INFLUENCE OF FREQUENCY AND INTENSITY OF CLIPPING ON FORAGE YIELD, CRUDE PROTEIN CONTENT AND DIGESTIBILITY OF SIX KENYAN RANGE GRASSES

A Dissertation

by

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Submitted to the Graduate College of
Texas A&M University
in partial fulfillment of the requirement for the degree of

DOCTOR OF PHILOSOPHY

December 1984

Major Subject: Range Science

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December 1984

ABSTRACT

Influence of Frequency and Intensity of Clipping on Forage Yield, Crude Protein Content and Digestibility of Six Kenyan Range Grasses. (December 1984)

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This investigation was conducted at two experimental sites on the National Range Research Station, Kiboko, to evaluate forage yield, leaf-to-stem ratio, crown area, tiller number. regrowth height, forage digestibility, and crude protein content of six native range grasses following defoliation at three frequencies (3. 6, and 9 weeks) with three cutting heights to leave 5-cm, 10-cm, and 15-cm stubble heights.

Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris produced higher forage amounts and tiller number than Chloris roxburghiana, Eragrostis superba, and Themeda triandra. The large number of tillers and leaf area produced by Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris, especially at the 6-week harvest frequency, allowed the three grasses to attain a maximum growth rate at an earlier age and recover soon after defoliation. Defoliation at the 3-week harvest frequency significantly suppressed tillering in all grasses and resulted in significant reductions in forage yield. Furthermore, plants defoliated at the 3-week interval with the 5-cm cutting height produced the lowest forage yield and tiller number.

Forage yield. tiller numbers. regrowth height, and crown area for

the six grasses were highest at the 6-week harvest frequency and lowest at the 3-week harvest frequency. In contrast, leaf-to-stem ratio, crude protein content, and digestibility values were highest at the 3-week harvest frequency and lowest at the 9-week harvest frequency. Crude protein content and digestibility values of the leaf fraction were higher than crude protein content and digestibility values of the stem fraction. Furthermore, crude protein content and digestibility showed a decline for all grasses as the interval between defoliations increased.

Recommendations for further research include studying the responses of grazing animals and native range plants to a grazing plan that utilizes a 42-day defoliation frequency leaving stubble heights of 10 cm to 15 cm, and continuing to explore the impacts of defoliation treatments at various phenological stages on native range plants.

DEDICATION

To Jedidah, Rachel, Woie and Malombe

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CHAPTER I

INTRODUCTION

In the Kenya National Livestock Development Policy published in 1980, it was observed that "despite warnings sounded as far back as 1929 on the overstocking conditions in pastoral areas, no satisfactory solution has been found to this problem yet." It is quite clear from the above statement that grazing management has not received the serious attention it deserves, particularly in the pastoral ranching areas. Prior to the recent land demarcation, consolidation and settlement programs, the majority of the range areas in Kenya were subjected to communal grazing and in some cases overgrazing. Extended periods of overgrazing have lowered the potential of the rangelands in a number of districts and generally have led to reduced protective cover, lowered soil organic matter, decreased infiltration rates, and increased runoff and erosion (Pratt and Gwynne 1977). More often than not native ranges are being subjected to abuse from overgrazing or to systems of grazing that may or may not be beneficial to the grazing animals and to the recovery process or production capacity of various range plants.

At the present time the utilization of grass in Kenya is confined almost entirely to the natural vegetation types and the bulk of the livestock is supported by the natural vegetation of woodland or bushland and the dwarf shrub grassland or bushed grassland types. Perenial grasses such as *Cenchrus ciliaris*, *Chloris roxburghiana*, *Digitaria*

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macroblephara, Eragrostis superba, Panicum maximum. and Themeda triandra can dominate but succumb readily if the range is harshly managed (Pratt et al. 1966). In the bushed grassland and the dwarf-shrub grassland, practically all the grasses present contribute to the forage supply. To a considerable degree the animals are always dependent upon browse derived from small shrubs and bushes (Edwards and Bogdan 1951).

Cenchrus ciliaris L., a perennial grass that forms spreading tufts and sends out stout rhizomes, is widely distributed in Kenya from sea level up to approximately 2000 m. It is one of the important grass constituents of the dwarf-shrub grassland and the bushed grassland over extensive northern and eastern regions. Chloris roxburghiana Schult., a tufted perennial that is widely distributed from sea level to 1200 m altitude, is a palatable native grass that frequently forms the main grazing in dry areas. Digitaria macroblephara (Hack.) Stapf., a perennial that forms tufts and produces rooting runners, grows in dry grassland or scattered bushland from 600 m up to approximately 1400 m altitude, and is frequently abundant or even dominant over considerable areas (Edwards and Bogdan 1951). It is considered among the more palatable species in East Africa because of its high leaf-to-stem ratio (Sinclair and Gwynne 1972). It is the most important grass species at Kiboko in terms of abundance and palatability especially, in the northern half of the station on sandy-clay to clay soils of the basement system plains. Eragrostis superba Peyr. is a tufted perennial with fairly stout and hard stems, but is moderately palatable in spite of its hard stems. Eragrostis superba is distributed from sea level up to 2000 m altitude. Its seeding qualities are good and it is easy to establish from seed (Edwards and Bogdan 1951). It is frequent on sandy-clay and clay soils throughout the Kiboko station. Panicum maximum Jacq., a tufted perennial with rather stout stems, is widely distributed from sea level to 2000 m altitude, chiefly in the wetter rangelands receiving more than 800 mm of rainfall per annum. Panicum maximum is widely distributed in the tropics both in natural vegetation and as a cultivated plant and is considered very valuable for grazing and for cutting as green fodder. It is palatable to cattle, although at the later stages of growth it becomes coarse and is not readily eaten (Edwards and Bogdan 1951). Themeda triandra Forsk., probably the most widely distributed and important grass of East Africa, occurs in all zones except that of the semidesert vegetation and the highest elevations of mountain masses above 3000 m. The grass does not assume importance in Kenya below about 1200 m altitude (Edwards and Bogdan 1951). In all regions where Themeda triandra is dominant under natural conditions, grass fires sweep through the herbage in the dry season. This grass is successful because it appears to be specially adapted to withstand these conditions (Pratt and Gwynne 1977).

Numerous experiments have been conducted to quantify the response of forage plants to defoliation, but the majority of these experiments have generally been carried out in the temperate areas of the world, particularly in the United States (Heady 1975). Since the main use of the grasses selected for study is the production of forage for livestock, an understanding of their responses to defoliation would allow use of vegetation manipulation plans that would benefit them and sustain rangeland productivity. The objectives of this research were (1) to evaluate certain plant growth parameters under various defoliation regimes in which harvesting dates, frequencies of harvest and heights of cutting were varied and (2) to determine the forage production potential and forage quality of six range grasses.

CHAPTER II

LITERATURE REVIEW

Forage Production

The relative persistence and production of range plants when subjected to defoliation at various stages of growth have been studied by imposing various intensities and frequencies of defoliation by clipping. Information from such studies is used to suggest the periods of rest and grazing that would have beneficial effects on plant growth (Heady 1961). Grazing on rangelands is, however, a little different from clipping in that it is more selective and perhaps less severe than clipping. Clipping studies do not consider the animal-associated physical effects such as mineral distribution and soil surface changes due to hoof action. Clipping removes all herbage above a given stubble height from all plants; whereas, grazing removes herbage at heights varying from plant to plant and even within the same plant (White 1973). For example, grazing of Festuca idahoensis by cows in an opening of ponderosa pine in California was not uniform from plant to plant. When the overall utilization of F. idahoensis herbage was 43%, for example, 40% of the plants were grazed to 2.5-cm stubble height, 29% to 5.1 cm, 13% to 7.6 cm, 3% to 10.2 cm and 15% were not grazed at all (Hormay and Talbot 1961).

Responses of plants to defoliation are influenced largely by the intensity and frequency of defoliation and the phenology of the plants at the time of defoliation. Defoliation according to any one of these three factors or any combination of them can cause plant deterioration, no obvious effects or even stimulation, depending upon the level or timing of application (Heady 1975). Singh and Mall (1976) reported that greater herbage was produced when Andropogon pumilus (Roxb.) plants were clipped at a height of 15 cm and at an interval of 45 days as compared to 10-cm and 5-cm stubble heights and 15-day and 30-day intervals. Perry and Chapman (1976) reported that yield and survival of Elymus cinereus were reduced with close and frequent clippings; 6 versus 9-week frequencies and 15-cm versus 30-cm stubble heights. Albertson et al. (1953) and Aldous (1930) obtained higher annual herbage yield from infrequent clipping of Bouteloua gracilis, Buchloe dactyloides, Bouteloua hirsuta, Andropogon furcatus, Andropogon scoparius, Bouteloua curtipendula and Sorghastrum nutans. Perry and Chapman (1975) reported that total seasonal dry matter yields of Elymus cinereus plants clipped to three heights and reclipped at three-time frequencies declined drastically each successive year from 1970 through 1973. Dry matter yields of plants clipped to 15 cm or at 3-week time frequencies declined the greatest with each successive year of clipping. Time of clipping during the growing season had less influence on total seasonal dry matter yields than did clipping height and frequency. Holt and McDaniel (1963) studied dry matter production of kleingrass plants subjected to two frequencies of harvest and two heights of cutting. Their highest yields were obtained when the grass was cut at a 5-cm height and harvested less frequently.

In East Africa, the use of habitats varies widely depending on growth form, height, density and composition of the vegetation, all of which can influence livestock production (Western 1982). Within savanna grasslands, tall fibrous grasses are less suitable for cattle, sheep and goats than shorter swards with a high ratio of protein to crude fiber (Bell 1969). Although numerous studies have addressed the effects of frequency and intensity of defoliation on range plants in many parts of the world, very few such studies have been carried out in East Africa. From his clipping studies at Buchuma in Kenya, Cassady (1973) found that close repeated defoliation four to eight times during the first year produced yields equal to or higher than check plots, but when severe defoliation was continued for 2 and 3 years, yields were reduced 22% and 63% and most of the grass stand was destroyed. In Tanzania, Voorthuizen (1972) reported that various intensities and frequencies of clipping induced varying grass growth responses. Panicum maximum yields, for example, were highest with close cutting (leaving 5-cm stubble height) and with longest intervals (8 weeks). Cenchrus ciliaris yields were highest with short intervals (4 weeks) and medium stubble heights (10 cm). Hyparrhenia rufa yields were highest with medium intervals (6 weeks) leaving 20-cm stubble heights on the plants. Close cutting or grazing of Cenchrus ciliaris to 5-cm to 10-cm stubble heights in Pakistan was reported to give higher yields and better quality herbage than cutting at higher levels (Khan 1970), but in India, Pandeya and Jayan (1970) found that frequent close clipping reduced the yields of the next cut and carbohydrate levels in Cenchrus ciliaris. In South Africa, Themeda triandra appears to withstand heavier grazing pressure under rotational grazing than under continuous grazing. Acocks (1966) found that

2 weeks of rest resulted in rapid recovery of Themeda triandra previously suppressed by heavy continuous grazing. McNaughton (1979) studied grass-ungulate relationships in the natural grassland ecosystem of the Serengeti region of Tanzania. He concluded that photosynthetic and other physiological properties of Serengeti plants are modified by defoliation in a fashion that will tend to compensate for reductions in leaf area accompanying grazing. The activation and proliferation of meristems, tillering and increased rates of leaf elongation are important mechanisms that allow grass plants to tolerate severe defoliation. Potter (1980) investigated the influence of frequency and intensity of defoliation on a grass stand situated in ecological zone IV in Kenya. He concluded that the grass stand, dominated by Themeda triandra and Pennisetum mezianum, could withstand frequent severe defoliation even at a 3-week harvest frequency with a 5-cm cutting height provided that the animal-associated physical damage to the grass stand was avoided. Taerum (1970) found that 5-week harvest intervals significantly reduced the total dry weight of Panicum maximum.

Tillering

Many range plants have morphological adaptations that permit them to survive repeated partial defoliation. Hyder (1977) reported that species that elevate apical meristems within vegetative tillers or that produce a large proportion of reproductive tillers are considered least tolerant of grazing and are most productive when grazed periodically, coincident with tiller maturity. Furthermore, the response of perennial grasses, such as *Themeda triandra*, *Eragrostis curvula*, *Tristachya hispida*, and *Hyparrhenia hirta*, to defoliation has been shown to be related to the seasonal development of their apical meristems (Booysen et al. 1968). Branson (1953) reported that grasses, such as *Panicum virgatum*, *Agropyron smithii* and *Andropogon gerardi*, in which apical meristems reached a height permitting their removal by grazing were generally less resistant to intensive grazing than grasses such as *Poa pratensis*, *Buchloe dactyloides* and *Bouteloua gracilis* with growing points remaining at ground level. Langer (1963) reviewed tillering in the grass family and reported that a shoot required a certain number of leaves before it could produce a tiller. The effect of defoliation on tiller numbers is quite variable depending on species, degree of defoliation, and environmental factors. Reasons for differences in tillering response to defoliation also relate to photosynthate supply and apical dominance (Troughton 1957). Cutting of stem apexes stimulates tillering by removing the major source of auxim which inhibits lateral bud development. Inactive lateral buds are then free to develop (Leopold 1949). Defoliation to remove leaves only retards tillering through a reduction of photosynthetically active tissue with a resulting reduction in carbon assimilation (Troughton 1957). Huokuna (1966) reported that tiller production in meadow fescue swards was reduced by cutting height only at a short harvest frequency while Turner and Begg (1973) found that reduced tillering and more rapid death of leaves and tillers resulted from moisture stress. Peterson (1962) reported that certain changes in structure and response induced by prolonged heavy grazing appeared to favor persistence of Stipa comata plants. These changes included a relatively rapid regrowth after clipping and a more prostrate growth which further facilitated escape from grazing. This resulted in more leafage being concentrated near the soil surface. Some of this leafage was not grazed and thereby permitted more rapid replenishment of reserves (Hyder and Sneva 1959). It appears, therefore, that injury from foliage removal during any stage of plant growth is not due primarily to loss of apical meristems but to loss of photosynthetic tissue and potential seed production (Vogel and Bjugstad 1968). Branson (1956), for example, found that recovery from a 2-week harvest interval was much slower than for the intermediate frequency of 4 weeks. Owensby et al. (1974) reported that as clipping frequency increased, tiller density in Andropogon gerardi decreased. Tiller densities on plots clipped more than once did not differ but were significantly lower than those on unclipped or clipped-once plots. Panicum virgatum plants tolerated one clipping during the growing season with little or no reduction in herbage production, clonal survival, tiller number per clone or tiller height, but two or more clippings per season reduced all of the above (Beaty and Powell 1976).

Although basal tillering occurs in tropical grasses, a reproductive culm does not die after one growing season but continues to produce nodal tillers on primary, secondary and tertiary branches that live for several seasons (Jewiss 1972). Plants that tend to branch prolifically from elevated leaf axils provide better adaptation to endure grazing, particularly among nongrass forages. Numerous branches with enough of them decumbent to assure that some apical meristems escape removal by grazing animals is therefore an important adaptation.

Leaf Production

In order to maintain a maximum rate of dry matter production, sufficient leaf area must be present to effectively intercept incoming radiation. A forage species that produces a large number of tillers early will also produce sufficient leaf area to attain a maximum growth at an earlier age and recover soon after defoliation (Troughton 1957). The importance of energy reserves in regrowth after defoliation depends in part on the amount of leaf area removed and the environmental factors affecting growth and photosynthesis at that time (Larcher 1980). Wilson and Ng (1975) reported that moisture stress was associated with a reduced leaf-to-stem ratio. Davidson and Milthorpe (1965) found that when orchard grass (Dactylis glomerata L.) was severely defoliated, photosynthesis by remaining leaf area was insufficient to supply substrate demands of the plant for the first 4 days.

Forage Quality

The quality of herbage is of great practical and economic importance to livestock owners since livestock performance is not only a reflection of dry matter production but also a reflection of nutrient production. Percentage of crude protein of a plant is dependent on many factors including growing conditions, class of herbage, plant species, plant part, soil fertility, and stage of maturity of tissue (Kothmann 1980). For example, Cook and Harris (1963) reported large differences in crude protein contents between three forage classes as well as various plant parts in northern Utah rangelands. Percentage of crude protein was greater in leaves than stems of grasses, forbs, and shrubs, with all three forage classes declining in crude protein as the season progressed. Huston et al. (1981) reported similar findings in the Edwards Plateau region of Texas. However, Heitschmidt et al. (1982) reported that the major factor altering crude protein content of grasses was the stage of maturity of plant tissue, not differences among grasses. Crude protein content of both leaves and stems of grasses tended to rise to a peak at ear emergence, whereas the digestibility tended to decline with advancing maturity, which was more marked in the case of the stem (Haggar and Ahmed 1971). Pine and Burton (1956) reported that percentage of crude protein of Cynodon dactylon decreased with increased clipping frequency. Osman (1979) found that percentage of crude protein in grasses clipped at 2-week intervals was double (13.5%) that in grasses clipped at 6-week intervals (6.5). Cook et al. (1958) reported that plants harvested most frequently during the growing season produced herbage in the fall that was more leafy and consequently higher in percentage of crude protein than herbage harvested less frequently.

Relative digestibility of leaves and stems was found to vary among species. Both leaves and stems exhibited decreased digestibility with advancing maturity but the leaf sheath and stem fractions decreased more rapidly (Pritchard et al. 1963, Terry and Tilley 1964, Haggar and Ahmed 1971). Kilcher and Troelsen (1973) reported a decline in digestibility of smooth bromegrass (Bromus inermis Leyss.)

from 72% to 57% in the leaves and from 73 to 35% in the stems as the plant progressed from a very immature to mature stages. Similarly, the digestibility of dead tall fescue (Festuca arundinacea Schred.) was less than half that of the same forage while green (Taylor and Templeton 1976). These responses to defoliation may be modified by other factors such as soil, climate, nutrients, light, and the time of clipping (Alberda 1966).

CHAPTER III

MATERIALS AND METHODS

Study Area

Field research was conducted on the National Range Research Station, Kiboko, situated about 168 km from Nairobi on the Nairobi-Mombasa Highway. The station lies between latitudes 2° 10' S and 2° 25' S and longitudes 37° 40' E and 37° 55' E. The station land area is approximately 30,000 ha and the elevation is about 1000 m above sea level (Fig. 1).

The climate of Kiboko falls under the influence of the Inter-tropical Convergence Zone (Whyte 1968) characterized by a bimodal distribution of rainfall. The months of January and February characterize the short dry season, followed by a long rainy season from March through May. The period from June to October is usually a harsh dry season which is followed by a rather short rainy season from November to December. Data from the general area over the last 45 years indicate a long-term annual average rainfall of approximately 600 mm and an annual mean relative humidity of 62.5% (Michieka and Van der Pouw 1977).

Two separate study areas were selected early in 1981, one within the Wildlife Center in the southern ranch and the other within the Old Plant Nursery near Cattle boma 1 in the northern ranch (Fig. 2). The two study areas were situated in ecological zone V, which comprises the bulk of rangelands in Kenya (Pratt et al. 1966). The study areas were located within the basement system plains that

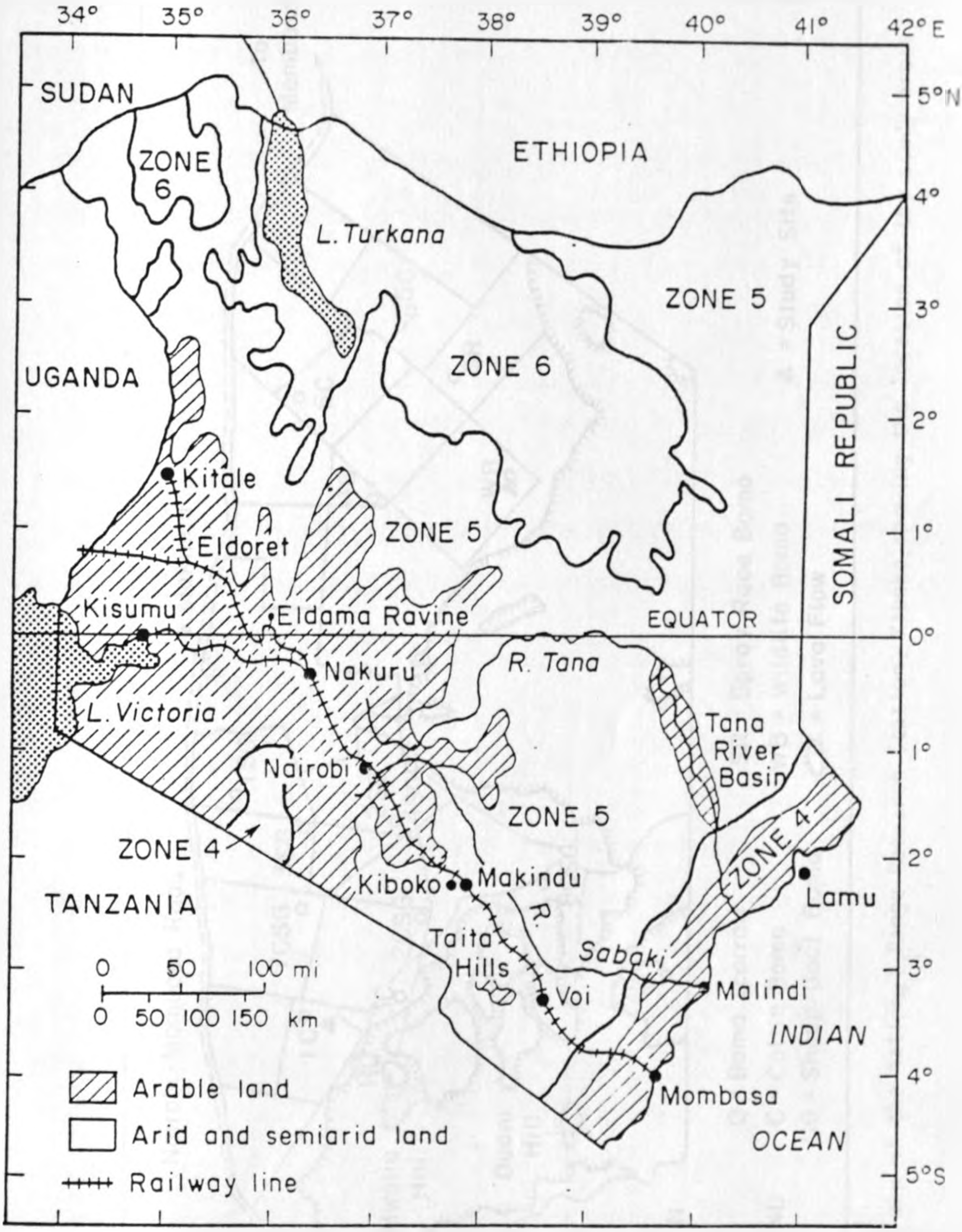

Fig. 1. A map of Kenya showing the location of the National Range Research Station, Kiboko, and the ecological zones.

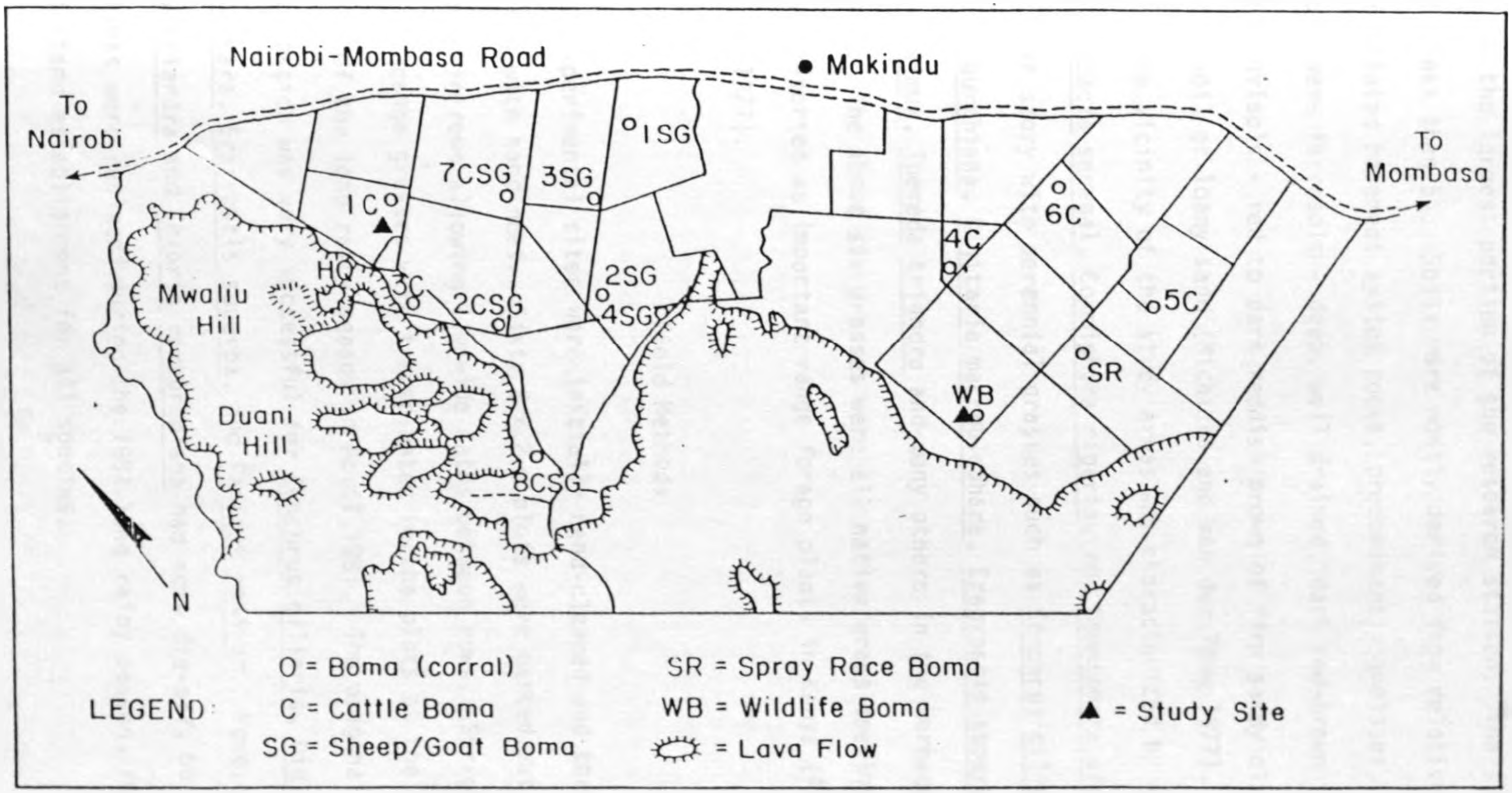

Fig. 2. A map of the National Range Research Station, Kiboko, showing the location of the study areas.

account for the largest portion of the research station. The slope was generally less than 5%. Soils were mostly derived from relatively undifferentiated basement system rocks, predominantly gneisses. Soil types were ferrosols - deep, well drained, dark red-brown to dark brown and luvisols - red to dark reddish brown of firm sandy clay with a top soil of loamy sand (Michieka and Van der Pouw 1977). Vegetation in the vicinity of the study areas was characterized by *Acacia tortilis*, *Acacia senegal*, *Commiphora riparia*, and *Commiphora africana* in the upper story with perennial grasses such as *Cenchrus ciliaris*, *Chloris roxburghiana*, *Digitaria macroblephara*, *Eragrostis superba*, *Panicum maximum*, *Themeda triandra* and many others in the herbaceous understory. The above six grasses were all native grass species and have been reported as important range forage plants in Kenya (Pratt and Gwynne 1977).

Field Methods

The experimental sites were initially hand-cleared and then cultivated with hand hoes. Sixty 2 x 2 m plots were marked out with steel pegs in rows allowing 1 m wide paths between rows. Sprigs of the six range grasses were transplanted in the plots at the beginning of the long rainy season in April 1981. The original transplantation was very successful for *Cenchrus ciliaris*, *Digitaria macroblephara*, *Eragrostis superba*, and *Panicum maximum*. However, *Themeda triandra* and *Chloris roxburghiana* had some die-off, but the dead plants were replaced during the 1981 long rainy season, resulting in good stand establishment for all species.

Each of the six grasses was assigned randomly to nine 2 x 2 m plots. Each plot was subsequently subdivided into four parts. Three stubble heights and a control were randomly assigned to the four subdivisions of each plot resulting in a split-split plot design with 2 x 6 x 4 x 3 x 3 x 3 arrangement of treatments (2 experimental sites, 6 grasses, 4 seasons, 3 frequencies of harvest, 3 heights of cutting, and 3 replications).

In addition to forage yield and leaf-to-stem ratio, growth responses to frequency of harvest and height of cutting were analyzed by measurements of crown diameter, counts of tillers and measurements of regrowth height just before clipping on predetermined individual plants in each quadrant three weeks after the onset of the 1983 short rainy season.

Plants were clipped at three heights (5 cm, 10 cm, and 15 cm) and at three frequencies of harvest to give one, two, and three clippings during the growing season at an interval of 9, 6, and 3 weeks, respectively. An additional clipping was carried out during each of the dry seasons at each frequency of harvest and height of cutting combination. Forage yield data consisted of herbage above clipped heights and samples were collected during the 1982 long rainy season through the 1983 short rainy season. Leaf and stem parts were separated, but no separation of live and dead plant material was made.

Laboratory Methods

The clipped grass material was put into paper bags, dried at 60°C in a forced air drying oven for about 24 hours and thereafter separated into leaf and stem portions. The oven-dried samples of leaves and stems were ground in a Wiley mill fitted with a 1.00 mm screen in the case of samples for nylon bag digestion and with a 0.5 mm screen in the case of samples for nitrogen determination. All chemical constituents analyzed in the herbage samples were expressed on an oven-dry matter basis.

Total nitrogen content of all samples was determined by the micro-Kjeldahl procedure (A.O.A.C. 1970). This procedure consisted of the following steps. A 0.5 g herbage sample was digested in sulfuric acid. Sodium hydroxide was then added to release the ammonia, which was then distilled into a boric acid solution. This solution was titrated with hydrochloric acid. Percentage of crude protein was calculated by multiplying percentage of total nitrogen by 6.25.

The procedure used to estimate digestible dry matter of the clipped plant samples was the _in vivo_ microdigestion nylon bag (Van Dyne 1962, Simonson et al. 1982). In this procedure 2-g of ground forage were placed inside a bag made of fine-weave nylon and suspended for 12 hours in the rumen of a fistulated steer. After removal from the steer's rumen, the samples were washed alternately in cold and hot tap water until no color in the wash water was evident. After rinsing, the samples were oven-dried and then weighted to determine material lost through digestion expressed as a percentage of original material.

Statistical Analysis

The experiment was laid out as a split-split plot trial with three replications. The whole plots were experimental sites, grass species and frequencies of harvest. The split plots in whole plots were heights of cutting and the within split plots were seasons.

Data were analyzed using the Statistical Analysis System (SAS) software package (Barr et al. 1976). Analysis of variance techniques were employed to analyze forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, percentage of crude protein, and percentage of dry matter digestibility. All 3- and 4-factor interactions had been pooled into their appropriate error terms. Duncan's new multiple range test was performed for variables having significant F-values ($P \leq .05$). In all analysis of variance tables, F-values followed by an * were significant at $P \leq .05$ unless otherwise stated. All references to significant differences in the text related to differences at the .05 level of significance.

CHAPTER IV

RESULTS

Forage Yield

An analysis of variance on forage yield shown in Table A1 revealed that there were significant differences in forage yield among grasses, experimental sites, frequencies of harvest, and seasons.

The rank in forage yield in g/m^2 from highest to lowest was Panicum maximum, Cenchrus ciliaris, Digitaria macroblephara, Eragrostis superba, Chloris roxburghiana, and Themeda triandra. Except for Panicum maximum and Cenchrus ciliaris, all differences in mean forage yield for the six grass species were significant (Table 1). Although the experimental site by grass interaction was significant, Panicum maximum, Cenchrus ciliaris, and Digitaria macroblephara consistently produced highest forage yield values at both experimental sites while Themeda triandra produced the lowest forage yield with Chloris roxburghiana and Eragrostis superba producing intermediate forage yield values (Table 2).

Forage yield was lowest at the 3-week harvest interval. The highest amount of forage was produced at the 6-week harvest frequency while intermediate amounts were produced at the 9-week harvest interval (Table 3). Cenchrus ciliaris, Digitaria macroblephara, and Themeda triandra produced the highest amount of forage at the 9-week interval while the 6-week interval resulted in highest forage yield in Chloris roxburghiana, Eragrostis superba, and Panicum maximum. Forage yield

Table 1. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, percentage of digestibility, and crude protein of six grasses across experimental sites, frequencies, intensities and dates of clipping.

Grass	Forage yield (g/m^2)	Leaf to stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
C. ciliaris	171.2 ab	4.3 d	11.6 a	25.3 b	21.8 abc	72.8 b	57.4 ab	10.8 b	6.3 c
C. roxburghiana	98.7 d	4.9 c	9.2 b	13.3 c	18.6 bc	65.7 d	56.3 b	11.4 ab	7.6 ab
D. macroblephara	161.4 b	5.5 b	11.8 a	60.3 a	25.4 a	76.3 a	51.6 c	11.5 ab	7.9 a
E. superba	137.3 c	4.2 d	7.3 c	12.9 c	17.7 c	71.6 bc	56.0 b	10.8 b	7.3 b
P. maximum	182.9 a	7.9 a	10.3 ab	30.6 b	22.9 ab	73.2 b	59.4 a	11.8 a	7.6 ab
T. triandra	50.1 e	4.2 d	6.1 c	10.6 c	22.0 abc	70.6 c	52.7 c	9.4 c	5.7 d

Means for the grass species followed by the same letter are not significantly different at the .05 level.

Table 2. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller numbers, and regrowth heights of six grasses at the Old Plant Nursery (OPN) and Wildlife Center (WC) across frequencies, intensities and dates of clipping.

Grass	Forage yield (g/m²)		Leaf-to-stem ratio		Crown diameter (cm)		Tiller number		Regrowth height	
	OPN	WC	OPN	WC	OPN	WC	OPN	WC	OPN	WC
C. ciliaris	130.9 b	211.5 a	3.9 c	4.6 c	10.3 ab	13.0 a	16.2 b	34.4 c	18.4 bc	25.2 ab
C. roxburghiana	106 c	90.9 c	4.9 b	5.0 bc	8.9 bc	9.4 b	13.3 b	14.3 d	18.9 bc	18.3 b
D. macroblephara	142.3 ab	180.4 b	5.4 b	5.7 b	11.4 a	12.2 a	51.5 a	69.1 a	27.3 a	23.6 ab
E. superba	94.3 c	180.3 b	4.2 c	4.2 c	5.3 e	9.4 b	3.3 b	22.5 cd	13.1 c	22.3 ab
P. maximum	156.3 a	209.5 a	7.6 a	8.3 a	7.8 cd	12.9 a	9.3 b	51.9 b	18.2 bc	27.7 a
T. triandra	53.2 d	47.1 d	4.2 c	4.3 c	6.1 de	6.1 c	6.8 b	13.4 d	23.0 ab	20.9 ab

Means for grass species within an experimental site followed by the same letter are not significantly different at the .05 level.

Table 3. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller numbers, regrowth height, percentage of DMD and CP in leaves and stems resulting from three frequencies across grasses, intensities and dates of clipping, and experimental sites.

Frequency (weeks)	Forage yield (g/m^2)	Leaf to stem ratio	Crown diameter (cm)	Tiller number per plant	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	CP in leaves (%)	CP in stems (%)
3-week	116.3 b	6.0 a	9.2 b	21.4 c	20.1 b	74.9 a	57.6 a	13.4 a	7.7 a
6-week	145.6 a	5.2 b	10.1 a	29.3 a	24.2 a	71.6 b	57.3 a	9.9 b	7.3 b
9-week	138.9 a	4.3 c	9.0 b	26.1 b	19.9 b	68.6 c	51.8 b	9.6 b	6.1 c

Means for the frequencies of harvest followed by the same letter are not significantly different at the .05 level.

values for the 6-week and 9-week harvest frequencies were significantly different only in Eragrostis superba and Panicum maximum (Table 4).

Mean forage yield for the three harvest frequencies with three cutting heights is shown in Table 5. Plants clipped at 3-week intervals produced highest amount of forage with the 15-cm cutting height and lowest amount of forage with the 5-cm cutting height. Intermediate forage yield values were produced by plants harvested at 3-week intervals with the 10-cm cutting height. The three cutting heights at the 9-week interval resulted in forage yield values that were not significantly different. Plants clipped at 6-week intervals, however, produced highest forage yield values with the 5-cm cutting height. The 10-cm cutting height resulted in lowest forage yield values while the 15-cm cutting height resulted in intermediate forage yield values (Fig. 3).

Seasonal effects on forage yield are shown in Table 6. The response patterns of the six grasses under investigation depended strongly on the amount of rain received. For example, the 1982 short rainy season had the highest amount of rainfall and consequently producted the highest amount of forage.

Leaf-to-Stem Ratio

There were significant differences in leaf-to-stem ratio among grasses, frequencies of harvest, cutting heights, experimental sites, and seasons (Table A2). The rank in mean leaf-to-stem ratio values from highest to lowest was Panicum maximum, Digitaria macroblephara, Chloris roxburghiana, Cenchrus ciliaris, Themeda triandra, and Eragrostis superba (Table 1). Differences in mean leaf-to-stem ratio

Table 4. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller numbers, and regrowth height of six grasses harvested at three frequencies across experimental sites, intensities and dates of clipping.

Grass	Frequency (weeks)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm/plant)	Tiller number	Regrowth height (cm)
C. ciliaris	3	128.2 c	5.1 a	10.5 b	20.2 b	17.8 c
	6	187.3 ab	4.3 ab	12.9 a	33.0 a	27.5 a
	9	198.1 a	3.4 b	11.5 ab	22.8 b	20.0 b
C. roxburghiana	3	92.0 a	6.2 a	10.0 a	14.9 a	21.5 a
	6	111.2 a	4.8 b	10.3 a	17.3 a	21.8 a
	9	93.1 a	3.9 c	7.3 b	9.3 a	12.6 b
D. macroblephara	3	134.6 b	6.7 a	10.1 b	40.5 b	23.3 b
	6	174.1 a	5.4 b	14.0 a	69.8 a	27.6 a
	9	175.4 a	4.4 c	11.3 b	70.5 a	25.4 ab
E superba	3	125.1 c	4.9 a	7.3 a	13.6 a	15.4 c
	6	151.0 a	4.1 ab	7.0 a	15.2 a	19.8 a
	9	135.9 b	3.5 b	7.6 a	9.9 a	17.8 b
P. maximum	3	181.8 ab	8.1 ab	10.6 a	28.5 a	28.8 a
	6	196.2 a	8.5 a	10.5 a	31.6 a	23.9 b
	9	170.7 b	7.2 b	9.9 a	31.8 a	21.1 c
T. triandra	3	36.0 b	5.1 a	6.5 a	10.5 a	18.8 b
	6	54.0 a	3.9 b	5.5 a	9.1 a	24.7 a
	9	60.3 a	3.7 b	6.2 a	12.2 a	22.5 ab

Means for a given grass species for different frequencies of harvest followed by the same letter are not significantly different at the .05 level.

Table 5. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller numbers, and regrowth height of six grasses harvested at three frequencies and three intensities.

Frequency	Height of cutting (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm/plant)	Tiller number per plant	Regrowth height (cm)
3 weeks	0	-	-	10.6 a	31.2 a	33.9 a
	5	108.7 b	6.2 a	9.1 ab	14.7 b	11.8 c
	10	116.2 ab	5.6 b	8.9 ab	17.1 b	15.7 bc
	15	124.1 a	6.2 a	8.1 b	22.5 ab	19.1 b
6 weeks	0	-	-	10.9 a	36.0 a	36.1 a
	5	151.9 a	5.9 a	9.8 a	23.6 b	17.4 b
	10	136.8 b	4.4 c	9.6 a	30.4 ab	21.4 b
	15	148.2 ab	5.2 b	9.8 a	27.3 ab	21.9 b
9 weeks	0	-	-	9.1 a	25.4 ab	28.0 a
	5	136.4 a	3.7 b	8.2 a	22.1 b	17.0 b
	10	137.0 a	4.6 a	8.9 a	32.5 a	17.1 b
	15	143.3 a	4.7 a	9.6 a	24.3 ab	17.6 b

Means for a given harvest frequency for different cutting heights followed by the same letter are not significantly different at the .05 level.

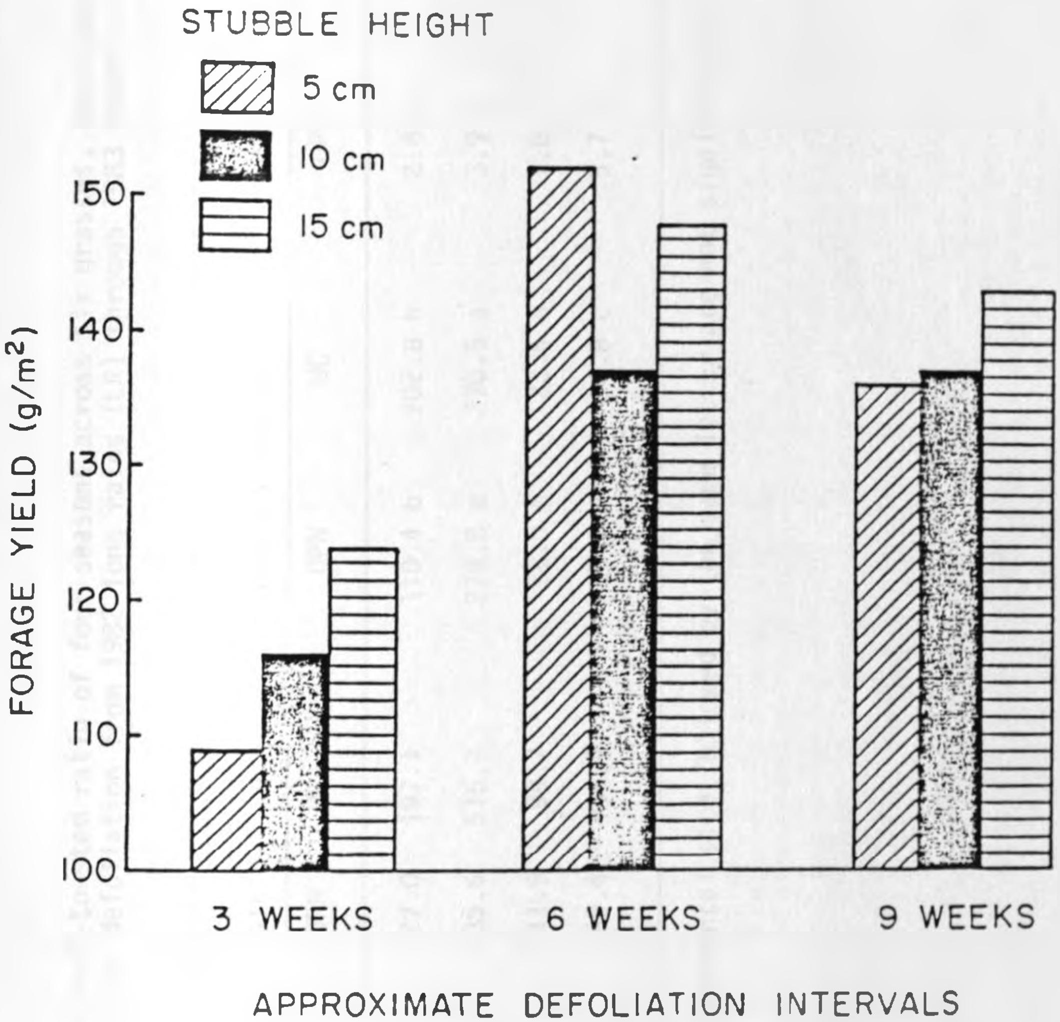

Fig. 3. Mean forage yield resulting from three frequencies of harvest with three cutting heights across experimental sites, grasses, and dates of clipping.

Table 6. Mean forage yield and leaf-to-stem ratio of four seasons across six grasses, two experimental sites, frequency and intensity of defoliation from 1982 long rains (LR) through 1983 short rains (SR).

Seasons	Rainfall (mm)		Forage yield (g/m^2)		Leaf-to-stem ratio	
	OPN	WC	OPN	WC	OPN	WC
1982 LR April-June	127.0	197.1	110.4 b	202.8 b	2.8 d	3.0 d
1982 SR September-December	435.6	515.7	279.8 a	270.5 a	3.9 c	4.4 c
1983 LR February-May	111.9	99.7	28.0 c	23.6 d	7.6 a	7.5 a
1983 SR October-December	169.4	186.9	37.5 c	76.8 c	5.7 b	6.4 b

Means for seasons within an experimental site followed by the same letter are not significantly different at the .05 level.

between the last three grasses in the rank order were not significantly different.

Plants defoliated at the 3-week interval produced highest leaf-to-stem ratio values in all six grasses. The 9-week harvest frequency resulted in lowest leaf-to-stem ratio values while the 6-week harvest frequency resulted in intermediate values (Table 4). Plants clipped at 3, 6 and 9-week harvest frequencies produced 6.0, 5.2 and 4.3 mean leaf-to-stem ratios, respectively. These leaf-to-stem ratio values were all statistically significant (Table 3).

The effects of frequency and height of cutting on leaf-to-stem ratio are shown in Table 5. The 3-week harvest frequency resulted in higher leaf-to-stem ratio values with the 5-cm and 15-cm cutting heights. The 10-cm cutting height resulted in significantly lower values. Plants clipped at 6-week intervals with the three cutting heights produced leaf-to-stem ratio values that were significantly different. The 10-cm and 15-cm cutting heights resulted in leaf-to-stem ratio values that were not different, but values from the 5-cm cutting height were statistically different at the 9-week harvest frequency (Fig. 4).

Growing seasons that received the least rainfall produced the highest leaf-to-stem ratios. Thus, the 1982 long rainy season produced the lowest while the 1983 long rainy season produced the highest mean leaf-to-stem ratio values (Table 6).

Crown Diameter

There were significant differences in crown diameter among

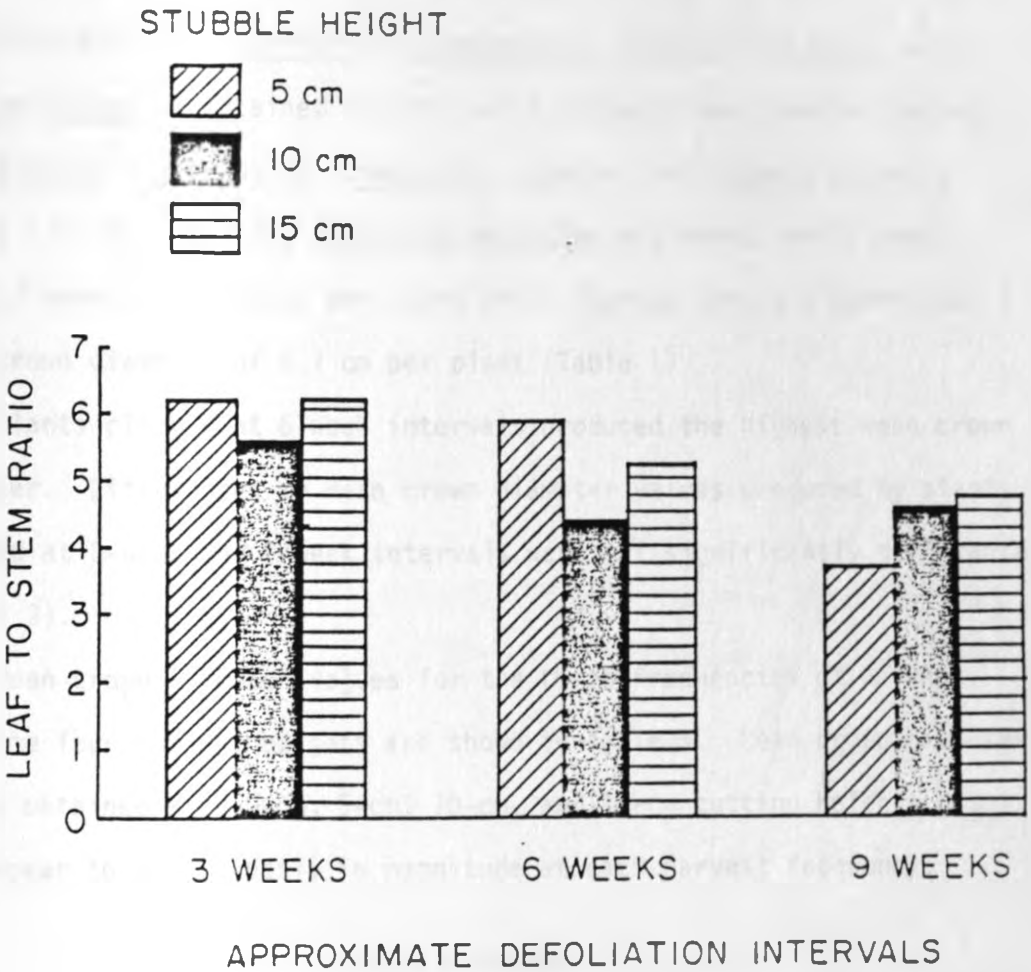

Fig. 4. Mean leaf-to-stem ratio resulting from three frequencies of harvest with three cutting heights across experimental sites, grasses, and dates of clipping.

grasses, experimental sites, and cutting heights (Table A3). At both experimental sites, Digitaria macroblephara, Cenchrus ciliaris, and Panicum macimum maintained significantly higher crown diameter values than Chloris roxburghiana, Eragrostis superba, and Themeda triandra (Table 2). For example, Digitaria macroblephara maintained a mean crown diameter of 11.8 cm per plant while Themeda triandra maintained a mean crown diameter of 6.1 cm per plant (Table 1).

Plants clipped at 6-week intervals produced the highest mean crown diameter. Differences in mean crown diameter values produced by plants clipped at 3-week and 9-week intervals were not significantly different (Table 3).

Mean crown diameter values for the three frequencies of harvest with the four cutting heights are shown in Table 5. Mean crown diameter values obtained with 0-cm, 5-cm, 10-cm, and 15-cm cutting heights did not appear to vary greatly in magnitude at each harvest frequency.

Tiller Number

An analysis of variance on tiller numbers for the six grasses revealed that there were significant differences in tiller production among grasses, experimental sites, and cutting heights (Table A4). Digitaria macroblephara produced significantly more tillers than the other species. Mean tiller number values produced by Panicum maximum and Cenchrus ciliaris were intermediate while mean tiller number values produced by Chloris roxburghiana, Eragrostis superba, and Themeda triandra were the lowest (Table 1).

Tiller numbers were highest at the 6-week interval and lowest at the 3-week interval. The 9-week interval resulted in intermediate tiller number values (Table 3). Tiller number values for the six grass species were higher at the Wildlife Center site than at the Old Plant Nursery site (Table 2).

The 5-cm cutting height resulted in lowest tiller numbers for plants clipped at the three frequencies of harvest. Plants clipped at 6-week and 9-week intervals appeared to produce higher mean tiller numbers with the 10-cm cutting height. Differences in mean tiller number values between the control and defoliated plants were not significantly different (Table 5). Plants clipped at 3-week intervals with the 5-cm cutting height produced the lowest mean tiller number (Fig. 5). Both aerial (nodal) and basal tillers were recorded together.

Regrowth Height

There were significant differences in regrowth height prior to clipping among grasses, frequencies of harvest, experimental sites, and cutting heights (Table A5).

The rank in mean regrowth height values from highest to lowest was Digitaria macroblephara, Panicum maximum, Themeda triandra, Cenchrus ciliaris, Chloris roxburghiana, and Eragrostis superba. Except for Chloris rosburghiana and Eragrostis superba whose mean regrowth height values were in the upper 10s, the rest of the grasses had mean regrowth height values between 21 cm and 25.4 cm (Table 1).

Plants clipped at 6-week intervals produced the highest regrowth height values, while the 3-week and 9-week intervals resulted in lowest

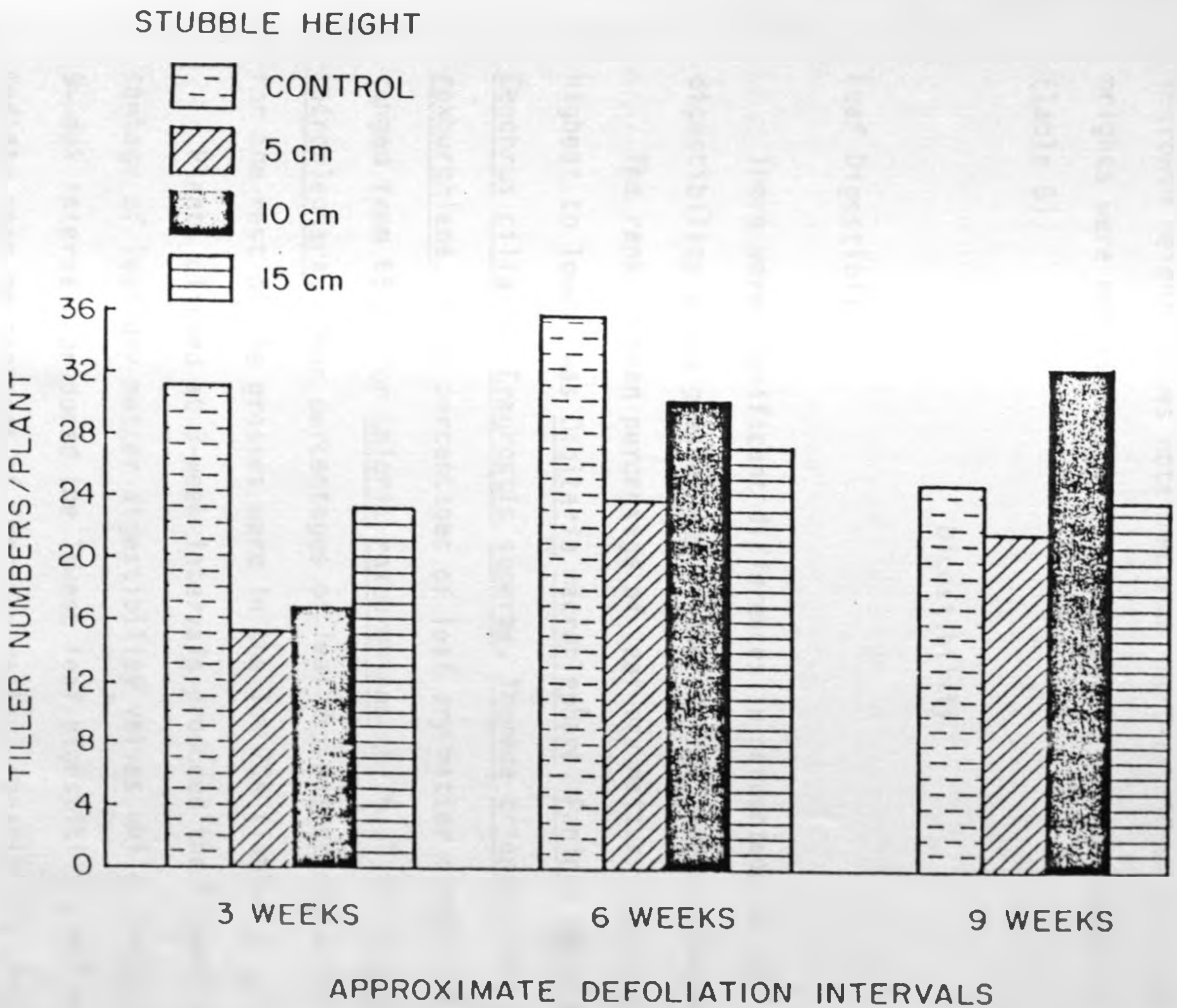

Fig. 5. Mean tiller number resulting from three frequencies of harvest with four cutting heights across experimental sites, grasses, and dates of clipping.

regrowth height values (Table 3).

The control plants produced regrowth height values that were significantly different from values obtained from defoliated plants. Mean regrowth height values obtained with the 5-cm, 10-cm and 15-cm cutting heights were not significantly different at each frequency of harvest (Table 5).

Digestibility

Leaf Digestibility

There were significant differences in percentage of leaf dry matter digestibility among grasses and frequencies of harvest (Table A6).

The rank in mean percentage of leaf dry matter digestibility from highest to lowest was *Digitaria macroblephara*, *Panicum maximum*, *Cenchrus ciliaris*, *Eragrostis superba*, *Themeda triandra*, and *Chloris roxburghiana*. Mean percentages of leaf dry matter digestibility ranged from 65.7% for *Chloris roxburghiana* to 76.3% for *Digitaria macroblephara*. Mean percentages of leaf dry matter digestibility for the rest of the grasses were in the low 70s (Table 1).

Plants clipped at 3-week intervals produced the highest mean percentage of leaf dry matter digestibility values while plants clipped at 9-week intervals produced the lowest leaf digestibility values. Intermediate mean percentages of leaf dry matter digestibility were obtained from plants clipped at 6-week intervals. Differences in mean percentage of leaf dry matter digestibility values for the three frequencies of harvest were significantly different (Table 3). The difference in mean leaf digestibility between the 3-week and the 9-week harvest frequencies was 10 units for Digitaria macroblephara, 6.6 units for Chloris roxburghiana and Eragrostis superba, 6.1 units for Cenchrus ciliaris, 5.2 units for Panicum maximum, and 3.4 units for Themeda triandra (Table 7).

The height of cutting appeared to have little effect on percentage of leaf dry matter digestibility (Table 8).

Stem Digestibility

There were significant differences in mean percentage of stem dry matter digestibility values among grasses, experimental sites, and harvest frequencies (Table A7).

The rank in mean percentage of stem dry matter digestibility from highest to lowest was Panicum maximum, Cenchrus ciliaris, Chloris roxburghiana, Eragrostis superba, Themeda triandra, and Digitaria macroblephara. Mean percentage of stem dry matter digestibility ranged from 51.6% for Digitaria macroblephara to 59.4% for Panicum maximum. Percentages of stem digestibility for Cenchrus ciliaris, Chloris roxburghiana, and Eragrostis superba were in the mid 50s (Table 1).

Plants clipped at the 3-week and the 6-week intervals produced mean percentages of stem dry matter digestibility that were significantly different from stem digestibility values obtained from plants clipped at the 9-week intervals (Table 3).

There were small differences in mean percentage of stem dry matter digestibility values between heights of cutting at each harvest frequency (Table 8).

Table 7. Mean percentage of DMD and crude protein of six grasses harvested at three frequencies across experimental sites, intensities and dates of clipping.

Grass	Frequency (weeks)	Leaf (% DMD)	Stem (% DMD)	CP in leaves (%)	CP in stems (%)
C. ciliaris	3	76.6 a	61.7 a	13.1 a	6.8 a
	6	71.4 b	56.0 b	9.2 c	6.2 b
	9	70.5 c	54.6 c	10.2 b	6.0 b
C. roxburghiana	3	69.8 a	63.5 a	13.6 a	8.1 a
	6	64.0 b	58.1 b	10.5 b	8.4 a
	9	63.2 b	47.2 c	10.2 b	6.5 b
D. macroblephara	3	80.3 a	50.0 b	15.8 a	9.3 a
	6	78.2 a	54.5 a	9.7 b	8.0 b
	9	70.4 b	50.2 b	9.0 b	6.4 c
E. superba	3	74.8 a	55.8 b	13.0 a	8.7 a
	6	71.7 b	58.6 a	9.8 b	7.5 b
	9	68.2 c	53.6 c	9.6 b	5.7 c
P. maximum	3	76.3 a	60.7 a	14.5 a	7.6 b
	6	72.1 b	60.3 a	11.2 b	8.5 a
	9	71.1 b	57.3 b	9.7 c	6.6 c
T. triandra	3	71.5 a	53.8 b	10.4 a	6.0 a
	6	72.1 a	56.3 a	9.1 b	5.8 ab
	9	68.1 b	48.0 c	8.8 b	5.4 b

Means for a given grass species for different frequencies of harvest followed by the same letter are not significantly different at the .05 level.

Table 8. Mean percentage of dry matter digestibility and percentage of crude protein in leaves and stems of grasses harvested at three frequencies and three intensities across grasses and sites.

Frequency	Height of cutting (cm)	Leaf (% DMD)	Stem (% DMD)	CP in leaves (%)	CP in stems (%)
3 weeks	5	74.9 a	60.1 a	13.7 a	7.5 a
	10	75.5 a	57.8 ab	13.2 a	7.8 a
	15	74.3 a	54.9 b	13.3 a	7.8 a
6 weeks	5	73.8 a	57.6 a	10.2 a	7.3 a
	10	69.7 b	58.5 a	9.7 a	7.4 a
	15	71.2 ab	55.9 a	9.8 a	7.4 a
9 weeks	5	68.7 ab	51.2 a	9.4 a	6.0 a
	10	67.8 b	51.4 a	9.6 a	6.0 a
	15	69.2 a	52.8 a	9.7 a	6.3 a

Means for a given harvest frequency for different cutting heights followed by the same letter are not significantly different at the .05 level.

Crude Protein

CP in Leaves

There were significant differences in mean percentage of crude protein in leaves among grasses and frequencies of harvest (Table A8). The rank in mean percentage of leaf crude protein from highest to lowest was *Panicum maximum*, *Digitaria macroblephara*, *Chloris roxburghiana*, *Cenchrus ciliaris*, *Eragrostis superba*, and *Themeda triandra*. Not all differences in percentage of leaf crude protein values for the six grasses were statistically different (Table 1).

Plants clipped at the 3-week frequency produced the highest mean percentage of crude protein. Percentages of crude protein at the 6-week and 9-week harvest frequencies were not statistically different (Table 3).

The 3-week harvest frequency resulted in highest mean percentage of leaf crude protein values across the three heights of cutting. Percentages of crude protein for the 5-cm, 10-cm, and 15-cm heights of cutting were not statistically different at each frequency of harvest (Table 8).

CP in Stems

There were significant differences in mean percentage of stem crude protein among grasses and frequencies of harvest (Table A9). The rank in mean percentage of stem crude protein values from highest to lowest was *Digitaria macroblephara*, *Panicum maximum*, *Chloris roxburghiana*, *Eragrostis superba*, *Cenchrus ciliaris*, and *Themeda triandra*.

Not all differences in mean percentage of stem crude protein values for the six grasses were statistically different (Table 1).

Plants clipped at the 3-week harvest frequency produced the highest mean percentage of stem crude protein values while plants clipped at the 9-week harvest frequency produced the lowest crude protein values. The 6-week harvest frequency resulted in intermediate crude protein values. Differences in percentage of crude protein values among the three harvest frequencies were statistically significant (Table 3).

Mean percentages of stem crude protein for the 5-cm, 10-cm, and 15-cm heights of cutting were not statistically different at each harvest frequency (Table 8).

CHAPTER V

DISCUSSION AND CONCLUSIONS

Variability in both total rainfall and seasonal rainfall was high. The period was characterized by poor rainfall during the 1982 LR at the Old Plant Nursery and during the 1983 LR at the two sites. The 1982 LR was fair at the Wildlife Center while the 1983 SR was fair at both sites. The 1982 short rainy season received the highest rainfall. In addition to defoliation treatment effects, forage yield, and leaf-to-stem ratio of the six grasses showed a seasonal response pattern. In addition to clipping treatments, lack of effective rainfall in 1983 was, therefore, partly responsible for the reduction in forage yield, tillering, and regrowth height, especially in plants clipped most frequently. Reduced forage response pattern due to inadequate soil moisture agreed in trend with the response pattern reported by Turner and Begg (1978), and Wilson and Ng (1975).

Forage yield, tiller number, regrowth height, and crown diameter of the six grasses showed similar response patterns to defoliation treatments. The values of these dependent variables were highest at the 6-week harvest frequency and lowest at the 3-week harvest frequency. These results agreed with results reported by Singh and Mall (1976), Perry and Chapman (1976), Albertson et al. (1953), Aldous (1930), Holt and McDaniel (1963), Cassady (1973), Voorthuizen (1972), and Taerum (1970). Under the most frequent and intense cutting, new tillers apparently never fully expanded. Less of each tiller was removed at the 3-week harvest frequency than either at the 6-week or 9-week harvest frequency, which resulted in lower yields at the 3-week harvest frequency. The more frequent defoliation at 3-week intervals removed mostly grass leaves and retarded tillering through a reduction of photosynthetically active tissue as reported by Troughton (1957), Davidson and Milthorpe (1965), Vogel and Bjugstad (1968), Beaty and Powell (1976). It appears that the 6-week harvest frequency was sufficiently long to permit a large number of tillers to develop to the point that their removal did not reduce growth rate.

Tillering is important in forage plants because of its effect on leaf area production and dry matter yield. A high rate of tiller production would be beneficial in attaining high yields and maintaining a stand under severe defoliation. Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris were found to produce large numbers of tillers and sufficient leaf area to attain a maximum growth height at an earlier age and recover soon after defoliation, especially at the 6-week harvest frequency. With increased defoliation interval, tillers were allowed to reach a more mature stage, which resulted in increased forage yield. Furthermore, tiller numbers also increased since the older tillers could initiate nodal tillers before they were removed, thereby enlarging the crown area. Tillering and expansion of the crown area were suppressed by the 3-week harvest frequency.

In contrast, defoliation treatments resulted in a response pattern whereby leaf-to-stem ratio, percentage of dry matter digestibility, and percentage of crude protein values were highest at the 3-week harvest frequency and lowest at the 9-week harvest frequency. Most of the treatment differences appeared to be due to the frequency of harvest.

Effects of cutting heights on forage yield and tillering resulted in large differences at the 3-week frequency. Plants clipped at 3-week intervals with the 5-cm cutting height produced the lowest forage yield and tiller numbers. As frequency of defoliation decreased, intensity of defoliation had less influence on forage production.

Grass species that produced relatively high leaf-to-stem ratios correspondingly gave high mean percentage of dry matter digestibility values and mean percentage of crude protein values. The digestibility of the leaf fraction exceeded the digestibility of the stem fraction by as many as 9 units in *Chloris roxburghiana*, 14 units in *Panicum maximum*, 15 units in *Digitaria macroblephara*, *Cenchrus ciliaris*, and *Eragrostis superba* and 18 units in *Themeda triandra*. These results indicated that the leaf fraction was more digestible than the stem fraction and that digestibility declined as the interval between defoliations increased. These results agreed in trend with results reported by Heitschmidt et al. (1982), Haggar and Ahmed (1971), Pritchard et al. (1963), Terry and Tilley (1964), and Kilcher and Troelsen (1973).

Crude protein content of grass leaves and stems showed a pattern similar to that shown in leaf and stem digestibility. The crude protein content of the leaf fraction exceeded the crude protein content of the stem fraction by 4.5%, 4.2%, 3.8%, 3.7%, 3.6% and 3.5% for *Cenchrus ciliaris*, *Panicum maximum*, *Chloris roxburghiana*, *Themeda triandra*, *Digitaria macroblephara*, and *Eragrostis superba*, respectively. Similarly the crude protein content of both leaf and stem fractions declined as the interval between defoliations increased. These results agreed in trend with results reported by Cook and Harris (1968), Huston et al. (1981), Heitschmidt et al. (1982), Pine and Burton (1956), and Osman (1979).

The response patterns exhibited by the six grass species indicated that Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris were the most important grasses in this study in terms of forage yield, tillering, forage digestibility, crude protein content, and regrowth characteristics.

Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris showed a strong tiller producing capacity, especially at the 6-week harvest frequency. The three grass species produce abundant basal tillers which develop from axillary buds at a series of very short internodes and nodes at ground level of the basal shoot. In addition Digitaria macroblephara and Cenchrus ciliaris produce stolons at which nodal tillers may develop at various stages of development. The prostrate growth habit and closely overlapping leaves, characteristic of Cenchrus ciliaris and Digitaris macroblephara permit a large portion of green leaves to remain after moderate defoliation, thus a high level of photosynthesis can be maintained as found by Weinmann and Goldsmith (1948) in their investigations.

In contrast, Chloris roxburghiana, Eragrostis superba, and Themeda triandra produce abundant nodal tillers. The nodal tiller originates at axillary buds and it differs from the basal tiller in that there are no root primordia at the nodes. As reported by Jewiss (1972), a reproductive culm does not die after one growing season but continues to produce nodal tillers on primary, secondary, and tertiary branches that live for several seasons. The 3-week interval between defoliations was not sufficiently great to permit a large number of secondary tillers to develop to the point of being removed, thus resulting in lower forage yields in Chloris roxburghiana, Eragrostis superba, and Themeda triandra.

There were no apparent die-offs in plots planted with Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris, but significant die-offs occurred in Chloris roxburghiana, Eragrostis superba, and Themeda triandra. Forage yield and tiller numbers from the six grasses decreased with the more frequent clipping and closer harvesting. As frequency of defoliation decreased, however, intensity of defoliation had less influence on forage yield and tiller production. These results agreed in trend of response with results reported by Cassady (1973), Holt and McDaniel (1963), Perry and Chapman (1975), and Huokuna (1966). In contrast, Potter (1930) reported that clipping Themeda triandra and Pennisetum mezianum plants at 3-week intervals with a 5-cm stubble height did not suppress forage yield. His investigations were carried out at Athi River plains presumably under wetter conditions than at Kiboko National Range Research Station.

Large herbivores have been reported to consume an average of 66% and a maximum of 95% of aboveground biomass at the Serengeti region of Tanzania (McNaughton 1979). Although grasses in this region appeared to have mechanisms of compensatory growth following grazing, heavy grazing led to the evolution of dwarfed genotypes that produced dense canopies with a high concentration of plant biomass in the canopy volume. This growth form enabled the grasses to escape excessive grazing.

Examination of tillering and forage yield of the six grasses revealed that the amount of forage yield under the three frequencies and the three intensities of clipping was not proportional to the number of tillers recorded. Apparently residual plant material below the clipped heights consisted of a number of tillers which had not fully expanded enough to be harvested at the time of clipping. This morphological characteristic allowed Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris to have adequate leaf area to carry on photosynthesis and thus enabled the plants to tolerate removal of foliage especially at intensities that left 10-cm and 15-cm stubble heights. Such characteristics allowed Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris to avoid excessive defoliation, and perhaps gave these species a comparative advantage in grazing resistance. Because total aboveground forage production of the six grasses was not quantified in this investigation, the amount of residual forage could not be estimated in order to determine total herbage production. Future studies of this nature should include some measurement of total herbage yield to adequately test this relationship.

In addition to using total herbage production as a basis for differentiating species response to clipping, the length of growing seasons and dormant seasons would need to be considered when analyzing results and planning grazing systems. The southern region of Kenya is characterized by relatively short growing seasons and a long dormant season. In developing a grazing plan, total herbage production capacity of the forage species involved, their response to defoliation during the growing season, and the total feed requirement for the entire year must be considered. If the range is in poor condition and range improvement is the main emphasis, a grazing plan which optimizes plant growth would offer the best option. Such a plan should provide utilization of the forage at the intensities and frequency which would result in the most forage production yet utilization of the forage during its high nutritional stage.

If the range is already in good condition, frequent and less intensive grazing during the growing season might give greater livestock production than moderate, continuous seasonal grazing. Frequent utilization would produce a stand of vegetation in which differences in plant maturity within and among plant species would be minimal. This would aid in reducing selective grazing because available forage would be young and readily acceptable to livestock. Less intensive utilization during the growing season, leaving a stubble height of about 10 cm, would assure adequate residual forage in the stubble for providing yearlong availability of forage to support livestock maintenance during dormant seasons. Therefore, based on results of this study, a short duration grazing system which provided uniform defoliation to a stubble height of 10 cm in about 42-day intervals would yield best livestock performance during growing periods and provide maximum herbage for use during dormant seasons. Defoliation to a stubble height of 15 cm would probably be needed during the April-May growing season, which precedes the June-October dormant season, in order to leave enough residual forage to support livestock during the rather long dormant seasons.

During the 1983 short rainy season, clipped plant samples for forage digestibility and nitrogen determinations consisted largely of leaf material as indicated by the high leaf-to-stem ratios. The crude protein content and digestibility of the six grasses in this study were higher than CP and DMD values generally reported for tropical grasses and do not corroborate results reported by Stobbs and Minson (1980). For example, in comparing tropical and temperate pasture species, Stobbs and Minson (1980) found that tropical grasses had lower crude protein and digestibility than temperate grasses. For a wide range of samples, the mean protein levels were 9.5% for tropical grasses and 13.2% for temperate grasses. Mean dry matter digestibility levels of immature tropical and temperate pastures were 60% and 75%, respectively. Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris produced higher forage yield, leaf-to-stem ratio, tiller number, regrowth height, and percentages of DMD and CP than Chloris roxburghiana, Eragrostis superba, and Themeda triandra. In mixed stands, seasonal preference and utilization of different species will probably vary. Although chemical differences in crude protein and digestibility may be important, differences in animal preference will probably be as a result of the leaf-to-stem ratio and morphological characteristics of the grasses. Therefore, Digitaria macroblephara, Panicum maximum, Cenchrus ciliaris, and Chloris roxburghiana would probably be the most preferred species.

Recommendations for further research include (1) studying the responses of forage plants and grazing animals to a grazing plan which utilizes frequent grazing at 42-day intervals, and less intensive grazing leaving 10-cm to 15-cm stubble heights. (2) determining total herbage production, and amount and distribution of forage resulting from various clipping intensities, and (3) continuing to explore the responses of plants to defoliation treatments at different phenological stages, such as, vegetative, reproductive, flowering, seed set and senescence stages.

CHAPTER VI

SUMMARY

A study was conducted at two experimental sites on the National Range Research Station, Kiboko, to evaluate forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, forage digestibility, and crude protein content of six native range grasses following defoliation at three frequencies (3, 6, and 9 weeks) with three cutting heights to leave 5-cm, 10-cm, and 15-cm stubble heights.

The original transplantation was very successful for *Cenchrus ciliaris*, *Digitaria macroblephara*, *Panicum maximum*, and *Eragrostis superba*. However, *Themeda triandra* and *Chloris roxburghiana* had some die-off but the dead plants were replaced during the 1981 long rainy season resulting in good stand establishment for all species.

Forage yield data consisted of total biomass and were collected during the 1982 long rainy season through the 1983 short rainy season. Leaf and stem parts were separated, but no separation of live and dead plant material was made. Tiller counts, crown diameter and regrowth height measurements were carried out during the 1983 short rainy season just before clipping on predetermined individual plants in each plot.

Total nitrogen content of ground forage samples collected during the 1983 short rainy season was determined by the micro-Kjeldahl procedure while the *in vivo* microdigestion nylon bag procedure was used to estimate digestible dry matter.

The experiment was laid out as a split-split plot trial with three replications. The whole plots were experimental sites, grass species.

and frequencies of harvest. The split plots in whole plots were heights of cutting, and the within split plots were seasons.

Analyses of variance techniques were employed to analyze forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, percentage of dry matter digestibility, and percentage of crude protein. All 3- and 4-factor interactions were pooled into their appropriate error terms. Duncan's new multiple range test was performed for variables having significant F-values ($P \leq .05$).

Following defoliation treatments, responses of six range grasses were investigated in 1982 and 1983 at two experimental sites on the National Range Research Station, Kiboko. Of the six grasses under investigation, Digitaria macroblephara, Panicum maximum, and Cenchrus ciliaris exhibited a strong capacity to produce relatively higher forage yield, larger tiller numbers, and higher digestibility and crude protein content values than Chloris roxburghiana, Eragrostis superba, and Themeda triandra.

Maximum forage yields, tiller number, crown area and regrowth rate values were obtained when plants were harvested at the 6-week frequency. In all grasses, however, the undefoliated plants produced highest crown area, tiller numbers and regrowth rate. Minimum forage yields, tiller numbers, crown area, and regrowth rate values were obtained for all grasses at the 3-week frequency.

In contrast, maximum leaf-to-stem ratio, digestibility, and crude protein content values for the six grass species were obtained by harvesting plants at the 3-week frequency. The digestibility values and crude protein content values of the leaf fraction were higher than digestibility values and crude protein content values of the stem fraction. As the interval between defoliations increased, digestibility values and crude protein content values of both leaf and stem fractions declined.

In general, the values of the characteristics under investigation did not vary greatly in magnitude over the cutting heights at each harvest frequency. However, plants clipped at the 3-week frequency with the 5-cm cutting height produced the lowest forage yield and tiller number.

Although results obtained from this study did not adequately address the long-term effects of defoliation on these six range grasses, it would be appropriate to suggest that anticipated response patterns in forage yield, forage quality, and persistence for these grasses would be similar to response patterns exhibited by the six grasses in 1982 and 1983. These data did not consider, however, the animal-associated physical damage to the grass plants in a grazing situation.

Frequent utilization would produce a stand of vegetation in which differences in plant maturity within and among plant species would be minimal. This would aid in reducing selective grazing because available forage would be young and readily acceptable to livestock. Less intensive utilization during the growing season, leaving a stubble height of about 10 cm, would assure adequate residual forage in the stubble for providing yearlong availability of forage to support livestock maintenance during dormant seasons.

Recommendations for further research include (1) studying the responses of forage plants and grazing animals to a grazing plan which utilizes frequent grazing at 42-day intervals, and less intensive grazing leaving 10-cm to 15-cm stubble heights, (2) determining total herbage production, and amount and distribution of forage resulting from various clipping intensities, and (3) continuing to explore the responses of plants to defoliation treatments at different phenological stages, such as, vegetative, reproductive, flowering, seed set and senescence stages.

LITERATURE CITED

Acocks, J. P. 1966. Non-selective grazing as a means of veld reclamation. Proc. Grassl. Soc. South Africa. 1:33-39.

Alberda, T. 1966. The influence of reserve substances on dry matter production after defoliation. Proc. 10th Intern. Grassld. Congr. Helsinki, Finland.

Albertson, F. W., A. Reigel, and J. L. Launchbaugh. 1953. Effects of different intensities of clipping on short grasses in west-central Kansas. Ecology 34:1-12.

Aldous, A. E. 1930. Effect of different clipping treatments on yield and vigor of prairie grass vegetation. Ecology 11:752-759.

A.O.A.C. 1970. Official Methods of Analysis. 10th ed. Association of Official Agricultural Chemists. Washington, D. C.

Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. A users guide to SAS76. Sparks Press, Raleigh, North Carolina. 329 pp.

Beaty, E. R., and J. D. Powell. 1976. Responses of switchgrass (Panicum virgatum L.) to clipping frequency. J. Range Manage. 29: 132-135.

Bell, R. H. V. 1969. A grazing ecosystem in the Serengeti. Sci. Amer. 225:86-93.

Booysen, P. de V., N. M. Tainton, and J. D. Scott. 1968. Shoot-apex development in grassland and its importance in grassland management. Herb. Abstr. 33:209-213.

Branson, F. A. 1953. Two new factors affecting resistance of grasses to grazing. J. Range Manage. 6:165-171.

Branson, F. A. 1956. Quantitative effects of clipping treatments on five range grasses. J. Range Manage. 9:86-88.

Cassady, J. T. 1973. The effect of rainfall, soil moisture and harvesting intensity on grass production on two rangeland sites in Kenya. E. Afr. Agric. For. J. 39:26-36.

Cook, C. W., L. A. Stoddart, and F. E. Kinsinger. 1958. Responses of crested wheatgrass to various clipping treatments. Ecol. Monogr. 28:237-272.

Cook, C. W., and L. E. Harris. 1968. Nutritive value of seasonal ranges. Utah Agr. Exp. Sta. Bull. 472, 55 pp.

Davidson, J. L., and F. L. Milthorpe. 1965. Carbohydrate reserves in the regrowth of cocksfoot (Dactylis glomerata L.). J. Br. Grassld. Soc. 20:15-18.

Edwards, D. C., and A. V. Bogdan. 1951. Important grassland plants of Kenya. Sir Isaac Pitman and Sons Ltd., Nairobi. 124 pp.

Haggar, R. J., and M. B. Ahmed. 1971. Seasonal production of Andropogon gayanus. III. Changes in crude protein content and in vitro dry matter digestibility of leaf and stem portion. J. Agr. Sci. 77:47-52.

Heady, H. F. 1961. Continuous versus specialized grazing systems: A review and application to the California annual type. J. Range Manage. 14:182-193.

Heady, H. F. 1975. Rangeland Management. McGraw-Hill Book Company, New York. 460 pp.

Heitschmidt, R. K., R. A. Gordon, and J. S. Bluntzer. 1982. Short duration grazing at the Texas Experimental Ranch. I. Effects on aboveground biomass dynamics. J. Range Manage. 35:372-374.

Holt, E. C., and J. C. McDaniel. 1963. Influence of clipping on yield, regrowth and root development of Dallisgrass, Paspalum dilatatum Poir., and Kleingrass, Panicum coloratum L. Agron. J. 55:561-564.

Hormay, A. L., and M. W. Talbot. 1961. Rest rotation-grazing: A new management system for perennial bunchgrass ranges. U. S. Dept. Agr. Prod. Research Rept. 51.

Huokuna, Erkii. 1966. Tillering in meadow-fescue swards. Proc. X Intern. Grassld. Cong. pp. 129-134.

Huston, J. E., B. S. Rector, L. B. Merrill, and B. S. Engdahl. 1981 Nutritional value of range plants in the Edwards Plateau region of Texas. Texas Agr. Exp. Sta. Bull. B-1357. 16 pp.

Hyder, D. N., and F. A. Sneva. 1959. Growth and carbohydrate trends in crested wheatgrass. J. Range Manage. 12:271-279.

Hyder, D. N. 1977. In: R. E. Sosebee (ed.) Rangeland plant physiology. Range Science Series No. 4.

Jewiss, O. R. 1972. Tillering in grasses—its significance and control. J. Br. Grassld. Soc. 27:65-82.

Khan, C. H. A. 1970. Effects of clipping intensities on forage yield of Cenchrus ciliaris in Thal, Pakistan. Pakist. J. For. 20:75-37.

Kilcher, M. R., and J. E. Troelsen. 1973. Contribution of stems and leaves to the composition and nutrient content of irrigated bromegrass at different stages of development. Can. J. Plant Sci. 53:767-771.

Kothmann, M. M. 1980. Nutrition of livestock grazing on range and pasture lands. In: D. C. Church (ed.) Digestive physiology and nutrition of ruminants. O & B Books, Inc., Corvallis, Ore. pp. 56-78.

Langer, R. H. M. 1963. Tillering in herbage grasses. Herb. Asbtr. 33:141-148.

Larcher, W. 1980. Physiological Plant Ecology. Springer-Verlag, New York. 252 pp.

Leopold. A. C. 1949. Control of tillering in grasses by auxin. Amer. Jour. Bot. 36:437-440.

McNaughton, S. J. 1979. Grazing as an optimisation process: Grass-ungulate relationships in the Serengeti. Am. Nat. 113:691-703.

Michieka, D. O., and B. J. A. Van der Pouw. 1977. Soils and vegetation of the Kiboko Range Research Station. A semidetailed report. No. 53 National Agricultural Labs., Min. of Agric. Kenya.

National Livestock Development Policy. 1980. Ministry of Livestock Development, Nairobi, Kenya.

Osman, Ahmed E. 1979. Productivity of irrigated tropical grasses under different clipping frequencies in the semidesert region of the Sudan. J. Range Manage. 32:182-185.

Owensby, C. E., J. R. Rains, and J. D. McKendrick. 1974. Effects of one year of intensive clipping on big bluestem. J. Range Manage. 27:341-343.

Pandeya, S. C., and P. K. Jayan. 1970. Population differences in buffel grass (Cenchrus ciliaris) at Ahnedabad, India: Productivity under various agronomic conditions. Proc. 11th Intern. Grassld. Congr., Surfers Paradise 239-244.

Perry, L. J., and S. R. Chapman. 1975. Effects of clipping on dry matter yields and survival of basin wildrye. J. Range Manage. 28:271-274.

Perry, L. J., and S. R. Chapman. 1976. Clipping effects on dry matter yields and survival of basin wildrye. J. Range Manage. 29:311-312.

Peterson, R. A. 1962. Factors affecting resistance to heavy grazing in needle-and-thread grass. J. Range Manage. 15:183-189.

Pine, G. M., and G. W. Burton. 1956. The effect of nitrogen rate and clipping frequency upon the yield, protein content and certain morphological characteristics of coastal bermudagrass, Cynodon dactylon (L). Pers. Agron. J. 48:296-301.

Potter, H. L. 1980. Herbage height and frequency cutting trial. Record of Research 1977-1980. Kenya Agricultural Research Institute, Muguga, Kenya.

Pratt, D. J., P. J. Greenway, and M. D. Gwynne. 1966. A classification of East African rangeland. J. Appl. Ecol. 3:369-382.

Pratt, D. J., and M. D. Gwynne. 1977. Rangeland Management and Ecology in East Africa. Hodder and Stoughton, London.

Pritchard, G. I., L. P. Folkins, and W. J. Pigden. 1963. The in vitro digestibility of whole grasses and their parts at progressive stages of maturity. Can. J. Plant Sci. 43:79-87.

Simonson, D. J., R. M. Hansen, and M. J. Trlica. 1982. Comparison of four methods to estimate the dissolved nitrogen fraction in range plants. J. Range Manage. 35:18-21.

Sinclair, A. R. E., and M. D. Gwynne. 1972. Food selection and competition in the East African buffalo (Syncerus caffer, Sparrman) E. Afr. Wildl. J. 10:77-89.

Singh, V. P., and L. P. Mall. 1976. Response of Andropogon pumilus Roxb. to various heights and intervals of clipping. J. Range Manage. 29:135-137.

Stobbs, T. H., and D. J. Minson. 1980. Nutrition of ruminants in the tropics. In: D. C. Church (ed.) Digestive Physiology and Nutrition of Ruminants. O&B Books, Inc., Corvallis, Ore. pp. 257-274.

Taerum, R. 1970. Comparative shoot and root growth studies on six grasses in Kenya. E. Afr. Agric. For. J. 36:94-113.

Taylor, T. H., and W. C. Templeton. 1976. Stockpiling Kentucky bluegrass and tall fescue for winter pasturage. Agron. J. 68:235-239.

Terry, T. A., and J. M. A. Tilley. 1964. The digestibility of the leaves and stems of perennial ryegrass, cocksfoot, timothy, tall fescue, lucerne and sainfoin as measured by an in vitro procedure. J. Br. Grassld. Soc. 19:363-372.

Troughton, A. 1957. The underground organs of herbage grasses. Common Bureau of Pastures and Field Crops. Bull. 44, Hurley, Berkshire.

Turner, N. C., and J. E. Begg. 1978. Response of pasture plants to water deficits. In: J. R. Wilson (ed.) Plant relations in pastures. C. S. I. R. O., Melbourne, Australia.

Van Dyne, G. M. 1962. Micro-methods for nutritive evaluation of range forages. J. Range Manage. 15:303-314.

Vogel, W. G., and A. J. Bjugstad. 1968. Effects of clipping on yield and tillering of little bluestem, big bluestem and indiangrass. J. Range Manage. 21:136-140.

Voorthuizen, E. G. van. 1972. The effects of cutting frequency and cutting height on four naturally occurring pasture grasses in Tanzania. E. Afr. Agric. For. J. 37:258-264.

Weinmann, H., and E. Goldsmith. 1948. Underground reserves of Cynodon dactylon Pers. Publ. Afr. Explosives & Chem. Industr. Ltd. and South Afr. Turf. Res. Fund. pp. 56-75.

Western. D. 1982. The environment and ecology of pastoralists in arid savannas. World Development 13:183-211.

White, L. M. 1973. Carbohydrate reserves of grasses: A review. J. Range Manage. 26:13-18.

Wilson, J. R., and T. T. Ng. 1975. Influence of water stress on parameters associated with herbage quality of Panicum maximum var. Trichoglume. Aust. J. Agric. Res. 26:127-136.

Whyte, O. R. 1968. Grasslands of the monsoon. Frederick A. Paeger Publ., New York.

APPENDIX

Table 41. Analysis of variance on the dry matter yield of six grasses harvested at three frequencies and three intensities.

Source of variation	df	MS	F
Grasses	5	553464.44	31.16**
Sites	1	501803.01	28.25**
Grasses * sites	5	99115.97	5.58**
Frequency	2	102091.68	5.75**
Frequency * sites	2	141541.45	7.97**
Frequency * grasses	10	16464.14	0.93
Error (a)	82	17763.96	3.04**
Intensity	2	8362.45	1.43
Intensity * sites	2	11160.41	1.91
Intensity * grasses	10	11360.31	1.94*
Intensity * frequency	4	5605.93	0.96
Error (b)	198	5851.56	1.11
Seasons	3	3822460.65	724.81**
Seasons * sites	3	233423.76	44.26**
Seasons * grasses	15	147341.48	28.03**
Seasons * frequency	6	34567.98	6.55**
Seasons * intensity	6	11307.81	2.14*
Error (c)	939	5273.77	

* Significant at the .05 level.
** Significant at the .01 level.

Table A2. Analysis of variance on the leaf-to-stem ratio data of six grasses harvested at three frequencies and three intensities.

Source of variation	df	MS	F
Grasses	5	450.27	54.24**
Sites	1	36.17	4.36*
Grasses * sites	5	5.82	0.70
Frequency	2	307.04	36.98**
Frequency * grasses	10	10.92	1.32
Frequency * sites	2	7.81	0.94
Error (a)	82	8.30	2.67**
Intensity	2	27.59	8.97**
Intensity * sites	2	6.22	2.00
Intensity * grasses	10	7.81	2.51**
Intensity * frequency	4	51.40	16.52**
Error (b)	198	3.11	0.50
Seasons	3	1362.51	218.42**
Seasons * sites	3	9.48	1.52
Seasons * grasses	15	83.39	13.37**
Seasons * frequency	6	97.56	15.64**
Seasons * intensity	6	38.09	6.11**
Error (c)	939	6.24	

* Significant at the .05 level.
** Significant at the .01 level.

Table A3. Analysis of variance on the crown diameter of six grasses harvested at three frequencies and four intensities.

Source of variation	df	MS	F
Grasses	5	393.08	20.18**
Sites	1	522.06	26.80**
Grasses * sites	5	80.89	4.15**
Frequency	2	46.11	2.37
Frequency * grasses	10	31.75	1.63
Frequency * sites	2	109.11	5.60**
Error (a)	82	19.48	1.84**
Intensity	3	37.05	3.49*
Intensity * grasses	15	14.69	1.38
Intensity * sites	3	27.04	2.55
Intensity * frequency	6	14.47	1.36
Error (b)	297	10.61	

* Significant at the .05 level.
** Significant at the .01 level.

Table A4. Analysis of variance on the tiller numbers of six grasses harvested at three frequencies and four intensities.

Source of variation	df	MS	F
Grasses	5	25255.60	29.16**
Sites	1	32552.08	37.58**
Grasses * sites	5	3783.47	4.37**
Frequency	2	1304.62	2.66
Frequency * grasses	10	1308.83	1.51
Frequency * sites	2	912.53	1.05
Error (a)	82	866.13	2.28**
Intensity	3	2155.62	5.68**
Intensity * sites	3	1163.54	3.07*
Intensity * grasses	15	933.78	2.46**
Intensity * frequency	6	745.80	1.97
Error (b)	297	379.22	

* Significant at the .05 level.
** Significant at the .01 level.

Table A5. Analysis of variance on the regrowth height of six grasses harvested at three frequencies and four intensities.

Source of variation	df	MS	F
Grasses	5	580.56	3.32**
Sites	1	1095.70	6.26*
Grasses * sites	5	645.11	3.69**
Frequency	2	848.64	4.85*
Frequency * sites	2	1288.78	7.37**
Frequency * grasses	10	181.63	1.04
Error (a)	82	174.97	1.38*
Intensity	3	6336.69	50.09**
Intensity * sites	3	591.35	4.67**
Intensity * grasses	15	142.13	1.12
Intensity * frequency	6	239.61	1.89
Error (b)	297	126.51	

* Significant at the .05 level.
** Significant at the .01 level.

Table A6. Analysis of variance on the percentage of leaf dry matter digestibility of six grasses harvested at three frequencies and three intensities.

Source of variation	df	MS	F
Grasses	5	663.66	25.25**
Sites	1	12.72	0.48
Grasses * sites	5	68.39	2.58*
Frequency	2	1075.53	40.61**
Frequency * sites	2	50.85	1.92
Frequency * grasses	10	51.79	1.96*
Error (a)	82	26.48	0.89
Intensity	2	59.91	2.01
Intensity * sites	2	123.94	4.16*
Intensity * grasses	10	67.95	2.28*
Intensity * frequency	4	62.36	2.09
Error (b)	198	29.73	

* Significant at the .05 level.
** Significant at the .01 level.

Table A7. Analysis of variance on the percentage of stem dry matter digestibility of six grasses harvested at three frequencies and three intensities.

Source of variation	df	MS	F
Grasses	5	468.59	15.32**
Sites	1	429.18	14.49**
Grasses * sites	5	87.54	2.96*
Frequency	2	1143.97	38.63**
Frequency * sites	2	58.35	1.97
Frequency * grasses	10	196.01	6.62**
Error (a)	82	29.62	0.91
Intensity	2	89.82	2.75
Intensity * sites	2	11.23	0.34
Intensity * grasses	10	48.67	1.49
Intensity * frequency	4	121.51	3.72**
Error (b)	198	32.66	

* Significant at the .05 level.
** Significant at the .01 level.

Table A8. Analysis of variance on percentage of crude protein in leaves of six grasses harvested at three frequencies and three intensities.

Source of variation	df	MS	F
Grasses	5	39.92	8.59**
Sites	1	9.34	2.01
Grasses * sites	5	3.89	0.84
Frequency	2	489.03	105.25**
Frequency * sites	2	0.48	0.10
Frequency * grasses	10	18.41	3.96**
Error (a)	82	4.65	1.12
Intensity	2	1.31	0.44
Intensity * sites	2	5.49	1.33
Intensity * grasses	10	2.80	0.68
Intensity * frequency	4	1.83	0.44
Error (b)	198	4.14	

** Significant at the .01 level.

Table A9. Analysis of variance on percentage of crude protein in stems of six grasses harvested at three frequencies and three intensities.

Source of variation	df	MS	F
Grasses	5	39.04	27.03**
Sites	1	0.74	0.51
Grasses * sites	5	9.75	6.76**
Frequency	2	79.65	55.25**
Frequency * sites	2	1.55	1.07
Frequency * grasses	10	7.50	5.21**
Error (a)	82	1.44	1.23
Intensity	2	1.09	0.93
Intensity * sites	2	0.93	0.80
Intensity * grasses	10	0.62	0.53
Intensity * frequency	4	0.64	0.55
Error (b)	198	1.17	

** Significant at the .01 level.

Table A10. Mean percentage of dry matter digestibility and crude protein in leaves and stems of six grasses at two experimental sites harvested at three frequencies and three intensities during the 1983 short rains.

Grass	Leaf (% DMD)		Stem (% DMD)		CP in leaves (%)		CP in stems (%)	
	OPN	WC	OPN	WC	OPN	WC	OPN	WC
C. ciliaris	73.3 b	72.3 ab	59.2 ab	55.7 ab	11.1 a	10.6 bc	7.3 ab	5.4 b
C. roxburghiana	67.0 d	64.4 c	58.0 b	54.5 b	11.3 a	11.5 ab	7.5 ab	7.8 a
D. macroblephara	77.2 a	75.4 a	53.1 c	50.0 c	11.5 a	11.5 ab	7.8 a	7.9 a
E. superba	70.3 c	72.8 ab	54.6 c	57.4 ab	10.3 ab	11.3 ab	7.1 b	7.4 a
P. maximum	72.0 bc	74.4 a	60.9 a	58.0 a	11.4 a	12.2 a	7.6 ab	7.6 a
T. triandra	71.5 bc	69.7 b	54.5 c	50.9 c	9.2 b	9.6 c	5.5 c	5.9 b

Means for grass species within an experimental site followed by the same letter are not significantly different at the .05 level.

Table A11. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, and percentage of DMD and crude protein of Cenchrus ciliaris following clipping at three frequencies with three cutting heights.

Frequency (weeks)	Cutting height (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
	5	143.4	5.2	10.1	21.4	15.9	73.9	57.8	12.3	6.9
3	10	131.2	4.8	10.8	21.4	18.3	73.1	58.3	11.8	7.1
	15	156.7	5.3	9.7	21.5	17.9	74.6	56.4	12.2	7.1
	5	155.0	5.0	10.4	25.8	18.6	73.4	56.6	10.6	6.9
6	10	141.5	4.3	11.2	28.0	21.2	70.2	58.7	10.1	6.9
	15	168.8	4.8	10.6	23.8	19.3	73.0	56.9	10.5	6.8
	5	157.3	4.0	9.7	25.0	18.8	70.8	53.4	10.1	6.2
9	10	141.6	4.3	11.4	29.0	19.0	69.2	55.1	10.0	6.1
	15	166.3	4.5	10.2	22.4	16.8	72.0	55.4	10.4	6.3

Table A12. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, and percentage of DMD and crude protein of *Chloris roxburghiana* following clipping at three frequencies with three cutting heights.

Frequency (weeks)	Cutting height (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
	5	102.0	5.7	9.9	10.8	11.4	72.2	59.0	12.5	7.5
3	10	105.8	5.1	8.7	13.5	14.7	68.9	57.6	12.5	7.7
	15	114.7	5.5	8.0	18.4	20.2	69.8	54.1	12.2	7.7
	5	113.6	5.6	10.3	15.3	14.2	71.7	57.8	10.7	7.4
6	10	116.2	4.5	9.0	20.2	17.5	65.9	57.9	10.7	7.5
	15	126.8	5.0	8.8	20.8	21.6	68.2	54.7	10.5	7.5
	5	115.8	4.5	9.4	14.5	14.3	69.1	54.6	10.3	6.8
9	10	116.3	4.6	9.0	21.2	15.4	65.0	54.4	10.7	6.8
	15	124.3	4.8	8.4	19.3	19.1	67.2	53.1	10.4	7.0

Table A13. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, and percentage of DMD and crude protein of <u>Digitaria macroblephara</u> following clipping at three frequencies with three cutting heights.

Frequency (weeks)	Cutting height (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
3	5	131.6	6.1	6.1	10.0	14.1	75.9	56.0	12.7	7.6
	10	146.6	5.4	10.3	42.2	18.2	75.9	54.7	12.3	7.8
	15	138.2	5.7	9.7	38.7	21.4	74.9	53.0	12.4	7.9
6	5	143.2	5.9	10.4	31.8	16.9	75.4	54.8	10.9	7.4
	10	156.9	4.8	10.6	48.9	21.1	73.0	55.0	10.6	7.6
	15	150.3	5.3	10.5	41.2	22.8	73.4	53.6	10.7	7.8
9	5	145.4	4.9	9.6	31.1	17.0	72.9	51.6	10.5	6.8
	10	157.1	4.9	10.6	49.8	18.9	72.0	51.5	10.5	6.9
	15	147.8	5.0	10.0	39.7	20.4	72.3	52.0	10.7	7.2

Table A14. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, and percentage of DMD and crude protein of *Eragrostis superba* following clipping at three frequencies with three cutting heights.

Frequency (weeks)	Cutting height (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
	5	122.9	5.2	7.9	14.0	13.0	73.0	58.3	12.3	7.3
3	10	128.7	4.7	8.4	14.6	15.1	74.3	57.1	11.9	7.5
	15	128.8	5.5	7.3	17.0	16.7	72.4	55.0	12.1	7.6
	5	134.5	5.0	8.2	18.5	15.8	72.4	57.0	10.5	7.3
6	10	139.1	4.1	8.7	21.3	17.9	71.4	57.4	10.1	7.3
	15	140.8	4.9	8.1	19.4	18.1	70.9	55.5	10.4	7.4
	5	136.7	3.9	7.4	17.8	15.9	69.9	53.8	10.1	6.6
9	10	139.2	4.2	8.7	22.3	15.7	70.4	53.9	10.1	6.6
	15	138.4	4.7	7.7	17.9	15.6	69.9	54.0	10.4	6.8

Table A15. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, and percentage of DMD and crude protein of *Panicum maximum* following clipping at three frequencies with three cutting heights.

Frequency (weeks)	Cutting height (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
	5	142.7	6.9	9.2	19.7	13.4	73.7	60.4	13.2	7.4
3	10	145.7	6.5	9.7	25.4	17.8	74.3	57.8	12.3	7.7
	15	160.4	7.4	9.4	29.4	20.2	74.1	57.3	12.4	7.9
	5	154.3	6.8	9.5	24.2	16.2	73.1	59.2	11.4	7.3
6	10	156.0	5.9	10.0	32.1	20.6	71.4	58.2	10.5	7.5
	15	172.4	6.9	10.2	31.9	21.6	72.5	57.8	10.7	7.7
	5	156.5	5.7	8.7	23.4	16.3	70.5	55.9	11.0	6.7
9	10	156.1	6.0	10.0	33.1	18.4	70.5	54.7	10.4	6.7
	15	170.0	6.6	9.8	30.4	19.2	71.6	56.2	10.6	7.2

Table A16. Mean forage yield, leaf-to-stem ratio, crown diameter, tiller number, regrowth height, and percentage of DMD and crude protein of *Themeda triandra* following clipping at three frequencies with three cutting heights.

Frequency (weeks)	Cutting height (cm)	Forage yield (g/m^2)	Leaf-to-stem ratio	Crown diameter (cm)	Tiller number	Regrowth height (cm)	Leaf (% DMD)	Stem (% DMD)	Leaf (% CP)	Stem (% CP)
	5	80.5	5.2	7.4	11.2	14.5	73.4	57.5	11.6	6.7
3	10	80.2	4.9	7.0	14.2	17.3	72.9	55.5	11.4	6.8
	15	88.9	5.3	7.0	16.5	19.0	71.9	52.4	11.3	6.7
	5	92.2	5.0	7.3	15.6	17.4	72.8	56.3	9.8	6.6
6	10	90.6	4.3	7.4	20.9	20.2	70.0	55.8	9.7	6.6
	15	100.9	4.8	7.9	18.9	20.4	70.3	52.9	9.5	6.5
	5	94.4	4.0	7.0	14.9	17.5	70.3	53.1	9.4	5.9
9	10	90.7	4.4	7.4	21.9	18.0	69.1	52.3	9.6	5.9
	15	98.4	4.5	7.4	17.4	17.9	69.3	51.4	9.5	6.0

VITA

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