15
Trichoneura grandiglumis	37.50	0.00	100.00	0.00	0.00	0.00	10.00	0.00	100.00	22.00	5.50	82.25
Urochloa mosambicensis	111.50	13.00	89.13	152.00	0.00	100.00	141.50	32.00	74.95	103.00	34.50	63.23

4.1.3.3 Seasonal differences in biomass production between species

In autumn, *P. maximum* and *T. triandra* had similar response of decrease in biomass as a result of defoliation while *T. triandra* and *B. nigropedata*, *D. eriantha*, *H. contortus*, *P. maximum* and *U. mosambicensis* had similar response of decrease in biomass as a result of defoliation (Table A5). *Eragrostis lehmanniana*, *E. rigidior*, *E. superba*, *M. repens*, *S. festivus* and *S. pappophoroides* had similar decrease in biomass as a result of defoliation. The difference in biomass production between species which had different response of decrease in biomass production as a result of defoliation was highly significant ($P<0.001$).

In winter, *P. maximum* and *B. nigropedata, D. eriantha, E. superba, H. contortus, P. squarrosa, S. festivus* and *S. pappophoroides* had similar decrease in biomass as a result of defoliation. *Brachiaria nigropedata, E. superba, P. squarrosa* and *S. festivus* also had similar response to defoliation. *Eragrostis lehmanniana, M. repens* and *U. mosambicensis* had similar response of decrease in biomass as a result of defoliation (Table A5). The difference in biomass production between species which had different response of decrease in biomass production as a result of defoliation was highly significant ($P<0.001$).

In spring, *Aristida spp*, *B. nigropedata*, *D. eriantha*, *E. gummiflua*, *E. lehmanniana*, *E. muticus*, *E. rigidior*, *E. superba*, *H. contortus*, *M. repens*, *P. maximum*, *P. natalense*, *P. squarrosa, S. pappophoroides* and *U. mosambicensis* had similar response of decrease in biomass as a result of defoliation (Table A5). The difference in biomass production between species which had different response of decrease in biomass production as a result of defoliation was highly significant ($P<0.001$).

In summer, *D. eriantha* and *H. contortus* had similar response to defoliation, whereas *B. nigropedata*, *E. rigidior*, *P. maximum* and *S. pappophoroides* similar response to decrease in biomass as a result defoliation as *D. eriantha* and *H. contortus. Pogonarthria squarrosa* and *P. natalense* had similar response of decrease in biomass as a result of defoliation (Table A5). The difference in biomass production between species which had different response of decrease in biomass production as a result of defoliation was highly significant ($P<0.001$).

In autumn, the biomass production of *P. maximum* decreased the most compared to most grass species; the decreases in biomass production was not significantly different from the decrease in biomass production of *T. triandra* (Table 4.9). The biomass production of the following grasses decreased the most; *P. maximum*, *T. triandra*, *B. nigropedata*, *D. eriantha*, *H. contortus* and *U. mosambicensis.*

The biomass production of *P. maximum* decreased the most in winter compared to most of grasses (Table 4.9). The decrease in biomass production was not significantly different from the decrease in biomass production of *T. triandra.* Other species that had severe decrease in biomass production are *P. maximum*, *T. triandra, H. contortus*, *D. eriantha, S. pappophoroides, B. nigropedata* and *Melenis repens.*

The biomass production of *T. triandra* decreased the most during spring. The decrease in biomass production, however, was not significantly different between most grasses that occurred in the spring camp, except *S. festivus.*

In autumn, the biomass production of *P. maximum* decreased the most compared to most grass species; the decrease in biomass production was not significantly different from the decrease in biomass production of *T. triandra* (Appendix A and Table A5). The biomass production of the following grasses decreased the most; *P. maximum*, *T. triandra*, *B. nigropedata*, *D. eriantha*, *H. contortus* and *U. mosambicensis.*

The biomass production of *P. maximum* decreased the most in winter compared to other species (Appendix A and Table A5). The decrease in biomass production was not significantly different from the decrease in biomass production of *T. triandra.* Other grasses that had severe decrease in biomass production are *P. maximum*, *T. triandra, H. contortus*, *D. eriantha, S. pappophoroides, B. nigropedata* and *M. repens.*

The biomass production of *T. triandra* decreased the most during spring. The decrease in biomass production, however, was not significantly different to most grasses that occurred in the spring camp except *S. festivus.* The response to defoliation of most grass species in spring was similar; the decrease in biomass production was high.

4.2 DISCUSSION

4.2.1 Grass species utilization

4.2.1.1 Palatability, intensity and frequency of utilization

Grass species that were highly palatable during the study period included *B. nigropedata*, *P. maximum*, *D. eriantha*, *S. pappophoroides*, *T. triandra* and *H. contortus*. Irrespective of the season, they were utilized at the highest intensities and frequencies and were therefore considered the most important species overall. In terms of palatability, four grasses stood out (Pi > 200), namely *B. nigropedata*, *P. maximum*, *D. eriantha* and *U. mosambicensis*. *Cynodon dactylon* was also one of the palatable grass species in the camps where it occurred.

In this study, *Brachiaria nigropedata* and *P. maximum* had the highest palatability indices; this, supported by their frequency of utilization (Table 4.2) and intensity of utilization (Table 4.3), is an indication that they were utilized repeatedly, more than any other grass species. *Brachiaria nigropedata* was one of the grass species that cattle selected first when they entered different camps. However, due to its growth form and low production (Van Oudtshoorn, 2012), fewer bites were required to remove most of the available material (Jordaan *et al*., 1996). Cattle selected *P. maximum*, in winter and spring, above *B. nigropedata*. This is probably due to the fact that *P. maximum* is one of the first grasses to turn green after spring rains, as well as its high biomass during winter. During summer, grasses with softer leaves (thus a higher nutrient content, i.e. *B. nigropedata*) are selected first (Jordaan, 1991). Similar to findings of Gammon and Roberts (1978a) in Zimbabwe, cattle preferred *B. nigropedata* ahead of *T. triandra*.

Panicum maximum was one of a few grass species that were highly preferred in all the seasons, but during summer, *B. nigropedata*, *U. mosambicensis* and *D. eriantha* were preferred ahead of *P. maximum*. However, due to its high biomass production (Van Oudtshoorn, 2012) and high intensity and frequency of utilization and Pi in all seasons, this study supports the findings of Jordaan (1991), who considered *P. maximum* the most important grass species in the diet of cattle in the Limpopo Bushveld areas. He suggested that veld management should be based on maintaining *P. maximum*, while lower producing, palatable species such as *B. nigropedata* and *D.eriantha*, which were identified as important by Low (1975), should be regarded as slightly less important.

Digitaria eriantha was the dominant grass species in all four camps. It was also highly palatable during all seasons, which makes it an important grass species in the diet of cattle in this study. This agrees with Kiguli *et al*. (1999) that *D. eriantha* is a dominant grass species in savanna biome and it is also palatable throughout the year, but according to Van Oudtshoorn (2012) and Fourie *et al*. (1985), despite being highly palatable, this species has a low to moderate leaf production. According to Jordaan (1991), this puts it in the same category as *B. nigropedata*, where fewer bites are required to remove most of available material, which is then followed by a period where little available material is left to utilize.

Despite its high Pi, *U. mosambicensis* did not contribute much to the diet of cattle in this study, due to its low occurrence. Although it is a highly palatable species (Jordaan *et al*., 1996) with an average biomass production (Van Oudtshoorn, 2012), it contributed less to diet component of cattle due to its low percentage species composition (Table 4.1).

Findings from this study are in contrast with findings of (Fourie *et al*., 1985) that *T. triandra* was more palatable than *D. eriantha*. Both *T. triandra* and *D. eriantha* were highly palatable, but the latter had higher palatability index than the former.

Schmidtia pappophoroides was one of the grass species that was moderately present at the site, occurring in all camps. It contributed fairly to the diet selected by cattle in this study, similar to results observed in the Sourish Mixed Bushveld of the Limpopo Province by Jordaan *et al.* (1996) and by Rothauge *et al.* (2007) in Namibia. It was a highly palatable grass species in all four grazing camps. This species is considered as palatable, with an average leaf yield (Van Oudtshoorn, 2012), and being repeatedly defoliated during different seasons (Jordaan *et al*., 1996) makes it an important grass species in the diet of cattle. However, it must be noted that it has relatively slow post utilization recovery rate (Jordaan *et al.,* 1996) and not being a typical tufted grass, increased stemminess during late summer had a negative influence on its utilization during the dormant season.

Themeda triandra was highly palatable in all four grazing camps. It is regarded as an important species, critical for livestock production and conservation of biodiversity. Cattle consistently selected *T. triandra* particularly in the early growth stages depending on season and availability of more palatable alternatives within its vicinity (Snyman *et al.,* 2013). Theron and Booysen (1966) indicated that *T. triandra* improve in relative palatability with the passage of time. It produces medium to high biomass yield (Van Oudtshoorn, 2012). However, the general palatability of *T. triandra* varies between geographic locations. In other veld types such as False Thornveld in the Eastern Cape, *T. triandra* is regarded as the most palatable grass species (O'Connor, 1992), but in the bushveld areas of Limpopo Province, its palatability depends on the ecotype that occurs (Jordaan, 1991).

Heteropogon contortus, a highly palatable grass species in all camps (Table 4.8), played a major role in the diet selected by cattle, as it was one of the dominant grass species in the study area (Table 4.1). However, findings from this study are in contrast with findings of Gammon and Roberts (1978a) in Zimbabwe, where *H. contortus* is a least palatable grass species. Gibbs-Russell and Spies (1988) indicated that there were more than 200 recorded ecotypes/landraces of *H. contortus*, causing the same species to react differently to grazing in different topographical localities as well as between sub-habitats of the same topographical unit (Janse van Rensburg and Bosch, 1990).

Cynodon dactylon only occurred in the summer and winter camps and was classified as highly palatable in summer and palatable in winter. According to Van Oudtshoorn (2012) and similar results in this study, *C. dactylon* is stoloniferous, remains green until late winter, can endure heavy grazing and it is palatable. In general, this species, which is the basis of several currently available cultivated pastures (Dannhauser, 1985; Truter *et al.,* 2015) is considered highly palatable, but its importance in the diet of cattle in this study was severely influenced by its low occurrence (Table 4.1).

Only one grass species was recorded as palatable in all four camps, namely *Eragrostis rigidior* (Table 4.8). *Eragrostis rigidior* was classified as a palatable grass species in summer and autumn, mainly due to its high occurrence and utilization the relevant camps. However, this species is known for severe quality and yield decreases during dormant periods, with hard stems occurring due to its growth form (Trollope, 1984) which led to it being less palatable in winter. However similar to results of Jordaan (1991), regrowth (young leaves and soft stems) in this study were heavily utilized during spring and as a result, it was classified as highly palatable during this season.

Less palatable grass species only occurred in autumn and winter, and included *E. lehmanniana*, *E. superba*, *E. rigidior* and *M. repens* (Table 4.8). In general, they played a lesser role in the diet of cattle in this study, due to their low and sporadic occurrence in different camps.

However, in this group of less palatable grass species, attention must be given to *M. repens* and *E. lehmanniana*, which occurred at relatively low numbers in all camps (Table 4.1) but varied in palatability during different seasons (Tables 4.4 to 4.7). The variation in palatability can be as a result of other palatable grass species that occurred within their vicinity (Pellissier *et al.,* 2015).

Melenis repens was recorded as highly palatable in autumn, less palatable in winter, palatable in spring and was avoided in summer. This species occurred at low percentages in all camps (Table 4.1). This result were in contrast with a study done by Jordaan *et al.* (1996) in the Sourish Mixed Bushveld where *M. repens* was generally classified a palatable grass species in that veld type. However, in summer, it was unpalatable and in winter, it was less palatable. It is low producing and weak perennial grass species (Van Oudtshoorn, 2012). The availability of highly palatable species within the vicinity of *M. repens* influenced its palatability index.

Eragrostis lehmanniana was recorded as less palatable in autumn, it was avoided in winter, in spring it was highly palatable and least palatable in summer. In accordance with Fourie *et al*. (1985), it appears as if this low-producing species' palatability depended on the emergence of early season regrowth and the general availability of biomass during the season. *Eragrostis superba*, as a less palatable species, did not form a significant part in the diet selected by cattle due to its low occurrence (Table 4.1).

Least palatable species were *T. grandiglumis* in autumn, *S. festivus* in winter, *Aristida* spp and *M. caffra* in spring and *E. lehmanniana* and *E. gummiflua* in summer. *Eragrostis gummiflua* only occurred in the summer camp and was least palatable due to it having hard stems and leaves, especially during winter (Van Oudtshoorn, 2012).

In autumn, winter and summer, *Aristida spp*, which is general accepted for being unpalatable, was totally avoided. In this study, *Aristida* spp was poorly utilized during spring only (Figure 4.3), which agrees with Kiguli *et al.* (1999), that *Aristida* spp are unsuitable for commercial cattle farming as it is low producing with a low availability of biomass (Figure 4.4), inferior in quality and therefore either a least palatable species or is avoided. *Aristida spp* was avoided in autumn, winter and summer (Figure 4.1 and 4.2); it was only utilized in spring, although the frequency and intensity of utilization was low.

Hyparrhenia hirta only occurred in the spring; where it was a highly palatable grass species. This agrees with Van Oudtshoorn (2012) and Meissner *et al.* (2013), that it is mostly grazed early in the growing season (spring and early summer, especially before flowering), but that it becomes less acceptable to cattle as it becomes increasingly stemmy as the growing season progresses.

Cattle avoided some grass species for various reasons; mostly because of their physical characteristics (hard stems and leaves, awns etc.) in relation to the season in which those grasses are grazed and the occurrence of more palatable grasses in their vicinity (Meissner *et al*., 2013). Grasses that were totally avoided during all seasons were *E. muticus*, *E. racemosa*, *E. viscosa* and *P. squarrosa*.

4.2.1.2 Patterns of utilization

Frequency and intensity of utilization dropped at the beginning of each season, when cattle moved to a different camp. Thereafter, it increased as the occupation period progressed (Tables 4.2 to 4.4). The apparent reason might be the unfamiliarity of animals with the new grazing area, where initial recognisance and dietary adaptations to the vegetation could have influenced diet selection for a short period. This is a regularly recorded phenomenon, similar to results obtained by Daines (1980) as well as Gammon and Roberts (1976a).

When cattle entered camps, a range of grass species were available to utilize (whether palatable or not), each differed in their dietary qualities, morphology and structure (O'Connor, 1992). Utilization was not uniform, as cattle preferred some grass species above others. Cattle selected grass species that were on offer in a set sequence, as indicated by Daines (1980) in Figure 2.1. During the first few days, they utilized mostly highly palatable species such as *B. nigropedata, D. eriantha, P. maximum* and *T. triandra* (creaming). As the occupation period progressed, palatable grasses such as *H. contortus* and *S. pappophoroides* (notable pattern)**,** less palatable such as *E. rigidior* and *M. repens* (pattern developing), and later unpalatable grasses such as *S. festivus* (accentuated pattern), were included in their diet. However, in this study, a correct stocking rate prevented the stage of total utilization to occur (some grass species were not utilized), and adequate regrowth occurred during the growing season for animals to return to palatable tufts (indicated by differences in frequency of defoliation under section 4.1.1.2)

4.2.2 Differences in tuft traits

4.2.2.1 Turf circumference

Generally, during autumn, grasses lose leaves and stems, especially annuals and weak perennials, as they enter the dormant season. Table 4.2 and Table 4.3 showed that *Aristida* spp and *T. grandiglumis* were not utilized during autumn. Both grass species are weak perennials (Van Oudtshoorn, 2012), and the decrease in tuft circumference of grasses was therefore possibly as a result of die off.

Highly significant decreases in the tuft circumference of highly palatable and palatable grasses (*B. nigropedata, D. eriantha, H. contortus, P. maximum, S. pappophoroides* and *T. triandra*) during different seasons were attributed to these species being highly utilized during the respective seasons in which decreases occurred. Table 4.2 and Table 4.3 showed that these grass species were utilized at high intensities and high frequencies during those seasons. The decrease in tuft circumference of those grasses was therefore, probably influenced by utilization.

4.2.3.2 Utilizable leaves

Significant decreases in utilizable leaves of annual and weak perennial species (i.e. *Aristida* spp), that were not severely utilized during the active growing season, occurred during autumn and winter, due to die-off of leaves, which generally occur during the dormant season (Scholes and Archer, 1997, Grasses, 2000).

The decrease in height of utilizable leaves of perennial grass species, especially during the active growing season, was mostly as a result of intensive and frequent utilization that took place in that season (Table 4.2 and Table 3.3). In agreement with findings from this study, O'Reagain and Mentis (1989) indicated that there is positive correlation between palatability of grass species and the decrease height of utilizable leaves. It is assumed that leaf loss due to dormancy during autumn and winter could also have had an influence, but the extent thereof was not determined.

4.2.3.3 Height of the highest leaves

What must be noted is that the highest leaf of a grass plant usually occurs on the flowering stem (Grasses, 2000; Van Oudtshoorn, 2012). Therefore, decreases in the height of the highest leaf indicates if the flowering stem and/or the inflorescence of a grass is utilized. Grasses where no significant decreases occurred were thus species where the flowering stems were moderately utilized or not utilized at all, while differences indicated the utilization thereof.

Since perennial grass species are less likely to lose leaves when grasses become dormant in the absence of utilization (Grasses, 2000), decrease in height of the highest leaves of different grasses (*B. nigropedata, D. eriantha, H. contortus, P. maximum, H. hirta, E. superba, E. rigidior, C. dactylon, T. triandra* and *S. pappophoroides*) that occurred was as a result of utilization of leaves and flowering stems in a particular season. Most of grass species that had significant decreases in height of the highest leaves were palatable grasses (Table 4.4 to 4.7); and findings from this study thus agree with those of O'Reagain and Mentis (1989), who described a positive correlation between palatability and the decrease in tuft height after utilization.

However, Tables 4.2 and 4.3 showed that *Aristida* spp, *P. squarrosa* and *E. muticus* were not utilized during autumn. The decrease in height of their first leaves occurred during the dormant season. *Aristida* spp and *P. squarrosa* are weak perennials (Van Oudtshoorn, 2012) and loss of leaves during autumn and winter are common among weak perennials and annuals. The decrease in the height of utilizable leaves was probably because of dormant season die off. The utilizable leaves of *T. triandra* in autumn was utilized significantly but the height of highest leaf remained unchanged, indicating that flowering stems were not utilized. There was significance decrease (Table A2 and Table A3, see appendix A) in the utilizable leaves and highest leaves of *H. contortus* and *H. hirta* in spring, indicating that the flowering stems of these species were utilized during spring grazing period.

4.2.3 Differences in available biomass before and after defoliation

The growth rate of grasses, and therefore their ultimate biomass production, depends on various factors (Schulze and Lynch, 2007), which were highlighted in Chapter 2 (2.9 to 2.12). Table 4.2 and Table 4.3 shows that vigorous growth occurred between spring and autumn, leading to high biomass production during this period (Figure 4.3).

The autumn camp had the highest biomass production. This is attributed to the autumn camp being rested for the whole previous growing season, with preceding rainfall during the previous summer (Magandana, 2016). The findings of this study are thus in agreement with findings of Magandana (2016) in Bisho Thornveld (Mucina and Rutherford, 2006) that the highest production occurred during the growing season and that rested veld would have a high aboveground production during autumn. The total biomass production in spring and summer were not significantly different from each other.

Annual grass species such as *U. mosambicensis* had faster regrowth in summer than perennial grasses, and it had the smallest decrease in biomass (63.23%). The biomass of *Aristida spp* was totally removed in autumn, winter and spring (mostly due to die off), which indicates that no regrowth occurred after defoliation during those seasons. Perennial grasses reacted different to defoliation. Big tufted perennial grass species such as *H. contortus* (60.31%), *T. triandra* (65.15%) and *P. maximum* (61.24%) had a low total percentage decrease in biomass after defoliation compared to smaller tufted perennials, such as *B. nigropedata* (69.95%) and *D. eriantha* (69.53%).

Different grass species can react differently to defoliation in different seasons. Grass species with different growth forms such as *P. maximum* and *S. pappophoroides* had a similar response to decrease in biomass availability in summer. Seasons played a vital role in biomass availability and how grasses react to defoliation. The frequency and intensity of defoliation also played a role on regrowth (Tainton, 1999). According to Tainton (1999), lenient and frequent defoliation provide higher biomass over season. Differences were encountered between species in their reaction to defoliation. Studies done by Wolfson (2013) as well as Robinson and Jordaan (2000) in Towoomba ADC agrees with findings from this study, that annual grasses and weak perennials generally had higher decreases in biomass compared to strong tufted perennial grasses, which had a major impact on the availability of biomass of annuals during autumn and winter.

During summer, autumn and spring, biomass production was high. The highest biomass was produced by *P. maximum* in autumn, followed by *T. triandra* in autumn, *P. maximum* in summer, *P. maximum* in spring, *H. contortus* in autumn, *D. eriantha* in autumn and *B. nigropedata* also in autumn. Both *D. eriantha B. nigropedata* were widely available grass species with high species composition and consequently, higher biomass production in terms of production ha^{-1}, although it is known for a medium to low production $tuft^{-1}$ (Van Oudtshoorn, 2012). The higher the species composition often resulted in more biomass produced, which equates higher available biomass for cattle.

4.2.4 Key grass species in the diet of cattle in the Pietersburg Plateau Bushveld.

Important grass species are identified by their composition/occurrence and a high frequency of utilization, while palatability relates to traits of the grass itself which determine the absolute attractiveness thereof to the animal (Mentis, 1981), and is measured by determining the preference of the animal (Theron and Booysen, 1966). Important grass species comprise large proportion of animal's intake, irrespective of preference or palatability. Therefore, important grass species are determined by circumstance (Meissner *et al.*, 2013). The causes for differences in palatability amongst grasses are not clearly understood yet, although numerous attempts have been made in the past to relate palatability differences to several plant traits (Theron and Booysen, 1966; Mentis, 1981; Van Rooyen and Bothma, 2016).

Their palatability index, their importance in the diet of the relevant ruminant, growth form, perenniality and productivity are factors that are considered in the determination of the grazing value of grass species (Van Rooyen and Bothma, 2016). The grazing value of grasses that are present in the veld is normally evaluated through a veld condition index to indicate the health or condition of the veld.

In this study, the term "key species" are used to describe the grass species that is important and highly palatable for cattle and are considered the species on which veld management in the specific veld type should be based. To determine which species are key species in the diet of cattle in the Pietersburg Plateau Bushveld, grass species were ranked, based on data obtained in this study, namely frequency and intensity of utilization, their palatability index and biomass production. Since there were 23 species at the experimental site, each species was allocated a score out of 23 for each of the mentioned factors. The result is presented in Table 4.10.

In the past, the main attention was given to the maintenance of highly palatable species under grazing conditions [i.e. *B. nigropedata* and *D. eriantha* in the Mixed and Sourish-

Mixed Bushveld (Low, 1975) and *T. triandra* in the different veld types of the Free State, KwaZulu-Natal and Mpumalanga Highveld (Dannhauser and Jordaan, 2015)], while the role of species that are slightly less palatable were overlooked. However, in this study, two main arguments arose.

1. The chemical composition of veld grasses is determined by environmental factors such as climate, soil type, and growth stage, thus, chemical composition vary within species as determined by multitude of external factors. In the Sourish Mixed Bushveld, Jordaan (1991) indicated that *Panicum maximum* had a lower high crude protein and *in vitro* digestibility, compared to *D. eriantha* and *B. nigropedata,* which indicates the latter two as "better" in terms of palatability. However, in this study, which was done in a closely related veld type, *P. maximum* produced higher and was utilized at higher intensities than *D. eriantha* and *B. nigropedata,* and, according to Table 4.10, scored the best of all grasses in this study. The question can thus be asked if more attention should not be given to the maintenance of grasses with a higher biomass production but a slightly lower chemical composition, instead of focussing on palatable species (high chemical composition) only.
2. Most of the highly palatable and palatable grass species identified in this study, except *T. triandra*, which is generally regarded as a Decreaser species, are Increaser II species [Tainton (1980); Vorster (1982); Mentis (1983); Smit 1988)]. Based on research by Lüdemann *et al*., (1988) in the Mopani veld, Lüdemann (1990) in the Arid Sweet Bushveld, Jordaan (1991) in the Sourish Mixed Bushveld of Limpopo Province and this study in the Pietersburg Plateau Bushveld, it thus appears as if slightly degraded veld is more advantageous to livestock in veld types of the Limpopo Bushveld, while ecologically stable veld is the better in other veld types, especially sourveld.

Table 4.10 Proposed key grass species at the Pietersburg Plateau Bushveld.

Grass species	Frequency of utilization	Score	Intensity of utilization	Score	Palatability index	Score	Biomass production	Score	Total score
Panicum maximum	18.00	18	45.02	17	243.62	18	1560.66	22	75
Brachiaria nigropedata	19.96	19	50.70	18	264.25	19	751.75	18	74
Digitaria eriantha	16.35	17	41.88	16	218.94	16	945.27	19	68
Themeda triandra	13.63	16	39.8	15	181.49	15	1340.36	21	67
Heteropogon contortus	13.34	15	34.35	14	176.47	13	1104.58	20	62
Schmidtia pappophoroides	13.05	14	30.49	12	180.08	14	681.295	17	57
Urochloa mosambicensis	12.88	13	32.50	13	228.33	17	428.47	13	56
Eragrostis rigidior	6.05	12	13.50	10	81.67	10	458.51	15	47
Melenis repens	4.86	10	10.41	9	66.03	9	456.46	14	42
Cynodon dactylon	5.43	11	15.63	11	143.06	12	152.00	6	40
Eragrostis superba	2.43	7	2.91	7	22.48	7	482.99	16	37
Eragrostis lehmanniana	3.60	9	2.91	7	47.32	8	399.54	12	36
Hyparrhenia hirta	2.72	8	9.22	8	141.18	11	0.00	1	28
Microchloa caffra	1.22	5	1.20	5	15.38	6	158.50	7	23
Trichoneura grandiglumis	1.81	6	0.35	2	11.11	4	242.50	10	22
Aristida spp	0.31	3	1.39	6	4.17	2	240.57	9	20
Sporobolus festivus	0.40	4	1.17	4	10.42	3	172.00	8	19
Pogonarthria squarrosa	0.00	1	0.00	1	0.00	1	273.13	11	14
Eragrostis gummiflua	0.27	2	1.00	3	13.64	5	48.00	3	13
Panicum natalense	0.00	1	0.00	1	0.00	1	118.50	5	8
Elionurus muticus	0.00	1	0.00	1	0.00	1	96.00	4	7
Eragrostis viscosa	0.00	1	0.00	1	0.00	1	25.00	2	5
Eragrostis racemosa	0.00	1	0.00	1	0.00	1	0.00	1	4

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Digitaria eriantha, *B. nigropedata, T. triandra*, *S. pappophoroides*, *H. contortus, P. maximum* and *U. mosambicensis* were the most important grasses in the diet selected by cattle during autumn and winter seasons. They were utilized at high intensities and frequencies. They had high percentage species composition and biomass production, which indicates that they contributed significantly to the diet selected by cattle during autumn and winter. During spring, *B. nigropedata, D. eriantha, T. triandra, S. pappophoroides, H. contortus and P. maximum, together with M. repens* and *H. hirta,* were the most important grasses selected by cattle. These grasses were utilized at high intensities and frequencies, they had high species composition and biomass production. During this season grass leaves were young and palatable, hence less palatable grass species such as *H. hirta* formed part of grasses selected by cattle. *B. nigropedata, D. eriantha, T. triandra, S. pappophoroides, H. contortus, P. maximum* and *U. mosambicensis* were the most important grasses selected by cattle during summer season, together with *E. rigidior* and *C. dactylon*. They were utilized at higher intensities and frequencies. They were dominant grass species and contributed significantly to diet selected by cattle. *Digitaria eriantha*, *B. nigropedata, T. triandra*, *S. pappophoroides*, *H. contortus* and *P. maximum* were regarded as palatable throughout all four seasons.

Tuft circumferences of unpalatable, weak perennial grasses such as *Aristida spp* and *T. grandiglumis* decreased after one season. *Themeda triandra* required more one season of utilization for their tuft circumference to decrease significantly. Decreases in tuft height of palatable grasses were mainly due to utilization, while annuals deceased in height, mainly due to die-off in autumn. Although *T. triandra, S. pappophoroides* and *H. contortus* had tough stems during autumn and winter, that did not prove to affect their utilization during those seasons.

Grasses with low biomass production included mostly annuals such as *Aristida* spp*, P. squarrosa* and *T. grandiglumis,* while *S. pappophoroides, D. eriantha, B. nigropedata* and *U. mosambicensis* were medium producers*. A* high occurrence of

D. eriantha increased, whereas a low occurrence of *U. mosambicensis* decreased its biomass production. High producers such as *H. contortus, P. maximum* and *T. triandra* had high occurrences, which added to their biomass production.

Based on different traits that were monitored in this study, *P. maximum*, *B. nigropedata*, *D. eriantha*, *T. triandra*, *H. contortus* and *S. pappophoroides,* were identified as key grass species in the Pietersburg Plateau Bushveld. They had high intensity and frequency of utilization, high palatability indices and high biomass production.

5.2 Recommendations

Grazing management in the Pietersburg Plateau Bushveld should be based on the key species that were identified in this study. The maintenance and improvement of these and other perennial grass species is important, keeping in mind that biomass production is just as important in the diet of cattle as palatability. From results of this study, iit appears as if ecologically stable veld is not necessarily the best for maintaining animal production in the Limpopo Bushveld.

The information obtained from this study can be used to improve grazing management of this veld type. Knowledge of diet selection of cattle is also essential for designing effective grazing systems and formulating economical supplementation programs.

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APPENDIX A

Table A1 T-test results for differences in tuft circumference of different grasses before and after grazing

Season	Species	Difference	t (Observed value)	|t| (Critical value)	DF	p-value (Two-tailed)	Significance
Autumn	*Aristida spp*	-4.571	-3.388	2.16	13	0.005	**
	Brachiaria nigropedata	-0.167	-0.21	2.069	23	0.836	NS
	Digitaria eriantha	0.25	0.914	1.972	203	0.362	NS
	Eragrostis lehmanniana	-2.667	-2.219	2.571	5	0.077	NS
	Eragrostis rigidior	-2.351	-4.218	1.993	73	<0.0001	**
	Eragrostis superba	-4.714	-2.174	2.447	6	0.073	NS
	Heteropogon contortus	-1.519	-1.61	2.006	53	0.113	NS
	Melenis repens	-2.667	-2.765	2.145	14	0.015	*
	Panicum maximum	1.483	0.808	2.048	28	0.426	NS
	Pogonarthria squarrosa	-2	-1.309	4.303	2	0.321	NS
	Schmidtia pappophoroides	-1.907	-2.886	2.006	53	0.006	**
	Themeda triandra	-5.333	-2.044	2.306	8	0.075	NS
	Trichoneura grandiglumis	-3.333	-5	4.303	2	0.038	*
	Urochloa mosambicensis	-0.75	-0.878	3.182	3	0.444	NS
Winter	*Aristida spp*	0	0	2.042	30	1	NS
	Brachiaria nigropedata	3.828	3.466	2.048	28	0.002	**
	Cynodon dactylon	1.556	1.406	2.306	8	0.198	NS
	Digitaria eriantha	2.623	8.064	1.979	129	<0.0001	**
	Elionurus muticus	0	0	2.08	21	1	NS
	Eragrostis lehmanniana	0	0	12.706	1	1	NS
	Eragrostis rigidior	0.773	2.39	2.017	43	0.021	*
	Eragrostis superba	2.471	1.763	2.12	16	0.097	NS
	Heteropogon contortus	3.762	4.5	2.02	41	<0.0001	**

	Melenis repens	0.583	1.865	2.201	11	0.089	NS
	Panicum maximum	6	5.028	2.069	23	<0.0001	**
	Pogonarthria squarrosa	0	0	3.182	3	1	NS
	Sporobolus festivus	0.292	1.159	2.069	23	0.258	NS
	Schmidtia pappophoroides	3.444	4.372	2.015	44	<0.0001	**
	Themeda triandra	2.875	3.962	2.004	55	0	**
	Trichoneura grandiglumis	0	0	4.303	2	1	NS
	Urochloa mosambicensis	1.8	1.616	2.776	4	0.181	NS
Spring	*Aristida spp*	-0.083	-1	2.201	11	0.339	NS
	Brachiaria nigropedata	1.042	2.225	2.069	23	0.036	*
	Digitaria eriantha	1.928	8.135	1.97	234	<0.0001	**
	Eragrostis lehmanniana	0.5	1.732	3.182	3	0.182	NS
	Eragrostis rigidior	0.465	0.921	2.018	42	1.362	NS
	Eragrostis superba	0	0	2.571	5	1	NS
	Heteropogon contortus	2.745	4.503	2.009	50	<0.0001	**
	Hyparrhenia hirta	0.824	1.304	2.12	16	0.211	NS
	Melenis repens	0.294	0.472	2.12	16	0.643	NS
	Microchloa caffra	-0.154	-0.1	2.179	12	0.337	NS
	Panicum maximum	8.394	6.103	2.037	32	<0.0001	**
	Pogonarthria squarrosa	1.167	0.729	2.571	5	0.499	NS
	Schmidtia pappophoroides	1.429	2.366	2.086	20	0.028	NS
	Themeda triandra	1.059	1.492	2.12	16	0.155	NS
Summer	*Aristida spp*	0	0	2.131	15	1	NS
	Brachiaria nigropedata	2.091	2.642	2.228	10	0.025	*
	Cynodon dactylon	2.167	1.817	2.201	11	0.097	NS
	Digitaria eriantha	3.5	9.219	1.982	111	<0.0001	**
	Elionurus muticus	0	0	2.228	10	1	NS
	Eragrostis gummiflua	0.897	1.633	2.048	28	0.114	NS
	Eragrostis lehmanniana	1.143	1	2.447	6	0.356	NS
	Eragrostis rigidior	1.019	4.066	1.983	106	<0.0001	**

Eragrostis superba	-0.222	-1	2.306	8	0.347	NS
Eragrostis viscosa	-1.5	-1	12.706	1	0.5	NS
Heteropogon contortus	1.938	3.19	2.04	31	0.003	*
Melenis repens	-0.714	-1.987	2.447	6	0.094	NS
Microchloa caffra	0	0	3.182	3	1	NS
Panicum maximum	5.585	3.038	2.179	12	0.01	*
Panicum natalense	0	0	4.303	2	1	NS
Pogonarthria squarrosa	-0.571	-2.104	2.16	13	0.055	NS
Sporobolus festivus	0	0	4.303	2	1	NS
Schmidtia pappophoroides	3.063	3.006	2.04	31	0.005	**
Themeda triandra	2.292	6.154	1.994	71	<0.0001	**
Urochloa mosambicensis	0.5	0.243	3.182	3	0.824	NS

NS = Not significant, * = Significant at P < 0.05, ** = Highly significant at P < 0.01

Table A2 T-test results for differences in height of utilizable leaves of different grass species before and after grazing

Season	Species	Difference	t (Observed value)	t (Critical value)	DF	p-value (Two-tailed)	Significance
Autumn	*Aristida spp*	-5.385	-2.344	2.179	12	0.037	*
	Brachiaria nigropedata	6.792	6.536	2.069	23	<0.0001	**
	Digitaria eriantha	5.417	14.098	1.972	203	<0.0001	**
	Eragrostis lehmanniana	-3.333	-2.076	2.571	5	0.093	NS
	Eragrostis rigidior	-1.514	1.61	1.993	73	0.112	NS
	Eragrostis superba	-3.857	-5.473	2.447	6	0.002	*
	Heteropogon contortus	3.481	3.337	2.006	53	0.002	*
	Melenis repens	1.333	0.607	2.145	14	0.554	NS
	Panicum maximum	14.655	5.244	2.048	28	<0.0001	**
	Pogonarthria squarrosa	-0.667	-2	4.303	2	0.184	NS
	Schmidtia pappophoroides	5.204	4.99	2.006	53	<0.0001	**
	Themeda triandra	5.111	3.318	2.306	8	0.011	*
	Trichoneura grandiglumis	0.333	0.1	4.303	2	0.929	NS
	Urochloa mosambicensis	4.5	1.521	3.182	3	0.226	NS
Winter	*Aristida spp*	0	0	2.042	30	1	NS
	Brachiaria nigropedata	2.621	4.143	2.048	28	0	**
	Cynodon dactylon	4.444	1.955	2.306	8	0.086	NS
	Digitaria eriantha	2.885	8.734	1.979	129	<0.0001	**
	Elionurus muticus	0	0	2.08	21	1	NS
	Eragrostis lehmanniana	0	0	12.706	1	1	NS
	Eragrostis rigidior	1.886	2.676	2.017	43	0.011	*
	Eragrostis superba	1.059	1.965	2.12	16	0.067	NS
	Heteropogon contortus	4.31	5.817	2.02	41	<0.0001	**
	Melenis repens	1.417	1.689	2.201	11	0.119	NS
	Panicum maximum	13.25	7.361	2.069	23	<0.0001	**

	Pogonarthria squarrosa	0	0	3.182	3	1	NS
	Sporobolus festivus	0.25	1.446	2.069	23	0.162	NS
	Schmidtia pappophoroides	3.956	5.241	2.015	44	<0.0001	**
	Themeda triandra	4.661	5.066	2.004	55	<0.0001	**
	Trichoneura grandiglumis	0	0	4.303	2	1	NS
	Urochloa mosambicensis	4.8	1.596	2.776	4	0.186	NS
Spring	*Aristida spp*	-0.333	-0.938	2.201	11	0.368	NS
	Brachiaria nigropedata	2.292	2.924	2.069	23	0.008	**
	Digitaria eriantha	2.272	8.444	1.97	234	<0.0001	**
	Eragrostis lehmanniana	0.5	0.302	3.182	3	0.783	NS
	Eragrostis rigidior	2.047	2.029	2.018	42	0.049	*
	Eragrostis superba	-0.167	-1	2.571	5	0.363	NS
	Heteropogon contortus	1.804	2.49	2.009	50	0.016	*
	Hyparrhenia hirta	2.588	2.959	2.12	16	0.009	**
	Melenis repens	0.235	0.336	2.12	16	0.741	NS
	Microchloa caffra	-1.154	-2.645	2.179	12	0.021	*
	Panicum maximum	10.97	6.252	2.037	32	<0.0001	**
	Pogonarthria squarrosa	-1.5	-1.567	2.571	5	0.178	NS
	Schmidtia pappophoroides	2.905	2.318	2.086	20	0.031	**
	Themeda triandra	2.412	2.485	2.12	16	0.024	*
Summer	*Aristida spp*	-3.313	-4.908	2.131	15	0	**
	Brachiaria nigropedata	2.364	1.248	2.228	10	0.24	NS
	Cynodon dactylon	8.167	3.013	2.201	11	0.012	*
	Digitaria eriantha	2.438	3.843	1.982	111	0	**
	Elionurus muticus	-4.636	-6.84	2.228	10	<0.0001	**
	Eragrostis gummiflua	-2.414	-2.979	2.048	28	0.006	NS
	Eragrostis lehmanniana	-4.286	-2369	2.447	6	0.056	*
	Eragrostis rigidior	-2.215	-4.487	1.983	106	<0.0001	**
	Eragrostis superba	-4.889	-4.794	2.306	8	0.001	**
	Eragrostis viscosa	-6	-2	12.706	1	0.295	NS

Heteropogon contortus	0.188	0.186	2.04	31	0.013	*
Melenis repens	-7.286	-7.336	2.447	6	0	**
Microchloa caffra	-3.75	-2.611	3.182	3	0.08	NS
Panicum maximum	5.538	2.07	2.179	12	0.061	NS
Panicum natalense	-5	-8.66	4.303	2	0.013	*
Pogonarthria squarrosa	-5.071	-6.327	2.16	13	<0.0001	**
Sporobolus festivus	-4.667	-5.292	4.303	2	0.034	*
Schmidtia pappophoroides	0.438	0.292	2.04	31	0.773	NS
Themeda triandra	2.681	3.434	1.994	71	0.001	**
Urochloa mosambicensis	-2.25	-1.094	3.182	3	0.354	NS

NS = Not significant, * = Significant at $P < 0.05$, ** = Highly significant at $P < 0.01$

Table A3 T-test results for differences in height of the highest leaves of different grass species before and after grazing

Season	Species	Difference	t (Observed value)	t (Critical value)	DF	p-value (Two-tailed)	Significance
Autumn	*Aristida spp*	-8.643	-4.035	2.16	13	0.001	**
	Brachiaria nigropedata	20.333	6.905	2.069	23	<0.0001	**
	Digitaria eriantha	14.863	16.709	1.972	203	<0.0001	**
	Eragrostis lehmanniana	-1.5	-0.921	2.571	5	0.399	NS
	Eragrostis rigidior	-1.5	-1.078	1.993	73	0.284	NS
	Eragrostis superba	-7.286	-1.198	2.447	6	0.276	NS
	Heteropogon contortus	8.315	3.76	2.006	53	0	**
	Melenis repens	4.533	1.085	2.145	14	0.296	NS
	Panicum maximum	17.931	4.841	2.048	28	<0.0001	**
	Pogonarthria squarrosa	-4.667	-3.883	4.303	2	0.06	NS
	Schmidtia pappophoroides	9.704	5.648	2.006	53	<0.0001	**
	Themeda triandra	4.778	0.792	2.306	8	0.451	NS
	Trichoneura grandiglumis	-1.333	-0.319	4.303	2	0.78	NS
	Urochloa mosambicensis	6.5	2.566	3.182	3	0.083	NS
Winter	*Aristida spp*	0	0	2.042	30	1	NS
	Brachiaria nigropedata	15	6.122	2.048	28	<0.0001	**
	Cynodon dactylon	4.444	1.955	2.306	8	0.086	NS
	Digitaria eriantha	11	11.602	1.979	129	<0.0001	**
	Elionurus muticus	0	0	2.08	21	1	NS
	Eragrostis lehmanniana	0	0	12.706	1	1	NS
	Eragrostis rigidior	3.750	3.078	2.017	43	0.004	**
	Eragrostis superba	3.588	2.097	2.12	16	0.052	NS
	Heteropogon contortus	14.738	6.115	2.02	41	<0.0001	**
	Melenis repens	6.167	1.788	2.201	11	0.101	NS
	Panicum maximum	26.48	7.845	2.064	23	<0.0001	**

	Pogonarthria squarrosa	0	0	3.182	3	1	NS
	Sporobolus festivus	1.542	1.419	2.069	23	0.169	NS
	Schmidtia pappophoroides	14.978	8.508	2.015	44	<0.0001	**
	Themeda triandra	12.482	6.191	2.004	55	<0.0001	**
	Trichoneura grandiglumis	0	0	4.303	2	1	NS
	Urochloa mosambicensis	10.6	2.447	2.776	4	0.071	NS
Spring	*Aristida spp*	-0.417	-0.334	2.201	11	0.744	NS
	Brachiaria nigropedata	10.75	6.725	2.069	23	<0.0001	**
	Digitaria eriantha	11.213	17.997	1.97	234	<0.0001	**
	Eragrostis lehmanniana	5.25	1.219	3.182	3	0.31	NS
	Eragrostis rigidior	7.326	3.921	2.018	42	0	**
	Eragrostis superba	-1	-1.936	2.571	5	0.111	NS
	Heteropogon contortus	7.725	5.322	2.009	50	<0.0001	**
	Hyparrhenia hirta	11.765	3.498	2.12	16	0.003	**
	Melenis repens	8.059	1.993	2.12	16	0.064	NS
	Microchloa caffra	1.706	0	2.179	12	1	NS
	Panicum maximum	26.97	10.584	2.037	32	<0.0001	**
	Pogonarthria squarrosa	-2.333	-2.445	2.571	5	0.058	NS
	Schmidtia pappophoroides	10.381	4.364	2.086	20	0	**
	Themeda triandra	11.765	3.839	2.12	16	0.001	**
Summer	*Aristida spp*	-3.188	-4.291	2.131	15	0.001	**
	Brachiaria nigropedata	16.455	4.807	2.228	10	0.001	**
	Cynodon dactylon	9.167	2.201	2.201	11	0.008	**
	Digitaria eriantha	13.875	10.787	1.982	111	<0.0001	**
	Elionurus muticus	-4.636	-3.963	2.228	10	0.003	**
	Eragrostis gummiflua	2.862	1.559	2.048	28	0.130	NS
	Eragrostis lehmanniana	-2.714	-1.020	2.447	6	0.0347	NS
	Eragrostis rigidior	1.327	1.216	1.983	106	0.227	NS
	Eragrostis superba	-2.333	-3.742	2.306	8	0.006	**

Eragrostis viscosa	-3	-1.500	12.706	1	0.374	NS
Heteropogon contortus	8.063	3.882	2.040	31	0.001	**
Melenis repens	-5	-2.546	2.447	6	0.044	*
Microchloa caffra	-2.250	-1.567	3.182	3	0.215	NS
Panicum maximum	17.385	4.220	2.179	12	0.001	**
Panicum natalense	-1.667	-5.000	4.303	2	0.038	*
Pogonarthria squarrosa	-3.571	-3.890	2.160	13	0.002	**
Sporobolus festivus	-4.667	-5.292	4.303	2	0.034	*
Schmidtia pappophoroides	6.156	2.303	2.040	31	0.028	*
Themeda triandra	10.375	7.060	1.994	71	<0.0001	**
Urochloa mosambicensis	4.500	1.877	3.182	3	0.157	NS

NS = Not significant, * = Significant at P < 0.05, ** = Highly significant at P < 0.01

Table A4 T-test analyses for differences in biomass availability within different grasses before and after defoliation

Season	Species	Difference	t (Observed value)	t (Critical value)	DF	p-value (Two-tailed)	Significance
Autumn	*Aristida spp*	12.714	7.462	2.447	6	0.000	**
	Brachiaria nigropedata	26.375	14.305	2.365	7	<0.0001	**
	Digitaria eriantha	27.147	11.087	2.120	16	<0.0001	**
	Eragrostis lehmanniana	16	3.301	3.182	3	0.046	*
	Eragrostis rigidior	19.625	9.281	2.365	7	<0.0001	**
	Eragrostis superba	15.800	5.352	2.776	4	0.006	**
	Forbs	16.625	7.423	3.182	3	0.005	**
	Heteropogon contortus	35.147	9.990	2.120	16	<0.0001	**
	Microchloa caffra	16	3.619	4.303	2	0.120	NS
	Melenis repens	18.214	6.213	2.447	6	0.001	**
	Panicum maximum	62.400	5.575	2.776	4	0.005	**
	Pogonarthria squarrosa	13.875	5.238	3.182	3	0.014	*
	Sporobolus festivus	8.333	6.934	4.303	2	0.020	*
	Schmidtia pappophoroides	23.591	6.726	2.228	10	<0.0001	**
	Themeda triandra	44	12.616	2.228	10	<0.0001	**
	Trichoneura grandiglumis	12.500	5.000	4.303	2	0.038	*
	Urochloa mosambicensis	19.700	4.166	2.776	4	0.014	*
Winter	*Aristida spp*	16	7.897	2.228	10	<0.0001	**
	Brachiaria nigropedata	26.875	3.273	3.182	3	0.047	*
	Digitaria eriantha	41.316	9.659	2.101	18	<0.0001	**
	Eragrostis lehmanniana	21.500	7.418	2.776	4	0.002	**
	Elionurus muticus	14	6.184	2.776	4	0.003	**
	Eragrostis rigidior	23.389	6.198	2.306	8	0.000	**
	Eragrostis superba	24.667	3.642	4.303	2	0.068	NS
	Forbs	6.667	7.258	2.571	5	0.001	**

	Heteropogon contortus	41.583	8.265	2.262	9	<0.0001	**
	Melenis repens	24.850	8.265	2.262	9	<0.0001	**
	Panicum maximum	60	5.813	3.182	3	0.010	*
	Panicum natalense	12	6.000	4.303	2	0.027	*
	Pogonarthria squarrosa	18.500	7.210	4.303	2	0.019	*
	Sporobolus festivus	34.538	7.414	2.179	12	<0.0001	**
	Themeda triandra	57.250	6.117	3.182	3	0.009	**
	Urochloa mosambicensis	23.667	4.914	2.571	5	0.104	NS
Spring	*Aristida spp*	15.900	4.905	2.776	4	0.008	**
	Brachiaria nigropedata	23.333	3.826	2.571	5	0.012	*
	Digitaria eriantha	24.711	9.611	2.101	18	<0.0001	**
	Eragrostis gummiflua	10.500	3.000	12.706	1	0.205	NS
	Eragrostis lehmanniana	10.750	8.600	12.706	1	0.074	NS
	Elionurus muticus	8.667	13.000	4.303	2	0.006	**
	Eragrostis rigidior	16.250	9.705	2.365	7	<0.0001	**
	Eragrostis superba	13.500	3.995	3.182	3	0.028	*
	Eragrostis viscosa	11	3.667	12.706	1	0.170	NS
	Forbs	9.500	3.212	3.182	3	0.049	*
	Heteropogon contortus	38.500	9.795	2.571	5	0.000	**
	Melenis repens	18.583	6.680	2.571	5	0.001	**
	Panicum maximum	37.143	9.119	2.447	6	<0.0001	**
	Panicum natalense	13.000	4.333	12.706	1	0.144	NS
	Pogonarthria squarrosa	11.400	8.359	2.776	4	0.001	**
	Sporobolus festivus	12.750	10.200	12.706	1	0.062	NS
	Schmidtia pappophoroides	18.889	13.385	2.306	8	<0.0001	**
	Trichoneura grandiglumis	9.000	9.000	12.706	1	0.070	NS
	Themeda triandra	41.889	15.001	2.306	8	<0.0001	**
	Urochloa mosambicensis	15.642	4.842	2.447	6	0.003	**
Summer	*Aristida spp*	8.450	5.301	2.262	9	0.000	**
	Brachiaria nigropedata	20.444	7.217	2.306	8	<0.0001	**

Digitaria eriantha	25.333	13.876	2.110	17	<0.0001	**
Eragrostis lehmanniana	7.167	5.054	2.571	5	0.004	**
Eragrostis rigidior	9.679	5.620	2.160	13	<0.0001	**
Eragrostis superba	11.100	4.740	2.776	4	0.009	**
Forbs	20.611	6.295	3.306	8	0.000	**
Heteropogon contortus	27.464	9.804	2.160	13	<0.0001	**
Microchloa caffra	6.667	5.547	4.303	2	0.031	*
Melenis repens	11.136	5.373	2.228	10	0.000	**
Panicum maximum	40.583	10.870	2.571	5	0.000	**
Panicum natalense	9.833	3.584	4.303	2	0.070	NS
Pogonarthria squarrosa	7.900	7.861	2.776	4	0.001	**
Sporobolus festivus	7.100	15.493	2.776	4	0.000	**
Schmidtia pappophoroides	14.727	7.636	2.228	10	<0.0001	**
Trichoneura grandiglumis	8.250	4.714	12.706	1	0.133	NS
Themeda triandra	29.357	7.850	2.447	6	0.000	**
Urochloa mosambicensis	9.857	4.258	2.447	6	0.005	**

NS = Not significant, * = Significant at P < 0.05, ** = Highly significant at P < 0.01

Table A5 Summarized LSD analysis for differences in biomass availability between different grasses before and after defoliation

Species	Mean							
	Summer		Autumn		Winter		Spring	
Aristida spp	9.60	cdefg	12.90	d	17.71	de	15.21	ab
Brachiaria nigropedata	35.90	abc	25.31	bcd	26.55	abcde	22.90	ab
Digitaria eriantha	79.37	a	27.11	bcd	40.89	abc	22.88	ab
Eragrostis gummiflua							17.44	ab
Eragrostis lehmanniana	8.63	defg	15.79	cd	22.11	bcde	8.47	ab
Elionurus muticus					13.95	de	16.68	ab
Eragrostis rigidior	24.64	abcde	19.31	cd	22.69	cde	23.49	ab
Eragrostis superba	10.73	bcdefg	15.97	cd	22.53	abcde	22.65	ab
Eragrostis viscosa							17.91	ab
Forbs	15.97	bcdef	19.49	bcd	2.60	e	12.75	ab
Heteropogon contortus	66.23	a	35.44	bc	42.85	abc	28.88	ab
Microchloa caffra	2.67	g	14.79	cd				
Melenis repens	17.23	bcdef	17.46	cd	26.29	bcde	17.78	ab
Panicum maximum	40.23	ab	63.51	a	59.49	a	31.03	ab
Panicum natalense	5.03	fg			10.98	cde	11.05	ab
Pogonarthria squarrosa	5.67	fg	14.28	cd	20.89	abcde	13.85	ab
Sporobolus festivus	6.37	efg	9.79	cd	22.50	abcde	9.29	b
Schmidtia pappophoroides	26.77	abcd	23.31	cd	35.92	abcd	17.35	ab
Trichoneura grandiglumis	2.50	g						
Themeda triandra	39.50	ab	43.54	ab	56.74	ab	38.49	a
Urochloa mosambicensis	11.53	bcdefg	19.61	bcd	24.35	bcde	18.34	ab

*Corresponding letters indicate non-significant differences.

Table A6 One-way ANOVA of biomass differences between species during summer

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+Plot	4	1141.4	312.4	2.69	0.041
+Species	**225.77**	**17**	**13.28**	**250.0**	**<0.001**
Residual	99	11854.8	119.7		
Total	118	29562.8	258.3		

Table A7 descriptive statistics for the summer season

Species	No observed	Mean	s.d.
Aristida spp	15	9.60	9.87
Brachiaria nigropedata	15	35.90	24.05
Digitaria eriantha	15	79.37	44.01
Eragrostis lehmanniana	15	8.63	9.20
Eragrostis rigidior	15	24.64	13.09
Eragrostis superba	15	10.73	9.41
Forbs	15	15.97	20.05
Heteropogon contortus	15	66.23	36.38
Melenis repens	15	17.23	18.89
Microchloa caffra	15	2.67	6.23
Panicum maximum	15	40.23	28.16
Panicum natalense	15	5.03	8.41
Pogonarthria squarrosa	15	5.67	4.03
Schmidtia pappophoroides	15	26.77	17.94
Sporobolus festivus	15	6.37	8.32
Themeda triandra	15	39.50	33.73
Trichoneura grandiglumis	15	2.50	4.40
Urochloa mosambicensis	15	11.53	10.61

Table A8 Predictions from the regression model during summer season

Species	Prediction	se
Aristida spp	15.21	4.151
Brachiaria nigropedata	22.90	3.931
Digitaria eriantha	22.88	2.685
Eragrostis lehmanniana	8.47	5.561
Eragrostis rigidior	16.68	3.904
Eragrostis superba	23.49	5.033
Forbs	22.65	5.694
Heteropogon contortus	17.91	2.693
Melenis repens	12.75	6.381
Microchloa caffra	28.88	4.156
Panicum maximum	17.78	4.940
Panicum natalense	31.03	5.694
Pogonarthria squarrosa	11.05	6.671
Schmidtia pappophoroides	13.85	3.308
Sporobolus festivus	9.29	3.374
Themeda triandra	17.35	4.943
Trichoneura grandiglumis	38.49	3.301
Urochloa mosambicensis	18.34	3.619

Table A9 One-way ANOVA of biomass differences between species during autumn

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Plot	4	1241.4	310.4	2.59	0.041
+ Species	**15**	**16266.6**	**1084.4**	**9.06**	**<.001**
Residual	99	11854.8	119.7		
Total	118	29362.8	248.8		

Table A10 Summary of descriptive statistics during autumn

Species	No observed	Mean	s.d
Aristida spp	7	12.71	4.508
Brachiaria nigropedata	8	26.38	5.215
Digitaria eriantha	17	27.15	10.096
Eragrostis lehmanniana	4	16.00	9.695
Eragrostis rigidior	8	19.62	5.981
Eragrostis superba	5	15.80	6.601
Forbs	4	16.62	4.479
Heteropogon contortus	17	35.15	14.506
Microchloa caffra	3	16.00	10.583
Melenis repens	7	18.21	7.756
Panicum maximum	5	62.40	25.028
Pogonarthria squarrosa	4	13.88	5.297
Sporobolus festivus	3	8.33	2.082
Schmidtia pappophoroides	11	23.59	11.634
Themeda triandra	11	44.00	11.567
Urochloa mosambicensis	5	19.70	10.575

Table A11 Predictions from the regression model during autumn season

Species	Prediction	se
Aristida spp	12.90	4.151
Brachiaria nigropedata	25.31	3.931
Digitaria eriantha	27.11	2.685
Eragrostis lehmanniana	15.79	5.561
Eragrostis rigidior	19.31	3.904
Eragrostis superba	15.97	5.033
Forbs	19.49	5.694
Heteropogon contortus	35.44	2.693
Microchloa caffra	14.79	6.381
Melenis repens	17.46	4.156
Panicum maximum	63.51	4.940
Pogonarthria squarrosa	14.28	5.694
Sporobolus festivus	9.79	6.671
Schmidtia pappophoroides	23.31	3.308
Themeda triandra	43.54	3.374
Urochloa mosambicensis	19.61	4.943

Table A12 One-way ANOVA of biomass differences between species during winter

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Plot	4	3419.0	854.7	5.23	<.001
+ Species	**16**	**20926.9**	**1307.9**	**8.00**	**<.001**
Residual	96	15687.3	163.4		
Total	116	40033.2	345.1		

Table A13 Predictions from the regression model during winter

Species	Prediction	se
Aristida spp	17.71	3.876
Brachiaria nigropedata	26.55	6.418
Digitaria eriantha	40.89	2.947
Eragrostis lehmanniana	22.11	5.768
Elionurus muticus	13.95	5.717
Eragrostis rigidior	22.69	4.310
Eragrostis superba	22.53	7.451
Forbs	2.60	5.320
Heteropogon contortus	42.85	3.724
Melenis repens	26.29	4.059
Panicum maximum	59.49	6.424
Panicum natalense	10.98	7.449
Pogonarthria squarrosa	20.89	7.449
Sporobolus festivus	22.50	9.153
Schmidtia pappophoroides	35.92	3.874
Themeda triandra	56.74	6.424
Urochloa mosambicensis	24.35	5.236

Table A14 Summary of descriptive statistics during winter

Species	Nobservd	Mean	s.d.
Aristida spp	11	16.00	6.72
Brachiaria nigropedata	4	26.88	16.42
Digitaria eriantha	19	41.32	18.65
Eragrostis lehmanniana	5	21.50	6.48
Elionurus muticus	5	14.00	5.06
Eragrostis rigidior	9	23.39	11.32
Eragrostis superba	3	24.67	11.73
Forbs	6	6.67	2.25
Heteropogon contortus	12	41.58	17.34
Melenis repens	10	24.85	9.51
Panicum maximum	4	60.00	20.64
Panicum natalense	3	12.00	3.46
Pogonarthria squarrosa	3	18.50	4.44
Sporobolus festivus	2	19.75	7.42
Schmidtia pappophoroides	11	37.23	16.77
Themeda triandra	4	57.25	18.72
Urochloa mosambicensis	6	23.67	11.80

Table A15 One-way ANOVA of biomass differences between species during spring

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ Plot	4	766.6	191.7	1.42	0.235
+ Species	**18**	**5742.4**	**319.0**	**2.36**	**0.004**
Residual	87	11772.6	135.3		
Total	109	8281.6	167.7		

Table A16 Predictions from regression model during spring

Species	Prediction	se
Aristida spp	15.21	5.248
Brachiaria nigropedata	22.90	4.845
Digitaria eriantha	22.88	2.686
Eragrostis gummiflua	17.44	8.358
Eragrostis lehmanniana	8.47	8.348
Elionurus muticus	16.68	6.787
Eragrostis rigidior	23.49	4.168
Eragrostis superba	22.65	5.847
Eragrostis viscosa	17.91	8.349
Forbs	12.75	5.844
Heteropogon contortus	28.88	4.808
Melenis repens	17.78	4.803
Panicum maximum	31.03	4.496
Panicum natalense	11.05	8.333
Pogonarthria squarrosa	13.85	5.311
Sporobolus festivus	9.29	5.913
Schmidtia pappophoroides	17.35	3.901
Themeda triandra	38.49	3.912
Urochloa mosambicensis	18.34	4.419

Table A17 Summary of descriptive statistics during spring

Species	Nobservd	Mean	s.d.
Aristida spp	5	14.90	8.849
Brachiaria nigropedata	6	22.67	15.296
Digitaria eriantha	19	22.37	13.735
Eragrostis gummiflua	2	16.00	2.828
Eragrostis lehmanniana	2	10.75	1.768
Elionurus muticus	3	16.67	13.317
Eragrostis rigidior	8	23.12	11.816
Eragrostis superba	4	22.00	18.579
Eragrostis viscosa	2	17.50	4.950
Forbs	4	13.00	5.715
Heteropogon contortus	6	29.67	13.586
Melenis repens	6	19.17	8.116
Panicum maximum	7	30.21	17.647
Panicum natalense	2	13.00	4.243
Pogonarthria squarrosa	5	13.00	7.106
Sporobolus festivus	4	11.12	2.462
Schmidtia pappophoroides	9	17.17	4.950
Themeda triandra	9	38.89	12.101
Urochloa mosambicensis	7	18.36	7.857