# EFFECTS OF GRAZING MANAGEMENT ON LEAF AREA AND TOTAL NONSTRUCTURAL CARBOHYDRATES OF DWARF ELEPHANTGRASS[1]

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ABSTRACT - Effects of grazing management on leaf area and total nonstructural carbohydrates (TNC) of dwarf elephantgrass (*Pennisetum purpureum*) were studied in a grazing trial conducted in 1982 at the University of Florida, Gainesville, FL, USA. Two grazing management factors were studied as experimental variables: a) length of grazing cycle (GC), and b) grazing pressure (GP). The grass was subjected to five levels of each of these variables as follows: GC - continuous grazing, 14, 28, 42 and 56 days; and GP - 500, 1,000, 1,500, 2,000 and 2,500 kg of residual leaf dry matter $h^{-1}$ (RLDM $ha^{-1}$). Response surface methodology was used to analyse the data. The average number of leaves per main tiller was greater when long grazing cycles were combined with low grazing pressures. The number of senescent leaves per main tiller increased as the grazing cycle was increased. Leaf area of green leaf blades increased as the GC increased and the GP decreased. Concentrations of TNC in stem bases of the grass were affected mainly by the length of GC and were lower at short GCs and high GPs. The physiological responses observed indicate that short grazing cycles and high grazing pressures should be avoided in the management of dwarf elephantgrass.

Index terms: *Pennisetum purpureum*, length of grazing cicle, grazing pressure.

## EFEITOS DO MANEJO SOBRE A ÁREA FOLIAR E CARBOIDRATOS NÃO-ESTRUTURAIS DO CAPIM-ELEFANTE ANÃO

RESUMO - O objetivo deste trabalho foi estudar os efeitos do manejo sobre a área foliar e carboidratos não-estruturais (CNE) do capim-elefante (*Pennisetum purpureum*) anão, em um ensaio de pastejo, conduzido em 1982 na Universidade da Florida, em Gainesville, FL, EUA. As variáveis experimentais estudadas foram: ciclo de pastejo (CP) e pressão de pastejo (PP). O capim foi submetido à combinação dos seguintes níveis de cada variável experimental: CP - pastejo contínuo, 14, 28, 42 e 56 dias de PP - 500, 1.000, 1.500, 2.000 e 2.500 kg de matéria seca de folhas residual $ha^{-1}$ (MSFR $ha^{-1}$). Os dados foram analisados através da metodologia de superfície de resposta. O número médio de folhas por perfilho principal foi maior quando CPs longos foram combinados com PPs baixas. O número de folhas senescentes por perfilho principal aumentou com o aumento do CP. A área foliar de lâminas verdes aumentou com o aumento do CP e dimuição da PP. As concentrações de CNE na base do colmo do capim foram afetadas principalmente pelo CP e foram mais baixas em CPs curtos e PPs mais intensas. As respostas fisiológicas observadas indicam que ciclos de pastejo curtos e pressões de pastejo mais intensas devem ser evitados no manejo do capim-elefante anão.

Termos para indexação: *Pennisetum purpureum*, ciclo de pastejo, pressão de pastejo.

## INTRODUCTION

Responses of forage plants to defoliation has been discussed by Milthorpe & Davidson (1966), Humphreys (1966), Jewis (1966), Hyder (1972), Youngner (1972), Dahl & Hyder (1977), Harris (1978), Vickery (1981), Deregibus et al. (1982). All of these authors emphasize in a general way that regrowth after defoliation may be influenced by the morphology of the plants, by the amount of leaf area remaining after cutting or grazing and by the reserve carbohydrates in the residual tissue. In additon, morphological and physiological responses of plants are always associated with environmental factors such as light, water, and temperature (Cooper & Tainton 1968, Humphreys 1981). The basic morphology and physiology of tropical grasses, however, have not been studied under grazing.

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Grazing affects several basic components of regrowth and forage quality because of selective eating habits of the animal, trampling, and return of animal excreta (Arnold 1981). Grazing animals usually take repeated bites to harvest an individual plant but the frequency and intensity of grazing of any tiller is influenced by many factors, including stocking rate, bulk density, and length of herbage (Arnold 1981). Even under intensive grazing of monospecific grass swards a pattern of grazing occurs, and individual plants may escape defoliation for time. Hodgkinson & Williams (1983) ponted out that when a pasture is grazed the surviving plants usually respond by changes in form and function. Assuming a prostrate growth habit by horizontal tillering or altering their physiological characteristics, forage plants adapt themselves to the grazing situation and therefore insure their persistence in the pasture. Results concerning dry matter production, nutritive value, tillering, and morphological characteristics of dwarf elephantgrass (Pennisetum purpureum Schum) under grazing indicate that this grass is a promising forage for pastures (Veiga et al. 1985a, b, Rodrigues 1984). The effects of grazing management on leaf area and total nonstructural carbohydrates of dwart elephantgrass are discussed in this paper.

## MATERIAL AND METHODS

This study was conducted from April to November 1982 at the Beef Research Unity of the University of Florida in Gainesville, USA. The experimental pastures were established with dwarf elephantgrass and 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 residual leaf dry matter per hectare (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. The data obtained were analysed by response surface methodology using a complete second order polynomial model. More details concerning pasture establishment, grazing management, and statistical design can be found elsewhere (Veiga et al. 1985a, Rodrigues 1984).

The total number of visible leaves and leaves in senescence were counted in 20 marked tillers in each pasture before each grazing period in all pastures, except for those continuously grazed where observations were done at 28-day intervals. The degree of senescence was recorded by noting the presence of chlorotic or dead patches or tips on individual leaves. Leaf area of green blades was measured with a LI-COR leaf-area meter. For this purpose ten tillers were sampled at random, cut to ground level, and immediately taken to the laboratory where leaf blades were separated for further measurements. Samples to determine total nonstructural carbohydrates (TNC) of tiller bases were collected one day before the entry of animals into the pasture and three days after the removal of the animals from the pasture. Ten tillers, cut at ground level, were taken at random in each pasture on each sampling date, except for the continuously grazed pastures in which tillers were collected once each 28 days. Leaves were removed in the field and the culms immediately brought to the laboratory. Stem bases were considered to be the first 10 cm above ground level. Leaf sheaths were stripped from the stems and clean bases were cut into small pieces to facilitate drying. The small portions of stem were then exposed to a temperature of 100°C during one hour to inactivate plant enzymes. After this step was completed, the samples were dried in a forced air oven at 65°C for 72 hours. The dried stem bases were ground in the Wiley mill using a 1 mm screen. These samples were placed in whirl-pak plastic bags and later reground in a UDY-Cyclone mill fitted with a 0.5 mm screen. Samples were stored in small plastic vials for subsequent analysis. Determinations of TNC followed the procedure developed by Christiansen (1982).

## RESULTS AND DISCUSSION

### Number of leaves per tiller, and leaf senescence of dwarf elephantgrass

The effects of grazing pressure and grazing cycle upon the average number of leaves as well as the number of senescent leaves per main tiller of dwarf elephantgrass is given in Fig. 1 and 2. The average number of leaves per main tiller varied from, 10.4 (250 kg RLDM ha$^{-1}$ and continuous grazing) to 18.5 (2.500 kg RLDM ha$^{-1}$ and 56-day cycle). The average number of senescent leaves ranged from 0.2 (250 kg RLDM ha$^{-1}$ and 28-day cycle) to 1.2 (250 kg RLDM ha$^{-1}$ and 56-day cycle). Independently of the length of grazing cycle, the average number of leaves per tiller was increased when the grazing pressure was decreased (Fig. 1). A greater number of leaves per tiller was observed when low grazing pressures were combined with long grazing cycles. The effect of grazing pressure, illustrated in Fig 1, suggests that fre-

quent and intense defoliations result in the production of a minimum number of leaves per tiller. The lower number of leaves per tiller observed under conditions of higher grazing pressure, even when the grazing cycle is long enough to allow the appearance and extension of new leaves, may be related to a greater elimination of apical meristems in some treatment combinations.

The number of senescent leaves per main tiller was highly variable. Even though Fig. 2 indicates that the number of leaves in senescence was increased as the grazing cycle was increased, the effect of grazing pressure changes from shorter to longer grazing cycles suggesting an interaction of grazing pressure and grazing cycle. Leaf senescence is related to competition for nutrients between old and young leaves as well as light intensity, length of the day, drought, disease, and mineral nutrition (Laude 1972, Brady 1973, Salisbury & Ross 1978).

The development of more closed canopies under low grazing pressures, in combination with short and long grazing cycles, may have accelerated the senescence of leaves due to reduced light penetration and increased shading of the tillers (Laude 1972, Brady 1973, Wilson & Mannetje 1978). The greater number of senescent leaves observed under grazing cycles of 56 days and a high grazing pressure (250 kg RLDM ha$^{-1}$), besides being associated with increased shading, may be due to morphological changes of the plants.
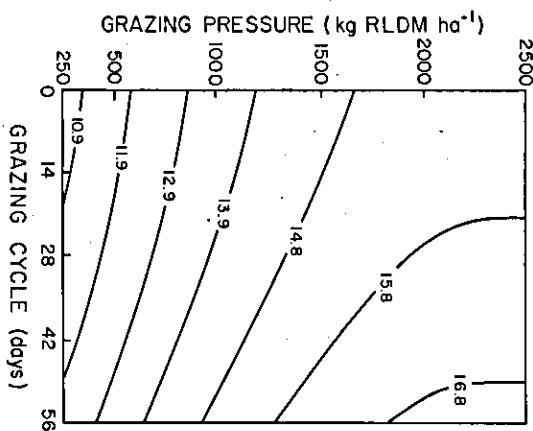


FIG. 1. Contour map of total number of leaves per tiller of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. ($R^2$ = 0.81, CV = 7.44%).
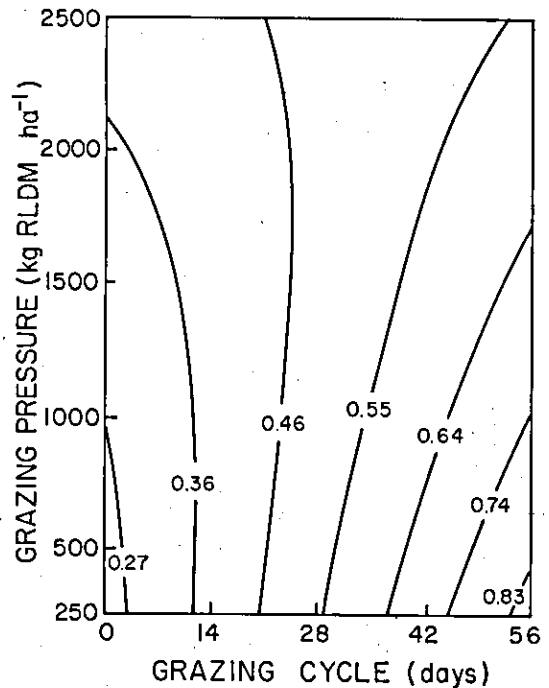


FIG. 2. Contour map of number of senescent leaves per tiller of dwarf elephantgrass as affected by length of grazing cycle and grazing pressure. ($R^2$ = 0.52, CV = 34.53%).

These observations are supported by Wilson (1976), Grant et al. (1981), and Wilson & Mannetje (1978) who reported that senescence rate may be affected by reduced light penetration in the sward, higher proportion of more aged tissue, and variation within the tiller due to the effects of leaf position. Furthermore, senescence and death of leaves were more pronounced in the second half of the experimental period and may be associated with a gradual reduction in day length or lack of soil moisture during short periods of time.

Several factors associated with frequency, intensity, and time of defoliation may affect the rate of appearance, senescence, and death of leaves under grazing conditions (Humphreys 1966, 1981, Jewiss 1966, Laude 1972, Brady 1973, Wilson & Mannetje 1978). In some circumstances, the use of higher stocking rates to achieve a desired grazing pressure resulted in the grazing of leaf sheaths, stem, apices, and dead leaves in some tillers. A greater proportion of leaves was generally removed at any locus

on the main tilllers at the beginning of the growing season due to the absence or presence of negligible amounts of dead and senescent leaves. As the growing season progressed, older leaves were defoliated less frequently. In addition to different patterns of removal and their subsequent development, during and after grazing, morphological changes of the plants may have altered the rates of senescence and death of leaves.

## Leaf area measurements

An examination of Fig. 3 indicates that leaf area of dwarf elephantgrass was increased as the grazing pressure was decreased and the grazing cycle was increased. The shape of the response surface indicates that under continuous grazing and higher grazing pressure the area of green blades was maintained at a minimum. A lower leaf area per tiller was consistent with the shortening of internodes and reduction in leaf size observed in plants under intensive management and may be interpreted as an adaptive measure to defoliation (Hodgkinson & Williams 1983). The growth rate of forage plants is primarily a function of the rate of net photosynthesis and the rate of increase in leaf area. Although photosynthesis occurs in all green surfaces of the plant, i.e., leaf blades, leaf sheaths, stems, and inflorescence, the area of leaf blades in the most useful way to describe the size of the
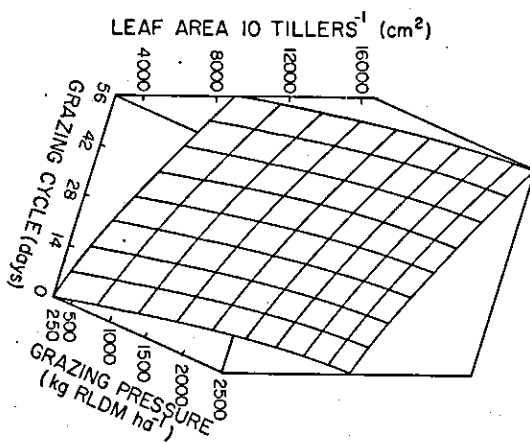


FIG. 3. Response surface of effect of grazing cycle and grazing pressure upon leaf area per 10 tillers of dwarf elephantgrass. ($R^2$ = 0.94, CV = 10.27%).

photosynthetic systems (Ludlow 1976). According to Humphreys (1981), the positive relationships between growth and both frequency and intensity of defoliation are due to their effects on the size of the sward canopy. Indeed, the regrowth and dry matter accumulation of tropical grasses have been positively related to residual leaf area index and light interception by the canopy (Ludlow & Chales-Edwards 1980, Jones & Carabaly 1981). In this research, the lower values of leaf area per tiller observed under high grazing pressures and short grazing cycles is related to morphological changes, such as redution in size of leaves and tillers, and is concomitant with favorable conditions for high leaf area indices at low grazing pressures in combination with long grazing cycles.

## Total nonstructural carbohydrates (TNC) in stem bases of dwarf elephantgrass

The lowest concentration of TNC were observed at heavy grazing pressures (250 and 900 kg RLDM $ha^{-1}$) and short grazing cycles (continuous and 14-day cycles), whereas the highest values were determined at more lenient grazing pressures in combination with long grazing cycles (Fig. 4). In samples taken before each grazing period, the variation in TNC concentrations was due mostly to the length of grazing cycle. In general, as the grazing cycle was increased the TNC concentration was increased. However, at short grazing cycles the imposition of more lenient grazing pressures was beneficial to the plants in allowing a fast recovery of reserves. Indeed, under intensive grazing the depletion of reserves may have resulted in a reduction in the number of tillers per plant as discussed by Rodrigues (1984).

Furthermore, lower concentration of TNC may have contributed to a reduction in the size of the root system of the grass. In plants dug at the end of the experimental period it was observed that larger root systems with well developed rhizomes were present in plants subjected to lower grazing pressure (2,000 and 2,500 kg RLDM $ha^{-1}$) and long grazing cycles (42 and 56-day cycles), whereas plants under continuous grazing and high grazing pressures 250 kg RLDM $ha^{-1}$) had small and thinner root systems in which rhizomes were absent. In addition, the results suggest that, even at higher graz-

ing pressures, a long grazing cycle (28-day cycle) would be sufficient to permit the plants to build up their reserves. The maintenance of an adequate level of soluble carbohydrates which could be used by the plants during the initial phase of regrowth or to insure survival after defoliation or periods of climatic stress has been emphasized by several investigators (Humphreys 1966, 1981, Smith 1972, Youngner 1972, White 1973, Trlica 1977, Harris 1978, Deregibus et al. 1982).
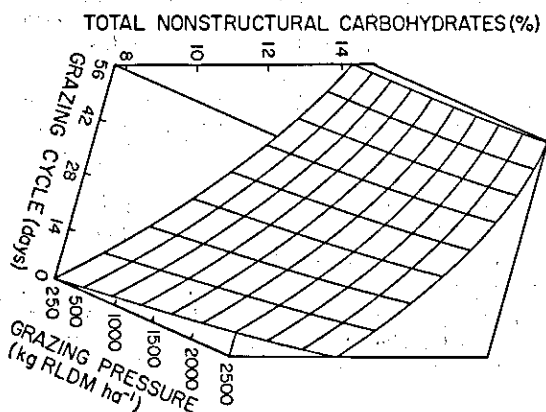


FIG. 4. Response surface of the effect of grazing cycle and grazing pressure upon the total nonstructural carbohydrates in stem bases of dwarf elephant-grass ($R^2$ = 0.86, CV = 8.11%).

Fluctuations of TNC concentrations in stem bases of dwarf elephantgrass followed a similar pattern in all pastures. In general, the level of reserves declined from April to July and increased thereafter towards the end of growing season. An example of this trend is shown in Fig. 5 for a pasture subjected to high grazing pressure (900 kg RLDM ha$^{-1}$) and short grazing cycles (14-day cycles). This response is consistent with many reports on reserve carbohydrates of temperate (Brown & Blaser 1965, Blaser et al. 1966, Trlica 1977) and tropical forage species (Ferraris 1978, Gomide et al. 1979, Ludlow et al. 1980) in which the use and storage of reserves have been associated with climatic conditions, stage of maturity of the plant, and to frequency, intensity, and time of defoliation.

As was expected, a fall in TNC concentrations was observed three days after the end of each defoliation period. The variation in the decline of

TNC concentrations may be explained by the sampling procedure adopted as well as by the dynamic nature of the experiment.

The reduction of TNC concentrations, even in plants subjected to lower grazing pressures and longer grazing cycles, is supported by several investigations and indicates that reserves were being used to start new growth or at least to maintain the root system alive during the first days after defoliation (Youngner 1972, Trlica 1977, Harris 1978, Deregibus et al. 1982). Similar results with dwarf elephantgrass were obtained by Castillo-Gallegos (1983) in a cutting experiment in which 0%, 50%, and 100% of leaf area were left after defoliation.

Although regrowth rates in tropical grasses has not been directly associated with TNC concentrations (Gomide et al. 1979, Jones & Carabaly 1981, Castillo-Gallegos 1983), the importance of reserves cannot be ignored. Larger root systems and higher number of tillers per plant were observed under conditions favorable for build-up of TNC concentrations and maintenance of higher leaf area per tiller; a situation found with more lenient grazing pressures and long grazing cycles. In this context, it is also suggested that short grazing cycles and high grazing pressures should be avoided in the management of dwarf elephantgrass in order to insure the productivity and persistence of the pasture.
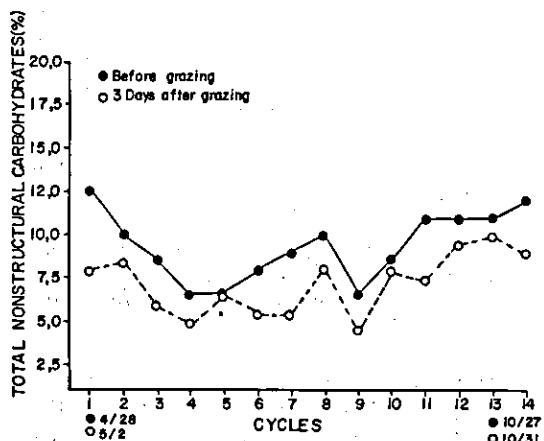


FIG. 5. Total nonstructural carbohydrates in stem bases of dwarf elephantgrass sampled in pasture subjected to 14-day grazing cycle and 900 kg RLDM/ha$^{-1}$.

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