TILLERING AND MORPHOLOGICAL CHARACTERISTICS OF DWARF ELEPHANTGRASS UNDER GRAZING[1]

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ABSTRACT - Morphological characteristics and tillering of dwarf elephantgrass (*Pennisetum purpureum* Schum.) were studied in a grazing trial conducted at the University of Florida - USA. The grass was subjected to the effects of two management factors, each at five levels as follows: length of grazing cycle (GC) (continuous grazing, 14, 28, 42 and 56 days) and grazing pressure (GP) (500, 1,000, 1,500, 2,000 and 2,500 kg of residual leaf dry matter ha^{-1}). Response surface methodology was used to analyse the data. Increases in GC and decreases in GP increased plant height, apical meristems height, number of internodes and dry matter produced per tiller. The percentage of apical meristems eliminated was greater under continuous grazing and high GP. The number of axillary buds per tiller was depressed under high GP. Shorter internodes were observed at short GC and high GP. Primary tillers constituted the predominant form of tillering in this grass. The results obtained indicate that short grazing cycles and high grazing pressures should be avoided in the management of dwarf elephantgrass in order to insure persistence and productivity of the pasture.

Index terms: *Pennisetum purpureum*, grazing trial, pasture management, management factors.

PERFILHAMENTO E CARACTERÍSTICAS MORFOLÓGICAS DO CAPIM-ELEFANTE ANÃO SOB PASTEJO

RESUMO - O perfilhamento e as características morfológicas do capim-elefante anão (*Pennisetum purpureum* Schum.) foram estudados num ensaio de pastejo conduzido na Universidade da Flórida - EUA. O capim foi submetido a 5 níveis de pressão de pastejo - PP (500, 1.000, 1.500, 2.000 e 2.500 kg de MS de folha residual ha^{-1}) e ciclo de pastejo - CP (pastejo contínuo, 14, 28, 42 e 56 dias). Os dados foram analisados através da metodologia de superfície de resposta. Aumentos no CP e reduções na PP resultaram no aumento da altura das plantas e dos meristemas apicais, no número de entrenós por perfilho e na produção de MS produzida por perfilho. A percentagem de meristemas apicais eliminados foi mais elevada sob pastejo contínuo e alta PP. O número de gemas axilares por perfilho foi reduzido sob alta PP. Entrenós mais curtos foram observados em CP curtos e alta PP. Perfilhos primários constituem a forma predominante de perfilhamento neste capim. Os resultados obtidos sugerem que CP curtos e altas PP devem ser evitados no manejo do capim-elefante anão a fim de assegurar a persistência e a produtividade da pastagem.

Termos para indexação: *Pennisetum purpureum*, ensaio de pastejo, manejo de pastagens, fatores de manejo.

INTRODUCTION

Elephantgrass (*Pennisetum purpureum* Schum.) is valued for its herbage yields, palatability, and good quality herbage (Bogdan 1977). Although widely cultivated as a fodder plant, it is not commonly used in pastures. Many researchers have suggested that the main limitation of elephantgrass under grazing results from management problems deriving from its growth habit. Differences in habit among grasses are due to the pattern of lateral shoot development and the length of stem internodes (Jewiss 1966). The elongation of internodes reduces the density of buds close to the ground, elevates the canopy, and increase apical meristems vulnerability to cutting or grazing. Thus, the position of the growing points at the time of cutting or grazing is an important factor in determining susceptibility of forage plants to defoliation (Booysen et al. 1963, Jewiss 1966, Langer 1972,

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Gomide et al. 1979, Dovrat et al. 1980, Humphreys 1981).

Dahl & Hyder (1977) indicated that tillering ability from axillary buds without the apical meristem being removed is considered an indication of an efficient forage producer. During growth of a controlled sward, the dry matter yield of shoots increases because of both the weight increase of individual tillers and the increase in number of tillers (Humphreys 1966, 1981, Dovrat et al. 1980). However, the rate of tiller initiation in the pasture environment may be significantly affected by grazing.

Youngner (1972) concluded that, when defoliation removes apices of elongated stems, apical dominance is broken and the rate of tiller production is increased. On the other hand, the intensity of defoliation can affect the characteristics of new tillers. Thus, Belyuchenko (1980) observed that the height of cutting modified the proportion of new tillers in the regrowth of elephantgrass. When plants were cut close to the ground, tillers originated from buds on the rhizome. Cuts at 10 or 15 cm produced an appreciable number of basal buds arising from the crown tillering area. Cutting at 15 cm or higher led to a predominance of aerial tillers arising from axillary buds on the stems.

Recently, a dwarf type of elephantgrass, known as line N-75, was isolated from a population of *P. purpureum* in the Coastal Plains Experimental Station, Tifton, Georgia. In 1979 this material was introduced at the Beef Research Unit of the University of Florida where it has been studied (Boddorff 1982, Castillo-Gallegos 1983, Veiga 1983, Rodrigues 1984). The objective of this research was to study the effects of grazing pressure and length of grazing cycle on morphological characteristics and tillering of dwarf elephantgrass under grazing.

MATERIAL AND METHODS

A grazing experiment was conducted, from April to November 1982, at the Beef Research Unit of the University of Florida, Gainesville, to study morphological and physiological responses of dwarf elephantgrass (*Pennisetum purpureum* Schum.) under grazing conditions. The experimental pastures were established with dwarf elephantgrass, line N-75, introduced from Dr. W.W. Hanna's nursery, located at Tifton, Georgia. The soil of the area belongs to Chipley series (Order Entisol), with Pomona series (Order Spodosol) occurring on a small part of the site. The climate is subtropical and humid with an average annual precipitation of 1,300 mm and a frost-free period of 276 days. The dwarf elephantgrass was propagated vegetatively by both small rooted cuttings and stem cuttings of 5 cm to 10 cm, planted in 1 m x 1 m spacing. The planting of the grass began in the summer of 1980 and was concluded in July 1981. Irrigation, weed control, and a complete fertilizer with micronutrients were provided during the establishment phase to insure a good stand of plants. In order to test the methodology, a preliminary grazing study was conducted from August to October 1981. Maintenance fertilizer was applied during 1981 and at the beginning of the 1982 grazing season.

Two grazing management factors were studied as experimental variables: a) length of grazing cycle, and b) grazing pressure. The grass was subjected to five levels of each of these variables as follows: length of grazing cycle: continuous grazing, 14, 28, 42, and 56 days, and grazing pressure: 500, 1,000, 1,500, 2,000 and 2,500 kg of residual leaf dry matter (RLDM ha^{-1}). Each grazing cycle, except for the continuously grazed treatments, consisted of two days of grazing followed by an appropriate rest period to complete the desired length of grazing cycle. Because residual dry matter is subjected to measurement errors, all efforts were made to have RLDM ha^{-1} as close as possible to the projected values. However, fluctuations in these values were observed throughout the grazing season and for clarity figures presented in this paper are extended to 250 kg RLDM ha^{-1}.

Response surface methodology was used to study 13 treatment combinations, arranged in a modified non-rotatable central composite design according to Littell & Mott (1975). All the design points shown in Fig. 1 were replicated twice, and the resulting 26 experimental units were distributed in a completely randomized design in the field. The central treatment (1,500 kg RLDM ha^{-1} and 28-day grazing cycle) was selected to represent the region where the combination of experimental variables was anticipated to be near optimum to insure productivity, quality, and persistence of the grass. The data obtained were analyzed using the complete second order polynomial model, $Y = b_0 + b_1x_1 + b_1x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 + \epsilon$, where y = observed response, x_1 = grazing cycle, and x_2 = estimated grazing pressure.

Grazing pressure was imposed as residual leaf dry matter in kg ha^{-1} and was estimated by Veiga (1983) using a double sampling technique. Visual estimation was used to determine the level of grazing pressure attained during the grazing period. It should be indicated that a lenient grazing pressure suggests a large amount of residual leaf left at the end of the grazing period and conversely a high grazing pressure suggests a small amount of residual leaf. Stocking rates were determined on the basis of available forage, and the number of animals was adjusted during the grazing period in order to achieve the desired grazing pressure in about two days. Animals were used solely to defoliate the pastures since the experiment was planned to study the effect of the animals on the pasture regrowth and not the effect of the pasture on the animals.

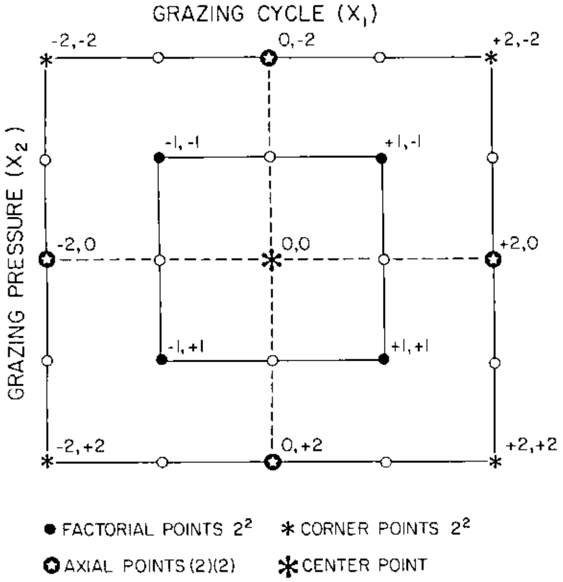

FIG. 1. Configuration of the modified central composite non-rotatable design, including the coded treatment combinations.

The study of the morphology of dwarf elephantgrass consisted in the measurements of the following morphological characteristics: apical meristems height, stem height, number of axillary buds and internodes per tiller, and length of internodes. For this purpose ten tillers were sampled at random before and after each grazing cycle, cut to ground level, and immediately taken to the laboratory. Plant height was measured as the length of the extended tiller from ground level to the ligule of the last expanded leaf. Percentage of apical meristems eliminated after grazing was calculated in relation to the total of tillers collected.

The number of tillers per plant was recorded before each grazing period in the rotationally grazed pastures and at each 28-day interval in the continuously grazed pastures. Two tillers were marked within each ten plants chosen at randon in each pasture. Suitable tillers were marked with hand made rings of plastic covered wire.

RESULTS AND DISCUSSION

Morphology of Dwarf Elephantgrass

Plant height, measured in terms of tiller height, varied from 17.2 cm (250 kg RLDM ha^{-1} and continuous grazing) to 104.1 cm (2,500 kg RLDM ha^{-1} and 56-day cycle). As the grazing cycle was increased and the grazing pressure was decreased, the plant height was increased (Figure 2). Increase in height as the plant advances in age has been reported in several tropical grasses (Tardin et al. 1971, Nascimento Júnior & Pinheiro 1975, Gomide et al. 1979, Garcia & Silva 1980), including tall varieties of elephantgrass (Vieira & Gomide 1968, Pedreira & Boin 1969, Andrade & Gomide 1971).

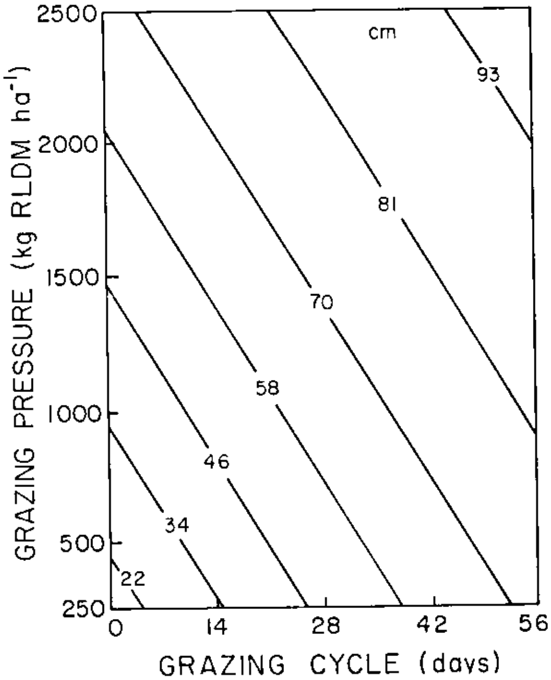

FIG. 2. Contour map of plant height of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure (R^2 = 0.98, CV = 5.24%, $P < 0.01$).

An analysis of Fig. 3 indicates that the apical meristems were relatively low at high grazing pressures and short grazing cycles and increased in height as the grazing pressure decreased and the grazing cycle increased. The response is similar to that of plant height suggesting that the grass tends to change its form under different grazing conditions. The data also suggest that grazing pressure had the greatest effect upon the elimination of apical meristems. The percentage of apical meristems eliminated varied from 25.0% (2,500 kg RLDM ha^{-1} and 56-day cycle) to 73.3% (250 kg

RLDM ha^{-1} and continuous grazing). It should be mentioned that at the beginning of the growing period the apical meristems were close to the ground in all pastures. However, the apices of some stems were grazed in pastures subjected to heavier grazing pressure (250 kg RLDM ha^{-1}). On the other hand, in the second half of the experimental period, after about August 1st, lower stocking rates were required to attain the projected grazing pressure which may have reduced the number of apical meristems removed at heavy grazing pressures and short grazing cycles. In fact, the use of high stocking rates or the maintenance of animals in the continuously grazed pastures resulted in the elimination of a large number of apical meristems. It has been suggested by several authors that the position of the growing points at the time of defoliation is an important morphological factor in determining the persistence of forage grasses (Booysen et al. 1963, Jewiss 1966, Langer 1972, Youngner 1972, Dahl & Hyder 1977, Gomide et al. 1979, Dovrat et al. 1980, Humphreys 1981). Indeed, regrowth of tropical grasses is associated with the fate of apical meristems following defoliation (Andrade & Gomide 1971, Tardin et al. 1971, Nascimento Júnior & Pinheiro 1975, Gomide et al. 1979, Dovrat et al. 1980). Andrade & Gomide (1971) observed that a rapid and early elongation of internodes in elephantgrass resulted in the elimination of a higher number of apical meristems. Stem growth, promoted by stem elongation, increases apical meristems vulnerability to defoliation (Booysen et al. 1963, Dahl & Hyder 1977, Gomide et al. 1979, Humphreys 1981). In the Andrade & Gomide (1971) trial all apical meristems were eliminated when the plants were cut at 56 days of age. Cutting each 28 days allowed the survival of apical meristems which in turn engendered good regrowth. Muldoon & Pearson (1979 b) reported that the initial regrowth of hybrid *Pennisetum* was delayed when the apical meristems were decapitated. When the apical meristems were left intact, a more rapid initial regrowth was observed.

The contours of equal response (Fig. 4, 5, 6 and 7) indicated clearly that the combined effect of grazing pressure and grazing cycle caused marked changes in the morphology of dwarf elephantgrass. Stem height ranged from 13.7 cm (250 kg RLDM ha^{-1} and continuous grazing) to 41.4 cm (2,500 kg RLDM ha^{-1} and 56-day cycle). Fig. 4 suggests that stem height was increased as the grazing cycle was increased and the grazing pressure was decreased. At high grazing pressures stem height was greatly reduced. Stems were smaller at high grazing pressures and short grazing cycles. However, even under continuous grazing, stem growth occurred when the plants were subjected to a more lenient grazing pressure.

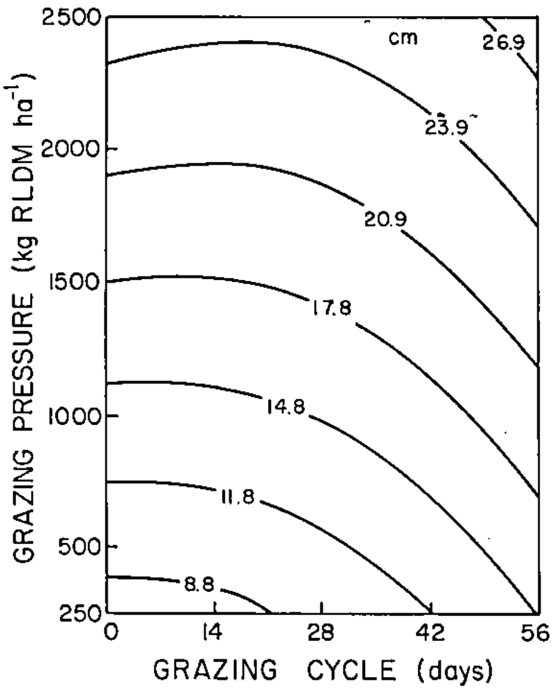

FIG. 3. Contour map of height of apical meristems of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. (R^2 = 0.94, CV = 9.16%, $P < 0.01$).

The number of axillary buds per tiller was influenced by the same conditions which affected stem growth. High grazing pressures, independently of grazing cycle, depressed the number of axillary buds per tiller (Fig. 5). An examination of Fig. 6 and 7 suggests that the appearance of axillary buds was associated with the growth of well developed stems. The interaction of grazing pressure and grazing cycle is also suggested since the effect of high grazing pressures is to increase the number of axillary buds at long grazing cycles, and low grazing pressures appear to compensate for the effect of short grazing cycles.

The number of internodes per tiller of dwarf elephantgrass varied from 12.3 to 19.8. Greater numbers of internodes were observed at low grazing pressures in all grazing cycles (Fig. 6). Although Fig. 6 suggests an increase in the number of internodes as grazing pressure is decreased and grazing cycle is increased, the low variation in number of internodes supports the idea that the number of internodes is genetically established and inherent to each genotype. Because only visible internodes were counted it is possible that greater elimination of apical meristems at higher grazing pressures prevented the full expression of this morphological characteristic.

Cultivars of elephantgrass differ in many morphological characteristics (Bogdan 1977, Muldoon & Pearson 1979 a). However, there is no doubt that differences in height between tall and dwarf varieties of elephantgrass are due to the length of internodes. The pattern of internode elongation is due to differentiation of cells of apical meristems.

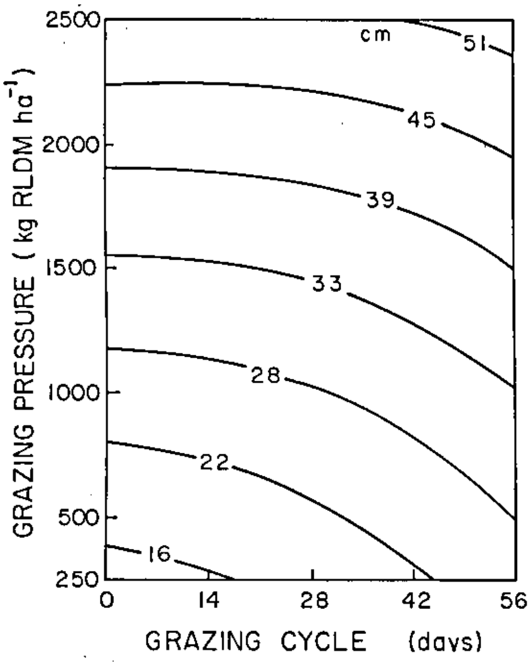

FIG. 4. Contour map of stem height of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. (R^2 = 0.95, CV = 6.41%, P < 0.01).

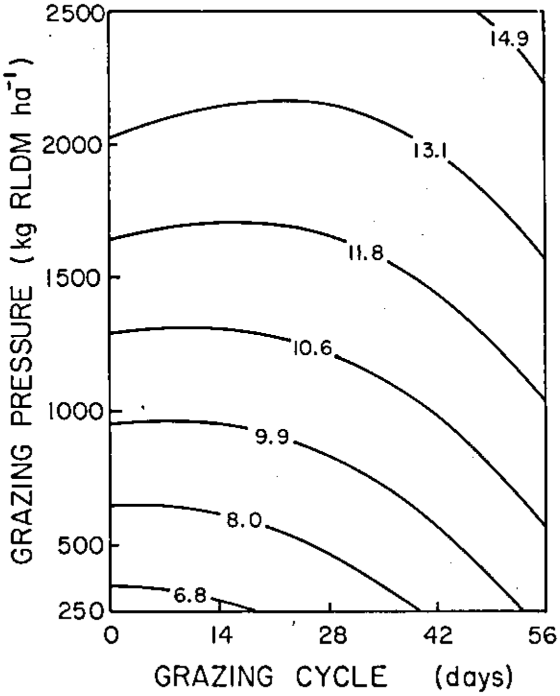

FIG. 5. Contour map of number of axillary buds per tiller of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. (R^2 = 0.88, CV = 9.36%, P < 0.01).

Furthermore, elongation of internodes increases plant height, reduces the density of buds close to the ground, changes canopy structure, reduces the number of growing points that remain after defoliation, and may also be associated with a decline in nutritive value (Booysen et al. 1963, Jewiss 1966, Langer 1972, Dahl & Hyder 1977, Gomide et al. 1979, Dovrat et al. 1980, Humphreys 1981). In this research, the most interesting response of dwarf elephantgrass was the reduction of the elongation rate of internodes at high grazing pressures and short grazing cycles. By maintaining shorter internodes and assuming a more prostrate growth habit the grass quickly adapted itself to frequent and intense defoliation. Although this phenotypic adaptation was clearly evident in plants subjected to continuous grazing and the highest grazing pressure (250 kg RLDM ha^{-1}), it was also observed at high grazing pressures in combination with grazing cycles of 14 and 28 days (Fig. 7). This morphological response prevented the removal of some apical meristems which in turn may have allowed herbage production to continue throughout the grazing season. Fig. 6 also suggests that as the grazing pressure was decreased and the grazing cycle was increased, the length of internodes was increased. Another interesting fact is that elongation of internodes was not affected by the length of grazing cycle when the plants were subjected to lower grazing pressures (2,500 kg RLDM ha^{-1}).

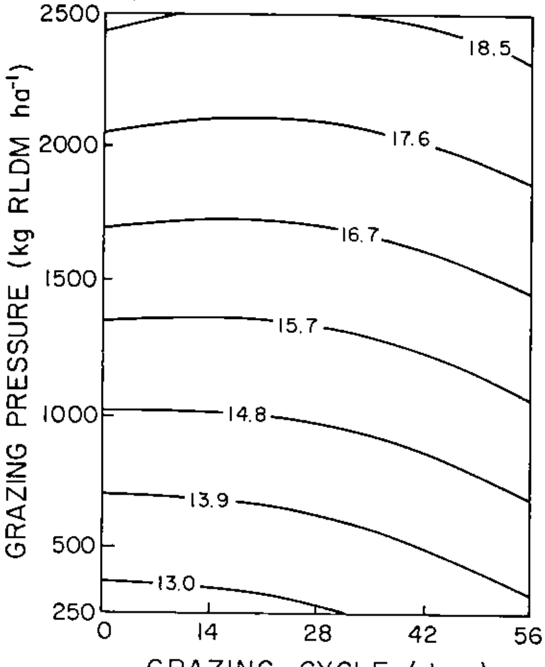

FIG. 6. Contour map of number of internodes per tiller of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. (R^2 = 0.82, CV = 6,80%, $P < 0.01$).

Tillering of Dwarf Elephantgrass

An analysis of Fig. 8 indicates a decrease in the number of main tillers per plant as the grazing cycle was shortened and the grazing pressure was increased. The number of main tillers per plant varied from 15.4 (250 kg RLDM ha^{-1} and continuous grazing) to 34.9 (2,500 kg RLDM ha^{-1} and 56 day cycle).

In tropical grasses the number of tillers per plant is usually low when compared with temperate species (Langer 1963, 1972, Jewiss 1966, 1972, Pedreira 1975, Bogdan 1977, Muldoon & Pearson 1979 a, Mott·1983). The number of main tillers per plant found in this research is in agreement with the low number of tillers found by Boddorff (1982) in dwarf elephantgrass and in interspecific hybrid of *Pennisetum americanum* x *P. purpureum*.

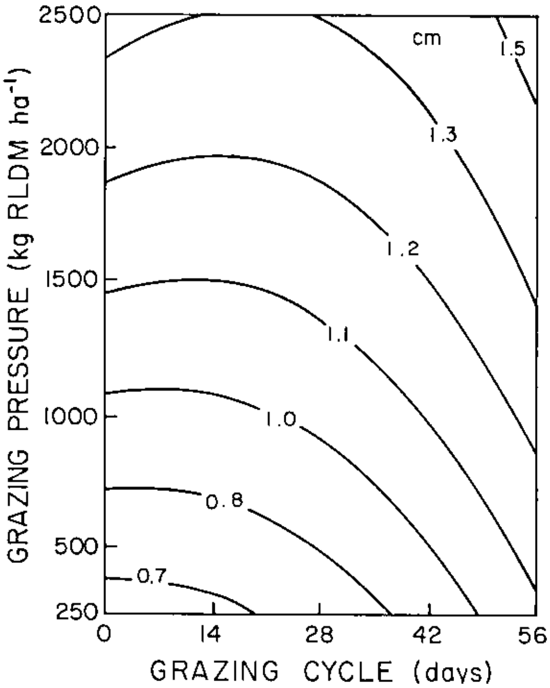

FIG. 7. Contour map of length of internodes of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. (R^2 = 0.94, CV = 5.78%, $P < 0.01$).

In contrast to the number of main tillers per plant, the number of basal tillers per tiller increased as the grazing cycle was shortened and the grazing pressure was increased (Fig. 9). The number of basal tillers per main tiller varied from 0.05 (2,500 kg RLDM ha^{-1} and 56-day cycle) to 0.65 (250 kg RLDM ha^{-1} and continuous grazing). The reduction in the length of internodes, as already discussed, and a higher production of basal tillers resulted in plants with a more prostrate growth habit. It should be emphasized that this morphological reaction is a clear evidence of the capacity of the grass to adapt itself to stress conditions. In the pasture environment tillering may be significantly affected by grazing. According to Youngner (1972), when stem apices are removed, apical dominance is broken and the rate of tiller production is increased by activation of basal and lateral buds. Defoliation may enhance tillering, even when apices remained undamaged, by creating a more favorable light environment which would be expected to stimulate the growth and activation of buds (Jewiss 1972, Laude 1972, Youngner 1972).

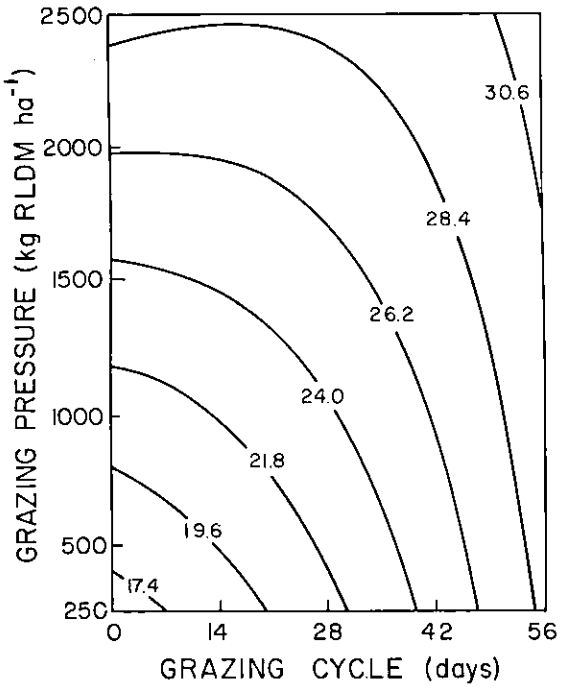

FIG. 8. Contour map of number of main tillers per plant of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. ($R^2 = 0.60$, CV = 14.54%, $P < 0.01$).

The number of primary tillers per tiller of dwarf elephantgrass affected by grazing pressure and grazing cycle is shown in Fig. 10. A greater number of primary tillers were observed at high grazing pressures and short grazing cycles. However, at longer grazing cycles the number of primary tillers tended to increase as the grazing pressure was decreased. This change in the effect of grazing pressure with grazing cycle is an indication of a grazing cycle-grazing pressure interaction (Fig. 10). From Fig. 8, 9 and 10, it can be concluded that primary tillers constitute the predominant form of tillering in dwarf elephantgrass under a wide range of management systems. Indeed, a greater number of primary tillers were found in all pastures in comparison to basal tillers. This tillering response is supported by the research of Belyuchenko (1980), who observed that the proportion of new tillers in the regrowth of elephantgrass is modified by the height of cutting. When plants were cut at 10 cm or 15 cm, tillers originated from basal buds of the crown. Cuts at 15 cm or higher produced a higher number of aerial tillers arising from axillary buds.

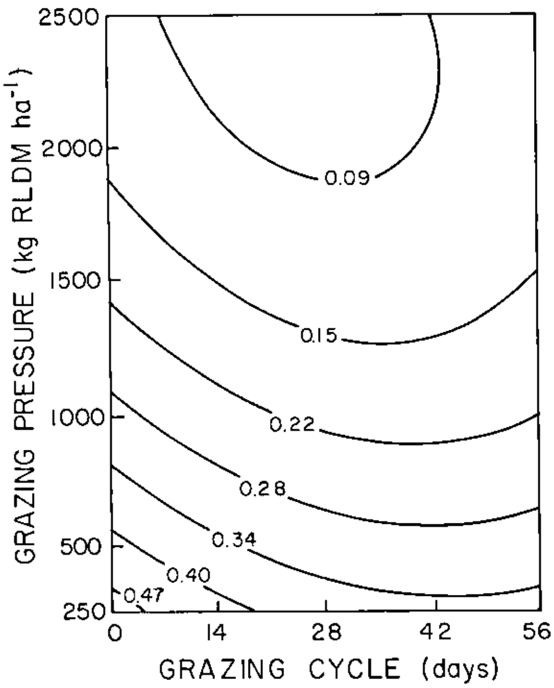

FIG. 9. Contour map of number of basal tillers per tiller of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. ($R^2 = 0.74$, CV = 39.25%, $P < 0.01$).

The presence of primary tillers in all treatment combinations, even in those with low percentage of apical meristems eliminated, should be considered as an indication of tillering ability of dwarf elephantgrass and as a measure of its efficiency as a forage producer.

Secondary tillers were absent or appeared at a low rate in pastures subjected to low grazing pressures. On the other hand, independent of the grazing cycle, high grazing pressure (250 kg RDLM ha^{-1}) stimulated the appearance of secondary tillers. Increased shading, due to the development of greater canopy closures, and low elimination of apical meristems may have induced bud inhibition at low grazing pressures and long grazing cycles.

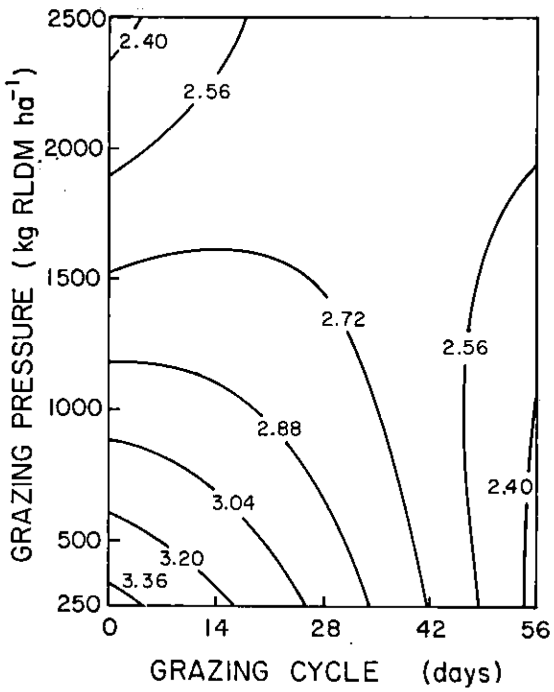

FIG. 10. Contour map of primary tillers per tiller of dwarf elephantgrass as effected by length of grazing cycle and grazing pressure. (R^2 = 0.83, CV = 14.82%, $P < 0.01$).

Dry Matter Distribution in Tillers of Dwarf Elephantgrass

Dry matter production in tillers was increased by reducing the grazing pressure and increasing the length of the grazing cycle (Fig. 11). From Fig. 11 it can be calculated that tillers of plants subjected to low grazing pressure and long grazing cycles (2,000 kg and 2,500 kg RLDM ha^{-1} and 42 - and 56-day cycles, respectively) were producing approximately 5 times the dry matter when compared with tillers subjected to continuous grazing and high grazing pressure (250 kg RLDM ha^{-1}). The magnitude of the response is even higher if we consider that in the highest grazing pressure and short grazing cycle (250 kg RLDM ha^{-1} and continuous grazing) the number of main tillers per plant was drastically reduced. There is no doubt that the decrease in DM produced per tiller under intensive grazing was due to the effects of short grazing cycles and high grazing pressures. Therefore, it should be expected that survival of the plants or number of tillers per plant may have affected the DM produced per tiller. From surveys conducted at the beginning and end of the experimental period it was determined that the population density was about 7,500 plants ha^{-1} and the survival of plants was 100% regardless of treatment. It was also observed that the basal area of plants subjected to continuous grazing and higher grazing pressure (250 kg RLDM ha^{-1}) was drastically reduced, whereas in pastures subjected to low grazing pressures and long grazing cycles the basal area of the clumps increased. Reductions and increases in the area occupied by the plants may be explained by changes in number and size of main tillers per plant as well as by the variation in number of basal and primary tillers per tiller. Furthermore, changes in canopy structure and size of the plants may have affected the competition for light, water, and nutrients, between tillers within plants, and hence the dry matter produced per tiller as indicated by Donald (1963) and Rhodes & Stern (1978).

The effect of the experimental variables upon leaf blade, leaf sheath, and stem DM produced per ten tillers was similar to that of total dry matter per ten tillers. Favorable conditions for high DM production of leaf blades, leaf sheaths, and stems were met at low grazing pressures in combination with long grazing cycles.

In this experiment, grazing pressure levels were imposed on the basis of residual leaf blade DM and therefore the increase in DM produced in different parts of the tillers as the grazing pressure is decreased and the grazing cycle is increased may be related to the interaction of several factors including: the residual leaf area left after each grazing period, fluctuations in carbohydrate reserves, and morphological changes of the plants as well as a greater elimination of apical meristems under high grazing pressures. The response observed is consistent with the increase in growth rate of this grass as reported by Veiga (1983). Since total DM production consists of the contribution of individual tillers these results are supported by results from cutting experiments (Werner et al. 1965/66, Vieira & Gomide 1968, Andrade & Gomide 1971), and grazing trials where conditions of low grazing pressures and long rest periods after each defoliation resulted in increased forage DM production (Maraschin 1975, Serrão 1976).

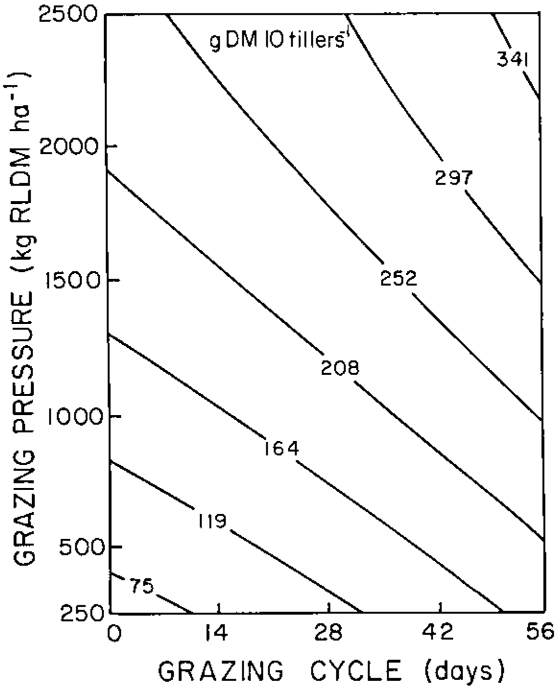

FIG. 11. Contour map of total dry matter in tillers of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. (R^2 = 0.96, CV = 8.75%, $P < 0.01$).

CONCLUSIONS

1. Plant height and stem height increased as the grazing cycle was increased and the grazing pressure was reduced. The apical meristems remained low at high grazing pressures and short grazing cycles and increased in height as the grazing cycle increased and the grazing pressure decreased. The percentage of apical meristems eliminated varied from 25.00% to 73.33% and was greater under continuous grazing and higher grazing pressure. The number of axillary buds per tiller was depressed under high grazing pressures, independent of grazing cycle. The number of internodes per tiller tended to increase as the grazing cycle was increased and the grazing pressure was decreased. The length of internodes was remarkably sensitive to the management imposed. Shorter internodes were observed at short grazing cycles in combination with high grazing pressures.

2. The number of main tillers per plant of dwarf elephantgrass was low and decreased from 34.9 to 15.7 as the grazing cycle was shortened and the grazing pressure was increased. Primary tillers constituted the predominant form of tillering in dwarf elephantgrass under the wide range of management systems studied.

3. The morphological responses observed indicate that short grazing cycles and high grazing pressures should be avoided in the management of dwarf elephantgrass in order to insure persistence and productivity of the pasture.

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