CENTRO AGRONOMICO TROPICAL DE INVESTIGACION Y ENSEÑANZA
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RESPONSE OF DWARF ELEPHANT GRASS (*Pennisetum purpureum*
Schum) TO DIFFERENT FREQUENCIES AND INTENSITIES OF
GRAZING IN THE HUMID ZONE OF GUAPILES
COSTA RICA

Tesis sometida a la consideración del Comité Técnico
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Agrícolas y Recursos Naturales del Centro Agronómico
Tropical de Investigación y Enseñanza, para optar al grado
de

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Por

MUHAMMAD AKBAR IBRAHIM

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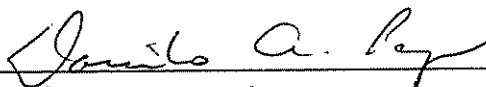
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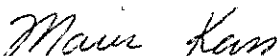
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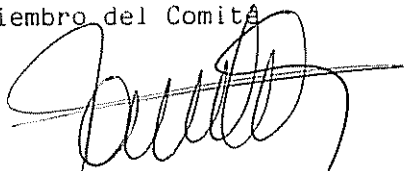COMITE ASESOR:

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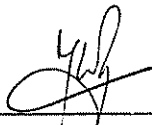
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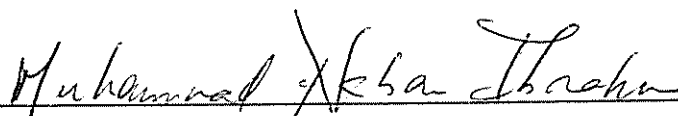Ramón Lastra Rodríguez, Ph.D.
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DEDICATED

To My Wife (Yasmin) and
My Daughter (Nafeeza)

To My Mother (Eva) and
My Father (Sulyaman)

To My Sisters (Yvonne,
Susan, Grace and Sandra)
and My Brother (Ryan)

To Dr. Hector Muñoz and Family

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BIBLIOGRAPHY

The author was born on the 20ᵗʰ of June 1958, in the county of Berbice, Guyana. He realised his primary and secondary education in the Cumberland Primary School and the Berbice Educational Institute, respectively.

He attended the Guyana School of Agriculture in September 1978 where he graduated in June 1980, receiving a diploma in Agriculture with credit. Following this period, he was employed in July 1980 in the Ministry of Agriculture as an Agricultural Technical Assitant, being responsible for seed production and quality control.

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Palabras Claves: Pasto Elefante enano, cv. Mott, frequencia de pastoreo, intensidad de pastoreo, manejo de pastoreo, pastoreo en el trópico, características morfológicas, calidad nutritiva, número de rebrotes, internudos, meristemo apical.

Resumen

Este experimento se realizó entre los meses de noviembre de 1988 hasta junio de 1989 en le Estación Experimental del Ministerio de Agricultura y Ganadería, Los Diamantes, localizada en Guápiles, Costa Rica. el objetivo del presente estudio fue determinar el efecto de varias combinaciones de intensidades y frecuencias de pastoreo, sobre la morfología, persistencia y producción del pasto elefante enano cv. Mott (*Pennisetum purpureum* Schum) bajo las condiciones del trópico húmedo. Se utilizó un diseño experimental de composición central no rotable con 17 combinaciones de tratamientos que incluyeron cuatro repeticiones del tratamiento central en 2.5 ha. Se utilizaron toretes cruzados (*B. Taurus* x *B. Indicus*) de aproximadamente 300 kg de peso vivo.

Las intensidades de pastoreo evaluadas fueron: 3.0, 4.5, 6.0, 7.5 y 9.0 kg de materia seca de hojas por 100 kg de peso vivo (M.S. hojas/100 kg P.V.). Las frecuencias de pastoreo, estudiadas fueron: 0, 14, 28, 42 y 56 días. Las variables de respuesta fueron: producción y calidad de materia seca (hojas y tallos) antes de cada ciclo de pastoreo, composición botánica, altura de las plantas, número de rebrotes por planta, número y largo de internudos por macolla y porcentaje de internudos removidos por el pastoreo.

Con respecto a los cambio morfológicos se encontró un efecto lineal y cuadrático positivos de la intensidad y frecuencia de pastoreo sobre la altura de la planta entera, altura de los tallos y número de internudos, respectivamente. Así, a medida que se alargaron los períodos de descanso y se aumentó la presión de pastoreo (disminución de intensidad de defoliación) se incrementó la

altura de la planta entera y de los tallos, además del número de rebrotes e internudos por cada rebrote. En general los cambios ocurridos en los aspectos morfológicos fueron más fuertemente influenciados por la intensidad de pastoreo que por la frecuencia del mismo. Respecto al número de meristemos removidos después de cada pastoreo se encontró que la frecuencia de pastoreo no tuvo ninguna influencia, mientras que a bajas intensidades de pastoreo (9 kg de hojas/100 kg P.V.) la remoción de meristemos apicales fue de 32%, incrementándose hasta 69% cuando la intensidad de pastoreo se aumentó a 3.0 kg de hoja/100 kg P.V.

Existió una interacción importante entre frecuencia e intensidad de pastoreo con relación a la proporción de hojas y tallos en las plantas. En el pastoreo continuo y hasta frecuencias de pastoreo de cada 28 días, se encontró que a medida que se ofrecía mayor cantidad de forraje por animal la relación hoja-tallo era mayor. Sin embargo, conforme los períodos de descanso aumentaron estas diferencias debidas a las intensidades se revirtieron, encontrándose que los potreros con alta presión de pastoreo tuvieron las mayores relaciones hoja-tallo, que oscilaron entre 2.2 y 2.9 para las intensidades de 9 y 3 kg de hojas MS/100 kg P.V., respectivamente, a los 56 días de descanso.

La disponibilidad de hojas por hectárea por ciclo, en los potreros con pastoreo continuo, y descansos de 14 y 28 días, fue función principalmente de la intensidad de pastoreo; encontrándose que a una intensidad de 3 kg hojas MS/100 kg P.V., la disponibilidad fue de 1.1 Mg MS/ha y con intensidades de 9 kg hojas MS/100 kg P.V. la disponibilidad de hojas aumentó a 3 Mg MS/ha. No obstante a medida que los períodos de descanso fueron superiores a los 28 días se encontró un aumento de un 89% en la disponibilidad de hojas independientemente de la intensidad de pastoreo aplicada, oscilando la disponibilidad desde 2.5 a 5 Mg/MS de hojas por ha por ciclo. Igual tendencia se obtuvo para la producción de hojas por ha/ciclo, obteniéndose producciones de 1 hasta 3 Mg MS/ha al aumentar la frecuencia desde el pastoreo continuo hasta cada 56 días.

La calidad del pasto, se evaluó en término de su concentración protéica (PC) y digestibilidad in vitro de la materia seca (DIVMS). En las hojas solo se encontró un efecto importante de la frecuencia de pastoreo sobre la PC la cual descendió desde 15.9% a los 28 días hasta 11.2% a los 56 días de descanso. La DIVMS de los tallos también fue afectada solo por la frecuencia de pastoreo disminuyendo de 64% a 55.9% a medida que los períodos de pastoreo aumentaron de 28 a 56 días.

La composición del pasto elefante-enano fue afectada significativamente (P<0.001) por los factores de pastoreo: frecuencia (0 y 14 días) y severidad de defoliación (3 kg de materia seca de hojas 100 kg PV^{-1}) que redujeron la composición inicial del pasto elefante-enano en más del 42%, mientras que la intensidad del pastoreo ()7.5 y 9.0 kg MSH 100 kg PV^{-1}) no presentó efecto detrimental cuando la pastura fue frecuentemente pastoreada. Similarmente, la composición del pasto elefante-enano tendió a incrementarse cuando el período de descanso fué disminuído, observándose un mayor efecto con mayor intensidad de pastoreo.

SUMMARY

This experiment was realised ind the experimental station of the Ministry of Agriculture (MAG-Guápiles), between the months of November 1988 and June 1989. The objective of the present study was to determine the effect of various combinations of grazing intensity and frequency on the morphology, persistence and dry matter production on dwarf elephant grass cv. Mott (*Pennisetum purpureum*) under tropical humid conditions. A modified central composite non-rotable (response surface) design with 13 treatment combinations, and with the central treatment being replicated four times was used in the experiment. Further, animals (B. Taurus x B. Indicus) weighing approximately 300 kg each, were used to defoliate the plots.

The grazing intensities evaluated were 3.0, 4.5, 6.0, 7.5 and 9.0 kg leaf dry matter 100 kg BW^{-1}. The grazing frequencies studied were 0, 14, 28, 42 and 56 days. The response variable were: dry matter production, leaf and stem forage quality, and morphology: plant height, number of tillers per plant, number of axillary buds and internodes per tiller, leaf/stem ratio, percentage of apical meristems removed during grazing, and changes in botanical composition.

With respect to morphological changes, the grazing frecuency and intensity resulted in positive linear ($P<0.05$) and quadratic ($P<0.01$) effect on plant and stem height, number of internodes and axillary buds, respectively. Consequently, plant and stem height as well as the number of axillary buds and internodes per tiller were elevated as the grazing intensity and frequency was descended. On the other hand, the grazing frequencies were not found to affect the percentage of apical meristems removed, whereas the grazing intensities were very significant ($P<0.0001$) showing that more than 69% of the apical meristems were removed in the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}) compared

to only 32% for the lowest grazing intensity (9.0 kg LDM 100 kg BW^{-1}).

There were important interactions (P<0.01) between grazing frequency and intensity on leaf/stem ratio which tended to increase as the levels of leaf allowance were increased in short resting periods (0-14- and 28- days). However, the leaf/stem ratio was detected to decline with long grazing intervals (42- and 56- daya), and it oscillated between 2.2 and 2.9 for the grazing intensities of 9 and 3 kg LDM 100 kg BW^{-1}, respectively, in the 56- days resting period.

Available leaf dry matter production over short grazing cycles (0, 14 and 28- days) was principally a function of grazing intensity. Under continous grazing available leaf dry matter was only 1.1 Mg DM/ha for the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}) but this value was elevated to 3.0 Mg DM/ha as the leaf allowance was increased to 9.0 kg 100 kg BW^{-1}.

Also, the levels of grazing frequency resulted in measurable changes in available leaf dry matter production, detecting an increase of 89% between the 28- and 56- days grazing interval.

Forage quality was not found to be seriously affected by the grazing factors, and there were only quadratic (P<0.05) effects of grazing frequency on leaf protein and stem digestibility were detected. Leaf protein was found to decrease from 15.9% to 11.2% when the resting period was extended from 28- to 56- days. While in vitro dry matter digestibility of stem fractions declined from 64% to 55.9% as the grazing interval was prolonged to 56 days.

The composition of dwarf elephant grass was also affected by interaction (P<0.001) of the two grazing factors. Frequent (0 and 14- days) and severe (3.0 kg LDM 100 kg BW^{-1}) defoliations were found to reduce the initial composition of dwarf elephant grass by more than 42%, whereas low grazing intensities (7.5 and 9.0 kg LDM 100 kg BW^{-1}) were not found to be detrimental when the pasture was frequently grazed. Similarily, the composition of dwarf elephant grass tended to increase as the resting period was decreased, observing the highest effect with high grazing intensities.

1. INTRODUCTION

Tropical regions present the greatest demographic rise and acute problems in overall food production. Although a significant proportion of the world's total ruminant animal population is found in tropical regions, animal production is generally poor, achieving productivities of only 10 to 25% of that considered as acceptable in developed temperate countries (Perez - Infante, 1977).

Low forage quality and seasonal forage production have been prominent among the factors identified for low animal production in the tropical regions (Whiteman, 1980). Tropical pastures are inherently of lower nutritional quality than those in the temperate zone, and it has been found that a difference of over 10 units in apparent digestibility exist between both type of species (Minson and Mcleod, 1970).

The value of tropical pastures for milk production has been the subject of excellent reviews by Stobbs and Thompson (1975) and Stobbs (1975-1976). These authors concluded that milk production from tropical pastures was limited by a reduced intake of digestible nutrients, in particular energy, and to a lesser extent by their lower mineral content.

Eventhough tropical pastures are generally of low quality, it is widely accepted that herbage under most farming situations is the cheapest source of nutrients for

herbivorous animals. Therefore, a major factor in increasing livestock productivity will be the improvement of animal nutrition through the increase of forage availability and quality (Whiteman, 1980).

The value of improved pastures for ruminant production has been emphasised by many scientist (Archibald, 1984; Humphreys, 1978; Whiteman, 1980). Improved pastures properly managed in the humid tropics have the capacity to allow relatively high levels of milk and beef production, both per cow and per hectare of land used (Archibald, 1984).

The usual aim of pasture management is to keep a high level of output from animals grazing the pasture. This requires an understanding of both how the pasture affects the animal performance, and also the effect of the grazing animals on the capacity of a pasture to persist, grow and provide nutritious feed.

Under grazing conditions, animal selectivity, grazing frequency and defoliation intensity all operate together. To separate these factors and to assess the influence of defoliation frequency and intensity per se on botanical composition and production, numerous clipping or heavy grazing experiments have been undertaken (Vickery, 1981).

The dwarf elephant grass has been identified as a potential forage specie for the subtropics and tropics. However, most of the information on this grass with respect to forage production and animal productivity is available for subtropical conditions. Thus, the lack of information

on the performance of dwarf elephant grass (cv.Mott) under humid tropical conditions has been one of the major constraints in the utilization of this pasture for grazing.

In view of the need for basic information on the dwarf elephant grass under tropical environments, this study was undertaken with the general objective of evaluating the effect of intensity and frequency of grazing on the productive characteristics of dwarf elephant grass.

2. LITERATURE REVIEW

Much of the available information on dry matter
production for the common cultivars of elephant grass
(Pennisetum purpureum) comes exclusively from cutting and
fertilization management systems, where high yields have
generally been achieved. However, under grazing conditions
the yields have been lower and many researchers have
suggested that the main limitation of elephant grass under
grazing results from management problems derived from its
growth habit (Rodrigues et al., 1987a).

Over the past twenty years, there has been considerable
research for selection and breeding of improved *Pennisetum*
cultivars that are adapted to grazing conditions (Hanna,
1988). The dwarf elephant grass cv. Mott referred to in the
literature as TIFT N-75 before its release, was selected
from among progenies, when the hybrid Merkeron elephant
grass was selfed (Hanna, 1988). It should be mentioned that
Merkeron is a tall hybrid selected from crosses between tall
and dwarf elephant genotypes made in 1941 by G.W. Burton
(Hanna, 1988).

2.1. PLANT MORPHOLOGY.

Responses of forage plants to defoliation were reviewed by various authors (Humphreys, 1966; Vickery, 1981; Mares Martins, 1984). All of these authors emphasised that regrowth after defoliation may be influenced by the morphology of plants, by the amount of leaf area remaining after cutting or grazing, and by the amount of reserve carbohydrates in the residual tissues. Furthermore, morphological and physiological responses of plants are associated with environmental factors such as light, water and temperature (Cooper and Tainton, 1968; Humphreys, 1981).

2.1.1. Plant Height and Apical Meristems.

The main differences between species in terms of their tolerance to grazing, appear to be related to morphological characteristics. Resistance to grazing tends to increase with a decrease in growth height, growth rate, leaf and shoot apex elevation, time of floral differentiation and the proportion of reproductive shoots (Booysen et al., 1963). Besides, the leaf replacement potential, which varies with the stage of growth as well as among species, is also considered as an important character for grazing resistance (Hyder, 1972).

The discovery of dwarf genes in the *Pennisetum* species has led to renewed interest in the use of elephant grass under grazing conditions. Studies conducted on dwarf elephant grass (cv. Mott) in subtropical Florida have demonstrated that this grass has a high capacity to persist under good grazing management (Veiga et al., 1985; Rodrigues et al., 1987ab). Dwarf elephant grass is characterized by short erect growth habit, short internodes and high proliferation of leaves (Hanna, 1988).

The dwarf cultivar grows into an uncut vegetative height of just over 1.4 m in comparison to 4.0 m for the MERKERON cultivar. Individual bunches produce large number of tillers with the diameter at the base extending greater than 0.6 m. The leaf canopy from a single bunch may occupy a diameter of 0.9 to 1.5 m (Hanna, 1988). Although not mentioned in the literature, it may be suggested that the semihorizontal orientation of the leaves will permit a high interception of light within the canopy.

Cultivars of elephant grass differ in many morphological characters (Muldoon and Pearson, 1979a). However, there is no doubt that differences in height between tall and dwarf varieties of elephant grass are due to the length of the internodes, which varies from 0.2 to 1.5 cm (Rodrigues et al., 1987a) for the dwarf elephant grass cv. Mott. In this respect, Rodrigues et al., 1987a

indicated that the pattern of internode elongation of dwarf elephant grass is due to the differentiation of apical meristems.

Grasses are different in their ability to tolerate grazing. The prostrate rhizomatous species are generally considered tolerant to grazing, because the growing points are protected from defoliation (Booysen et al., 1963). In contrast, the taller erect species are very susceptible to defoliation, mainly because early internode elongation reduces the density of buds close to the ground, elevates the canopy and increase apical meristems vulnerability to cutting or grazing (Booysen et al., 1963; Vickery, 1981).

Humphreys (1981), noted that the rhizomatous plants with buried buds such as *Pennisetum clandestinum* or some forms of *Cenchrus ciliaris*, and stoloniferous plants such as *Digitaria decumbens*, have many more sites remaining after grazing, than the lax plants like *Melinis minutiflora*, which tend to have elevated apices easily removed by animals. Although the *Desmodium* species are generally susceptible to heavy grazing, lines of *Desmodium intortum* have been identified as tolerant to grazing, due to a higher density of axillary buds close to the plant's crown, and a high proliferation of smaller leaves (Imrie, 1971).

In contrast, experimental results presented by Andrade and Gomide (1971) showed that tall elephant grass had a fast initial regrowth, which was evident by the total removal of growing points when defoliated at 56-day cutting intervals.

However, defoliations every 28 days allowed the survival of apical meristems, which in turn resulted in good regrowth.

The importance of growing points in grassland management has been stressed by several authors (Booysen et al., 1963; Jewiss, 1972; Hyder, 1972). These authors concluded that excessive removal of the apical meristems usually produce deleterious effects on the regrowth of grasses. Consequently, there is a cessation in leaf development which retards growth until new tillers are formed. The overall effect of it is the prevention of any further development of photosynthetic tissues on that tiller (Booysen et al., 1963). Any factor which prevents the development or replacement of photosynthetic tissue on tillers of the plant, will reduce the ability of the tiller to recover from defoliation and the plants will have a low degree of resistance to grazing as new foliage is dependent on the production of new tillers (Humphreys, 1966).

The induced effects following shoot apex removal were confirmed by many workers. For example, Nieland and Curtis (1956) found that elongated tillers died when the growing points were removed in a bunch grass such as *Panicum virgatum*. On the other hand, Muldoon and Pearson (1979b) reported that initial regrowth of the hybrid Pennisetum (*Pennisetum americanum x Pennisetum purpureum*) was delayed when apical meristems were decapitated, but a higher initial regrowth was observed with intact shoot apices.

Most of the morphological studies reviewed on forage evaluation have been conducted almost exclusively under clipping conditions. These results are generally not applicable for grazing conditions, because of additional variables imposed on the pasture by the grazing animal (Arnold, 1981). Grazing animals usually take repeated bites to harvest individual plant, but the frequency and intensity of grazing of any tiller is influenced by many factors including stocking rate, bulk density and the height of herbage (Arnold, 1981). Even under intensive grazing of monoculture grass swards, a grazing pattern occurrs and individual plants may escape defoliation for a time (Whyte, 1973).

Conclusions drawn from grazing trial with dwarf elephant grass (cv. Mott) in subtropical Florida (Rodrigues et al., 1987a), indicated that severe and frequent defoliation produced negative effects on plant growth. The percentage of apical meristems eliminated varied from 25 to 73%, and was greater with continuous grazing and higher grazing pressures. With increasing herbage removal, the grass responded by reducing its internode elongation which helped to keep the growing points closer to the ground. The height at which the apical meristems were located varied from 8.8 cm with severe and frequent grazing, to 26.9 cm for lenient and infrequent defoliations. Plant structure was not affected by lenient and infrequent grazing, besides there was little variation in the internode numbers which is

a clear indication that this character was genetically established, and therefore inherent to each genotype (Rodrigues et al., 1987a).

Unlike the responses observed with dwarf elephant grass, Pedreira and Boin (1969) reported that the growing points of tall elephant grass (*Pennisetum purpureum*) were elevated at the same rate at which plant height increased. For example, the height of the apical meristems increased from 0 cm at 21 days to 105 cm at 84 days (Pedreira and Boin, 1969). Similar responses were observed with defoliation studies on *Pennisetum typhoides* (Begg, 1965).

2.1.2. Axillary Buds and Tillering.

In tussock grasses subject to herbivory by large grazing mammals, the majority of the active meristematic regions of individual plants are often removed. Canopy replacement is then dependent on the outgrowth of axillary buds as tillers (Richards et al., 1988) or from residual active meristematic tissues (Hyder, 1972).

In herbaceous plants, the activity of axillary buds and hence branching is inhibited by the presence of the shoot apex (Richards et al., 1988), a condition referred to as apical dominance which appears to involve auxins. Dahl and Hyder (1977), indicated that tillering ability from axillary buds without the apical meristem being removed is considered as an indication of an efficient forage producer.

Stimulation in axillary bud activity should increase shoot yields, since both the weight and the number of individual tillers are elevated (Humphreys, 1966-1981; Dovrat et al., 1980).

The role of tillering in grasses was reviewed by Langer (1963) and Jewiss (1972). These authors noted that survival of perennial grasses is ensured by the continual production of new tillers. Maximum pasture production, therefore depends upon the provision of optimal growth conditions for as many tillers as possible, and the maintenance of adequate tiller density to ensure a good plant stand (Humphreys, 1966; Jewiss, 1972; Briske, 1986).

Tillering has been found to have a two fold role in the sustaniability of the grass sward (Jewiss, 1972). First, if component plants in a sward population perish for any reason, then the ability of the remaining plants to produce more tillers permit to fill the space created and prolongs the longevity of the sward as a productive unit. Secondly, a more important feature of regeneration is related to the annual replacement of tillers.

In recent studies conducted by Mott el al., (1987a), it was confirmed that in terms of tiller dynamics the controlling factor was not the number of tillers available at any one time, but the ability of the plant to form new tillers to replace any that died. These authors demonstrated that tropical grasses differed in their tillering patterns. The specie *Themeda triandra* exhibited

synchronous replacement of tillers, such that most of the tillers were of the same age at a given time. In comparison, the specie *Heteropogon contortus* was observed to show unsequential patterns of shoot initiation resulting in tillers at different stages of growth, which is considered essential for sward regeneration (Jewiss, 1972).

The Pattern of tillering originating from axillary buds is highly influenced by the intensity of defoliation (Younger, 1972). Belyuchenko (1980), observed that the height of cutting modified the proportion and orientation of new tillers in the regrowth of elephant grass. Tillers originated from buds on the rhizome with close defoliation (Clapp and Chamblee, 1970) in comparison to a proliferation of aerial tillers with lenient defoliations or higher cutting heights.

Under grazing, selection occurrs for taller vegetative tillers, which will tend to reduce the frequency of defoliation of individual tillers (Gammon and Roberts, 1978a). The three main factors that appear to influence defoliation frequencies within a specie are related to chance, selection for previously grazed tillers due to their palatability and rejection of previously grazed tillers due to their shortness (Gammon and Roberts, 1978c). In general, the most frequently defoliated tillers tended to be more severely grazed (Gammon and Roberts, 1978b).

In cutting trials with dwarf elephant grass (cv. Mott), Cruz and Wege (1988) observed that the number of shoots of the grass was not affected by different cutting intervals. However, under grazing conditions Rodrigues et al., (1987a) encountered that frequent and severe defoliation produced adverse effects on the tillering capacity of dwarf elephant grass (cv. Mott). The number of main tillers per plant was considerably lower at high grazing pressures and short grazing cycles. Although the number of main tillers were reduced, the grass responded with increased number of basal tillers per main tiller, which permitted some levels of dry matter production (Rodrigues et al., 1987a).

In response to severe and frequent defoliation, dwarf elephant grass (cv. Mott) responds by adapting a prostrate growth habit (Rodrigues et al., 1987a), which is mainly associated to reduced internode elongation and a higher production of basal tillers. This type of adaptation is considered very important for pasture production, since Hodgkinson and Williams (1983) explained that by assuming a prostrate growth habit through horizontal tillering or altering physiological characteristics, forage plants can adapt themselves to ensure persistence in the pasture.

Many workers have concentrated on morphological characters for selection of grazing tolerant species, however, there is also evidence that resistance to grazing in forage species can also be achieved through physiological alterations. Studies conducted by Richards and Caldwell

(1985) confirmed that there were inherent differences in the efficiency with which the plant utilizes carbohydrate reserves for shoot regrowth. Under different defoliation regimes it was found that the grazing tolerant specie *Agropyron desertorum* produced 1.3 to 18 times more tillers than the grazing intolerant *Agropyron spicatum.* Differences in tiller population between the two species was mainly attributed to a higher efficiency of utilization of the carbohydrate reserves in the grass *Agropyron desertorum* (Muller and Richards, 1986).

Results obtained in experiments on dwarf elephant grass (cv. Mott) under subtropical conditions may not be applicable for humid environments, because of genotype-environmental interactions. Mott et al., (1987a) demonstrated that more than 60% of the plants of *Themeda triandra* died when grown under low latitude tropical conditions, in comparison to low plant mortality with the same defoliation treatments under subtropical conditions. The main reason for higher plant mortality was related to a synchrony of tiller formation, which was accentuated with higher temperatures and rainfall conditions (Mott et al., 1987b). Consequently, a higher proportion of the tillers were removed in a single defoliation.

2.2. FORAGE QUALITY.

Tropical pastures are generally characterised with poor forage quality (Norton, 1982). However, there is evidence (Hacker and Minson, 1981; Rocha and Vera, 1981 and Vallejos 1988) that differences exist between and within forage species, which are essential for selection and breeding of improved forage cultivars. Apart from genetic variation, forage quality also varies with different plant parts, stages of maturity, soil fertility, as well as with local and seasonal conditions (Norton, 1982). Besides, grazing management factors such as grazing pressure, occupation period and grazing intervals can also influence the changes in forage quality (Pezo, 1981).

Breeding for improved forage quality in *Pennisetum* species has received considerable attention. Rodrigues and Blanco (1970) reported significant differences in chemical composition of 21 elephant (*Pennisetum purpureum*) cultivars and Muldoon and Pearson (1979b), noted that the hybrid (*Pennisetum americanum x Pennisetum purpureum*) was greater in crude protein by more than 23%, when compared to common elephant grass. Recently, the dwarf cultivar was released because of its superior forage quality in addition to other desirable characteristics (Sollenberger and Jones, 1986).

The most outstanding characteristics of dwarf elephant grass lies in its forage quality (Sollenberger et al., 1988). In all the locations in which the grass has been

tested, crude protein content and digestibility (IVDMD and IVOMD) have consistently exceeded 12.5 and 63%, respectively (Mott, 1984; Flores et al., 1989; Fuentes, 1989). This is a clear indication that qualitative traits are also genetically established.

2.2.1. Leaf/Stem Ratio and its Role as a Forage Quality Index.

Leafiness has been emphasized as an important criterion for selection of herbage grasses, because there is usually a positive correlation between leaf percentage in a given plant species and the protein and mineral content, as well as with the dry matter digestibility value (Norton, 1982; Van Soest, 1982). Furthermore, many workers (Minson, 1971; Stobbs, 1973a and Cowan et al., 1986) have indicated that there is a definite relationship between leaf composition and forage intake.

The leaf/stem ratio is generally used to study the growth characteristics of each forage species, and it has a marked importance for the correct management of pastures (Beliuchenko and Febles, 1980). It can also be used cautiously as an index of forage quality (Van Soest, 1982).

Low leaf density in tropical pastures has been identified as a major factor affecting harvestability and intake of grazing animals (Stobbs, 1973b). Results reported by Beliuchenko and Febles (1980) showed that the leaf/stem

ratio for five tropical grasses varied from 0.5 to 1.1 with *Panicum maximum* and *Digitaria decumbens* having the highest leaf coefficients. Consequently, species with long leafy stems (*P. maximum* and *D. decumbens*) or those with a high short stem percentage (*P. dilatatum*) were observed to have the highest leaf proportions (Beliuchenko and Febles, 1980).

Advances in maturity of tropical grasses is usually accompained by a sharp decline in leaf percentage (Norton, 1982). This condition is usually accelerated by favourable environmental conditions for growth which exist in the tropics (Wilson and Minson, 1980). Results presented by Beliuchenko and Febles (1980) on tropical grasses showed that the leaf fractions of the grass *Digitaria decumbens* declined from 51 to 21 % when defoliated at 20 and 60 days, respectively. Similarily, the leaf composition of tall elephant grass (*Pennisetum purpureum*) at the same cutting intervals decreased from 62 to 37%, respectively.

Eventhough leaf/stem ratios of tropical grasses are generally low, several lines as well as cultivars or varieties have been identified with better leaf characteristics (Vallejos, 1988). Among these, the dwarf elephant grass is recognised for its excellent leaf composition (Sollenberger et al., 1988). In cutting trials under tropical conditions, Rodrigues and Blanco (1970) and Carmona and Rodrigues (1979) reported that leaf percentage of dwarf elephant grass was superior than in other *Pennisetum* cultivars. Also, studies under subtropical

conditions with dwarf elephant grass (cv. Mott) demonstrated that leaf regrowth of 5 and 10 weeks of harvesting exceeded 75% and 60%, respectively (Boddorff and Ocumpaugh, 1986).

Excellent leaf composition for dwarf elephant grass was also reported for grazing conditions. Veiga et al., (1985) found that the leaf/stem ratio of this grass was higher with long resting periods, which is not characteristic for other forage species (Sollenberger et al., 1988). In contrast, Pedreira and Boin (1969), noted that the stem/leaf ratio of tall elephant grass (*Pennisetum purpureum*) increased considerably with age and was greater than 1.5 : 1.0, when harvested at 84 days.

Although, increases in stem/leaf ratio are associated with diminishing forage quality (Van Soest, 1982), breeding for improved stem quality offers scope because variation between genotypes is apparent in many species (Hacker and Minson, 1981). Selection of species for reduced stem elongation should increase forage quality by increasing dry matter digestibility and crude protein content (Stobbs, 1973b; Wilson and Minson, 1980). Beliuchenko and Febles (1980), indicated that shorter stems of *Digitaria decumbens* were greater in crude protein by more than 5 percentage units when compared to elongated fractions.

Excellent stem quality has also been discovered for dwarf elephant grass (Boddorff and Ocumpaugh, 1986). Under cutting trials, Fuentes (1989) observed significant differences in stem quality between dwarf elephant and king

grass (*Pennisetum purpureum*), being the dwarf cultivar superior in IVDMD and CP by more than 10 and 8 percentage units, respectively. In this respect, higher stem quality may be related to shorter and thicker internodes. Thicker succulent stems are often associated with higher soluble carbohydrate contents (Wilson and Minson, 1980) and thinly distribution of lignified tissue (Van Soest, 1982).

The superiority of dwarf elephant grass (cv. Mott) in leaf composition and forage quality compared to other grasses is an advantage, since higher levels of pasture utilization are attainable (Sollenberger et al., 1988). At the sward level, the major factor influencing intake is the bite size (Arnold, 1981) which is highly correlated with leaf bulk density (Minson, 1971; Stobbs, 1973b). Furthermore, at the ruminal level there is a higher rate of passage with leaf fractions (Poppi et al., 1981) which is also a determining factor in forage intake.

Field experiments conducted on dwarf elephant grass (cv. Mott) in Florida showed that grazing efficiency expressed as the percentage of leaf herbage accumulated that was consumed, was not different among years and it averaged 88% during the entire experimental period (Sollenberger and Jones, 1989).

2.2.2. Effect of Grazing Management on Forage Quality.

Variations in the quality of available forage during the grazing period are highly influenced by the selective behaviour of the grazing animals (Arnold, 1981). Diets selected from the top layers of the sward usually contain a higher portion of digestible leaf fraction (Cowan et al., 1986), but with successive days of occupation there is a sharp decline in the leaf content of the diet, with an associated increase in stem and dead leaf material (Stobbs, 1978). In studies with dairy cows, Cowan et al., 1986, noted that the crude protein content of the diet exceeded 12% only for the first two days of grazing, and there was less fluctuation in nutrient composition with diets selected from grass legume swards.

The quantity and quality of diet selected by grazing animals depends on the intensity of defoliation (Chacón and Stobbs, 1976). When the grazing pressure is low and the pasture supply is abundant, then grazing animals are able to select forage of a higher quality than the average on offer (Mileria et al., 1987). On the other hand, Hamilton et al., (1970) working with sheep observed that grazing animals failed to select a diet with a digestibility higher than that of the available forage, when the availability of green dry matter was below 550 kg ha^{-1}.

With increases in herbage allowance, intake approaches a linear increase up to a given level of allocation (Pezo, 1981) and consequently a higher digestible dry matter intake is achieved (Mileria et al., 1987). In recent grazing studies with *Cynodon dactylon*, Mileria et al., (1987) found that there were significant increases in dry matter digestibility and forage intake, as the level of herbage allowance was increased up to 40 kg DM Cow^{-1} day^{-1}.

Contrary to the general belief that forage quality and intake are increased at lower grazing pressures, it is often theorised that high forage availability can produce a decrease in digestibility and intake as a consequence of accumulated lignified residual forage (Maraschin and Mott, 1982). This condition may persist because of the seasonal nature of the high growth rate of tropical grasses which requires conservative stocking rates (Wilson and Minson, 1980). Under favourable environmental conditions, there is increased pasture availability and, therefore, low stocking rates will result in an accumulation of mature stemmy material in addition to a high rate of tissue senescence and low dry matter digestibility and intake (Hodgson, 1982).

Grazing interval is another important factor affecting forage quality, especially where prolonged resting periods are used in rotational grazing systems (Whiteman, 1980). As the grasses progress in age, there is a rapid decline in dry matter digestibility and crude protein content (Rocha and Vera, 1981). This is attributed to increases in

indigestible stem fractions together with other indigestible components such as dead leaf blades and sheats that are highly lignified (Van Soest, 1982; Herrera and Hernández, 1988).

During the rainfall period, the rate of decline in forage quality with age is accelerated because of a higher synthesis of cell wall fractions and linear increases in lignin concentration, resulting from increased growth rates and elevated temperatures (Herrera and Hernández, 1988). Furthermore, rapid senescence in the growing season, although coupled with fast regrowth of new leaves, results in a substantial waste of the pasture produced. As a result of this, with infrequent heavy grazing the animals would be exposed to large quantities of senescent leaves of low digestibility below the upper canopy (Wilson and 't Mannetje, 1978).

Forage species which maintain high digestibility for long periods during the growing season are of higher value for animal production than those which have high digestibility at young stages of growth but which decreases rapidly (Norton, 1982).

Unlike most tropical and subtropical grasses, dwarf elephant grass (cv. Mott) is recognized for its ability to maintain high forage quality over long defoliation intervals (Sollenberger et al., 1988). Under cutting trials in the humid zone, Fuentes (1989) working with dwarf elephant grass (cv. Mott) observed that its IVDMD was greater than

52% and the crude protein content exceeded the critical
levels of 7% (Minson, 1971) even when cut at 175 days. Also
in subtropical Florida, Boddorff and Ocumpaugh (1986) found
values for IVOMD and CP to be greater than 70% and 14%,
respectively, when the dwarf elephant grass was defoliated
at 35 days interval.

Under grazing conditions with dwarf elephant grass,
Mott (1984) observed that the indicators of forage quality
(IVOMD and CP) maintained values even with long grazing
intervals. When the grass was grazed in a 56-days grazing
cycle, CP and IVOMD measured were above 10.5 and 68.2%,
respectively. It should be mentioned that these values were
considered high when compared with prostrate species
defoliated at similar or shorter grazing intervals (Mislevy
et al., 1982). Also, in a 28 day rotational grazing system
Santillán and Mena (1988) noted that the crude protein
content of dwarf elephant grass (cv. Mott) was superior
than the other grasses (*Digitaria decumbens* and *Cynodon
nlemfuensis*) evaluated. The crude protein content was 8.7,
9.0 and 12.0% for *Digitaria decumbens*, *Cynodon nlemfuensis*
and *Pennisetum purpureum* cv. Mott, respectively.

In other grazing studies Váscones et al., (1988) found
that the IVOMD of dwarf elephant grass grown in monoculture
was not different from that associated with legumes
(*Neonotina wightii* and *Desmanthus virgatus*). However, the
crude protein content was significantly higher for the
mixtures.

Owing to the capacity of dwarf elephant grass to maintain high forage quality over long resting periods, grazing may be scheduled to ensure a continuous supply of forage during periods when there is a scarcity in pasture production (Sollenberger et al., 1988). Furthermore, grazing intervals can be fixed to coincide with high forage yield and, therefore, to capitalize on good animal performances together with high levels of animal production per hectare.

Forage quality is generally reflected in animal performance (Whiteman, 1980). Excellent forage quality reported for dwarf elephant grass was verified in grazing trials conducted in Florida and Honduras. In both locations, animals grazing dwarf elephant grass (cv. Mott) gained more than 790 g day^{-1} (Sollenberger et al., 1988, Vascones et al., 1988) which is considerably higher when compared to the values (< 600 g day^{-1}) reported by Mott and Moore (1977) for other perennial tropical grasses.

High animal performance detected for dwarf elephant grass (cv. Mott) is related to increased intake of total digestible nutrients (TDN), a characteristic which combines voluntary intake and digestibility (Flores et al., 1989). Qualitative studies conducted by Flores et al., (1989) showed that average TDN intake of dwarf elephant grass was 1.38% body weight compared to 1.1% for Bahiagrass (*Paspalum notatum*).

2.3. FORAGE YIELD.

The productive potential of improved tropical grasses managed under optimum conditions is significantly higher than that of temperate species. The majority of tropical grasses have a C_4 pathway of photosynthesis and a specialized leaf anatomy (Johnson, 1981). These modifications are associated with high efficiency to fix CO_2 and to utilize solar radiation, increased photosynthetic rates and low rates of photorespiration (Iturbide, 1983).

Ludlow and Wilson (1970) encountered higher relative growth rates with grasses (C_4) which varied from 0.354 to 0.475 g g^{-1} d^{-1}, while that for legumes (C_3) varied from 0.257 to 0.341 g $g^{-1}d^{-1}$. Net assimilation rates averaged 1.65 and 0.93 g dm^{-2} wk^{-1} for grasses and legumes, respectively.

Under intensive management systems, napier grass (*Pennisetum purpureum*) cut every 60 days and with high fertilization levels, has the capacity to produce more than 50 Mg DM ha^{-1}. Unlike the tall ecotypes, lower dry matter yields were observed with dwarf elephant grass which produced only one-third of the biomass obtained with the more vigorous tall cultivars (Sollenberger et al., 1988). However, these lower levels of production are compensated by its leafiness, since in the dwarf genotype 70% of the total

dry matter yield at 8 weeks of regrowth corresponds to leaves, in comparison to 46% for the MERKERON Cultivar (Boddorff and Ocumpaugh, 1986).

Forage yield is affected by various environmental and management factors. In the tropical zone, the production of plant biomass is highly influenced by the seasonality of rainfall. Even in the humid tropics, where the rainfall is almost evenly distributed along the year, the growth rate is not uniform owing to variation of other environmental factors that alters plant growth (Cubillos, 1981). These include: variation in the amount and distribution of solar radiation, changes in day length which affects photosensitive varieties and fluctuations in day and night temperatures.

Studies conducted by Hurtado (1988) in the humid zone of Turrialba showed that low temperatures (19°C) produced negative effects on available forage yield of Estrella (*Cynodon nlemfluensis*) and associations with *A. pintoi* and *kudzú* (*P. phaseoloides*), but associations with *D. ovalifolium* were unaffected which may be an indication that this specie is tolerant to low temperatures (Sweeney and Hopkinson, 1975).

Seasonal distribution of forage yield along the year is determinant of variations in the carrying capacity of pastures. With tall genotypes of elephant grass, Pedreira (1976) observed that the carrying capacity varied between

0.9 and 3.0 depending on the amount fo available forage. Lower carrying capacities coincided with a sharp decline (50.7 to 11.0 kg DM ha^{-1} d^{-1}) in forage growth rates during periods with lower precipitation.

2.3.1. Effect of grazing management on forage yield.

A common goal of pasture management is to maximize the yield of forage produced and harvested, without inducing pasture deterioration. Carrying capacity and grazing pressure along with the quantity and quality of herbage consumed by herbivores are largely determined by forage availability, which inturn is strongly affected by defoliation regimes (Whiteman, 1980; Vickery, 1981).

In general, several results have shown that as the intensity of defoliation increases, the yield of shoot tissue decreases. Similar results have been obtained by varying the frequency of defoliation, where the greatest reductions in dry matter production have occurred with frequent defoliations (Brougham, 1956). Reduced forage growth rate with these defoliation regimes is mainly associated with a depletion of organic reserves and large reductions in the residual photosynthetic leaf area (Humphreys, 1966).

The importance of soluble carbohydrates in regrowth was discussed by Whyte (1973). Carbohydrate reserves are mobilised for both respiration and shoot growth during the first two to four days after defoliation. This means that the rate and magnitude of growth depends on the concentration of soluble carbohydrates and the quantity of leaf area remaining after defoliation (Mares Martins, 1984).

Depletion in soluble carbohydrate reserves is proportional to the severity and frequency of defoliation (Humphreys, 1978). Christiansen and Svejcar (1987) encountered that the total non-structural carbohydrates for lightly grazed pasture was 10-20 fold higher for lightly than heavily grazed pastures. When organic reserves are low, initial regrowth will be slow and the total productivity of the stand will be reduced due to low levels of production from each cycle (Mares Martins, 1984).

The importance of leaf area in crop growth rate lies mostly in its role in intercepting sunlight. In general, increased leaf area causes greater light interception and hence accelerated growth rate under favourable environments (Brown and Blaser, 1968).

With severe and frequent grazing, maximum growth rates are obtained long after defoliation due to insufficient leaf area to intercept sunlight (Younger, 1972). In this respect Brougham (1956), observed that optimum leaf area index (LAI) with the temperate grass *Lolium perenne* occurred 24 days

after severe defoliation, but with lenient defoliations
sufficient herbage was left to intercept nearly all the
incident light immediately after cutting or grazing.

Forage growth of dwarf elephant grass is very
responsive to the amount of residual leaf dry matter (RLDM)
and the length of the grazing cycle (Mott, 1984). Under
subtropical conditions in Florida, leaf growth rates of
dwarf elephant grass exceeded 50 kg DM ha^{-1} d^{-1} with lenient
(2,500 kg RLDM ha^{-1}) and infrequent (56 days) defoliations,
but the same were depressed to values below 25 kg DM
ha^{-1} d^{-1} with high grazing pressures (500 kg RLDM ha^{-1}) and
frequent (0 and 14 days resting period) defoliations (Veiga
et al., 1985). Lower forage growth rates with severe and
frequent defoliations were associated to a small amount of
residual leaf area to intercept sunlight after grazing
(Veiga et al., 1985) and a depletion in carbohydrate
reserves in dwarf elephant grass (Rodrigues et al., 1987b).

Available dry matter yield of dwarf elephant grass was
affected by similar grazing conditions (Veiga et al., 1985)
that affected forage growth rates. Mott (1984) demonstrated
that severe and frequent defoliations resulted in
considerable reductions in available leaf dry matter yield
which was inferior to 1.2 Mg ha^{-1}. However, under good
grazing conditions, leaf herbage allowance was superior to 3
Mg DM ha^{-1}. In a 28 day cycle, there was an increase in
leaf allowance at the beginning of the cycle from 391 kg DM
ha^{-1} under heavy grazing pressure to 809 kg ha^{-1} at medium

grazing pressure and 1404 kg ha⁻¹ at low grazing pressure
(Mott, 1984).   Based on the yield responses, Mott (1984)
concluded that dwarf elephant grass can be grazed at
intervals of 28- to 42- days with a stocking rate of five
steers (300 kg) ha⁻¹.

Variations in yield of dwarf elephant grass with
different defoliation regimes are mainly due to differences
in yield components (Rodrigues el al., 1987b).   Frequent
and intense defoliations of dwarf elephant grass resulted in
a drastic reduction in the amount of dry matter per tiller,
mainly because of a sharp decline in the number of leaves
per tiller as well as the number of tillers per plant
(Rodrigues et al., 1987b).

Under tropical conditions, adequate levels of
production were also reported for dwarf elephant grass in
grazing experiments (Santillian and Mena, 1988; Váscones et
al., 1988).   Santillian and Mena (1988) found that available
forage yields of dwarf elephant grass (cv. Mott) exceeded
3.5 Mg ha⁻¹ with a 28 day grazing cycle.   It should be
mentioned that although this grass is rated for low
production when compared to tall genotypes of elephant
grass, the level of production achieved (Váscones et al.,
1988) was higher or similar to those obtained with other
tropical grasses (*Digitaria decumbens* and *Cynodon
nlemfluensis*).

2.4. BOTANICAL COMPOSITION AND GROUND COVER.

Pasture persistence may be measured quite simply as the way a plant continues to contribute to yield. It may also be assessed in terms of the percentage of ground covered by a given pasture specie (Humphreys, 1978). Therefore, the aim of measuring botanical composition of grasslands is to describe species composition or to monitor changes in composition (Tothill, 1978) which can be used to determine the effect of management practices upon species performance.

In animal production systems in which higher stocking rates are used to increase production per unit area, there are usually associated long term changes in botanical composition of the pasture (Vickery, 1981). As a result, some compromise between the requirements of the animal and the needs of the pasture must be made, as very heavy stocking rates usually cause the disappearance of the most valuable perennial species, which are replaced by weeds (Humphreys, 1978) that can interfere with the quantity and quality of herbage produced (Tothill et al., 1982).

2.4.1. The Effect of Grazing Management on Botanical Composition and Ground Cover.

The changes in botanical composition may be highly influenced by the level of grazing management applied (Tothill et al., 1982). High grazing intensities combined

with short resting periods favour a greater proportion of short grasses as *Axonopus* or *Paspalum spp.* because the growing points of these species are protected from grazing (Booysen et al., 1963). In contrast, tall erect species such as *Panicum maximum* are favoured by low stocking rates and long resting periods (Avendaño et al., 1986).

Few studies have been undertaken to determine the level of persistency of elephant grass under grazing conditions. However in cutting trials, Watkins and Van Severen (1951) found that low harvesting reduced the stand of tall elephant grass to 30% as compared to 66% at the highest cutting height. Elephant grass has been generally considered unsuitable for grazing because continuous close grazing resulted in reduced yields and ultimate loss of the stand (Sollenberger et al., 1988). However, Blaser et al.,(1955) noted that elephant grass stands were productive and persistent under rotational grazing. Persistence of dwarf elephant grass was also affected with high grazing pressures and continuous grazing or short grazing cycles (Sollenberger et al., 1988), but Mott (1984) explaind that good persistence is achievable under proper pasture management.

Under good grazing management, weeds are generally not a major problem in dwarf elephant grass pastures because the leaves of a full stand will shade the lower canopy, and consequently prevent the invasion of other species (Sollenberger et al., 1988). However, perennial grass weeds can be competitive for overgrazed stands. Sollenberger et

al .,(1988) noted that stands persisted for only two years due to competition from vasey grass (*Paspalum urvillei* Steud) and the lack of adaptation of dwarf elephant grass to sites where vasey grass grows.

Furthermore, close grazing of a bunch grass like dwarf elephant grass allows light penetration to the base of the canopy, and ecourages growth of other species like *Cynodon dactylon* and *Paspalum notatum* (Sollenberger et al., 1988).

In studies with dwarf elephant grass Rodrigues et al., (1987a) noted that when apical meristems of individual tillers are removed by close grazing, tillering is encouraged. However, long term persistence is detrimentally affected because regrowth must be primarily supported by organic reserves in stem bases and rhizomes. In order to insure persistence, it was suggested that the grazing interval of dwarf elephant grass should be 4 to 6 weeks and post-graze stubble heights be in the range of 14 to 18 inches, depending on the frequency of defoliation (Rodrigues et al., 1987b). Besides, Castillo-Gallegos (1983), concluded that consistent removal of more than 80% of the leaf material of dwarf elephant grass may reduce persistence.

3. MATERIALS AND METHODS.

3.1. LOCATION.

The study was conducted during the months of January and June 1989, at "Los Diamantes" Experimental Station of the Ministry of Agriculture and Livestock (MAG) of Costa Rica. This Experimental Station is located in Guápiles, Costa Rica, at latitude 10° 13'N and longitude 83° 47'W, and at 250 m.a.s.l. The mean annual temperature and rainfall of the region are 25°C and 4533 mm, respectively (Fig. 1). According to Cochrane (1982) the ecosystem of the region can be classified as a tropical rainforest. The soil within the experimental unit was classified as an Inceptisol typic Dystropepts with a sandy loam texture.

Soil samples were taken from the experimental area following recommended procedures of the Soil Fertility Laboratory of CATIE. Data on soil texture and fertility is given in Table A1. According with the results and general recomendations the soil can be regarded as being low to medium fertility.

3.2. PASTURE ESTABLISMENT.

Initially the experimental area was dominated by gamalote (*Paspalum fasciculatum*), native grasses (*Axonopus scoparicus*, *Paspalum notatum* and *Paspalum conjugatum*) and to a lesser extent by *Brachiaria ruziziensis*.

Approximately 2.5 hectares of dwarf elephant grass was established during the months of March and August 1988. The planting distance was 1.0 m x 0.8 m between and within rows, respectively. Vegetative material was planted at a depth of 4 cm inclined at about 45° to the soil. It should be mentioned that lower plant densities were recorded in areas with waterlogged conditions.

The experimental area was uniformed during the second week of December, 1988. The grass was cut at a height of 40 cm from ground level, following recomendations by Rodrigues et al., (1987b). Following plot uniformization, urea and triple superphosphate were applied at the rate of 50 kg N ha^{-1} and 10 Kg P ha^{-1}, respectively. Aftherwards, no fertilizer applications were made during the experimental period.

3.3. EXPERIMENTAL VARIABLES.

Two grazing management factors were studied in the experiment. These were intensity and frequency of defoliation.

3.3.1. Grazing Intensity

The severity of defoliation was expressed in the form of grazing intensity. In this experiment grazing intensities were fixed by varying the amount of available leaf dry matter (LDM) per unit animal bodyweight (BW). Five levels of grazing intensities were evaluated: 3.0, 4.5, 6.0, 7.5 and 9.0 Kg LDM 100 Kg BW^{-1}.

3.3.2. Grazing Frequency.

Grazing frequency was defined as the interval between successive defoliations. Five levels of grazing frequencies were studied in this experiment: continuous grazing (0), 14, 28, 42 and 56 days. With continuous grazing the animals were permanently kept on the plots except during periods when it was required to make changes to maintain the desired grazing intensity.

3.4. EXPERIMENTAL DESIGN AND LAYOUT.

A Modified Central Composite Non-Rotable (Response surface) design with 13 treatment combinations (Table 1) and with the central treatment replicated 4 times was used in the experiment. This resulted in 17 experimental units as shown in Fig. 2. The plot size varied from 600 to 5500 m^2 depending on the grazing system used. The objective being to have at least two animals grazing at the same time in each plot. Plot size was calculated from the formula given below.

$$S = \frac{N \times d \times R}{D \times G}$$

Where:

S = Size of plot (m^2)

N = Live weight, 100 kg^{-1} $plot^{-1}$

d = Number of grazing days

R = Kg leaf dry matter on offer 100 kg^{-1} body weight day^{-1}.

D = Number of days in the grazing cycle.

G = Assumed forage growth rate (kg m^{-2} day^{-1}).

3.5. EXPERIMENTAL RESPONSE VARIABLES.

The effect of various combinations of intensities and frequencies of grazing on the performance of the dwarf elephant grass was determined by changes in leaf dry matter production, quality, plant morphology, botanical composition and ground cover.

3.5.1. Dry Matter Yield.

The determination of available leaf dry matter was carried out using the Comparative Yield Method (Haydock and Shaw, 1975). Five plants were selected to establish a yield scale against which the samples of the pasture were rated through visual estimation. Consequently, forty visual observations were taken for plots ranging in size from 600-2000 m^2 and 60 observations for plots greater than 2000 m^2. The yield for any sample was calculated by regression analysis obtained by double sampling techniques using the formula given below:

$$Y = y + \bar{b} (X' - X^*)$$

Where:

    Y = Estimated production

    y = Mean for real samples

    b = Regression coefficient of real samples

    $x^{\cdot}$ = Mean of scores taken for visual samples

    x^{*} = Mean for ranges of real samples.

To obtain the real sample, only one fourth of the plant was harvested to avoid excessive reduction of green material from the field. The grass was harvested at about 30 cm from the ground. Samples harvested from the field were first weighed and leaf and stem fractions were separated and reweighed. Subsamples of approximately 250 grams of each fraction were subsequently taken for dry matter (DM) determination.

Initially available leaf dry matter production was recorded every 28 days with the plots under continuous grazing. However, due to the accumulation of leaf dry matter with this grazing system, a decision was taken to increase the frequency of measurement to every 7 days which allow the adjustment of animals to maintain the grazing intensity. Leaf dry matter production was summed for all the measurements and reported for every 28 days.

3.5.1.1. Available Leaf Dry Matter Production (Qi).

Net leaf dry matter production per cycle was estimated from available and residual leaf dry matter production, taking in consideration growth during the grazing period. The formula used is given below:

$$Qi = Bi + \left[\frac{Bi - A_{i-1}}{dr} \times dg \right]$$

Where:

Bi   =   LDM on offer at the beginning of the grazing period, kg ha^{-1}.

A_{i-1} =   Residual leaf dry matter (RLDM) at the end of the previous grazing cycle, kg ha^{-1}.

dr   =   Lenght of the resting period (days)

dg   =   Lenght of the grazing period (days)

3.5.1.2.   Growth Rate (Gi).

Growth rate was estimated assuming linearity of production between cycles using the formula given below:

$$G_i = \frac{B_i - A_{i-1}}{dr}$$

Where:

G_i =   leaf dry matter growth rate in the "i" grazing period, Kg day^{-1}.

B_i =   Available leaf dry matter in the "i" – grazing period, Kg ha^{-1}.

A_{i-1} =   Residual leaf dry matter in the previous grazing period (i – 1), Kg ha^{-1}.

dr   =   Length of the resting period, days.

It should be mentioned that due to the small plot size it was not possible to use cages to estimate growth rates with the treatments under continuous grazing. However, in order to generate information for the model, leaf growth rate for continuous grazing was estimated from short periods (7 days) assuming an intake of 2.5 kg LDM/100 kg BW.

3.5.1.3. Net Leaf Dry Matter Production per Cycle (Pi)

Net leaf dry matter production per cycle was estimated from available and residual leaf dry matter production, taking in consideration growth during the grazing period. The formula is given below:

$$Pi = B_i - (A_{i-1}) + \left[\frac{B_i - (A_{i-1}) \times dg}{dr} \right]$$

Where: B_i, A_i, dr and dg are the same defined above.

3.5.2. Leaf\Stem ratio.

For this estimation leaf and stem fractions were separated from a given weight of total plant and the green weight of each component was subsequently weighed. Subsamples of 200 grams of leaves and stems were taken separately for dry matter determination. The results obtained were expressed as a ratio of gram dry weight leaves to stem.

3.5.3. Forage Quality.

Leaf and stem fractions were taken for qualitative analysis. Samples were taken every two months for the determination of _in vitro_ dry matter digestibility (IVDMD) and crude protein (CP) content. IVDMD was analyzed by the method outlined by Tilley and Terry (1963) and crude protein content was determined by the micro-kjeldahl technique (Bateman, 1970).

3.5.4. Botanical Composition.

Botanical composition was measured before each grazing period and every 28 days in the plots under continuous grazing, using the Dry Weight Rank Method for Botanical Analysis of pasture ('t Mannetje and Haydock, 1963). The pasture flora was partitioned into Dwarf elephant grass, *Brachiaria sp.*, natural grasses, gamalote (*Paspalum fasciculatum*) and narrow and broad leaved weeds.

For each botanical determination, 40 and 60 visual observations were made for smaller (600 - 2000 m^2) and larger (2000 - 5500 m^2) plots, respectively. A quadrat (0.25 m^2) was thrown at random on the pasture and the species present with respect to first, second and third place in terms of dry weight was recorded. The percent composition of each specie was calculated from the formula given below, which was proposed by 't. Mannetje and Haydock (1963).

$$Y = 70.19 X_1 + 21.08 X_2 + 8.73 X_3$$

Where Y is the estimated percentage specie appearance and X_1, X_2 and X_3 represent the proportions of the species ranged as first, second and third place, respectively.

3.5.5. Degree of Coberture or Ground Cover.

Ground cover was estimated considering only the proportion of soil covered by the dwarf elephant grass. The sampling procedures were equal to those utilized for the determination of botanical composition. This measurements were taken every 28 days for the short grazing cycles (14 and 28 days) and before each grazing period for the 42-and 56-days cycle.

3.5.6. Plant Morphology.

Various measurements were made to determine the effect of grazing intensity and frequency on morphological characters. These included plant and stem height, number of axillary buds and internodes, and the changes in tiller populations. Furthermore, the number of apical meristems removed after grazing were also recorded.

3.5.6.1. Plant and Stem Height.

At the beginning of the experiment ten plants were randomly selected in each plot and marked with plastic rings. Plant and stem height measurements were taken from each of the ten plants every 28 days for the 0, 14 and 28 days cycle and before each grazing period for the 42- and 56- days cycle. Plant height was measured from ground level to the ligule of the last expanded leaf. Stem height was measured from ground level up to the height of the stem that was considered to be representative for the entire plant.

3.5.6.2. Number of internodes and axillary buds.

Ten tillers were sampled at random before grazing to determine these measurements. Leaves were stripped off and the number of axillary buds (buds found between the leaf axils) were counted. The number of visible internodes were counted from the base of the stem up to the shoot apex. Samples were taken every 28 days for the 0, 14 and 28 days cycle and before each grazing period for the other cycles.

3.5.6.3. Number of main tillers per plant.

The number of main tillers per plant were counted from each of the ten plants that were marked in the plots. This measurements were recorded every 28 days for the short grazing cycles (0- 14 and 28 days) and before each grazing period for the 42-and 56-days cycle.

There was a high variation in the number of main tillers per plant. Plots established earlier (March, 1988) produced plants with considerably higher tiller populations, especially where lower plant densities were encountered.

3.5.6.4. Percent apical meristems removed (% AMR).

Twenty tillers were randomly sampled after grazing to determine the number of apical meristems removed. Leaves were stripped to determine if the apical meristems were present. This measurement was carried out every 28 days for the short cycles (0, 14 and 28 days) and at the end of the grazing period for the longer cycles (42 and 56 days).

The number of apical meristems removed was expressed as a percentage to the number of tillers sampled:

$$\% \text{ AMR} = \frac{\# \text{ AMR}}{\# \text{ tillers sampled}} \times 100$$

3.6. GRAZING MANAGEMENT.

Grazing was initiated during the third week of January 1989 and the phase of the experiment considered for this study finished in the second week of June 1989. Fifty (50) crossbreed heifers weighing an average of 200 kg were used to graze the plots. Animals were treated against endo- and ecto-parasites one week before the beginning of the experiment. Throughout the experimental period the animals had access to water and mineral salts.

The length of the grazing period was two days for each grazing cycle, except for those treatments including continuous grazing where the animals were permanent on the plot. The number of animals allocated to each plot was estimated based on liveweight, using the following formula:

$$\text{Liveweight (kg)} = \frac{\text{ALDM} \times \text{A} \times 100}{\text{GI} \times \text{GP}}$$

Where:

ALDM = available leaf dry matter (kg ha^{-1})

A = Area (hectares)

GI = Grazing intensity (kg LDM 100 kg-1 BW^{-1})

GP = Grazing period (2 days)

There were some problems in fixing the correct grazing intensity for the treatments with continuous grazing. This resulted in over and under grazing of the plots; however, the animals were frequently adjusted to arrive at the correct grazing intensity.

3.6.1. Statistical analysis.

The data were processed and analyzed using the RSREG procedure for response surface designs outlined in the SAS procedures guide (1987). Response surface analysis using a second degree polynomial were used to evaluate the response variables as a function of the two management factors: grazing intensity and grazing frequency. The statistical model utilized is given below, where Y is the dependent variable, and, X1 and X2 are the grazing intensity and frequency respectively.

Model:

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_{11} X_1^2 + b_{22} X_2^2 + b_{12} X_1 X_2 + e$$

Those regression coefficients that were not significantly different from zero were dropped from the multiple regression fraction.

3.6.2. Plant disease.

During the months of February and March (1989), there was a fungal outbreak on the dwarf elephant grass. Plants infested expressed symptoms of profused chlorosis during the first two days, followed by necrosis and wilting in the advanced stages of the infection. The disease problem was more severe in the plots with poor drainage.

Three species of fungus were identified from samples taken for laboratory diagnosis. These were: *Pleospora sp, Cercospora sp. and Phoma sp. (E. Bustamante, personnal Comunication)*.
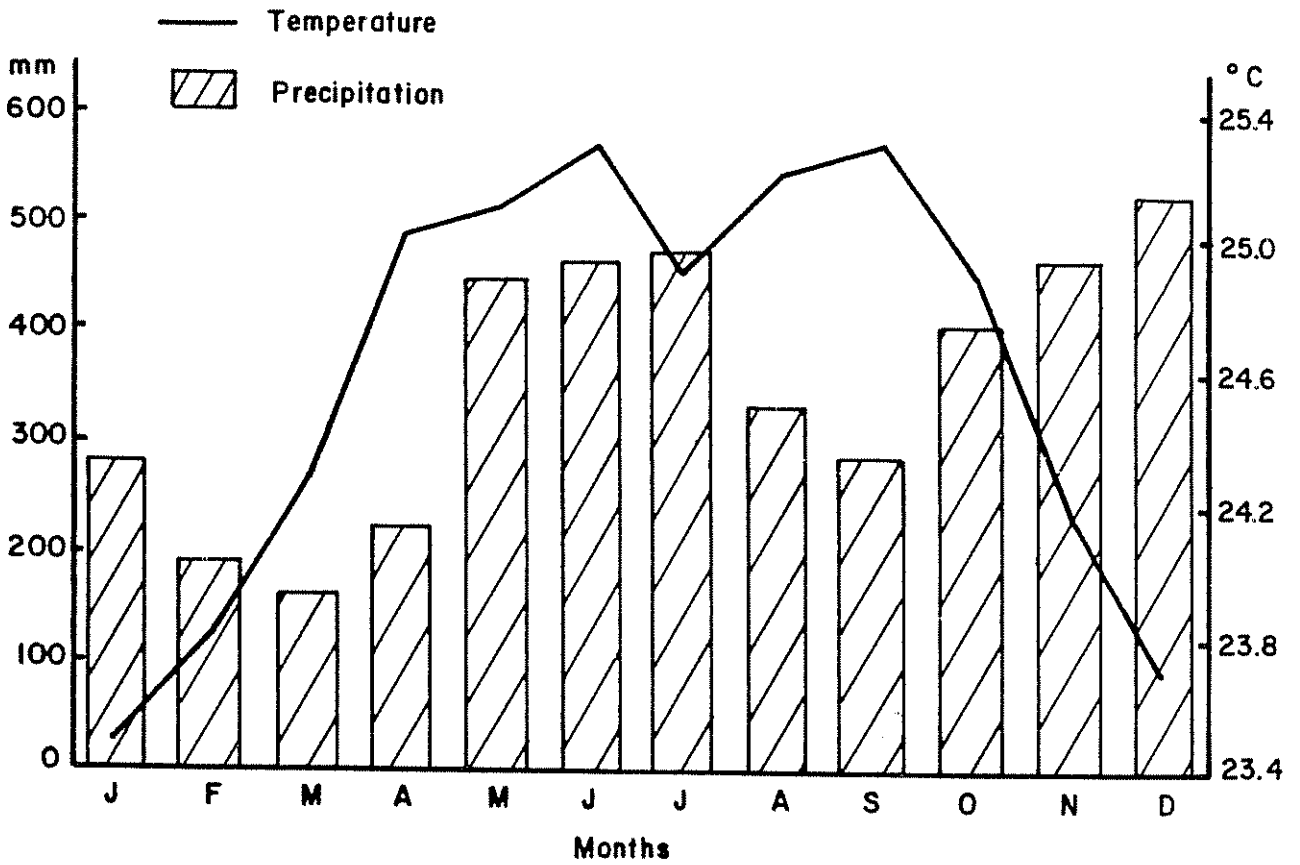
Fig. 1   Climatic characteristics of the Guápiles region, Costa Rica (1975 – 1989)
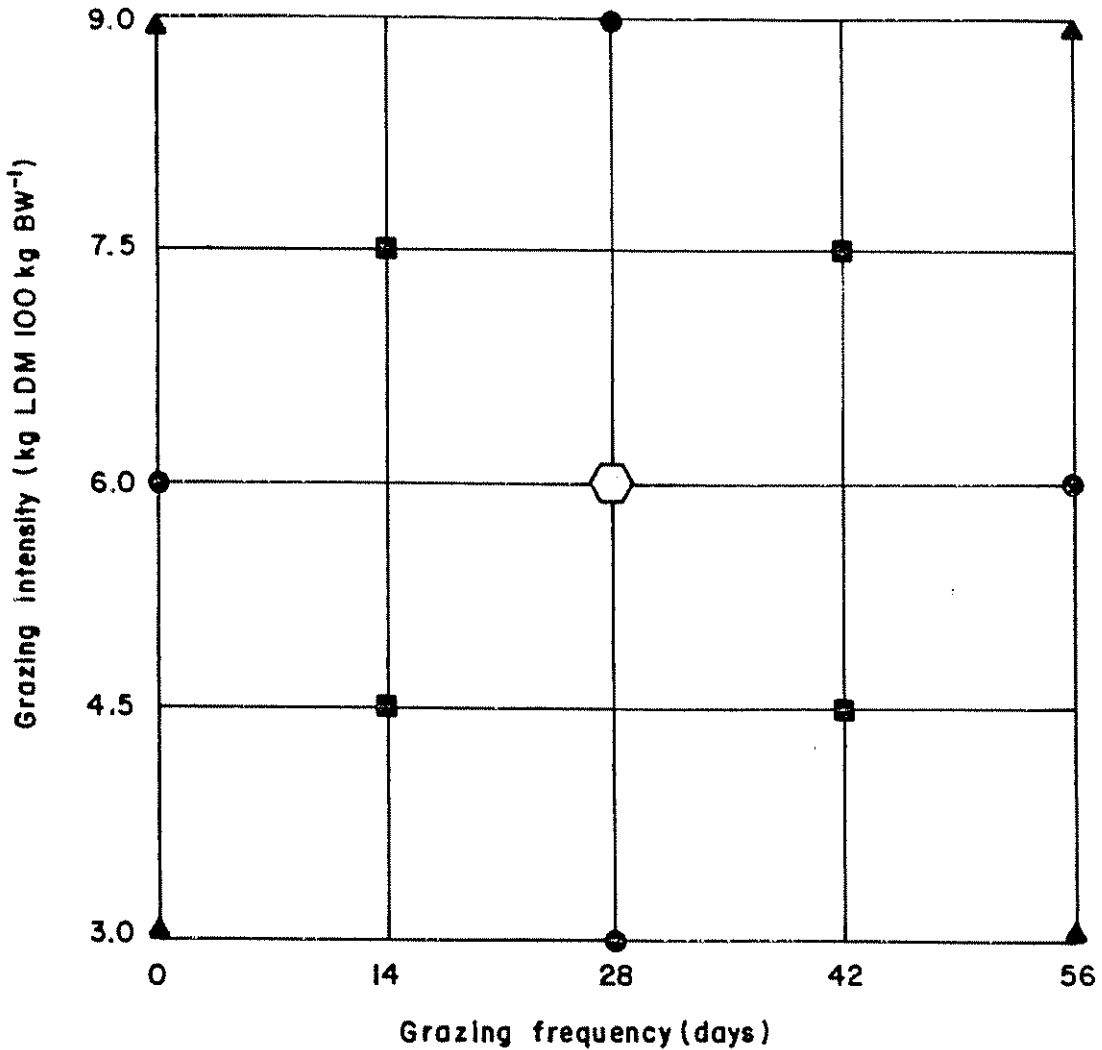
Fig. 2   Experimental design and arrangement of treatments

TABLE 1. Description of experimental units evaluated in
        this experiment.

PLOT No.	GRAZ.INT·*	GRAZING FREQ. DAYS	PLOT SIZE M²	BODY WEIG.
1	6.0	0	3440	230
2	3.0	56	697	2602
3	7.5	14	697	325
4	6.0	28	600	840
5	9.0	56	600	746
6	4.5	14	600	467
7	6.0	28	600	840
8	4.5	42	600	1400
9	6.0	28	600	840
10	6.0	56	600	1120
11	9.0	0	5502	245
12	3.0	0	2004	267
13	7.5	42	720	1008
14	6.0	28	600	840
15	9.0	28	720	672
16	3.0	28	697	1951
17	6.0	28	600	840

* Kg LDM 100 kg BW^{-1}

4.0. RESULTS AND DISCUSSION

4.1. MORPHOLOGY OF DWARF ELEPHANT GRASS.

In general, the levels of grazing intensity and frequency evaluated tended to modify the morphology of dwarf elephant grass cv. Mott, particularly when the pasture was subjected to high grazing intensities and frequencies. However, under good grazing management, the morphological characters measured tended to be similar to that reported for dwarf elephant grass in other environments (Rodrigues et al., 1987a).

4.1.1. Plant and stem height.

The results presented on plant height in Figure 3 and stem height in Figure 4 showed that there were only linear effects (P < 0.02) of grazing intensities on the height of the pasture, which tended to increase as the levels of grazing intensities were decreased. This effect according to Gammon and Roberts (1978 abc) and Avendaño et al., (1986) is reflected in the levels of herbage allowance, such that grazing animals are obligated to make deeper defoliations with smaller amounts of leaf assignation, whereas lower grazing intensities permitted selection for leaf material (Chacon and Stobbs, 1976) resulting in taller stubble material after grazing.

$$Y = -4.4089 + 14.7042 X_1 + 0.7472 X_2 + 0.011 X_2^2$$

$$R^2 = 0.86$$

X_1

9.0
7.5
6.0
4.5
3.0

Plant height, cm

Frequency

0   14   28   42   56 (X_2)
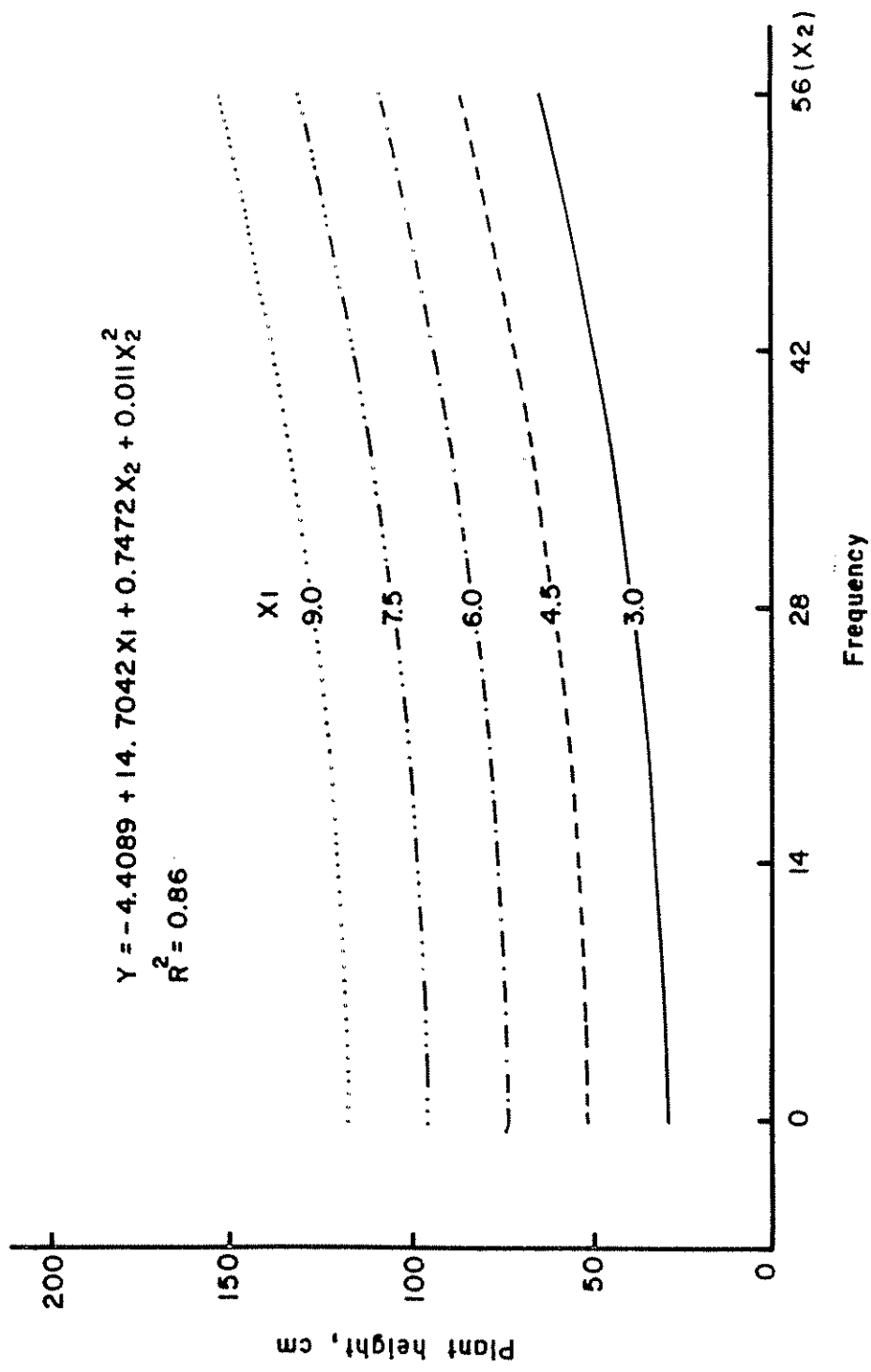
Fig. 3   The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on plant height in dwarf elephant grass

$$\hat{Y} = 16.0868 + 3.3111 X_1 + 0.0976 X_2 + 0.0054 X_2^2$$
$$R^2 = 0.95$$

X_1

9.0
7.5
6.0
4.5
3.0

Stem height (cm)

0   14   28   42   56(X_2)
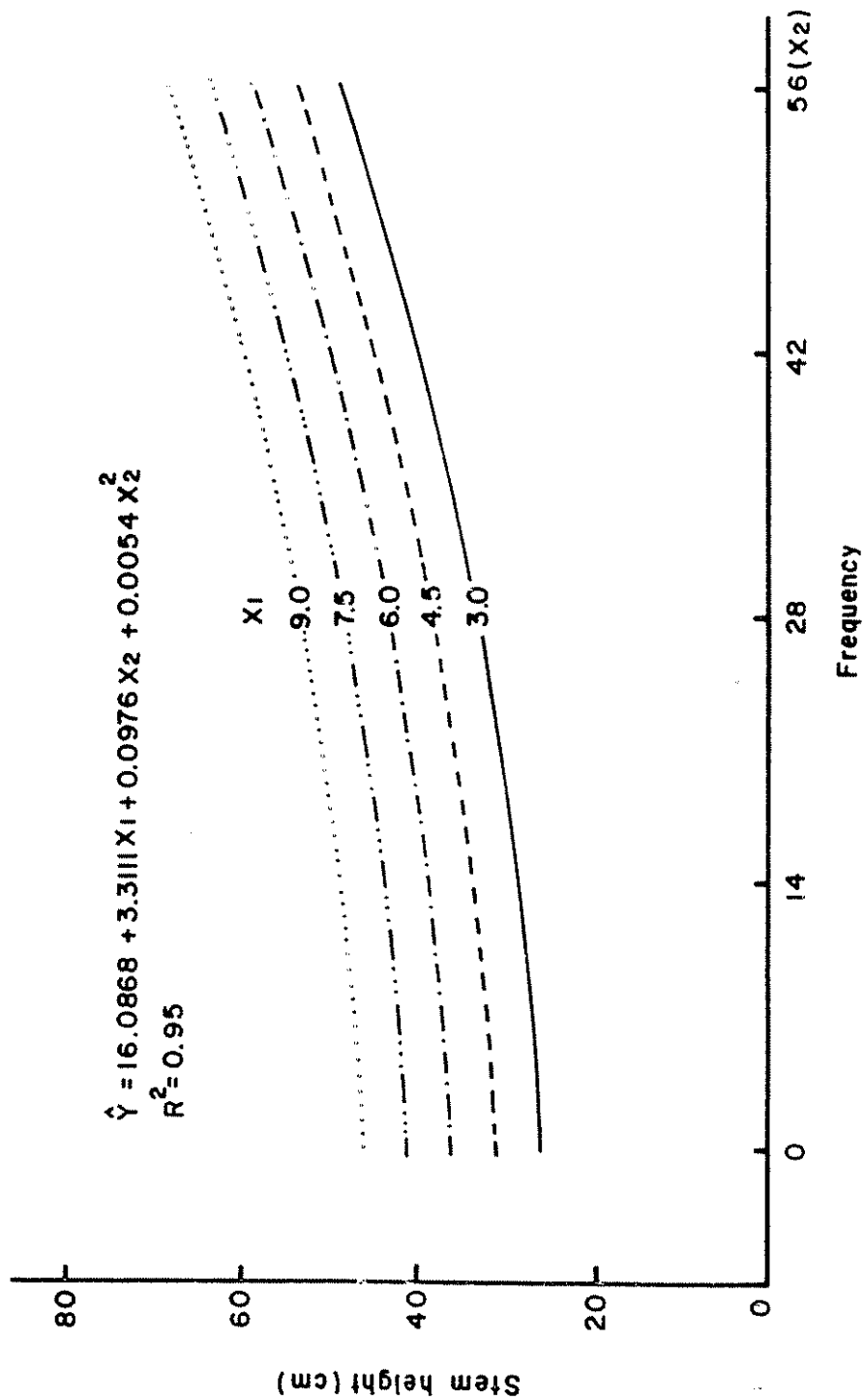
Frequency

Fig. 4   The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on stem height in dwarf elephant grass

On the other hand, the grazing frequency was observed to cause significant (P < 0.05) increases in plant (Fig. 3) and stem (Fig. 4) height as the resting periods were extended, showing the highest rate of increase between the 42- and 56- days grazing interval. Increases in height as the plant advances in age was also reported in several tropical grasses (Tardin et al., 1971), including tall and dwarf varieties of elephant grass (Andrade and Gomide, 1971; Rodrigues et al., 1987a).

Also in Figure 3, it is evident to note that the plant tended to adapt a more erect growth habit under lenient (9.0 kg LDM 100 kg BW^{-1}) and infrequent grazing (56-days), and estimated plant height (>165 cm) under this grazing management were similar to that reported for tall genotypes of elephant grass (Andrade and Gomide, 1971). Following Hodgson (1983), this modification is considered undesirable since it is associated with reduced leaf bulk densities, that was confirmed by Avendaño et al., (1986) in grazing experiments on degraded pastures including *Panicum maximum*. Besides, the formation of dense and erect canopy has been found to restrict accessability of grazing animals between the sward (Hodgson, 1982).

Further, the values estimated for plant height were superior to those encountered by Rodrigues et al., (1987a) and Cruz and Wege (1988) on dwarf elephant grass under both subtropical and tropical environments. Presumably, higher values detected for plant height in this study is related to

increased rates of stem elongation, being stimulated by optimum growth conditions. This was verified in environmental studies under controlled conditions with the hybrid *Pennisetum purpureum*, finding that an increase in plant height was accentuated with elevated temperatures (Muldoon and Pearson, 1979b).

4.1.2. Number of internodes.

The number of internodes per tiller depends on tiller height, and therefore it is expected that any alterations in stem height will affect the number of internodes.

The effect of grazing intensity on this variable was not considered to be very important although a trend for significant (P < 0.057) linear effect was detected. The results (Fig. 5) showed that there was a tendency for constant increases in internode numbers when the grazing intensity was diminished.

On the other hand, the grazing interval was identified as the main factor controlling the number of internodes per tiller which oscillated between 8.0 (3.0 kg LDM 100 kg BW^{-1} and continous grazing) and 17.0 (9.0 kg LDM 100 kg BW^{-1} and 56-days grazing intervals). In Figure 5, the quadratic effect of grazing frequency was highly significant (P < 0.0007) observing the highest increments in the number of internodes per tiller as the grazing frequency was varied
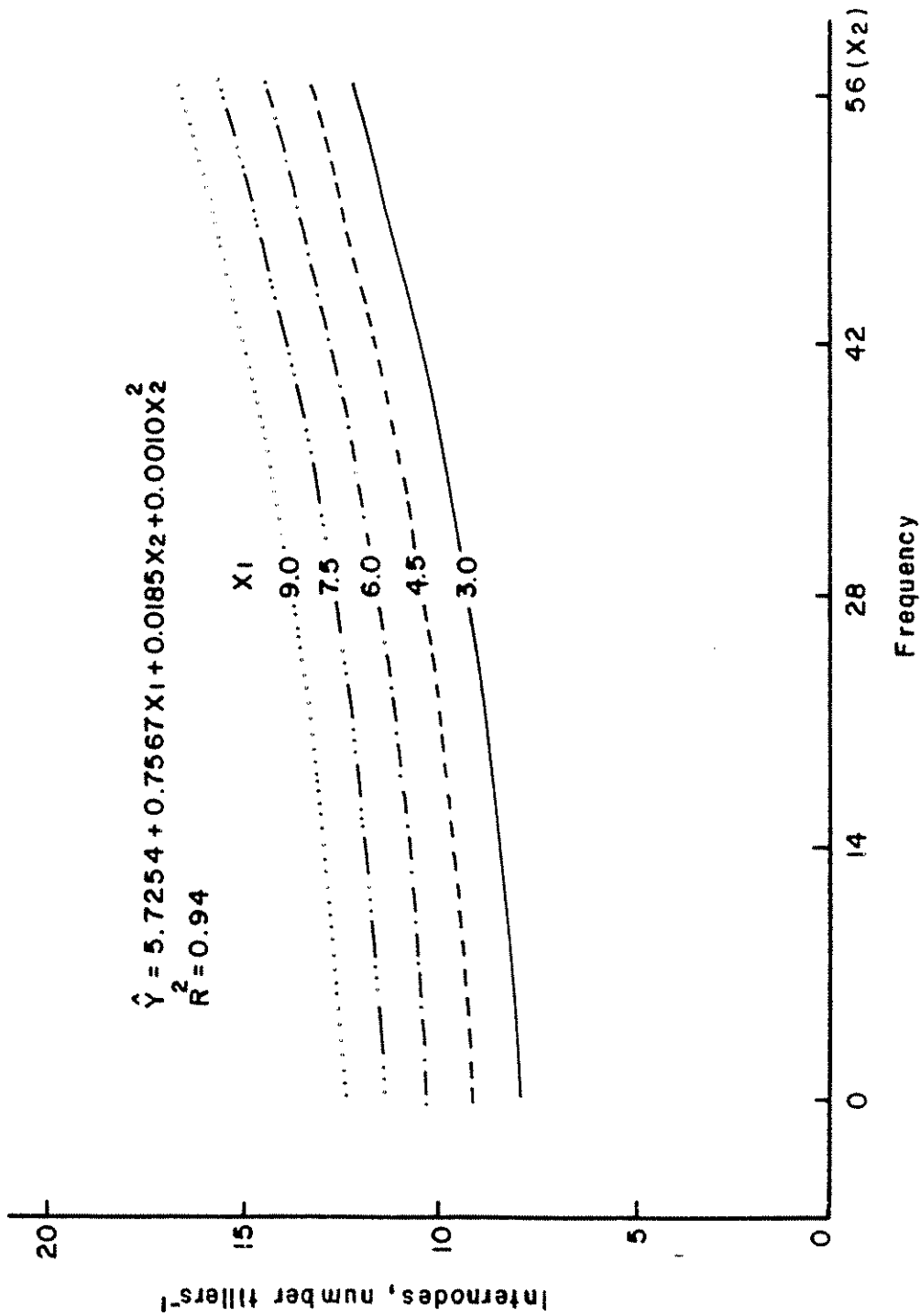
Fig. 5   The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on the number of internodes per tiller in dwarf elephant grass cv. Mott

$\hat{Y} = 5.7254 + 0.7567X_1 + 0.0185X_2 + 0.0010X_2^2$
$R^2 = 0.94$

X_1
9.0
7.5
6.0
4.5
3.0

Internodes, number tillers^{-1}

Frequency

between 42 and 56 days. It should be mentioned that at the same grazing intervals occurred the highest increases in plant height (Fig. 3).

Although the number of internodes per tiller was depressed with severe (3.0 kg LDM 100 kg BW^{-1}) and frequent defoliations (continous grazing), there was a tendency for a higher number of internodes per unit length which coincided with the results obtained by Rodrigues et al., (1987a). Various authors (Booysen et al., 1963; Hodgkinson and Williams 1983; Avendaño et al., 1986) associated this response to the prostrate growth habit which the plants adapted under intensive grazing, and thereby permitting some growing points to escape defoliations.

In general, the results obtained in this study for the number of internodes per tiller were lower than the values reported by Rodrigues et al., (1987a) on the same specie, but higher than that reported by Andrade and Gomide (1971) for A-Taiwan 146 elephant grass (*Pennisetum purpureum*), thus confirming that higher number of internodes is also characteristic of the dwarf elephant grass (Rodrigues et al., 1987a). However, lower values observed for this variable compared to that experienced under subtropical conditions may be related to conditions of higher temperatures and rainfall observed in this study (Fig.1), that have been found to stimulate internode elongation in both temperate and tropical grasses (Muldoon and Pearson, 1979b; Ross, 1986).

4.1.3. Removal of Apical Meristems (% AMR).

The effect of the levels of grazing frequency applied on the number of apical meristems removed was not found to be important. However, the number of growing points removed tended to increase with short grazing intervals (Table A2). It is possible that the true effect of grazing frequencies on this measurement was masked through overgrazing of the palatable dwarf elephant grass, compared to defoliation of less palatable forage components in the pasture. Besides, Arnold (1981) noted that the level of palatability of a given specie was one of the main factors influencing the selective behaviour of grazing animals.

According with the results presented in Figure 6, it is evident that the grazing intensity was the major factor affecting the number of apical meristems removed which varied from 32% with a leaf dry matter allowance of 9.0 kg 100 kg BW^{-1} to 69% when 3.0 kg LDM 100 kg BW^{-1} were available.

The linear effect of grazing intensity was highly significant (P < 0.0001), observing substantial reductions in the % AMR as the amount of LDM on offer was increased. Also in Figure 6, would be appreciated that there was a higher rate of increase in the removal of apical meristems as the grazing intensities were increased. The number of apical meristems removed increased by 6.8% when the grazing

intensity was varied from 9.0 to 7.5 kg LDM 100 kg BW^{-1}, whereas the same was elevated to 12% when the grazing intensity was varied from 4.5 to 3.0 kg LDM 100 kg BW^{-1}.

The amount of growing points removed at higher grazing intensities (3.0 and 4.5 kg LDM 100 kg BW^{-1}) was considered to be very critical for regrowth, especially when erect grasses are grazed with short grazing frequencies (Jones and Carabaly, 1981). This is mainly related to the importance that growing points have in the production of new leaf photosynthetic tissues (Booysen et al., 1963), as well as with persistence of herbage grasses (Humphreys, 1966).

In according with the results observed in Figure 6, it is evident that more than 52% of the growing points remained intact when leaf dry matter allowance was above 4.5 kg 100 kg BW^{-1}. Mares Martins (1984) noted that these levels of defoliation were not considered to be very detrimental to growth, since there was enough growing points to ensure continual production of photosynthetic tissues that were essential for leaf dry matter production.

The results obtained are not very different to those encountered on dwarf elephant grass cv. Mott by other authors (Rodrigues et al., 1987a). Also, the results obtained confirmed that severe grazing intensities in erect species are associated with excessive removal of growing points (Andrade and Gomide, 1971; Avendaño et al., 1986), indicating that excessive defoliation should not be

$$\hat{Y} = 97.3886 - 10.5046 X_1 + 0.3601 X_1^2$$
$$R^2 = 0.90$$
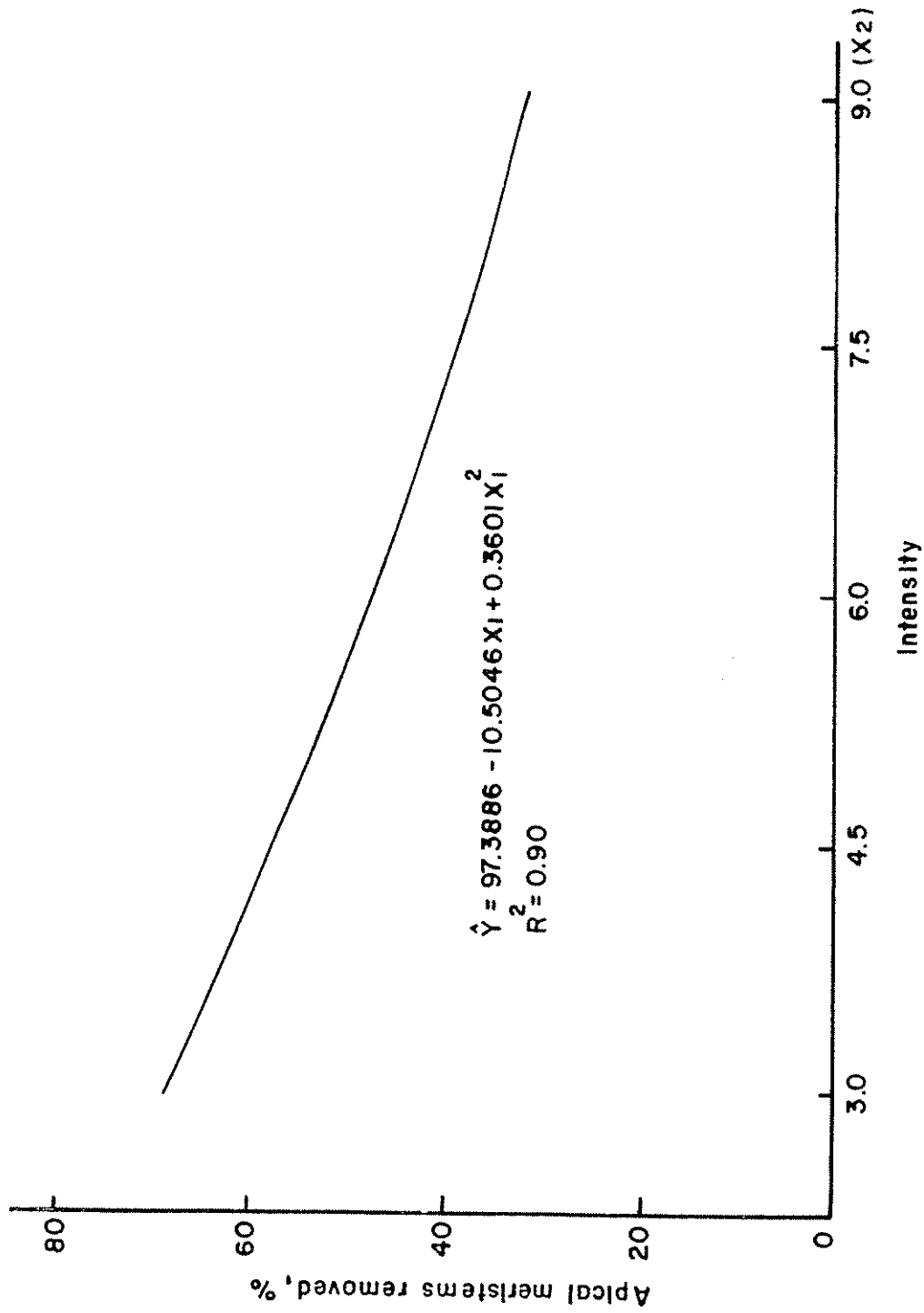
Fig. 6 The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) on the percentage of apical meristems removed in dwarf elephant grass cv. Mott

practiced   with   these _ specie   in   order   to   secure

photosynthetic tissues for continual production (Gonzales,

1979).

In _contrast, a number of workers have concluded that

prostrate species are not affected by severe and frequent

defoliations (Booysen et al., 1963; Humphreys, 1978;

Gonzáles, 1979; Sierra, 1980).   This is largely due to

morphological adaptation found in these species, offering

protection of the growing points to removal by the grazing

animals.   This was confirmed in morphological studies by

Beaty et al., (1970) who noted that resistance of Bahia

grass (*Paspalum notatum*) to grazing was related to the

position of the stolons which were observed embeded in the

soil. Also, this author observed that the young shoots were

initiated along the lower side of the stolon which afforded

protection from grazing.

4.1.4. Axillary buds.

The results showed (Fig. 7) that the number of axillary

buds per tiller was affected by similar grazing conditions

that affected stem height (Fig. 4) and the number of

internodes per tiller (Fig. 5).   The results observed in

Figure 7 showed that independently of the grazing frequency,

higher grazing intensities (3.0 and 4.0 kg LDM 100 kg BW^{-1})

resulted (P < 0.057) in a depression in the number of

axillary buds per tiller, which tended to increase as the grazing intensities were lowered.

On the other hand, the grazing frequency was identified as the major factor controlling the number of axillary buds per tiller which ranged from 7.0 (3.0 kg LDM 100 kg BW^{-1} and continous grazing) to 15.0 (9.0 kg LDM 100 kg BW^{-1} and 56-days). The equation reproduced in Figure 7 showed that the quadratic coefficients of grazing frequency was highly significant ($P < 0.0003$) resulting in positive changes in the number of axillary buds as the grazing intervals were prolonged.

It is interesting to note (Fig. 7) that the highest rate of increase in the number of axillary buds per tiller coincided with that of stem height (Fig. 3). Thus, it would appear that growth of well developed stems were involved in a higher propagation of axillary buds, and is supportive of the findings of Rodrigues et al., (1987a) in similar grazing experiments with dwarf elephant grass. Further, eventhough not measured, a higher number of lateral shoots was observed on plants that were severely (3.0 and 4.5 kg LDM 100 kg Bw^{-1}) and frequently (0- and 14- days) grazed, when compared to the paddocks that were less frequently and intensively grazed. In according with Younger (1972), this condition was associated with hormonal changes which occurred when the growing points are removed, resulting in stimulation of axillary bud activity, and consequently induction of lateral shoot development.
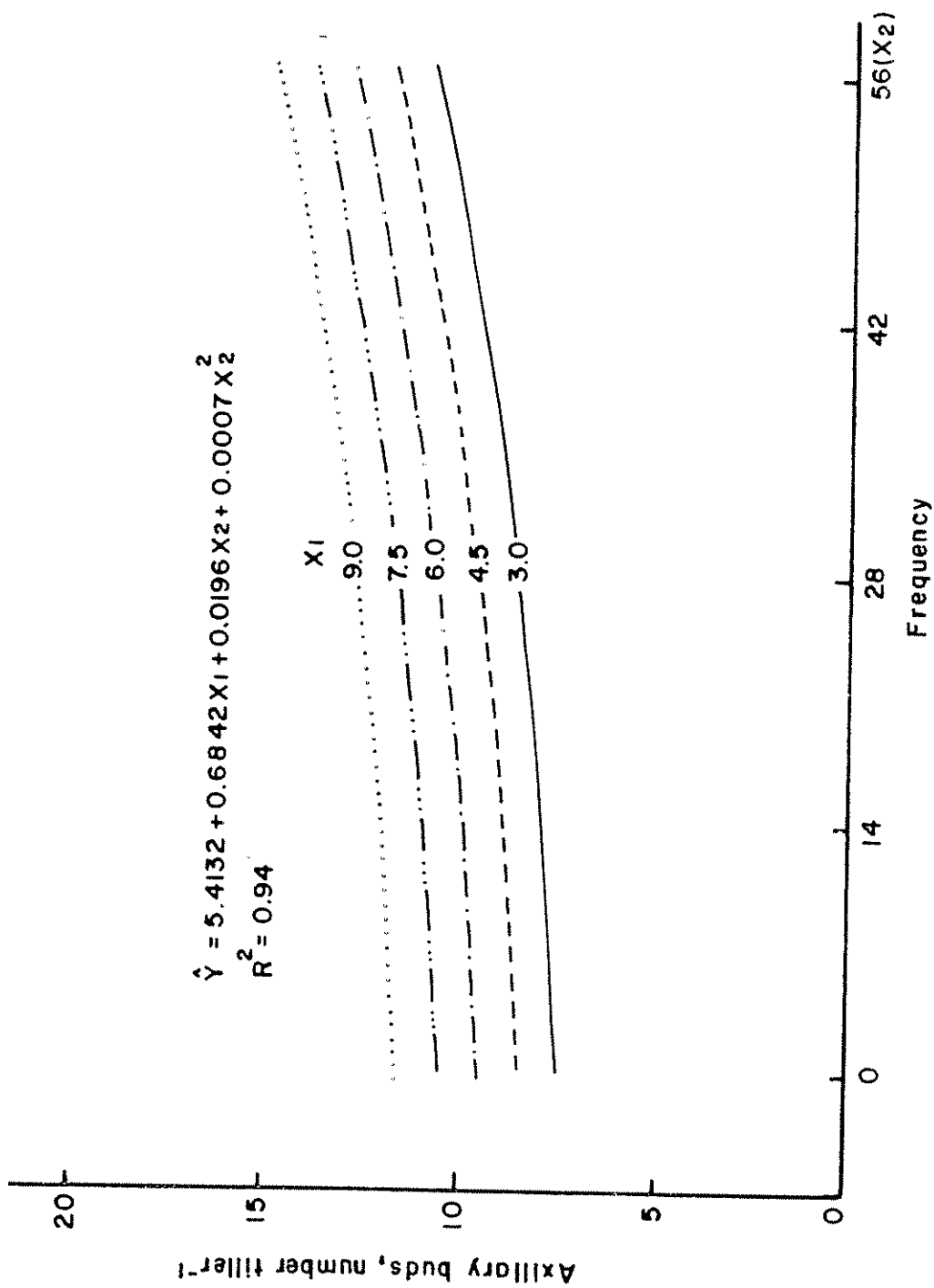
Fig. 7 The effect of grazing intensity (X_1, days) and frequency $(X_2, \text{kg LDM 100 kg BW}^{-1})$ on the number of axillary buds per tiller in dwarf elephant grass cv. Mott

$\hat{Y} = 5.4132 + 0.6842X_1 + 0.0196X_2 + 0.0007X_2^2$

$R^2 = 0.94$

The results obtained in this experiment for the number of axillary buds per tiller were similar to that observed by Rodrigues et al., (1987a) on dwarf elephantgrass cv. Mott. In other studies with erect species Clapp and Chamblee (1970) indicated that basal and axillary tillering were increased at lower defoliation heights, that are considered to be important for pasture production, since axillary buds are actively involved in leaf production when the growing points are removed (Hyder, 1972).

4.1.5. Tillers.

There was a high variation in the number of main tillers per plant at the beginning of the experiment (Table A3). As a result of this, the effect of grazing on this variable was expressed as relative changes that occurred with respect to the initial number of main tillers per plant.

In general, the number of main tillers per plant tended to decrease over all the grazing levels applied (Fig. 8), but there were significant (P < 0.02) interactions between the two grazing factors, resulting in modifications in the rate of tiller reduction.

The results illustrated in Figure 8, indicated that the effect of grazing intensity (kg LDM 100 kg BW^{-1}) on tillering capacity of this grass was more pronounced with short grazing cycles (0-14- and 28- days), and it tended to

decline in importance as the grazing frequency was decreased. There was considerable reduction (>46%) in the number of tiller per plant with severe (3.0 and 4.5 kg LDM 100 kg BW^{-1}) and frequent grazing (continous (0) and 14-days grazing interval), but the rate of tiller losses was found to decrease dramatically as the levels of leaf allowance were increased to 9.0 kg LDM 100 kg BW^{-1}. This clearly shows that grazing at 3.0 kg LDM 100 kg BW^{-1} constituted a grazing intensity that was very high for management of this grass, and was also detected in grazing studies with dwarf elephant grass under Florida conditions (Rodrigues et al., 1987a). Besides, this effect was also determined by Brougham (1959) who noted that tillering of the temperate ryegrass (*Lolium perenne*) was adversely affected with low defoliation heights.

Depressed tiller populations with severe grazing regimes may be associated to frequent defoliations of individual tillers, a condition which Briske (1986) reported to be exceedingly high (>80%) as the pasture is intensively grazed. Besides, frequent and severe grazing of dwarf elephant grass has been found to induce a depletion in reserve carbohydrate status in dwarf elephant grass (Rodrigues et al., 1987b) which according to Younger (1972) was used for new tiller development only when the demand of soluble carbohydrates for new leaf growth was satisfied. However, lenient defoliations are commonly known to promote a high accumulation of plant reserves (Mares Martins, 1984)

that are partially redistributed for tiller regeneration in herbage grasses (Younger, 1972).

On the other hand, a decline in the effect of grazing intensity on tiller dynamics with long grazing intervals is mainly due to the ability of the plant to recuperate over time, and therefore permitting the grass to generate new tillers (Brougham, 1959). This can be observed in Figure 8, detecting that 54% of the initial tiller population was lost with continous grazing (0) and the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}), however, at the same grazing intensity corresponded to a reduction of only 29% when the grass was infrequently (56-days) grazed. This response closely agrees with conclusions drawn by many workers (Brougham, 1959; Jones and Carably, 1981; Rodrigues et al., 1987ab), on the need for longer grazing intervals for erect species to ensure pasture regeneration.

Also, in Figure 8, of much importance was that the initial tiller numbers tended to decline (<16%) eventhough the pasture was leniently (9.0 kg LDM 100 kg BW^{-1}) and infrequently grazed (56-days). This may be related to the development of dense canopy under this grazing management that has been found to inhibit light penetration within the sward, that is essential for survival of tillers (Langer, 1963). Besides, the effect of treading on tiller uprooting should not be under estimated, since Tallowin (1985)

$$\hat{Y} = -82.9668 + 6.3981 X_1 + 0.7086 X_2 - 0.0599 X_1 X_2$$
$$R^2 = 0.91$$

X_1
9.0
7.5
6.0
4.5
3.0

Relative change of main tillers, %
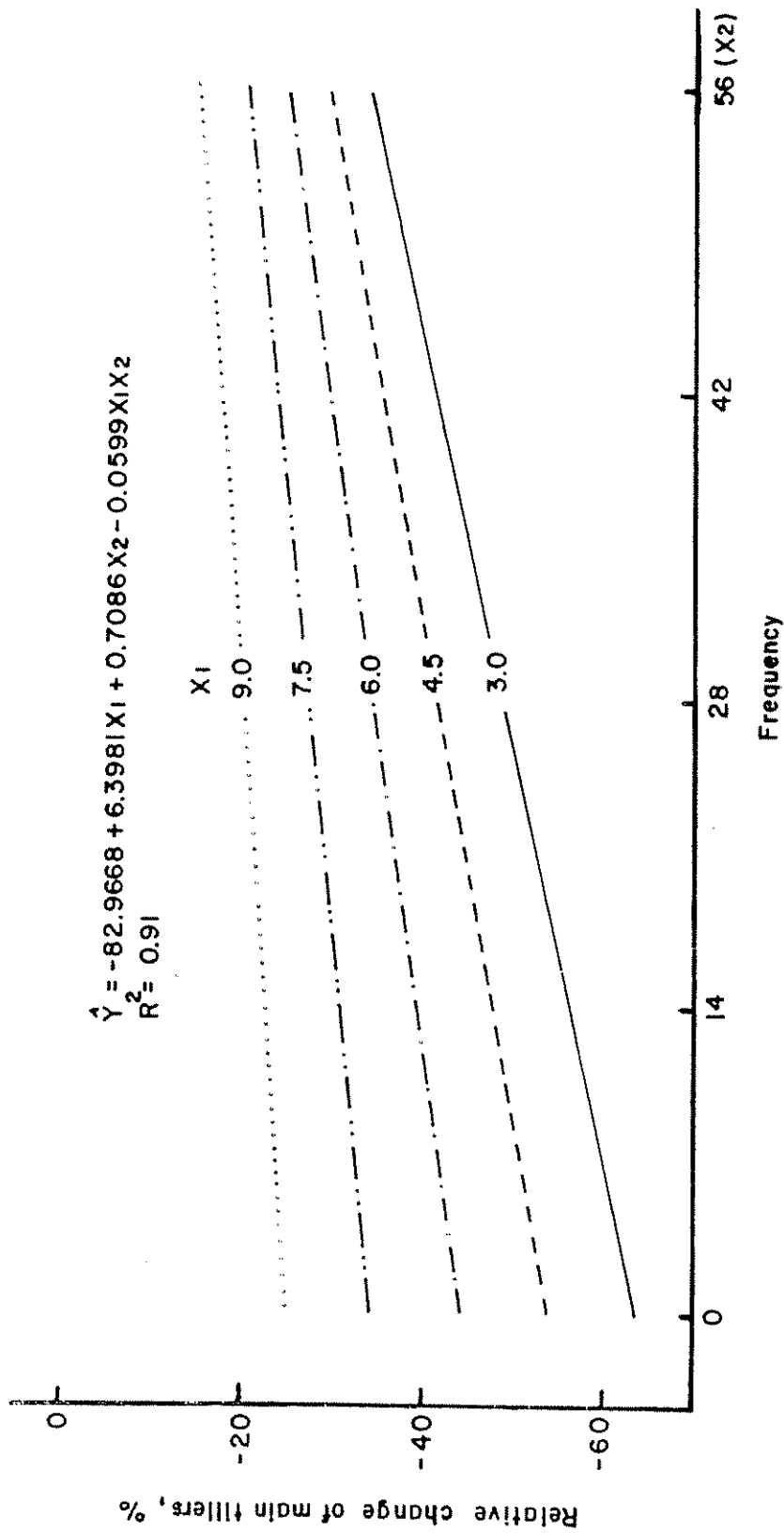
Frequency

Fig. 8 The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on the changes of main tillers $plant^{-1}$ in dwarf elephant grass

encountered that the highest losses in rye grass (*Lolium perenne*) tillers occurred in plots that were leniently grazed.

The results obtained follcwed a similar trend to that observed by Rodrigues et al., (1987a) on dwarf elephant grass, eventhough there was a tendency for higher rates of tiller losses determined in this study. This may be affilated to variations in environmental conditions, such that optimum conditions of temperature and rainfall observed under this experiment, promoted a higher synchronisation of tiller fromation which consequently resulted in a higher percentage of tillers being defoliated in a given grazing cycle (Mott et al., 1987ab).

In contrast, the information available for prostrate species, shows that the number of tillers are not reduced with frequent and severe defoliations, which has been mainly associated to their morphological characteristics that afford protection of the growing points from removal by grazing animals (Booysen et al., 1963; Vickery, 1981).

4.1.6. Leaf/Stem ratio.

The results obtained in this study showed that the leaf/stem ratio was not only affected by the simple effects of grazing intensity ($P < 0.01$) and frequency ($P < 0.0003$), but also by the interaction of both grazing factors.

The mean leaf/stem ratio over all the grazing levels was 2.6. The results presented in Figure 9 indicated that leaf proportions of this grass tended to be higher (> 2.7) with combinations of lenient (9.0 kg LDM 100 kg BW^{-1}) and frequent (14-days resting period) defoliations, as well as with severe (3.0 kg LDM 100 kg BW^{-1}) and infrequent (42-days grazing interval) grazing regimes. Consequently, the optimum (3.0) leaf/stem ratio corresponded to a 42-days grazing interval for the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}), whereas in the case of the lowest grazing intensity (9.0 kg LDM 100 kg BW^{-1}), this value (2.8) was obtained with the 14-days grazing interval.

Lower leaf/stem ratios observed (Fig.8) with severe (3.0 and 4.5 kg LDM 100 kg BW^{-1}) and frequent (0- 14-days) grazing are related to higher defoliation levels induced by grazing animals, between resting periods that were considered inadequate for leaf canopy recuperation in erect species (Avendaño et al., 1986). However, it should be noted that at the same grazing intensities (3.0 and 4.5 kg LDM 100 kg BW^{-1}) coincided to the highest rate of increase in leaf/stem ratio when the resting period was extended to 42-days (Fig.8). Many workers (Avendaño et al., 1986, Boddorff and Ocumpaugh, 1986) associated this increase to a higher production of leafy shoots that is normally developed from shorter stubbles as the grasses are severely and infrequently grazed.

$$\hat{Y} = 0.6979 + 0.1929 X_1 + 0.0921 X_2 - 0.00083 X^2 - 0.00554 X_1 X_2$$

$$R^2 = 0.69$$
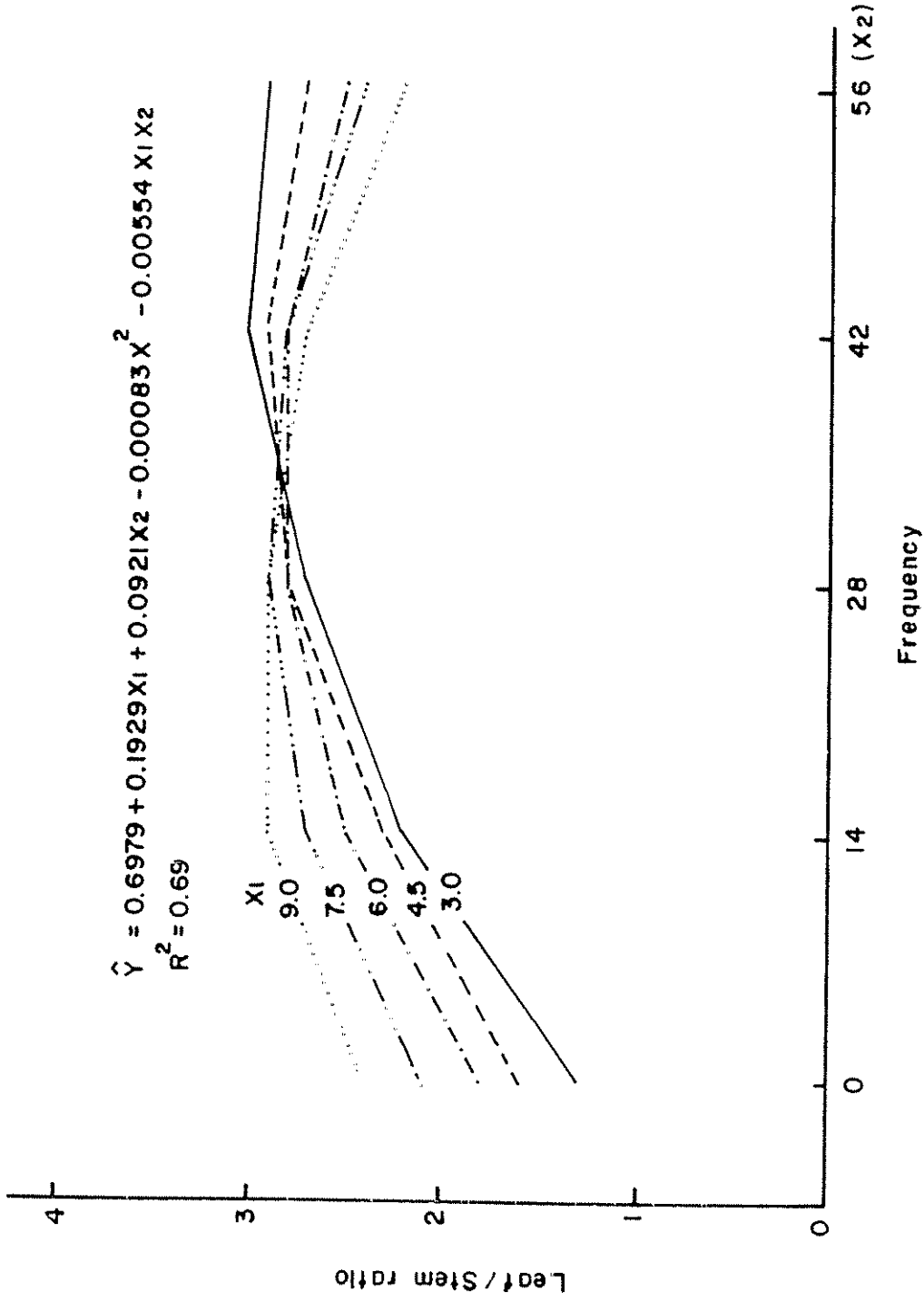
Fig. 9   The effect of grazing intensity (X_1, kg LDM kg BW^{-1}) and frequency (X_2, days) on leaf/stem ratio in dwarf elephant grass cv. Mott

On the other hand, a decline in leaf/stem ratios observed for lenient (7.5 and 9.0 kg LDM 100 kg BW^{-1}) and infrequent grazing (42- and 56-days) are related to the erect growth habit that the plant adapted under this grazing management, being promoted by increased stem elongation detected in Figure 4. However, it should be mentioned that higher rates of reduction in leaf/stem ratio with age was reported for tall *Pennisetum* genotypes (Pedreira and Boin, 1969) and the prostrate *Digitaria decumbens* (Rosete, 1983), when compared to the values experienced in this study.

The results encountered for this variable are similar to the values reported on leaf/stem ratio for dwarf elephant grass in other environments. Under cutting trials Boddorff and Ocumpaugh (1986) noted that the leaf/stem ratio of dwarf elephant grass (cv.Mott) exceeded 2.8 with 60 days cutting intervals. Also, under grazing conditions Veiga et al., (1985) observed that the highest leaf/stem ratios of dwarf elephant grass occurred with long grazing intervals, which coincides with the tendency observed in this study.

Futhermore, the values achieved in this experiment are significantly higher than those reported by Beliuchenko and Febles (1980) for tall genotypes of elephant grass and for prostrate tropical grasses (*Brachiaria mutica*, *Digitaria decumbens*). However, it should be indicated that some accessions of *Brachiaria* and *Panicum* spp. have been identified to have the same leaf characteristics (Vallejos, 1988) as that observed in this study.

Superior values obtained for leaf/stem ratio in this study confirms that this morphological character is also inherent to this cultivar (Sollenberger et al., 1988). This is considered important for pasture utilisation since in a number of studies (Stobbs, 1973ab; Poppi et al., 1981; Cowan et al., 1986) on tropical grasses revealed that grazing animals tended to select leaves in favour to stem fractions, which subsequently resulted in a high intake of digestible nutrients, and enhanced rumen fermentation dynamics (Poppi et al., 1981).

4.2. FORAGE QUALITY.

The results (Table 2) showed that there were only small alterations in forage quality (CP and IVDMD) when the grazing factors were varied. Grazing intensity was not discovered to exert important effects on the nutritional quality of leaf and stem fractions in dwarf elephantgrass cv. Mott. However, the levels of grazing frequency used were found to induce some modifications on leaf protein content and stem digestibility.

TABLE 2. The effect of grazing intensity (Int, kg LDM 100 kg
BW^{-1}) and frequency (Freq, days) on leaf and stem
crude protein (% CP) and digestibility (% IVDMD) of
dwarf elephant grass (cv. Mott).

TREATMENT		LEAF		STEM	
INT.	FREQ.	% CP	% IVDMD	% CP	% IVDMD
3	0	14.2	68.0	8	56.3
3	28	16.0	67.0	11.2	64.4
3	56	11.5	64.8	8.8	60.2
4.5	14	16.4	67.8	10.8	62.1
4.5	42	12.8	66.2	9.5	62.5
6	0	14.8	68.8	11.4	59.7
6	28	13.5	67.6	9.3	60.3
6	56	11.4	63.5	8.2	58.1
7.5	14	12.8	68.3	9.4	59.8
7.5	42	11.6	64.4	8.4	58.8
9	0	12.2	67.1	7.8	57.8
9	28	14.7	66.2	9.1	58.6
9	56	11.2	63.0	8.1	55.9

4.2.1. Leaf and Stem Crude Protein.

The results obtained on leaf protein are illustrated in Figure 10. It is evident that leaf fractions of this grass is capable of maintaining high crude protein values (> 11%) even with long grazing intervals (42-and 56-days).

Leaf CP content was 14.2% in the 28-days grazing cycle, compared to 11.2% for the 56-days grazing cycle, which represents a change of only three percentage units in 28 days. These values are consistent with those reported for dwarf elephantgrass (cv. Mott) by other authors (Mott, 1984; Boddorff and Ocumpaugh, 1986; Fuentes 1989). Also, in similar grazing studies Mott (1984) noted that the leaf protein content of this grass persisted above 11% in the longest grazing cycles (42-and 56-days), while under humid conditions Fuentes (1989) encountered values above 10% eventhough the dwarf elephantgrass was cut at 145 days.

Stem protein content was also maintained above the critical value of 7% (Minson, 1971) under long grazing cycles (Table 2). The results presented in Table 2 showed that there were no significant variations in stem protein content which averaged 9.2% over all the grazing conditions, and are supportive of the values reported for stem protein in dwarf elephant grass by Boddorff and Ocumpaugh (1986).

$$\hat{Y} = 14.10315 + 0.05374 X_2 - 0.00191 X_2^2$$

$$R^2 = 0.50$$

Leaf protein, %

Frequency

0   14   28   42   56 (X_2)
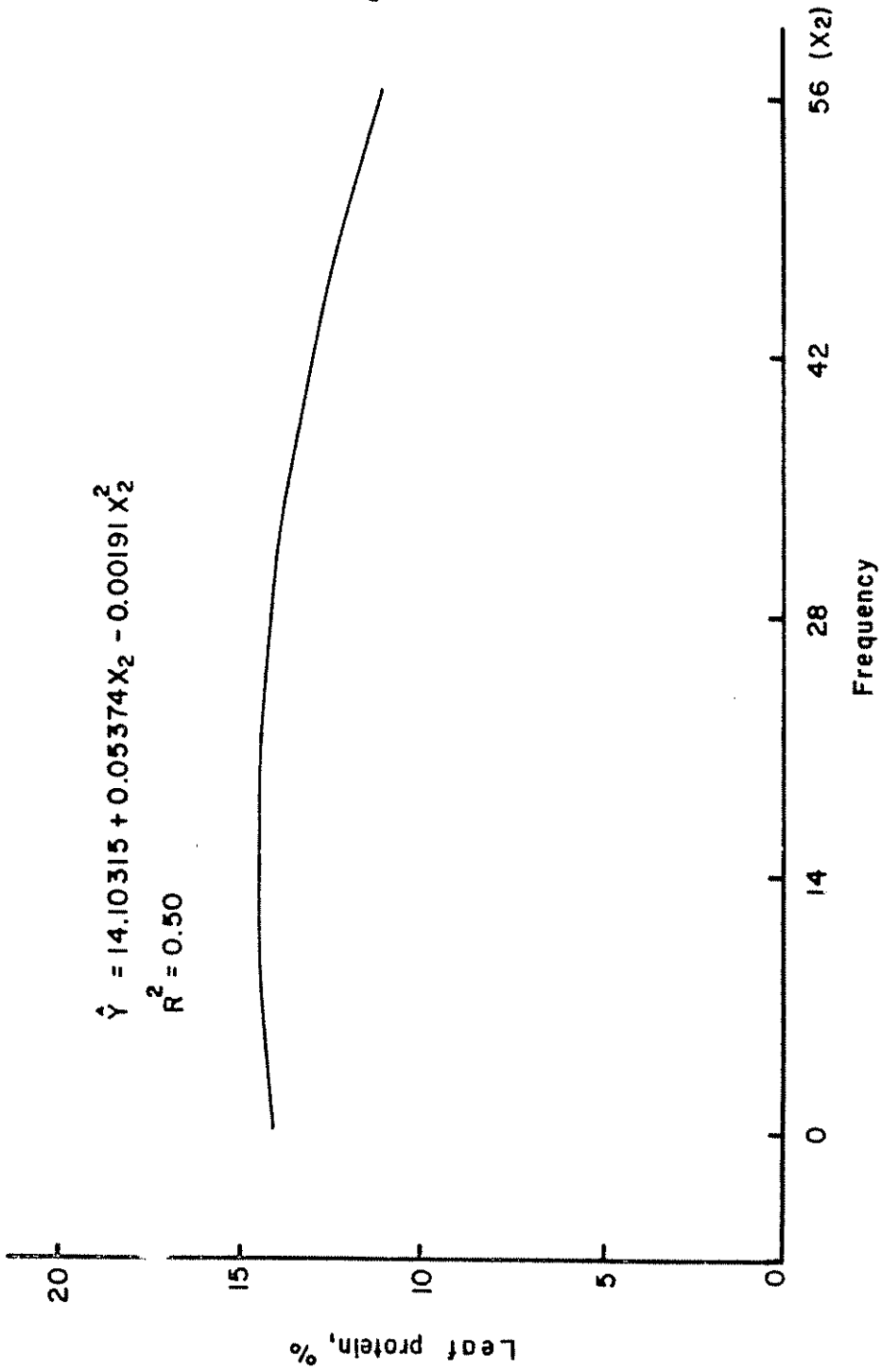
Fig. 10   The effect of grazing frequency $(X_2,$ days) on leaf protein in dwarf elephant grass (cv. Mott)

Contrary to these results, the information available for tropical perennial grasses is conclusive that both erect and prostrate species are incapable of maintaining high crude protein values ($>$ 7%) as the grasses advance in age (Rodriguez and Blanco, 1970; Andrade and Gomide, 1971; Norton, 1982; Mislevy et al., 1982). Under grazing conditions Mislevy et al., 1982 reported that the CP values of tropical stoloniferous grasses declined by approximately two percentage units per week as grazing frequencies decreased from 2 to 7 weeks, being superior to the rate of decline observed in this study. Also with erect species Rodriguez and Blanco (1970) determined that average crude protein of *Pennisetum* cultivars decreased from 10.7 to 6.0% when the cutting frequency was varied from 30 to 60 days.

Many workers (Johnson et al., 1973; Norton, 1982; Van Soest, 1982) affiliated a decline in crude protein as the plant matures, to increase formation of structural and cell wall components, in addition to a higher degree of ligninfication as the grasses are aged (Van Soest, 1982). This was confirmed in qualitative studies with the tropical grass *Cynodon dactylon* which showed that there were linear increases in the percentage of cell wall fractions as the grass matured, as well as in cellulose and lignin constitutents (Herrera and Hernandez, 1988).

4.2.2. Leaf and Stem Digestibility.

Leaf In Vitro dry matter digestibility (IVDMD) did not show major deviations when the grass was exposed to different grazing management, and it averaged 66.4% over all the grazing levels evaluated (Table 2). Under the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}) the values determined for leaf IVDMD were 67 and 64% for the 28-and 56-days grazing cycle, respectively, representing a change of only three percentage units in 28 days. This difference may be related to a higher production of young shoots in short grazing cycles (continous (0), 14- and 28-days grazing interval), that are usually characterised by a high proportion of digestible soluble substances (Hacker and Minson, 1981).

The values detected for leaf IVDMD of dwarf elephant grass are similar to that reported by various authors (Mott, 1984; Boddorff and Ocumpaugh, 1986; Fuentes, 1989) and they support the findings of Sollenberger et al., (1988) of the high capacity of dwarf elephant grass cv. Mott to maintain excellent forage quality over long growing seasons. Low variations in leaf digestibility of dwarf elephant grass were also reported by Mott (1984), who observed that the lowest and the highest values only differed by a marginal 4 percentage units over all the grazing frequencies and intensities tested.

High leaf IVDMD observed in this study, has several implications in grazing and conservation studies of the dwarf elephant grass, since a majority of tropical grasses are not commonly known to maintain high values of leaf IVDMD as the growing season progresses (Hacker and Minson, 1981; Norton, 1982). In studies with eight (8) tropical grasses Rocha and Vera (1981) observed that IVDMD of the grasses declined progressively as they increase in age, and Johnson et al., (1973) found that high forage quality in tall genotypes of elephant grass is only obtained when high yields are not achievable.

Many authors (Hacker and Minson, 1981; Norton, 1982; Mares Martins, 1984) attributed a decline in IVDMD of grasses with age, to increase formation of stem and other structural components, and therefore an increase in cell wall and lignin constituents that are known to cause a depression in IVDMD of grasses. Besides, increased rates of leaf senescence as the plants matures is also known to produce negative effects on IVDMD (Wilson and 't. Mannetje, 1978).

However, the true genetic cause for higher forage quality in dwarf elephant grass compared to other tropical grasses is unknown, but some differences in fiber quality may exist that could be important to elucidate in further studies. Also, according to Hacker and Minson (1981) and Norton (1982), grasses are different in forage quality because of anatomical differentiation, and this could be

used as another line of investigation for high forage quality in dwarf elephant grass.

On the other hand, the results presented in Table 2 and Figure 11 showed that there were some variations in stem *in vitro* dry matter digestibility (IVDMD) with grazing frequencies. IVDMD averaged 59.5% (Fig. 11) and it tended to be higher for intermediate grazing cycle (28-days), being 57.9, 62 and 58% for the continous (0), 28- and 56-days grazing cycle, respectively. Lower stem IVDMD observed with continous grazing is (0) presumably related to overgrazing of young succulent digestible stems, whereas lower stem IVDMD detected for longer grazing cycles (56-days) may be connected to increase formation of fibrous tissues (Hacker and Minson, 1981) as well as with contamination of indigestible leaf sheaths (Wilson and Minson, 1980).

The results achieved for stem IVDMD in this study were similar to those reported by Boddorff and Ocumpaugh (1986) but inferior to the value of 69% obtained by Fuentes (1989) when the dwarf elephant grass was cut at 115-days under humid conditions. This difference may be linked to higher growth rates observed in this study, leading to a higher translocation of soluble reserves to indigestible structural carbohydrates (Van Soest, 1982).

However, the values encountered for stem IVDMD in this study were higher than those found for king grass (*Pennisetum purpureum*) (Fuentes, 1989), and *Digitaria*

$$\hat{Y} = 57.9893 + 0.20098 X_2 - 0.0035 X_2^2$$

$$R^2 = 0.26$$
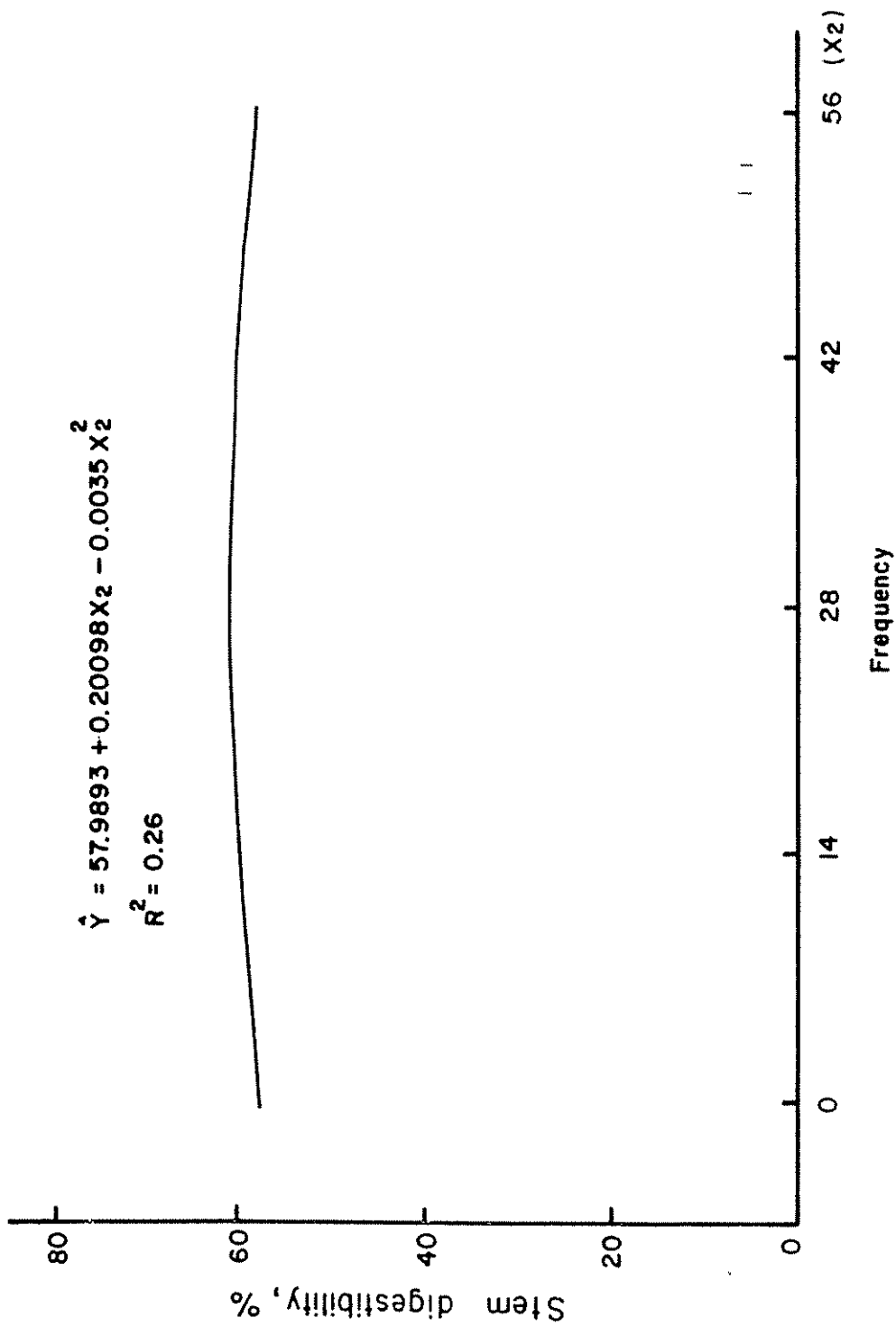
Fig. II The effect of grazing frequency (X_2, days) on stem digestibility in dwarf elephant grass

decumbens (Hacker and Minson, 1981), which is an indication
that high stem quality is also inherent to dwarf elephant
grass cv. Mott.

High stem quality in dwarf elephant grass is due to the
presence of shorter internodes that has a higher proportion
of soluble carbohydrates when compared to longer internodes
(Stobbs, 1973ab). Besides, the long upper internodes of
grasses have been found to have low IVDMD (Stobbs, 1973ab)
due to extreme lignification and degeneration of the central
parenchyma (Wilson and Minson, 1980).

4.3. DRY MATTER PRODUCTION.

4.3.1. Leaf Growth Rate (LGR d^{-1}):

Leaf growth rate (LGR d^{-1}) was suppressed with intense
(3.0 kg LDM 100 kg BW^{-1}) and frequent grazing (0-and 14-
days), but there were significant (P<0.003) interactions
between the two grazing factors which offered some options
in the management of this grass (Fig. 12).

The results described in Figure 12 showed that leaf
growth rate was elevated as the level of grazing intensity
(LDM 100 kg BW^{-1}) was descended, but this effect was found
to be more conspicuous for short grazing cycles (0-and 14-
days) than for less frequent grazing (42-and 56- days). It
should be noted (Fig. 12) that LGR d^{-1} was increased by 34
kg DM ha^{-1} day^{-1} with continous grazing in comparsion to

only 12 kg DM ha^{-1} day^{-1} for the 56- days grazing cycle, when leaf allowance was varied from 3.0 to 9.0 kg 100 kg BW^{-1}. These responses correspond to values reported by Veiga et al., (1985), indicating that leaf growth rate was positively correleated with the amount of residual leaf dry matter. Grazing to achieve a given amount of effective residual leaf dry matter was stressed by many authors (Brown and Blaser, 1968; Jones and Carably, 1981; Vickery, 1981), since its main function lies in interception of sunlight and therefore increased photosynthetic rates.

On the other hand, depressed leaf growth rates observed with frequent and severe defoliation (Fig. 12) have been commonly reported for erect species including dwarf elephant grass cv. Mott (Sierra, 1980; Veiga et al., 1985; Avendaño et al., 1986). This is largely due to removal of substantial amounts of photosynthetic tissues which are generally not generated over short grazing intervals, thus incorporating a depletion in carbohydrate reserves that are essential for regrowth during the first four days after grazing (Whyte, 1973; Vickery, 1981; Mares Martins, 1984). Consequently, a negative energy balance occurrs that is first detected in a reduction of root biomass, being of immense importance for nutrient absorption and water uptake (Humphreys, 1966, 1978).

However, a decline in the effect of grazing intensity observed (Fig. 12) with long resting periods was mainly contributed to the ability of dwarf elephant grass to
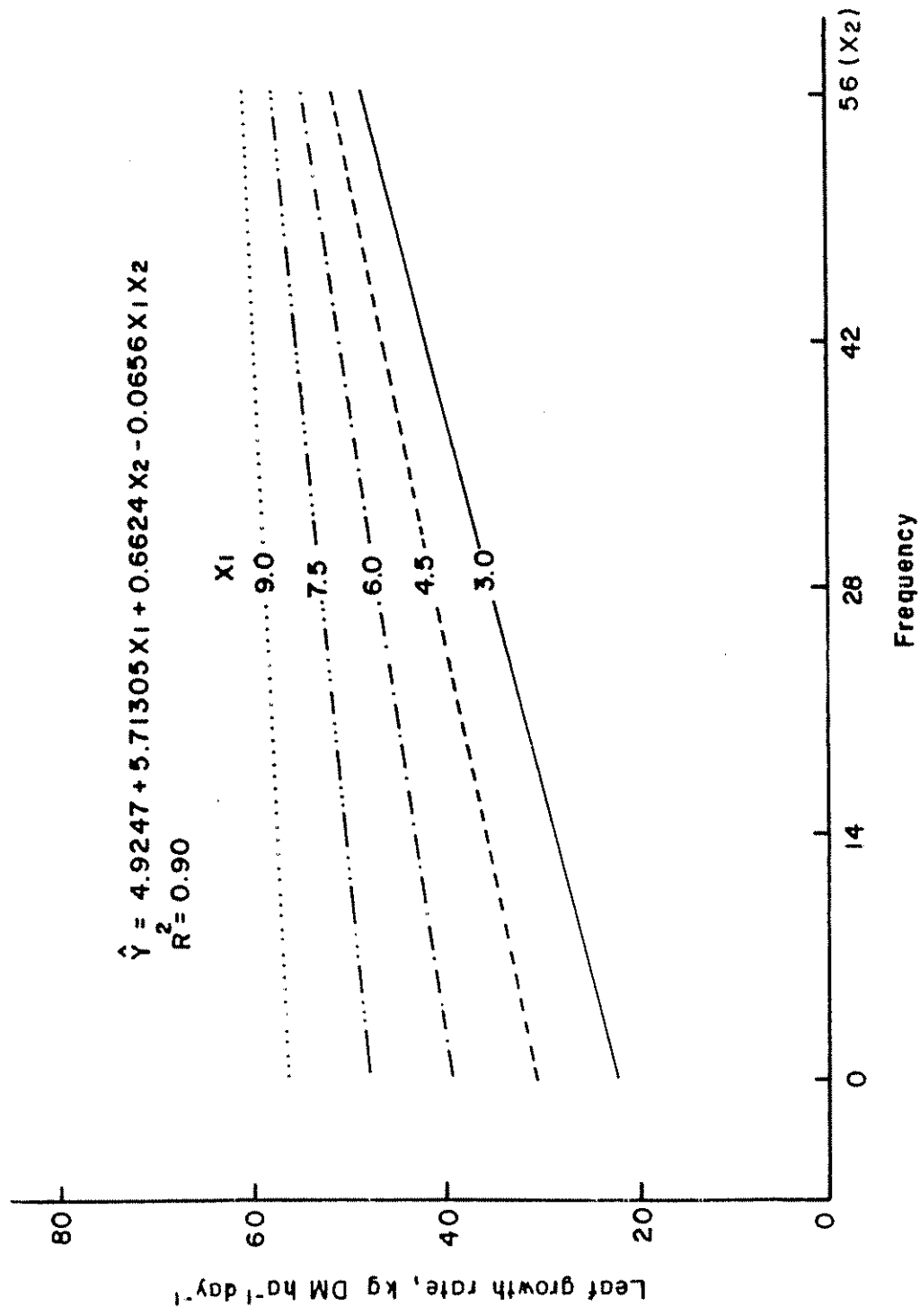
Fig. 12 The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on leaf growth rate in dwarf elephant grass cv. Mott

$\hat{Y} = 4.9247 + 5.71305 X_1 + 0.6624 X_2 - 0.0656 X_1 X_2$
$R^2 = 0.90$

X_1

9.0

7.5

6.0

4.5

3.0

Frequency

0   14   28   42   56 (X_2)

Leaf growth rate, kg DM $ha^{-1} day^{-1}$

0   20   40   60   80

recuperate and maintain high plant vigor and leaf growth as the grazing intervals were extended. This is evident in Figure 12 showing that leaf growth rate with the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}) was acclerated by 26 kg DM ha^{-1} day^{-1} when the grazing interval was switched from continous grazing to a 56-day grazing interval. The trend observed for growth response in this study are concurrent with the findings of Veiga et al., (1985) on dwarf elephant grass and Avendaño et al., 1986 for the erect *Panicum maximum*, both of which showed that leaf growth with intensive grazing was stimulated with long grazing intervals.

Also, in Figure 12, it is evident that leaf growth rate was unaffected when the lowest grazing intensity (9.0 kg LDM 100 kg BW^{-1}) was varied over all the grazing intervals, suggesting that the optimum leaf area index tended to lie with this grazing intensity. Further, although grazing to achieve optimum leaf area index is usually involved in high growth rates, it has generally received contradictory remarks, mainly because this grazing management results in lower effeciency of pasture utilisation and high accumulation of unpalatable material (Brougham, 1959; Brown and Blaser, 1968; Vickery, 1981).

The range of values determined in this study are slightly higher than the values reported for leaf growth rate of dwarf elephant grass under subtropical conditions (Veiga et al., 1985). Presumably, this difference is a

result of lower grazing intensities used in this experiment which permitted higher leaf growth after grazing. Also, favourable environmental conditions of temperature and precipitation observed in this study (Fig. 1), may also be involved in higher growth rates, since Pedreira and Boin (1969) noted that growth rates of tall genotype of elephant grass was increased by 70% during periods of higher precipitation. Besides in studies under controlled conditions with the hybrid elephant grass (*Pennisetum americanum* x *Pennisetum purpureum*), Muldoon and Pearson (1979a) found that rapid expansion of leaf area with high temperatures, was a consequence of greater expansion of individual leaves and higher leaf area per unit weight.

However, results presented by Cruz and Wege (1988) for growth rates of dwarf elephant grass under seasonal tropical conditions were inferior to the values encountered in this study. These authors noted that maximum growth rate of this grass was only 11.8 kg DM ha^{-1} day^{-1}, compared to values above 57 kg DM ha^{-1} day^{-1} observed for leaf growth rate in this study. The major reason for lower growth rates reported by Cruz and Wege (1988) are unknown, but according to results published by Castillo-Gallegos (1983), it may be postulated, that it is due to lower cutting heights which resulted in excessive removal of growing points and therefore reduced plant vigor.

On the other hand, the results obtained by Villalobos (1979) on grass legume mixture (*Brachiaria ruziziensis* and *Pueraria phaseoloides*) are conflicting to the growth patterns observed in this study. Forage growth rate of this association was found to be higher (>52 kg DM ha day^{-1}) with shorter grazing intervals (O- and 21- days) and it tended to decline (<26.7 kg DM ha^{-1} day^{-1}) with long grazing interval (63 days). Various authors related a decline in forage growth rate as prostrate species are infrequently grazed, to the effect of shading and increased rates of leaf senescence that are negatively correlated with growth rate (Brougham, 1959; Brown and Blaser, 1968; Vickery, 1981).

4.3.2. Leaf Dry Matter Production.

The results illustrated in Figure 13 showed that there was only linear (P < 0.0001) effect of grazing intensity on leaf availability which tended to increase as the levels of leaf allowance (kg LDM 100 kg BW^{-1}) were ascended. Under continous grazing, available leaf dry matter estimated was only 1170 kg ha^{-1} for the highest grazing intensity (3.0 kg LDM 100 kg BW^{-1}) as compared to values above 2900 kg ha^{-1} when the pasture was lightly grazed (9.0 kg LDM 100 kg BW^{-1}).

This is a clear indication that the dwarf elephant grass is very sensitive to the amount of herbage material remaining after grazing, supporting the results obtained by Mott (1984) who reported similar increases in leaf availability when the amount of residual leaf dry matter was considered as the grazing pressure. Another explaination for these results, is related to the higher number of growing points (Fig. 6) and tillers (Fig. 8) detected for lower grazing intensities, which have been recognised by Rodriguez et al., (1987ab) to be of valuable importance for leaf dry matter production in dwarf elephant grass, by promoting increased number of leaves per tiller and consequently increased leaf dry matter accumulation per plant (Booysen et al., 1963; Brougham, 1959; Mares Martins, 1984).

On the other hand, the length of resting period was identified to cause a more dramatic impact on total available leaf dry matter (Fig. 13) as well as in leaf dry matter production per cycle (Fig. 14). In Figure 13, it can be observed that available leaf dry matter production tended to show quadratic increases (P < 0.002) as the resting period was prolonged. Under the highest grazing intensity used (3.0 kg LDM 100 kg BW^{-1}), available leaf dry matter production was increased by only 433 kg ha^{-1} when the grazing frequency was varied from continous (0) to 28-days resting period, which was inferior to that of 1733 kg ha^{-1} observed between the 28 - and 56 - days grazing interval.
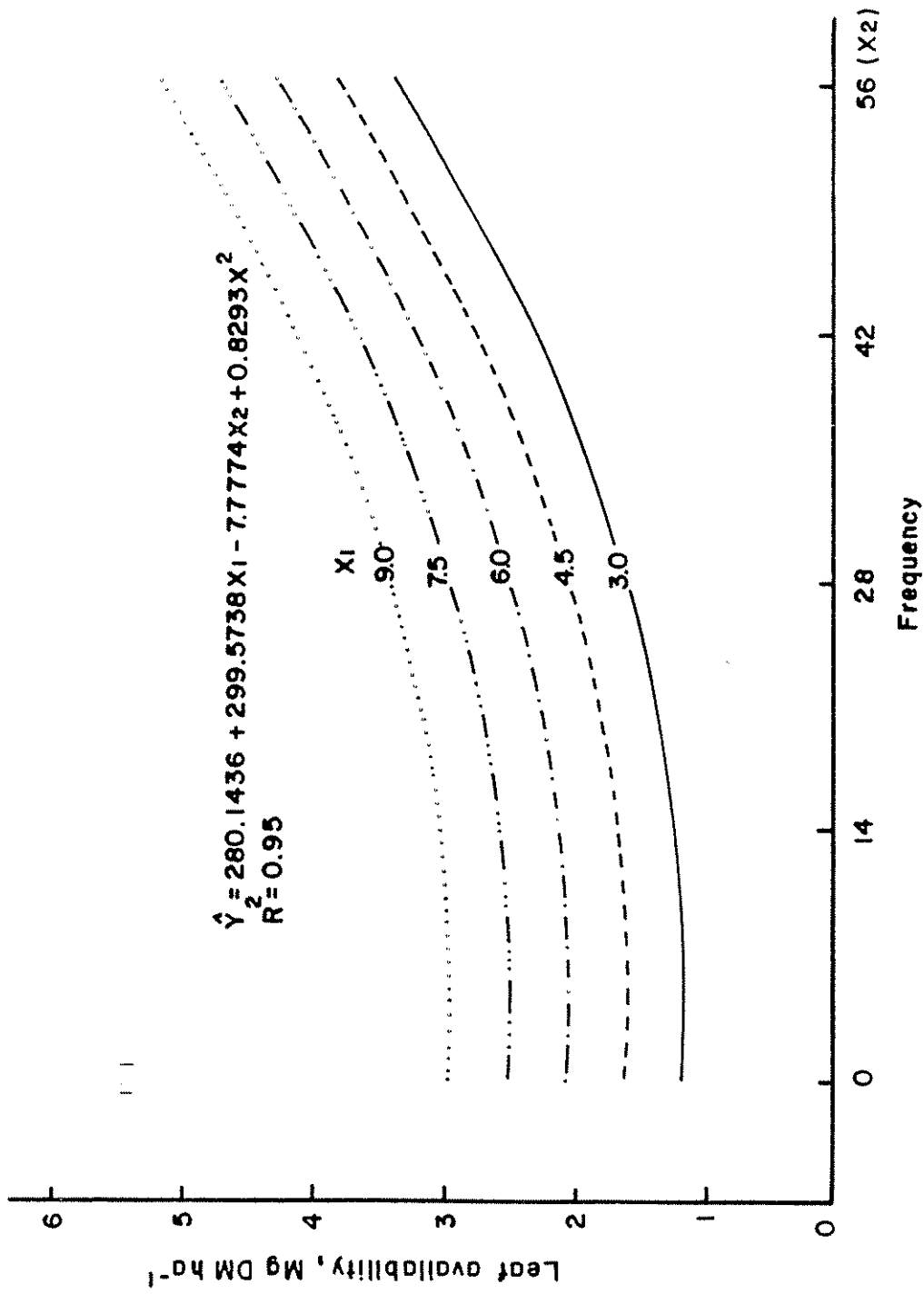
Fig. 13 The effect of grazing intensity(X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on leaf availability in dwarf elephant grass cv. Mott.

$$\hat{Y}_2 = 280.1436 + 299.5738X_1 - 7.7774X_2 + 0.8293X^2$$
$$R^2 = 0.95$$

X_1

9.0

7.5

6.0

4.5

3.0

Frequency

Leaf availability, Mg DM ha^{-1}

This trend was also manifested in Figure 14, detecting the highest rate of increase (>900 kg DM ha^{-1}) in leaf production per cycle^{-1}, occurring between the 42 - and 56 - days grazing interval. In according with these results, there is a clear reflection that the dwarf elephant grass has its highest potential to increase dry matter production between the 28 - and 56 - days grazing cycle and, is concurrent with the tendencies observed by Mott (1984) on this grass, and the information encountered for other erect species including tall genotypes of *Pennisetum purpureum*, *Panicum maximum* and *Hyparrenhia rufa* (Andrade and Gomide, 1971; Sierra, 1980; Galviz, 1981; Avendaño et al., 1986).

Further, the results obtained on leaf dry matter production (Fig. 13 and 14) may be conveniently used to define management practice, since eventhough the highest dry matter production occurred with lenient and infrequent defoliation, it has generally been accompained by lower pasture utilisation (Stuth et al., 1981). On the other hand, the results presented in Figure 14 may interpretated that the grass was capable to generate substantial amounts of leaf dry matter over long grazing intervals (42- and 56- days), regardless of the levels of leaf allowance used. This signifies that the dwarf elephant grass may be grazed between high (3.0 kg LDM 100 kg BW^{-1}) and medium (6.0 kg LDM 100 kg BW^{-1}) grazing intensities in combination with long resting periods (42- and 56- days), giving rise to high
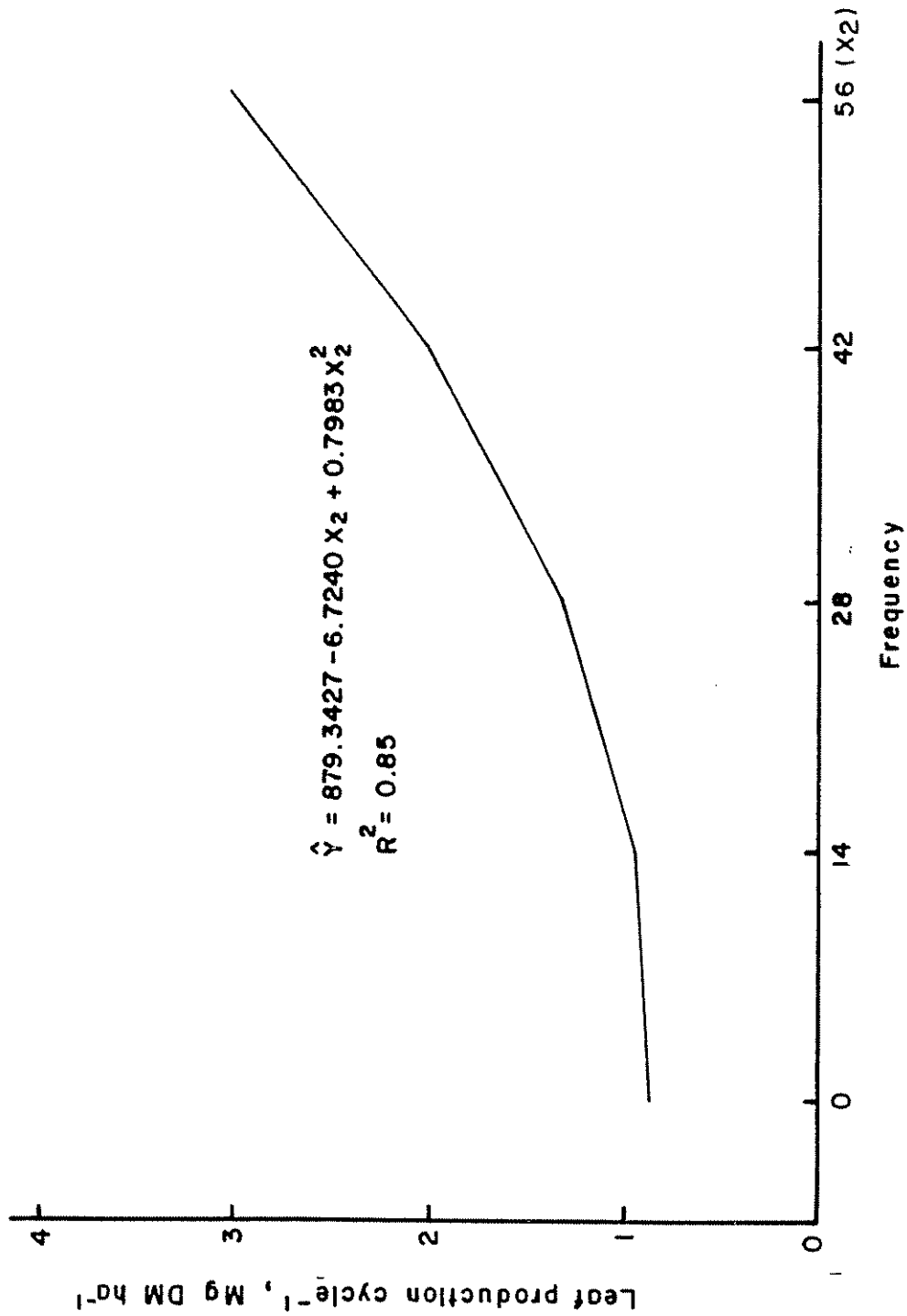
Fig. 14 The effect of grazing frequency (X_2, days) on leaf dry matter production per cycle in dwarf elephant grass cv. Mott

The figure shows a graph with:
- y-axis: Leaf production cycle^{-1}, Mg DM ha^{-1}
- x-axis: Frequency, $56 (X_2)$

$\hat{Y} = 879.3427 - 6.7240\, X_2 + 0.7983 X_2^2$

$R^2 = 0.85$

effeciency of pasture utilisation, and therefore permitting increased carrying capacities (Stuth et al., 1981; Mileria et al., 1987).

In Figure 13, it is interesting to note that a fair amount of leaf dry matter production (> 1100 kg ha^{-1}) was achieved even with severe (3.0 kg LDM 100 kg BW^{-1}) and frequent grazing (continous grazing). This may be associated to the prostrate growth habit that the grass adapted in response to severe grazing regimes, which according to Booysen et al., (1963) permitted some growing points to escape defoliation.

Although the dwarf elephant grass is generally known as a lower yielder when compared to tall genotypes of elephant grass, it should be indicated that the values obtained for leaf dry matter production in this study were similar or higher than those observed for king grass, a tall genotype of elephant grass (Fuentes, 1989). Besides, in grazing studies to determine pasture persistence, leaf yelds of king grass (*Pennisetum purpureum* x *Pennisetum typhoides*) declined progressively with successive grazing cycles, confirming that persistence of tall genotypes of elephant grass is seriously affected under grazing conditions (CARDI, 1987).

However, the information encountered in the literature for prostrate grasses is diverse, but a majority of workers (Gonzales, 1979; Sierra, 1980; Avendaño et al., 1986) reported higher dry matter production with shorter grazing intervals, being associated to better defense mechanisms

adapted by these species to protect the photosynthetic tissues (Jones and Carably, 1981). Under grazing studies, available forage yields of *Brachiaria humidicola* and *Cynodon nlemfuensis* were not affected with different grazing frequencies and intensities (Caro-Costas and Vicente-Chandler, 1981; Abramides et al., 1984), where as Mileria et al., (1987) found that leaf yields in *Cynodon dactylon* was acclerated with lower grazing pressures.

5.0. BOTANICAL COMPOSITION AND GROUND COVER.

5.1. BOTANICAL COMPOSITION.

The data on botanical composition showed that only three components were consistent in all the plots sampled, and there were high variations in other species. As a result of this, only the dominant species were analysed.

Persistence of dwarf elephant grass was endangered with severe (3.0 and 4.5 kg LDM 100 kg BW^{-1}) and frequent grazing (0- and 14- days), which resulted in a reduction of more than 12% of this grass composition (Fig. 15). This- is mainly due to excessieve removal of growing points (Fig. 5) and depressive effects induced on tillering capacity (Fig. 7) under this management practice, that have been considered to be of invaluable importance in sustainability and perennality of herbage grasses, and hence persistency under grazing (Langer, 1963; Humphreys, 1966; Younger, 1972).

Also, this decrease may be related to the selective behaviour of grazing animals (Arnold, 1981) for more palatable dwarf elephant grass which was evident in an increase in the unpalatable *Paspalum fasciculatum* (Fig. A1) and to a lesser extent broad leaved weeds (Fig. A2). Besides, Camacho et al., (1974) noted that gamalote (*Paspalum fasciculatum*) was more aggressive in mixed swards than in monoculture, and this may be used as a further explanation for lower dwarf elephant grass composition.

However, the results presented in Figure 15 showed that the composition of dwarf elephant grass was not only affected by the independent effects of grazing intensity (P < 0.01) and frequency (P < 0.002), but also by interactions (P < 0.01) in the two grazing factors. The composition of dwarf elephant grass tended to show positive changes as the levels of leaf assignation (kg LDM 100 kg BW^{-1}) were increased, but this effect was found to be more distinct for short grazing frequencies (0- and 14- days) than for infrequent grazing (42- and 56- days). In Figure 15, it should be noted that the composition of dwarf elephant grass under continous grazing was elevated by 46%, compared to only 17% observed with the 56- days grazing interval and the same variations in grazing intensity.

$\hat{Y} = -78.86 + 19.1961 X_1 + 0.6896 X_2 - 0.9977 X_1^2 - 0.07899 X_1 X_2$

$R^2 = 0.90$
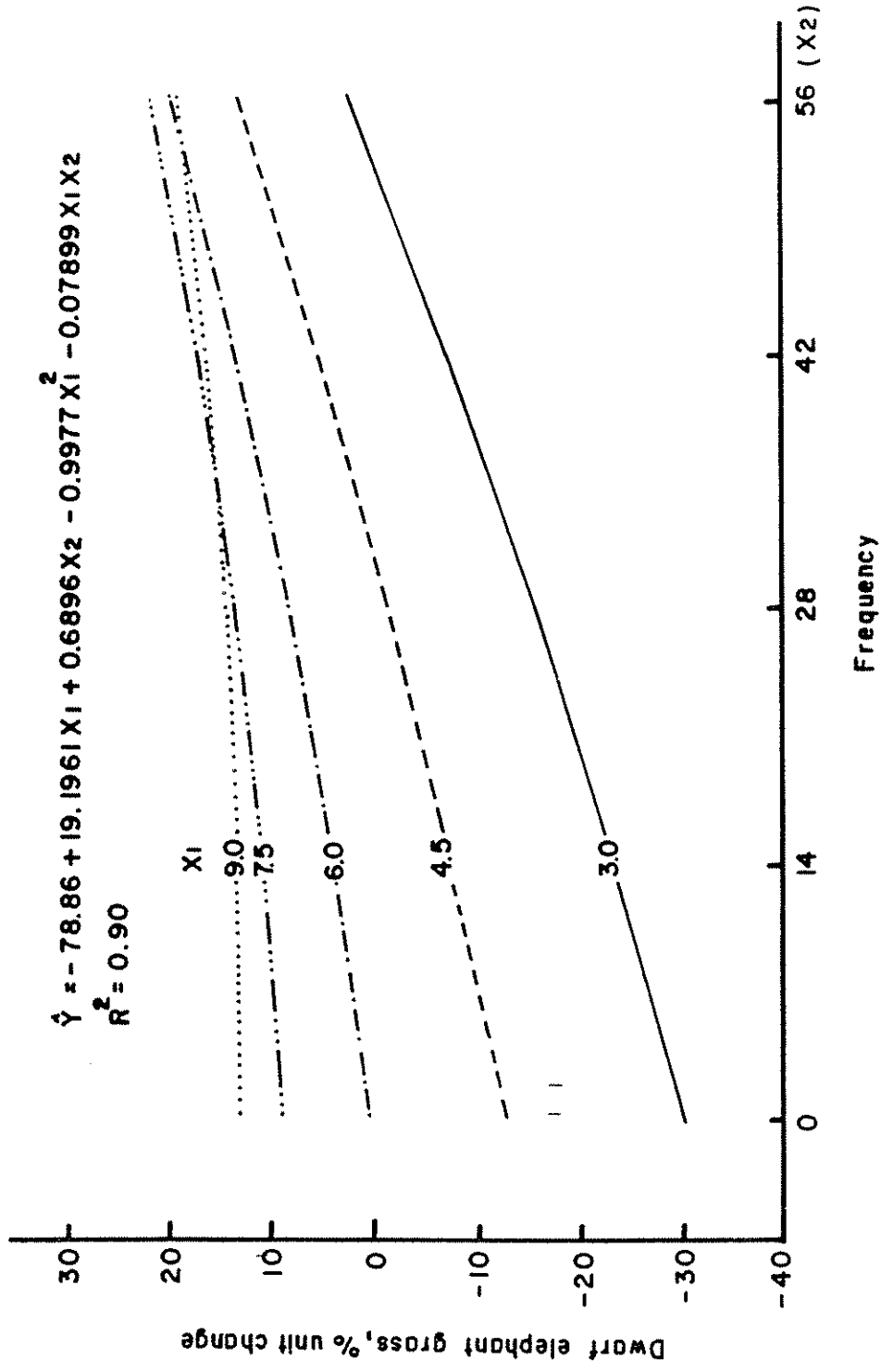
Fig.15 The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on the percentage unit change in dwarf elephant grass cv. Mott composition

Also, in Figure 15, it may be deduced that grazing above 4.5 kg LDM 100 kg BW^{-1} and 28- days grazing interval may be practical, since the composition of the dwarf elephant grass tended to increase or show similar values that was found at the beginning. This is a compartive advantage of dwarf elephant grass, since it has been recognised that tall genotypes of *Pennisetum purpureum* are susceptible to grazing (Rodrigues et al., 1987ab, CARDI, 1987).

In general, increased dominance of dwarf elephant grass with lenient and infrequent grazing, is linked by various authors to increased forage growth rates and hence plant vigor, being engendered by large amounts of photosynthetic tissues remaining after grazing, as well as improved tillering capacity under this grazing management (Humphreys, 1966; Younger, 1972; Mares Martins, 1984; Rodrigues et al., 1987b).

The results obtained in the literature closely agrees with the findings for other erect grasses like tall genotypes of *Pennisetum purpureum, Panicum maximum* and *Hyparrenhia rufa,* showing that these grasses are detrimentally affected by intense and frequent defoliations (Stobbs, 1969; Watkins and Van Severen, 1951; Galviz, 1981). On the other hand, intensive grazing regimes were not found to adversely affect composition of prostrate grasses (*axonopus compressus, Paspalum plicatum*).

5.2. GROUND COVER.

Ground cover was affected by linear effects of grazing intensity (P < 0.01) and frequency (P < 0.02), as well as in interaction (P < 0.001) between the two grazing factors.

The results obtained in Figure 16 showed that the effect of the grazing levels on ground cover of dwarf elephant grass was concordant to that observed in Figure 15 on the composition of dwarf elephant grass. Consequently, a reduction in ground cover (>12%) observed in Figure 16 was induced by the same grazing factors that caused a depression in composition of dwarf elephant grass (Fig. 14). This was associated by many authors (Langlands and Bennett, 1973) to the effect of overgrazing, leading to a greater proportion of the soil being denuded of vegetation. Also, in grazing studies with dwarf elephant grass, Rodrigues et al., (1987 ab) found that high grazing pressures and frequency seriousily affected basal area cover of the grass, being accentuated through high plant mortality.

In Figure 16, the rate of change in ground cover as the levels of grazing frequency was varied was also parallel to that observed on dwarf elephant grass composition in Figure 15. It should be noted that plant cover was unaffected or tendend to show increases when the grazing intensity and frequency was above 4.5 kg LDM 100 kg BW^{-1} and 28- days, respectively.

Excellent ground cover is of immense importance for maintaining competitive balance in grasses, particularly in monospecific erect swards. This is mainly connected to suppresion of volunteer weeds through shading, and therefore, restricting light penetration for growth in species found in the lower strata (Harris and Thomas, 1972). This was confirmed in grazing studies with diverse pasture species, indicating that the erect grasses (*Pannicum maximum* and *Hyparrenhia rufa*) dominated the pasture with lenient and infrequent grazing, whereas, prostrate grasses (*Axonopus compressus* and *Paspalum conjugatum*) were found to be dominant with high grazing intensities and frequencies (Galviz, 1981).

$$\hat{Y} = -83.9332 + 19.8599 X_1 + 0.69381 X_2 - 1.0077 X_1^2 - 0.08249 X_1 X_2$$

$$R^2 = 0.88$$
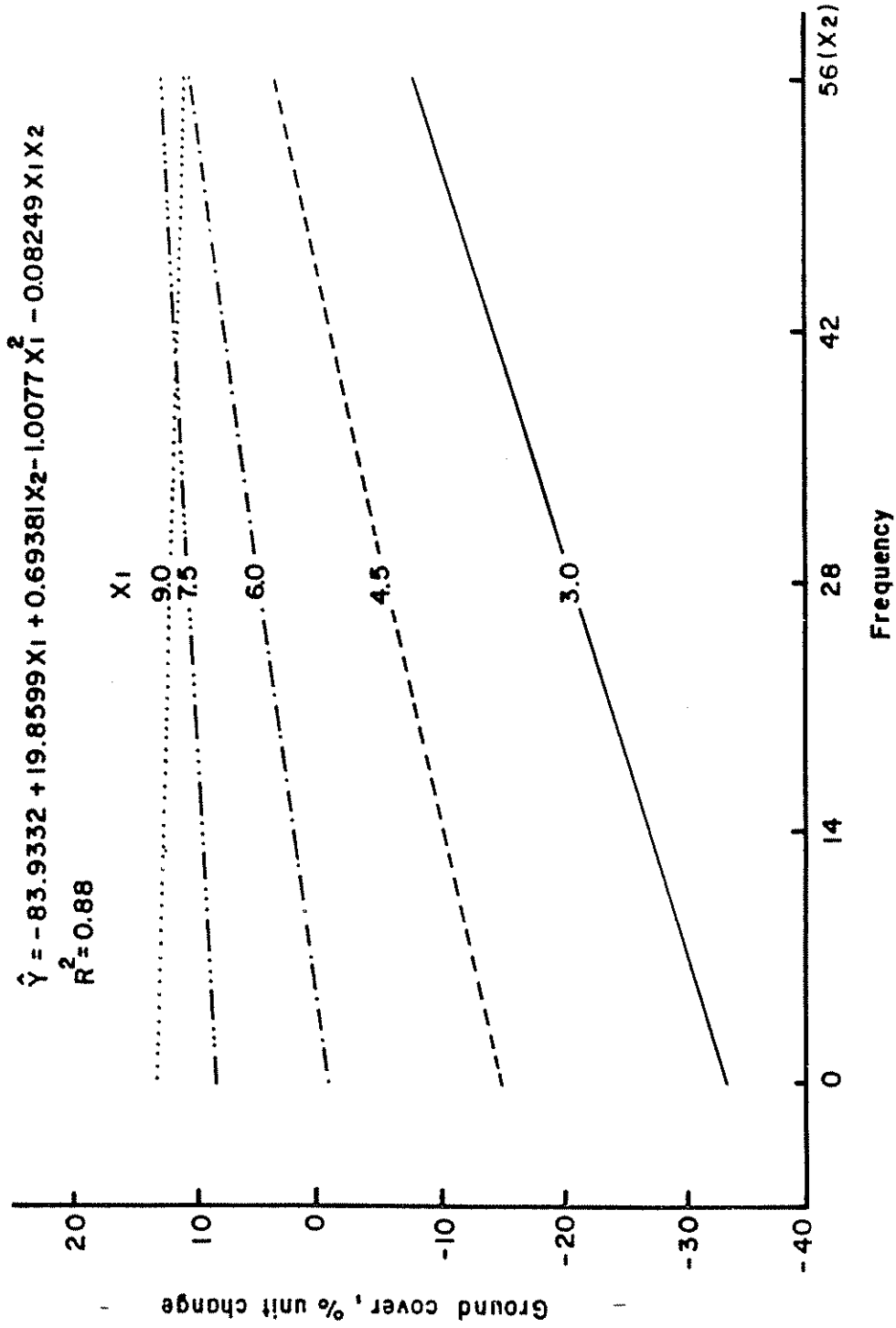
Fig.16 The effect of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) and frequency (X_2, days) on the changes of ground cover in dwarf elephant grass(cv. Mott)

6.0. CONCLUSIONS

1.   During   the   period   after   establishment,   high   grazing
intensities   and   short   resting   periods   are   prejudicial
management practices for this grass, and they may affect its
persistence since under these grazing management, there is a
reduction   in   leaf   dry   matter   production,   plant   and   stem
height, number of internodes, tillers and axillary buds, as
well as excessive removal of the grozing points.

2.   The crude protein content and in vitro dry matter
digestibility of leaves and stem in dwarf elephantgrass are
superior   to the values encountered for a majority of
tropical grasses. Besides, these attributes were marginally
affected by grazing intensities and high values were
maintained even when the grass was grazed infrequently.

7.0 RECOMMENDATIONS

1. The experiment should be continued to determine the effect of grazing intensity and frequency on the production and persistency of dwarf elephant grass over a long period.

2. Evaluation of this grass in association with herbaceous and tree legume should be implemented to determine performance under these management systems.

3. Given the nutritive value and forage production observed for dwarf elephantgrass, it is recommended that evaluations should be initiated to determine animal responses, especially in specialised milk production and dual purpose systems.

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ANNEX

Table A1. Chemical and Physical characteristics of the soil in the
experiment site

# Sample	pH H_2O	meq 100 ml^{-1}			Micrograms ml^{-1}			Texture
		Ca	Mg	k	P	Zn	Cu	
1	5.6	4.59	1.80	0.10	5.7	1.23	3.9	Loam
2	5.6	4.84	2.15	0.09	5.6	2.07	5.0	S. loam*
3	5.6	5.47	1.76	0.09	6.0	1.07	3.5	S. loam
4	5.6	5.61	1.93	0.10	5.4	1.01	3.3	S. loam
5	5.6	5.76	2.20	0.29	8.2	1.08	3.5	S. loam
6	5.6	5.16	1.88	0.12	8.1	1.06	3.0	S. loam
7	5.7	4.34	1.83	0.11	7.1	1.07	3.2	S. loam

*Sandy

TABLE A2. The effect of grazing intensity (kg LDM 100 kg
BW^{-1}) and frequency (days) on the % apical meristems
removed (AMR) in each period.

	TREATMENT		% AMR PERIOD		
PLOT	INTENSITY	FREQUENCY	1	2	3
2	3	56	66	60	64
10	6	56	47	46	44
5	9	56	29	29	26
8	4.5	42	58	56	54
13	7.5	42	35	41	39
16	3	28	64	68	69
7	6	28	47	48	51
9	6	28	47	49	48
14	6	28	49	51	46
4	6	28	46	44	49
17	6	28	46	45	48
15	9	28	31	32	34
6	4.5	14	58	62	60
3	7.5	14	37	35	37
12	3	0	73	75	77
1	6	0	45	46	47
11	9	0	28	39	33

TABLE A3. The effect of grazing intensity (kg LDM 100 kg BW^{-1}) and frequency (days) on the number of main tillers per plant.

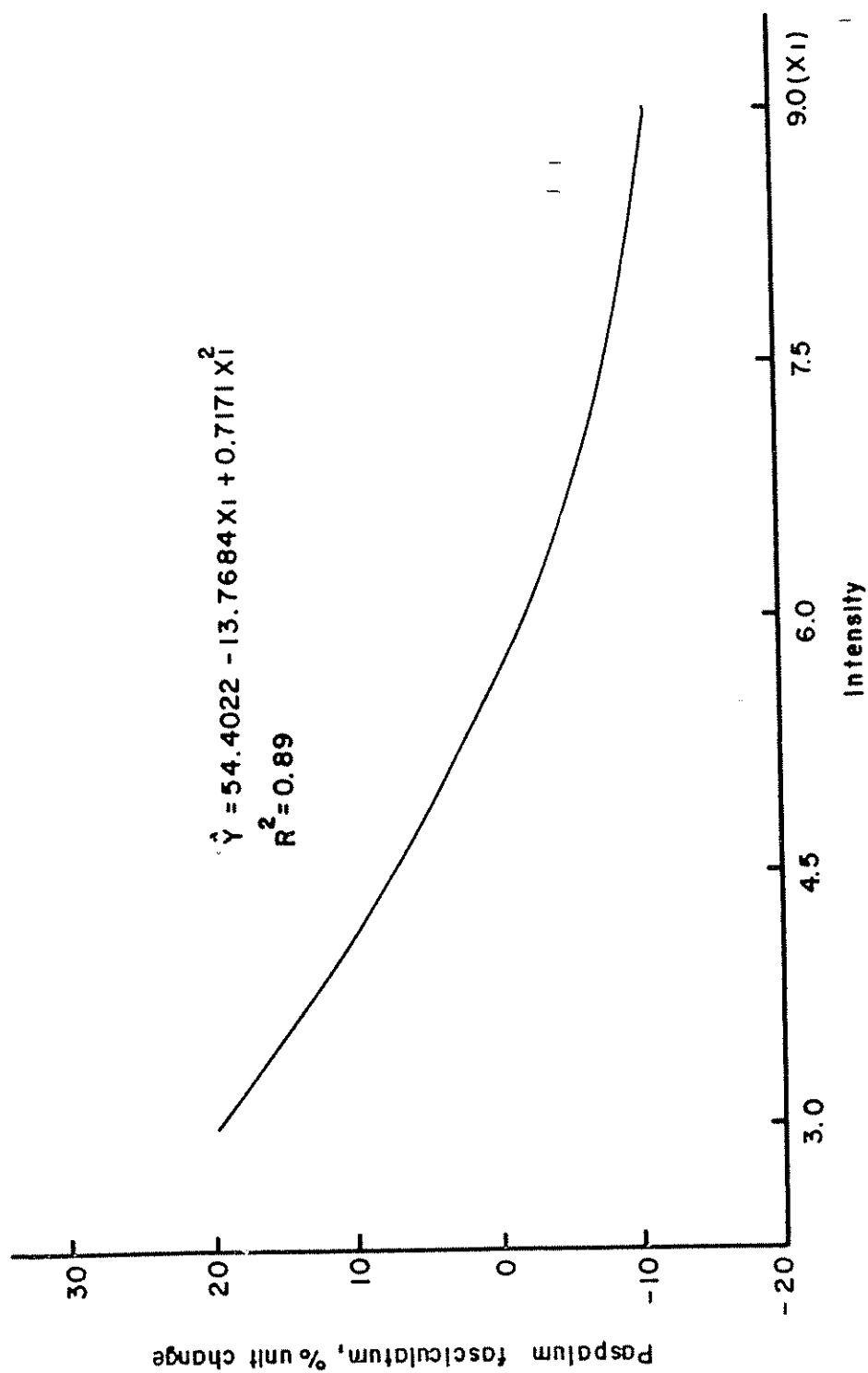| | TREATMENT | | TILLER PLANT^{-1} | | |
| | | | PERIOD | | |
PLOT	INTENSITY	FREQUENCY	1	2	3
2	3	56	87.6	60.4	54.4
10	6	56	56.2	45	41.4
5	9	56	55.8	47.9	46.7
8	4.5	42	53.9	44.9	38.6
13	7.5	42	46.3	41.4	36.8
16	3	28	97.6	68.5	53
7	6	28	55.6	41.6	36.3
9	6	28	57.3	45	36.6
14	6	28	45.1	36.2	30.3
4	6	28	86.8	62	53.4
17	6	28	84	59.4	50.6
15	9	28	46	38.6	35.6
6	4.5	14	55.2	37.5	27.5
3	7.5	14	91	75.3	67.2
12	3	0	47.67	29.8	15.9
1	6	0	88	63.6	52
11	9	0	57.4	45.4	41.5

Fig. A1 The effects of grazing intensity (X_1, kg LDM 100 kg BW^{-1}) on the percentage unit change of Paspalum fasciculatum in a dwarf elephant grass (cv. Mott) sward
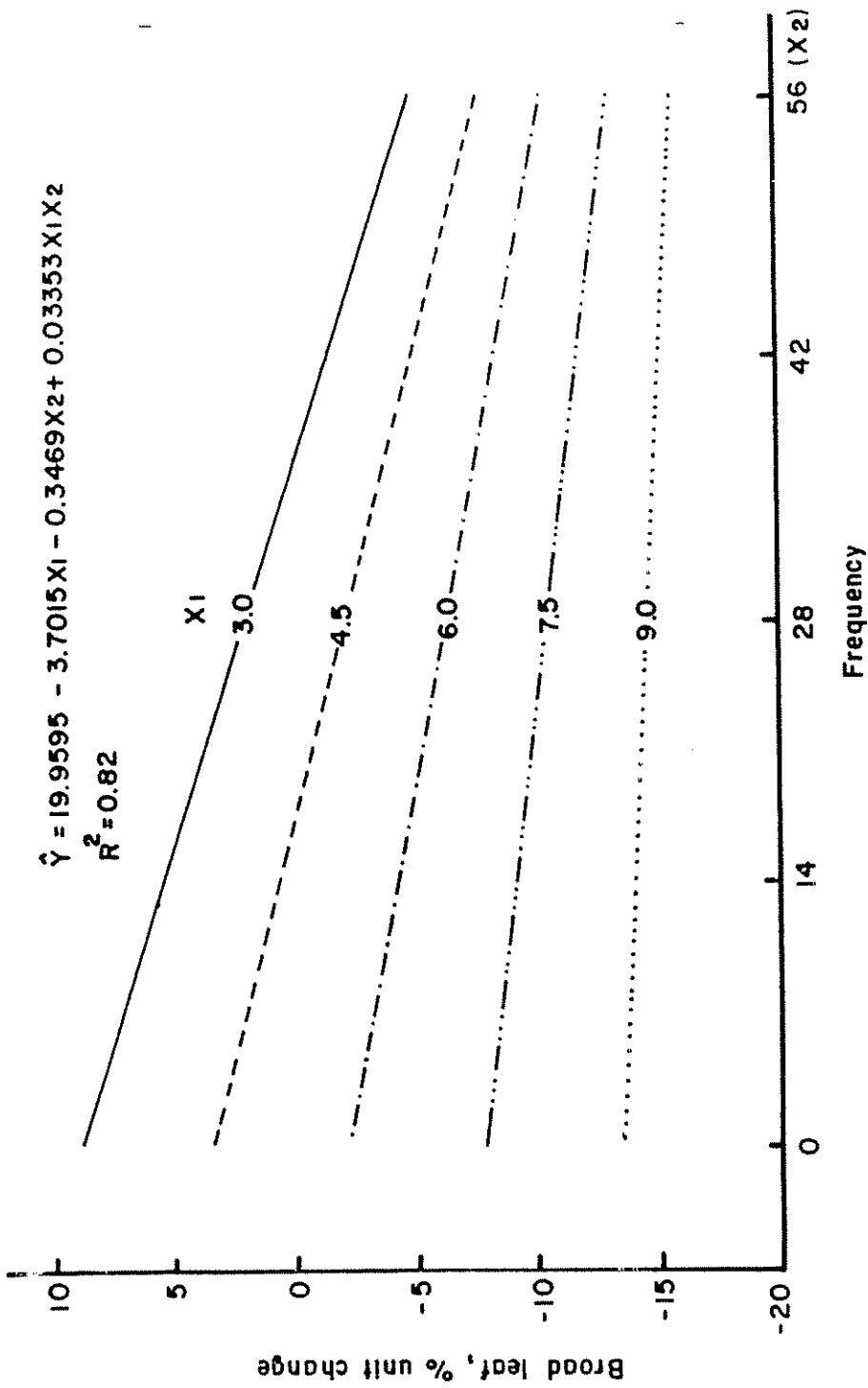
$\hat{Y} = 54.4022 - 13.7684 X_1 + 0.7171 X_1^2$

$R^2 = 0.89$

Fig. A2 The effect of grazing intensity(X_1, kg LDM 100 kg BW^{-1}) and frequency(X_2,days) on the percentage unit change of broad leaf weeds in a dwarf elephant grass (cv. Mott) sward

$\hat{Y} = 19.9595 - 3.7015X_1 - 0.3469X_2 + 0.03353X_1X_2$

$R^2 = 0.82$