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- I - SIMULATED SHORT DURATION GRAZING SYSTEM: EFFECTS ON PRODUCTION OF BIG BLUESTEM AND ASSOCIATED SPECIES,
  - II - SIMULATED SHORT DURATION GRAZING SYSTEM: EFFECTS ON ACID DETERGENT FIBER AND CRUDE PROTEIN CONTENT OF BIG BLUESTEM,
  - III - SIMULATED SHORT DURATION GRAZING SYSTEM: EFFECTS ON TOTAL NONSTRUCTURAL CARBOHYDRATE RESERVES OF BIG BLUESTEM RHIZOMES

by

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I - Simulated Short Duration Grazing System: Effects on  
Production of Big Bluestem and Associated Species

## Introduction

Increased livestock production and maintenance of desirable range plant vigor are the primary goals of most grazing systems. Smith (1895) formulated a rotation-grazing system that divided the range into units which were grazed successively thereby allowing the grasses to maintain their vigor and set seed.

Smith and Owensby (1978) found that livestock gains may be improved by intensive stocking (twice the normal rate) during the first half of the season from May 1 to July 15. The total grass yield as well as the percent basal cover of big bluestem (Andropogon gerardi Vitman) were greater under intensive early stocking (IES) than under continuous season-long stocking (CSLS) at the normal rate in Kansas Flint Hills range. They also showed that under both IES and CSLS, the later part of the growing season is most critical for carbohydrate and nitrogen reserve build-up in big bluestem.

Trlica and Cook (1972) noted that clipping during the later part of the growing season was detrimental to plant vigor and that the expected amount of new growth from the defoliated plants was positively correlated with the length of the remaining period in the growing season.

Although clipping results in more severe injury to grasses than does grazing (Whitman et al. 1961), considerable information may be obtained from the reaction of plant species to defoliation (Sarvis 1923).

The effects of intensive clipping on big bluestem and other major grass constituents of the Kansas Flint Hills Prairie have been reported

by different authors. Aldous (1930) and Biswell and Weaver (1933) found that the yield of prairie grasses decreased significantly with increased frequency and intensity of clipping, especially during the second half of the season.

Frequent clipping, particularly late in the season, depresses plant food reserves. Severe clipping intensities are likely to injure plant meristems resulting in delayed production of new tillers and as a consequence, both herbage yield and plant food reserves are lowered (Daubermire 1947, Singh and Mall 1976).

Goodloe (1969) reported a new ranching method referred to as the Short Duration Grazing (SDG) system which would improve the range condition even with intensive harvesting. Under SDG, the range is divided into several pastures. The period of occupation of any given pasture must be short enough so individual tillers are not grazed a second time, whereas the period of nonuse must be long enough to allow for recovery of the vegetation (Voisin 1959, Voisin and LeComte 1962, Lewis 1981).

The present study was designed to determine the response of big bluestem as well as the other associated species to clipping treatments at 2.5, 10, and 15 cm stubble heights under an 8-pasture SDG system. Two clipping frequency regimes were tested. The first consisted of 4-day intervals between pasture clippings season long. The second consisted of the same 4-day intervals from May 4 to July 15, then of 6-day intervals from July 16 to October 1.

## Study area and methods

### Study area

The study was conducted on a clay upland range site in the Flint Hills of the True Prairie, 7 miles northwest of Manhattan, Kansas. The soil was an Irwin silty clay loam (fine, mixed, mesic, Pachic Argiustoll). The study site had not been grazed the previous year, but it had been burned in the late spring, for the previous 2 years.

### Plant community

The clay upland range site constitutes over 26% of the Flint Hills grasslands and is dominated mainly by big bluestem, little bluestem (Andropogon scoparius Michx.) and Indiangrass (Sorghastrum nutans (L.) Nash) (Anderson and Fly 1955). The species scientific names reported here follow Anderson and Owensby (1969).

The botanical composition of the study area was sampled on October 20, 1981, using the modified step-point method developed by Owensby (1973). A sample of 125 points was read. It showed that the total basal cover was 8.8% (Table 1). Range condition was excellent, 81.8% (USDA-SCS 1968).

### Experimental design

The experimental design consisted of a split-split-plot replicated three times. Whole plots were eight randomized adjacent pastures. Two sub-plot treatments were applied. The first consisted of a 4-day clipping interval from one pasture to the next throughout the growing season; thus, resulting in five rotations. The vegetation was allowed a uniform rest period of 32 days within each rotation (clipping frequency regime (1) ). The second sub-plot treatment consisted of a 4-day clipping interval from

Table 1. Botanical composition and basal cover of species on the clay upland range site of the study area. October, 1981

| Species                           | Botanical<br>Composition % | Basal<br>Cover % |
|-----------------------------------|----------------------------|------------------|
| <u>Sorghastrum nutans</u>         | 20.8                       | 1.83             |
| <u>Andropogon gerardi</u>         | 17.6                       | 1.55             |
| <u>Andropogon scoparius</u>       | 14.4                       | 1.27             |
| <u>Panicum scribnerianum</u>      | 8.8                        | 0.77             |
| <u>Bouteloua curtipendula</u>     | 8.0                        | 0.70             |
| <u>Carex</u> sp.                  | 8.0                        | 0.70             |
| <u>Artemisia ludoviciana</u>      | 3.2                        | 0.28             |
| <u>Symphoricarpos orbiculatus</u> | 3.2                        | 0.28             |
| <u>Eragrostis spectabilis</u>     | 2.4                        | 0.21             |
| <u>Poa pratensis</u>              | 2.4                        | 0.21             |
| <u>Sporobolus asper</u>           | 2.4                        | 0.21             |
| <u>Antennaria neglecta</u>        | 1.6                        | 0.14             |
| <u>Buchloe dactyloides</u>        | 1.6                        | 0.14             |
| <u>Leptoloma cognatum</u>         | 1.6                        | 0.14             |
| <u>Panicum virgatum</u>           | 1.6                        | 0.14             |
| <u>Cornus drummondii</u>          | 0.8                        | 0.07             |
| <u>Sisyrinchium angustifolium</u> | 0.8                        | 0.07             |
| <u>Solidago altissima</u>         | 0.8                        | 0.07             |



pasture to pasture during the first half of the season from May 4 to July 15 of 1981; then a 6-day clipping interval between pastures during the second half of the season from July 16 to October 1 of the same year, resulting in four rotations only. This second sub-plot treatment (clipping frequency regime (2)) differed from the first by the progressive shift of the rest period given to the vegetation, from 32 to 48 days in a pasture during the later part of the growing season. Each pasture was clipped on a single day. The clipping calendars are given in Table 2.

The sub-sub-plot treatments were three cutting heights of 2.5, 10, and 15 cm from the ground.

The three replications were made within three blocks located within each pasture. Blocking was made against a gentle slope gradient.

The plots were 3 x 3 m in size. Within each of these plots, square 0.25 m<sup>2</sup> experimental units were selected such that they contained enough big bluestem plants to ensure measurement taking throughout the growing season, and avoid destruction of experimental material by excessive defoliation treatments.

The same process of experimental unit selection was carried out for two other important warm-season grasses which were little bluestem and Indiangrass.

### Methods

Defoliations were made on the experimental units within the plots at the assigned intensity and frequency, using hand manipulated mechanical shears. Clipping was first made on the species for which the experimental unit was selected, then other grasses, forbs and shrubs separately. Each of the listed categories of herbage were stored in a properly labelled paper sack after removal of the dead material. All samples were stored

Table 2. Clipping calendars using two different clipping frequency regimes throughout the growing season.

| Successive pastures  |        |        |        |        |        |        |        |        |
|--|--------|--------|--------|--------|--------|--------|--------|--------|
|  | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      |
| Clipping frequency regime (1): CFR1<br>4-day interval between pastures all season long.                                    |        |        |        |        |        |        |        |        |
| Rotation 1   | May 4  | May 8  | May 12 | May 16 | May 20 | May 24 | May 28 | Jun 1  |
| 2  | Jun 5  | Jun 9  | Jun 13 | Jun 17 | Jun 21 | Jun 25 | Jun 29 | Jul 3  |
| 3  | Jul 7  | Jul 11 | Jul 15 | Jul 19 | Jul 23 | Jul 27 | Jul 31 | Aug 4  |
| 4  | Aug 8  | Aug 12 | Aug 16 | Aug 20 | Aug 24 | Aug 28 | Sep 1  | Sep 5  |
| 5  | Sep 9  | Sep 13 | Sep 17 | Sep 21 | Sep 25 | Sep 29 | Oct 3  | Oct 7  |
| Clipping frequency regime (2): CFR2<br>4-day interval from May 4 to July 15,<br>then 6-day interval from July 16 to Oct 1. |        |        |        |        |        |        |        |        |
| Rotation 1   | May 4  | May 8  | May 12 | May 16 | May 20 | May 24 | May 28 | Jun 1  |
| 2  | Jun 5  | Jun 9  | Jun 13 | Jun 17 | Jun 21 | Jun 25 | Jun 29 | Jul 3  |
| 3  | Jul 7  | Jul 11 | Jul 15 | Jul 21 | Jul 27 | Aug 2  | Aug 8  | Aug 14 |
| 4  | Aug 20 | Aug 26 | Sep 1  | Sep 7  | Sep 13 | Sep 19 | Sep 25 | Oct 1  |

in a dark nylon bag while in the field, then they were dried at 60 C for 2 days in a forced-air oven and weighed to the nearest decigram.

Because of initial variability in the vegetation density of the experimental units, the yield at the first rotation (yield<sub>R=1</sub>) was used as a covariate in all subsequent rotations. Thus the response variables for either big bluestem alone or total vegetation (including big bluestem) were changes from initial yield<sub>R=1</sub> throughout the growing season. Since the two clipping frequency regimes differed in the number of rotations, a combination of two mathematical models was used for a split-split-plot analysis of variance of the change in production as follows:

$$\text{-If clipping frequency regime (1): "change"} = \sum_{R=1}^5 \text{yield} - 5 (\text{yield}_{R=1})$$

$$\text{-If clipping frequency regime (2): "change"} = \sum_{R=1}^4 \text{yield} - 4 (\text{yield}_{R=1})$$

In order to study the effect of rotation, clipping height and their interaction, the observations relative to the fifth rotation were deleted in order to have a balanced design in regard to the number of rotations which were added as a sub-sub-sub-plot treatment.

## Results and discussion

### Big bluestem responses

#### Pasture effect

There was a significant ( $P < 0.01$ ) effect due to the sequence of pasture clipping on the change of big bluestem production during the growing season (summed over rotations) using the initial clipped yield at the first rotation (R1) as a covariate after averaging over clipping frequency regimes and heights (Fig. 1). This general declining trend in productivity from the first pastures to the last sequentially clipped ones was earlier documented by Owensby and Anderson (1969) who found that with a single clipping, the bluestem plots that were clipped earlier in the season regrew quicker than those clipped later.

A significant ( $P < 0.01$ ) interaction between pastures and rotations was found (Fig. 2). Because of the initial variability in big bluestem stands, R1 yields were not included in Fig. 2. At the second rotation (R2), the change in big bluestem herbage yield was significantly lower in two of the last sequentially clipped pastures (6 and 7) compared to the other preceding pastures (Fig. 2). Furthermore, except for these pastures (6 and 7), all others yielded more big bluestem herbage at the second cut (R2) than initially (at R1). At the third rotation (R3), the change in big bluestem herbage yield was on the positive side for all pastures indicating an accelerated growth period particularly for the last four pastures (5, 6, 7, and 8) which yielded significantly more at R3 compared to R2 (Fig. 2). However, at the fourth cut (R4)

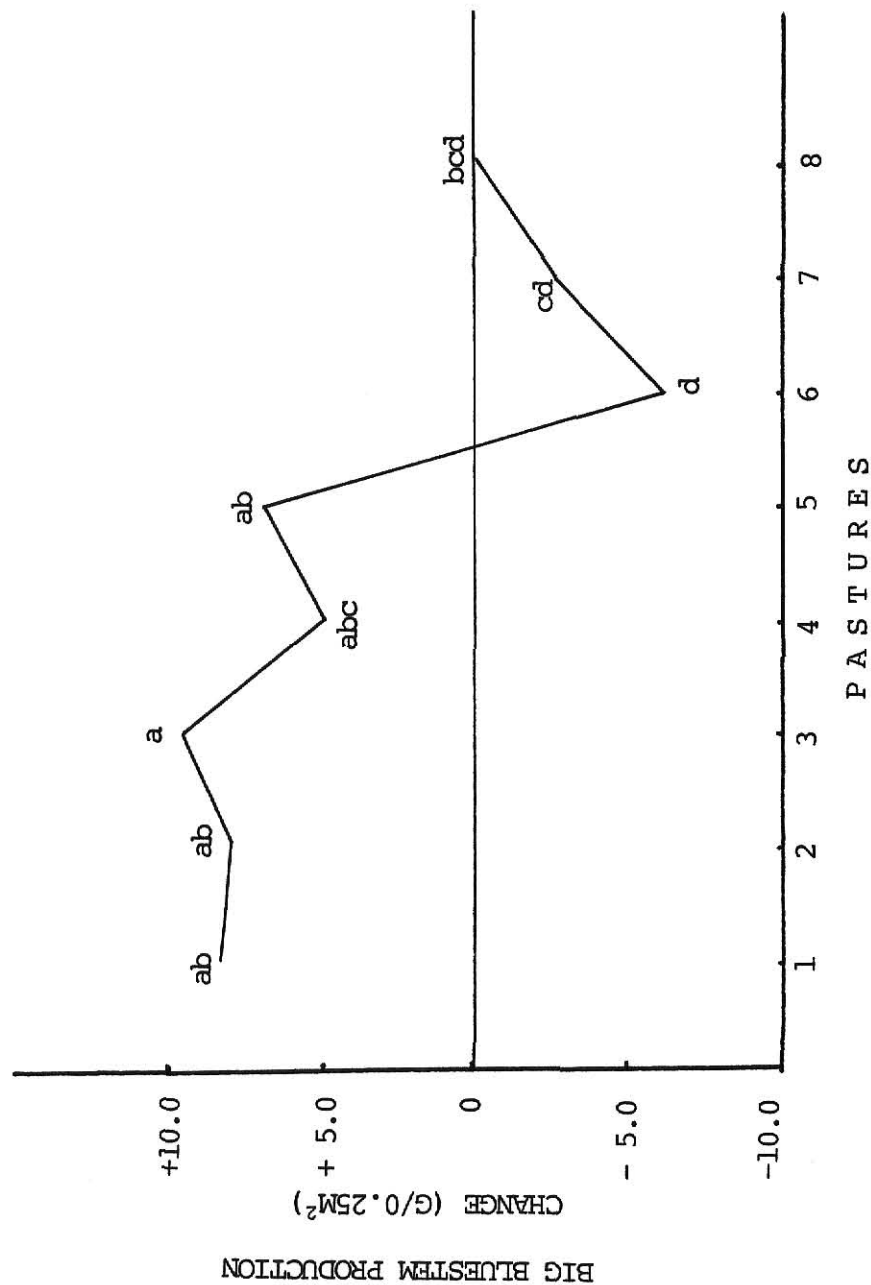


Fig. 1. Change in big bluestem herbage production across a simulated 8-pasture SDG system over the growing season (summed over rotations) using RL yield as a covariate. Averaged over clipping frequency regimes and heights. Means with same letter are not significantly different according to Duncan's multiple range test ( $P < 0.05$ ).

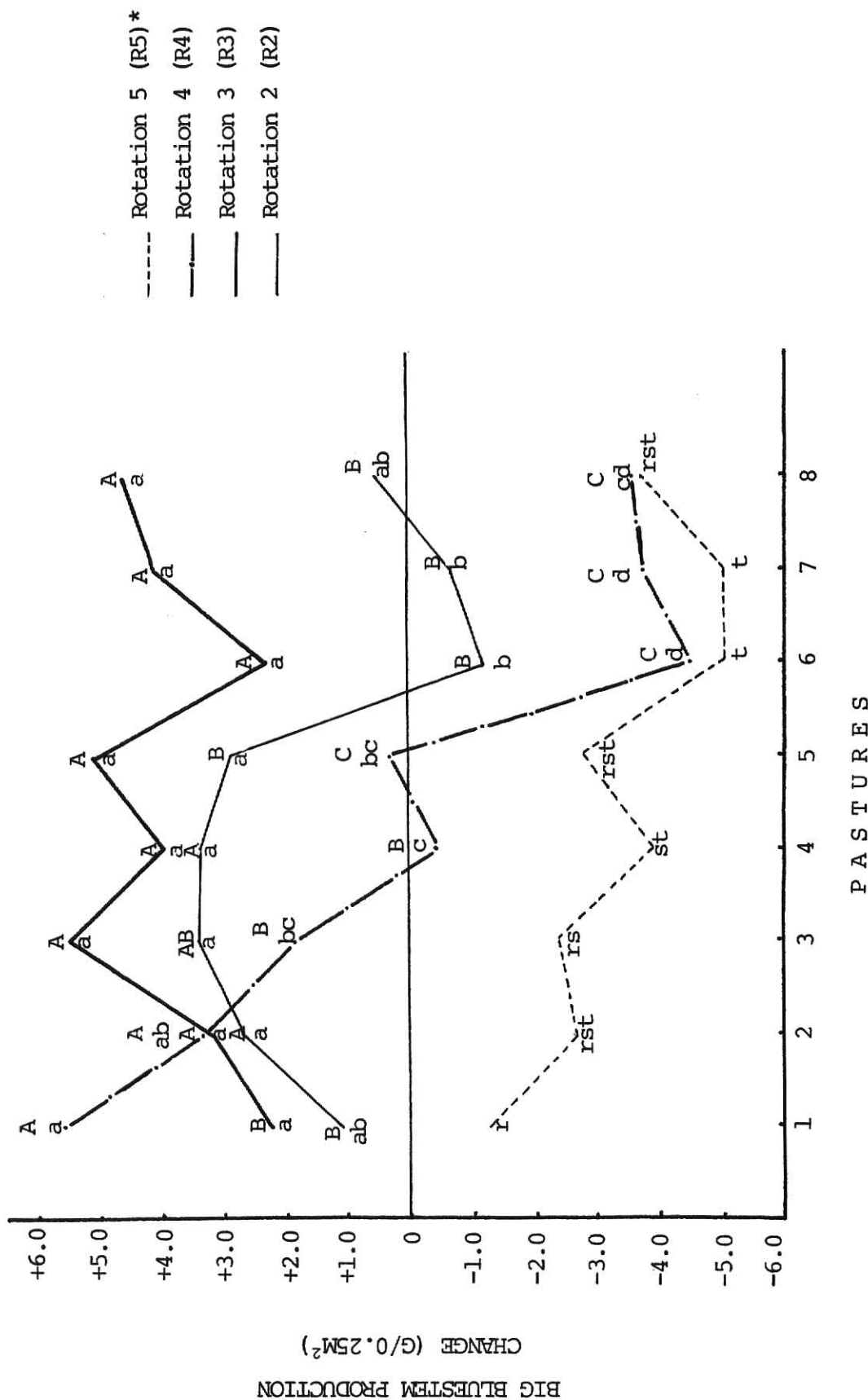


Fig. 2. Change in big bluestem herbage production across a simulated 8-pasture SDG system at different rotations, using RL yield as a covariate. Averaged over clipping frequency regimes and heights. Means of a given rotation with same lowercase letter are not significantly different ( $LSD_{0.05} = 3.26$ ). Means of a given pasture with same uppercase letter are not significantly different ( $LSD_{0.05} = 2.13$ ). \*Analyzed separately. Pasture means with same letter are not significantly different from

(Fig. 2), the general shape of the curve indicated that big bluestem growth may have levelled off and the variable "change" started to drop significantly ( $P < 0.05$ ) as one proceeded from pasture to pasture and became negative for pastures 4, 6, 7, and 8. Except for pasture 2, big bluestem herbage yield was significantly lower ( $P < 0.05$ ) at the fourth cut compared to that of the third cut. Owensby et al. (1974) found that with increased clipping frequency big bluestem herbage yields decreased linearly the following year.

Although the observations of the fifth cut (R5) were analyzed separately from the rest of the data, they still showed the slowing growth process by the season's end (Fig. 2).

Knowing that plant growth over time is sigmoidal in nature (Salisbury and Ross 1978), it may be assumed that the initial slow growth period started early in the season with R1. Rotations 2 and 3 might correspond to the accelerated growth phase of a general sigmoidal growth curve, and R4 and R5 obviously correspond to the second slow growth portion of the sigmoidal curve. The fourth cut (R4) started on August 8 and August 20 for clipping frequency regimes (1) and (2) respectively, but the "change" became negative at the fourth pasture which was clipped on August 20 and September 7 under clipping frequency regime (1) and (2) respectively. This corroborated earlier results of Hyde and Owensby (1975) and Owensby and Anderson (1969) who found that maximum bluestem production occurred in late August.

#### Clipping frequency regime effect

When averaged across pastures and clipping heights, plots cut five times at uniform intervals under clipping frequency regime (1) (CFR1) yielded significantly ( $P < 0.05$ ) less big bluestem herbage than

those clipped four times only, at increased intervals during the second half of the season under clipping frequency regime (2) (CFR2) (Fig.3). This is in agreement with the results of Owensby et al. (1974) which showed that under increased clipping frequency, big bluestem herbage yield, tiller density and carbohydrate reserves decreased. However, when the observations of the fifth cut (R5) were deleted, thereby making both clipping frequency regimes equal in regard to the number of successive defoliations, there was no significant ( $P < 0.44$ ) difference between big bluestem herbage yields at any clipping frequency regime. Thus, increased rest periods during the second half of the season under CFR2 did not result in increased yields compared to clipping at regular intervals throughout the growing season under CFR1 (Fig. 4). Although this may seem contradictory to the findings of Trlica and Cook (1972) who reported that the expected amount of growth from the defoliated plants was positively correlated with the time remaining for favorable photosynthesis processes before the onset of dormancy, the increased rest periods under CFR2 were in fact beneficial to big bluestem plants in that the excess photosynthates were translocated downward to replenish carbohydrate reserves. Indeed, Ben Mansoura (1983) found that by the third rotation big bluestem rhizomes in the plots clipped at increased rest periods had significantly higher total nonstructural carbohydrates than those in the plots clipped at regular intervals. He also observed the same difference by the next spring following defoliations. Thus, defoliation frequency is a two-fold matter in that not only the number of defoliations is of importance, but at equal numbers of defoliations, the time allowed for regrowth between successive defoliations is also equally important particularly for recovery of plant vigor.



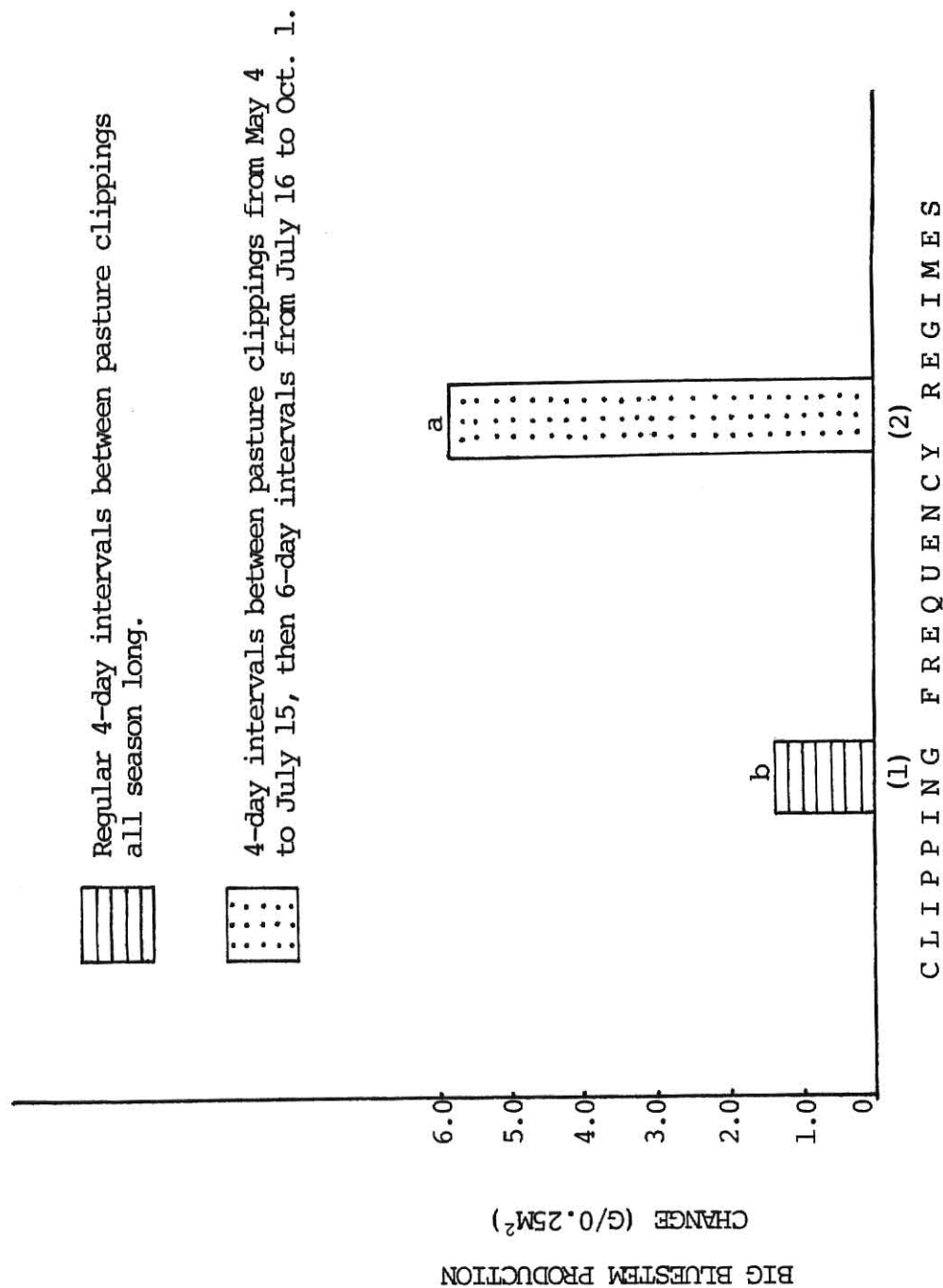


Fig. 3. Change in big bluestem herbage yield over the season (summed over rotations) using R1 yield as a covariate, as affected by two different clipping frequency regimes. Averaged over pastures and clipping heights. Bars with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ).

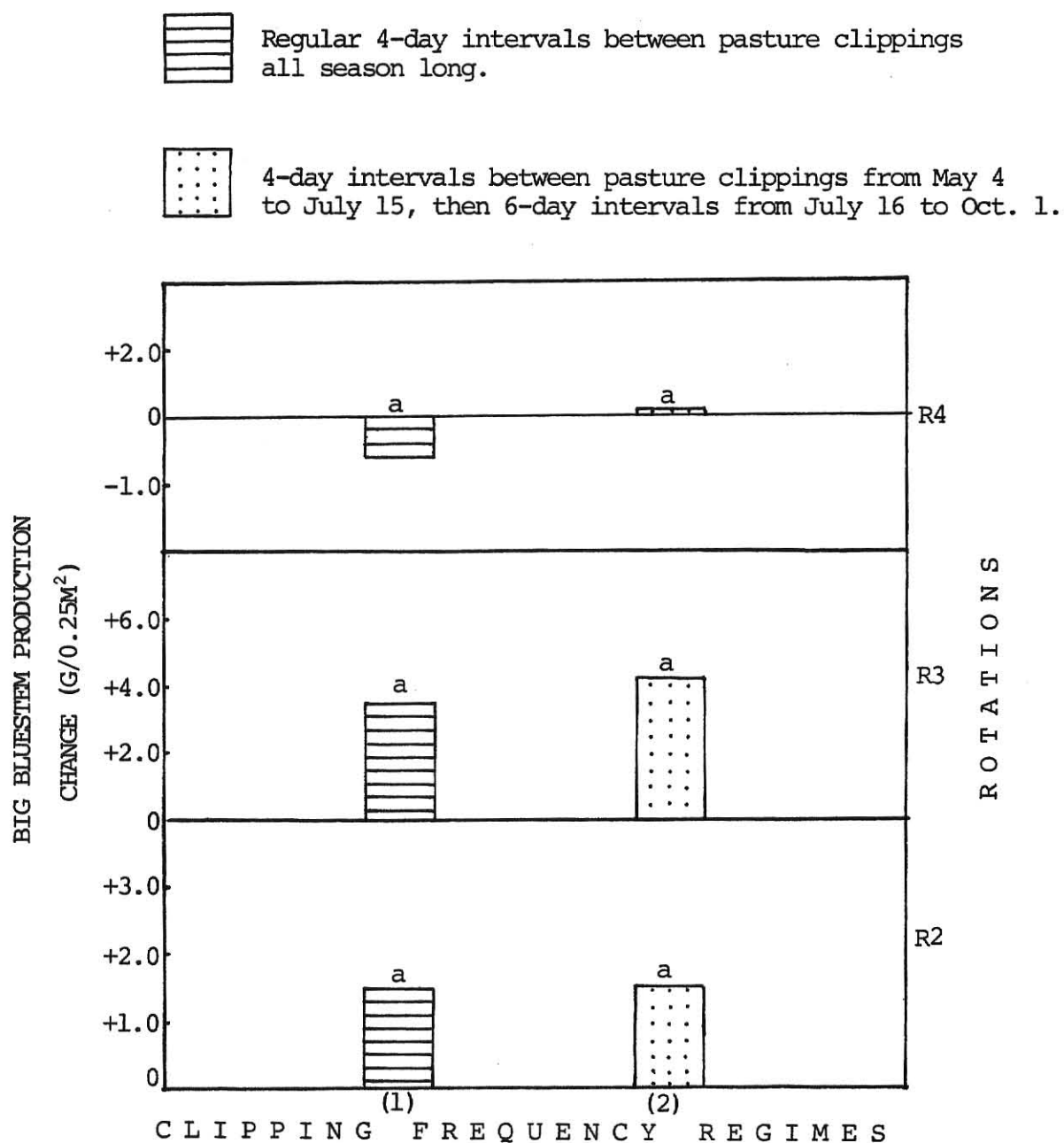


Fig. 4. Change in big bluestem herbage production as affected by two clipping frequency regimes at different rotations using R1 yield as a covariate. Averaged over pastures and clipping heights. Bars of a given rotation with same letter are not significantly different according to Duncan's multiple range test ( $P < 0.05$ )

### Clipping height effect

The entire data analysis of variance showed a significantly ( $P < 0.01$ ) increasing big bluestem herbage yield as the clipping height increased from 2.5 to 10 and to 15 cm from the ground when averaged over pastures and clipping frequency regimes but summed over rotations (Fig. 5). Neiland and Curtis (1956) reported a similar big bluestem response to defoliation intensity. Under the severe defoliation of 2.5 cm cutting height, the cumulated change in big bluestem herbage production over the different rotations using R1 yield as a covariate was negative (Fig. 5). This suggested that the photosynthetic area left at this clipping height (2.5 cm) was insufficient and growth limiting.

There was a significant pasture by clipping height interaction effect ( $P < 0.05$ ) which was due to big bluestem production being depressed in pastures 6 and 7 at the 2.5 cm stubble height and in pastures 7 and 8 at the 10 cm stubble height (Fig. 6). At the 15 cm cutting height, there was no pasture sequence effect (Fig. 6). The severe defoliation of 2.5 cm had a tremendous effect in that it masked the effects of the other two defoliation intensities when big bluestem change in yield was averaged across the three cutting heights in Fig. 1. Indeed there was a striking resemblance between the shape of the curve in Fig. 1 and that in Fig. 6 at the 2.5 cm stubble height. Hence, contrary to the belief that yield is supposed to be a reflection of the cutting height (Singh and Mall 1976), it may not always be so, particularly when dealing with severe defoliations. Although there was no significant difference ( $P < 0.05$ ) between big bluestem yields at 10 and 15 cm cutting heights when considering individual pastures (Fig. 6), the total above-ground big bluestem yield was significantly higher at 15 cm than at

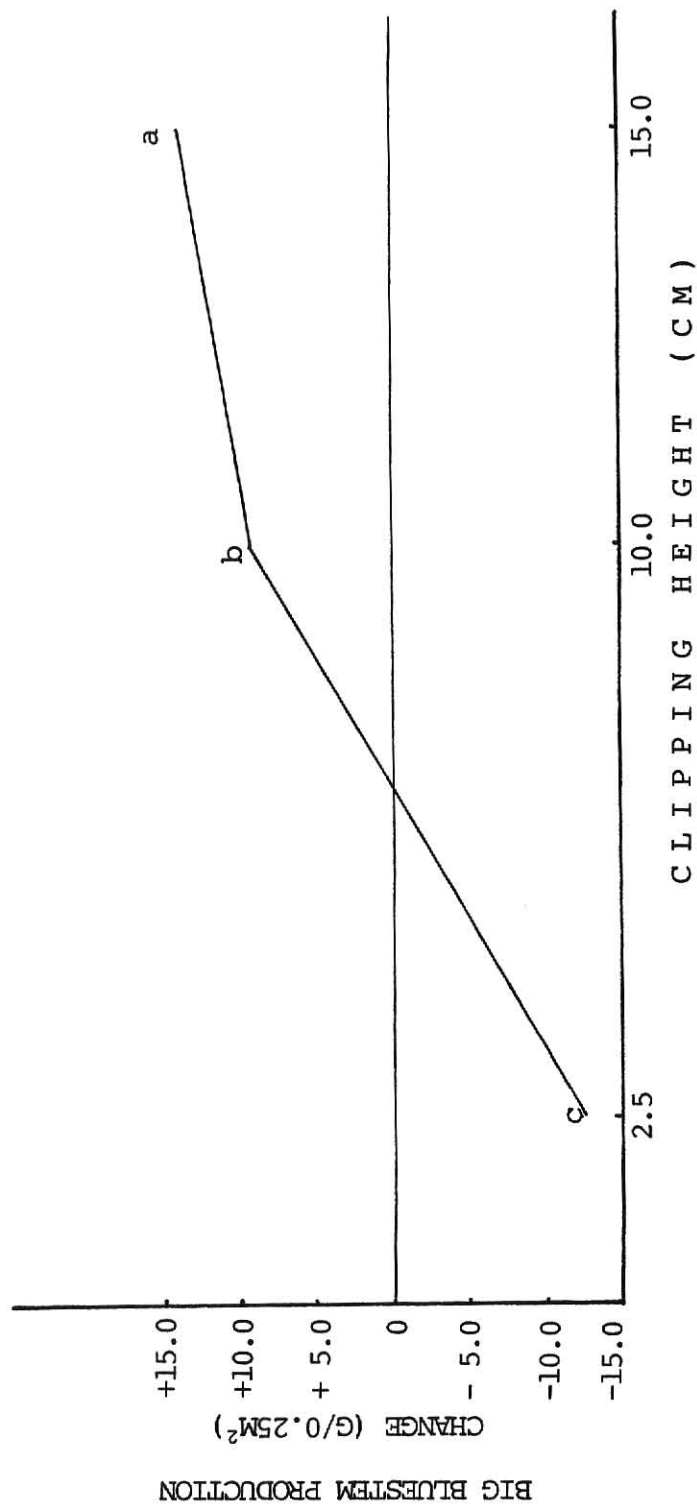


Fig. 5. Change in big bluestem herbage production over the season (summed over rotations) using R1 yield as a covariate as affected by three cutting heights. Averaged across pastures and clipping frequency regimes. Means with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ).

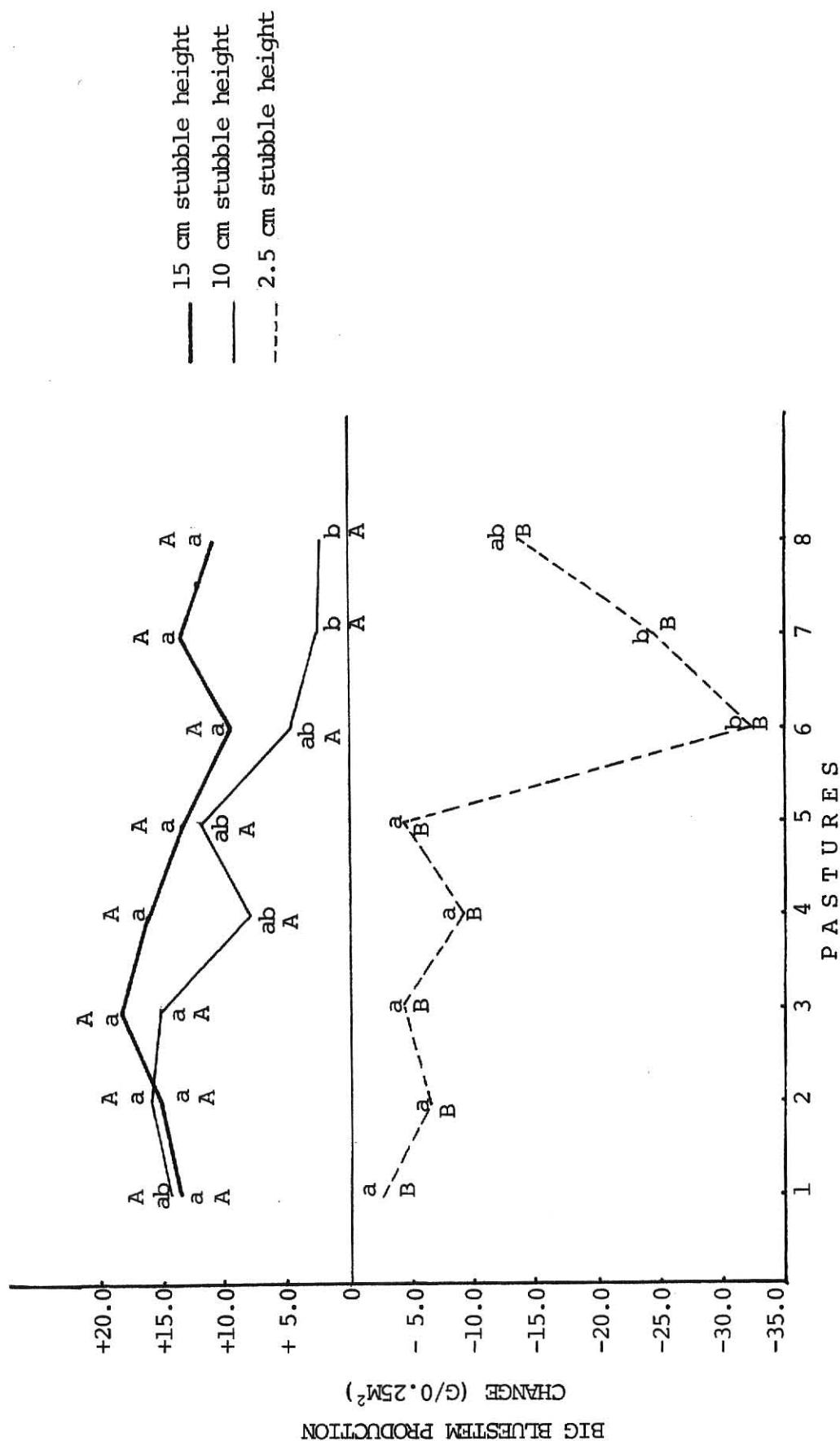


Fig. 6. Change in big bluestem herbage production over the growing season (summed over rotations) using RL yield as a covariate at different pastures as affected by three cutting heights. Averaged across clipping frequency regimes. Means of a given cutting height with same lowercase letter are not significantly different ( $LSD_{0.05} = 11.87$ ). Means of a given pasture with same uppercase letter are not significantly different ( $LSD_{0.05} = 9.86$ ).

10 cm clipping height when averaged over pastures (Fig. 5). In both cases, yields at 2.5 cm were significantly less than at the other clipping heights.

No significant interaction effect between clipping frequency regime and height existed ( $P < 0.34$ ). However, Fig. 7 showed that when big bluestem plants were subjected to the 15 cm cutting height, the change in yield over the season (summed over rotations using R1 yield as a covariate) was not affected by the difference in the two clipping frequency regimes, when averaged across the eight pastures. This supports the finding of Perry and Chapman (1976) who concluded that the survival of basin wildrye (Elymus cinereus Scribn. and Merr.) plants was not affected by clipping frequency when subjected to the highest clipping height. However, at the most severe clipping intensity, the same authors found that basin wildrye survival was proportional to clipping frequency. An analogous result was found here since at the defoliation of 2.5 cm from the ground, the less intensive clipping frequency regime (2) favored a significantly better big bluestem regrowth compared to that under clipping frequency regime (1) (Fig. 7).

At the critical 10 cm clipping height, big bluestem plants yielded significantly less herbage than when clipped at 15 cm under the same CFR1. Thus in order to eliminate the deleterious effect of more frequent clipping, an increase in cutting height was necessary (Aldous 1930). Nonetheless, under CFR2, less defoliations and increased rest periods during the late season allowed big bluestem plants clipped at 10 cm stubble height to regrow and produce herbage at levels comparable to those of plants subjected to the 15 cm stubble height treatment.

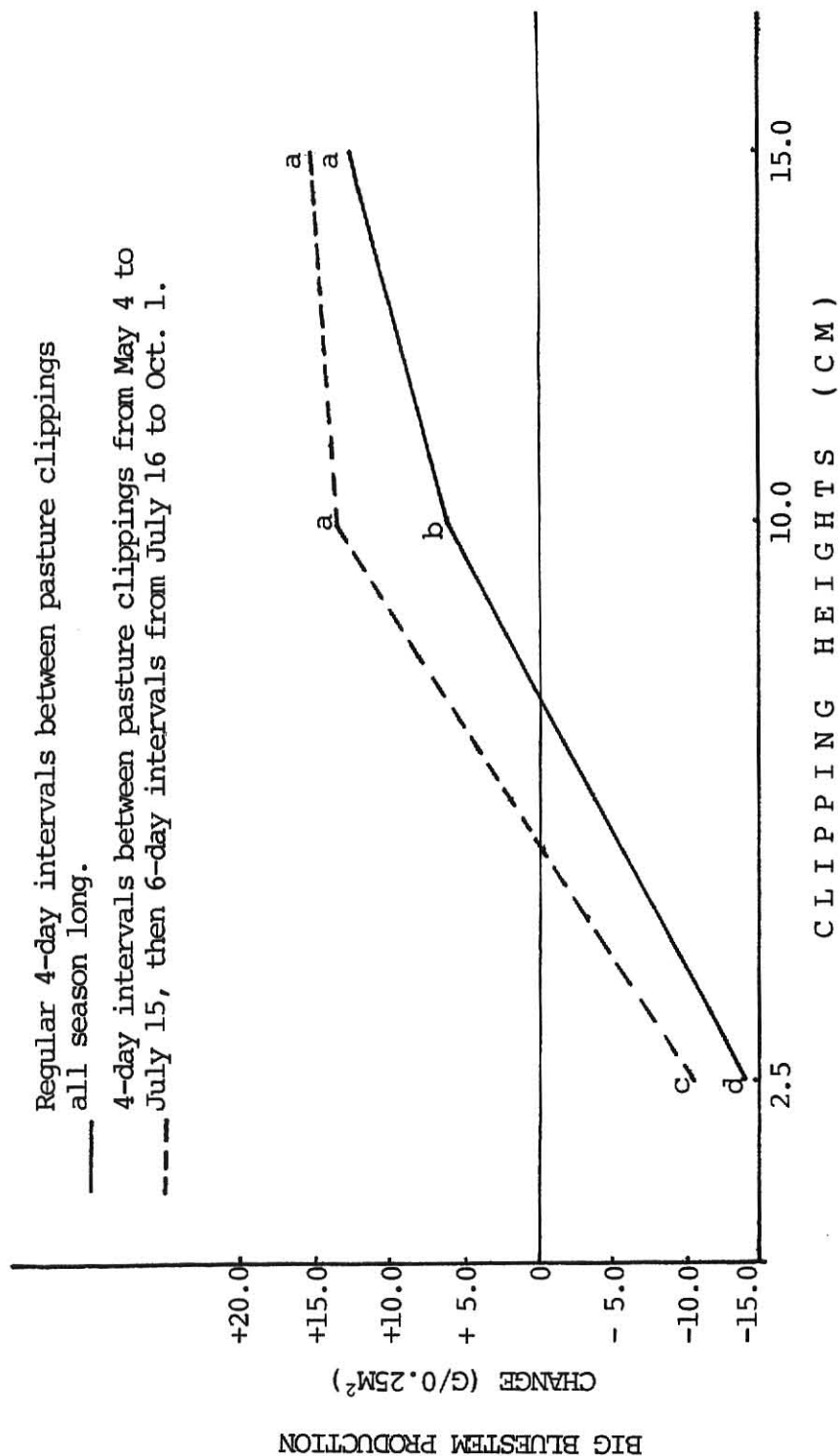


Fig. 7. Change in big bluestem herbage production over the growing season (summed over rotations) using R1 yield as a covariate as affected by two clipping frequency regimes and three cutting heights. Averaged over pastures. Means with same letter are not significantly different ( $LSD_{0.10} = 3.31$ ).

### Rotation effect

Averaging over all treatments, the third cut (R3) showed the highest ( $P < 0.05$ ) yield in big bluestem herbage compared to that of the second or fourth cut using the initial cut (R1) yield as a covariate (Fig. 8). At R2 which occurred earlier in the season, big bluestem plants had a positive change in yield compared to that of R1, but their regrowth was significantly slower than at R3. Late in the season however, the aboveground regrowth of big bluestem between the third and fourth cut was significantly depressed resulting in negative yields which meant that the yields at R4 were less than those of the initial cut (R1) (Fig. 8). These results agreed with Buwai and Trlica (1977) and Trlica and Cook (1971) who found that with late season defoliations plant regrowth and consequently plant herbage yields were drastically reduced.

A highly significant ( $P < 0.01$ ) interaction effect due to rotation by clipping height was found. Fig. 9 showed that at the two cutting heights of 10 and 15 cm, the cumulative change in big bluestem production culminated by the time of the third cut, then dropped by late season (R4). Under close defoliation (2.5 cm stubble height), the change in big bluestem yield was negative at all subsequent cuts compared to the initial one. Early in the season there was no difference between the growth rate after one or two clippings under close use (Fig. 9). However, after a third cut, herbage production ability of big bluestem worsened significantly. Hence, close clipping, particularly late in the season, reduced big bluestem herbage yield drastically. Owensby et al. (1974) working in the Tallgrass Prairie warned against intensive use during the entire growing season as it resulted in lower tiller density, herbage yield, and carbohydrate reserves the following year.



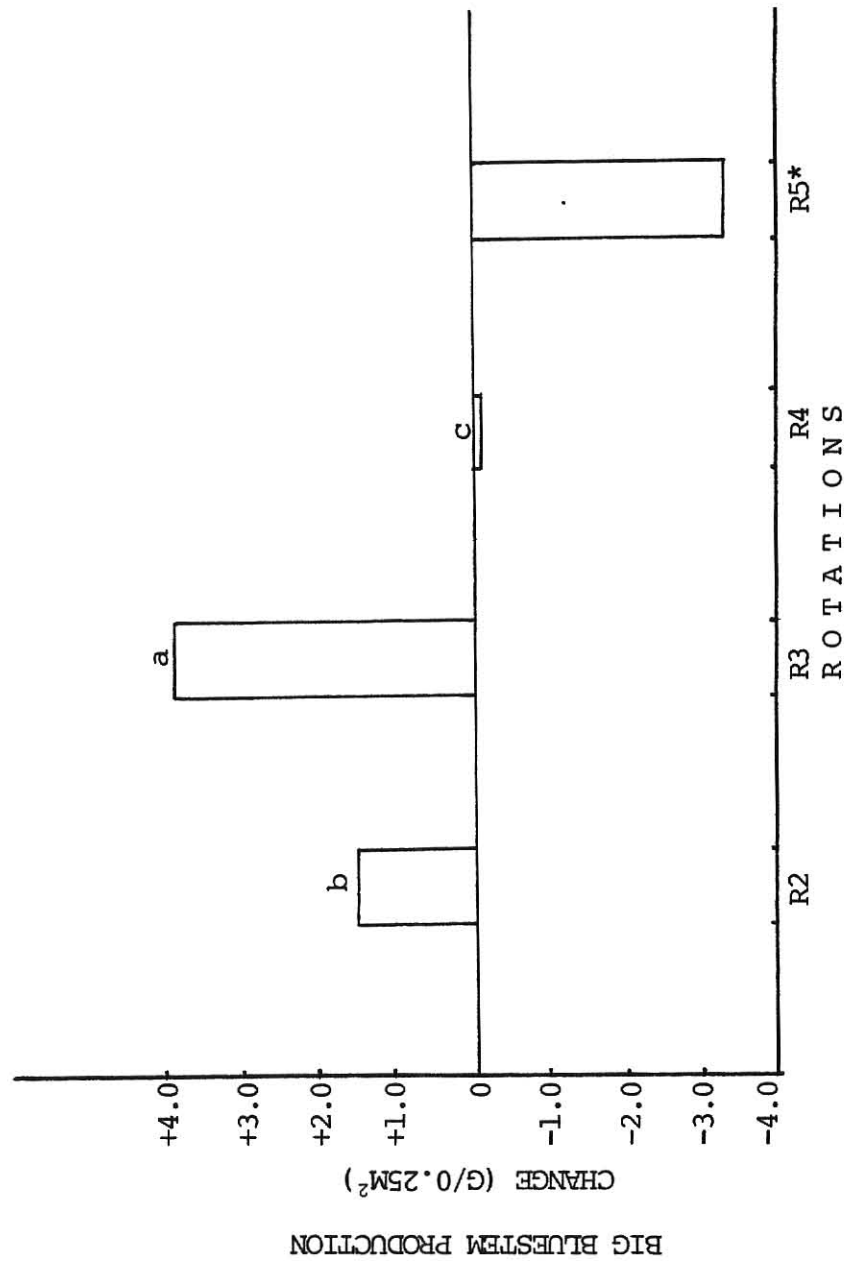


Fig. 8. Change in big bluestem herbage production at different rotations using R1 yield as a covariate. Averaged over pastures, clipping frequency regimes and heights. Bars with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ). \*R5 analyzed separately.

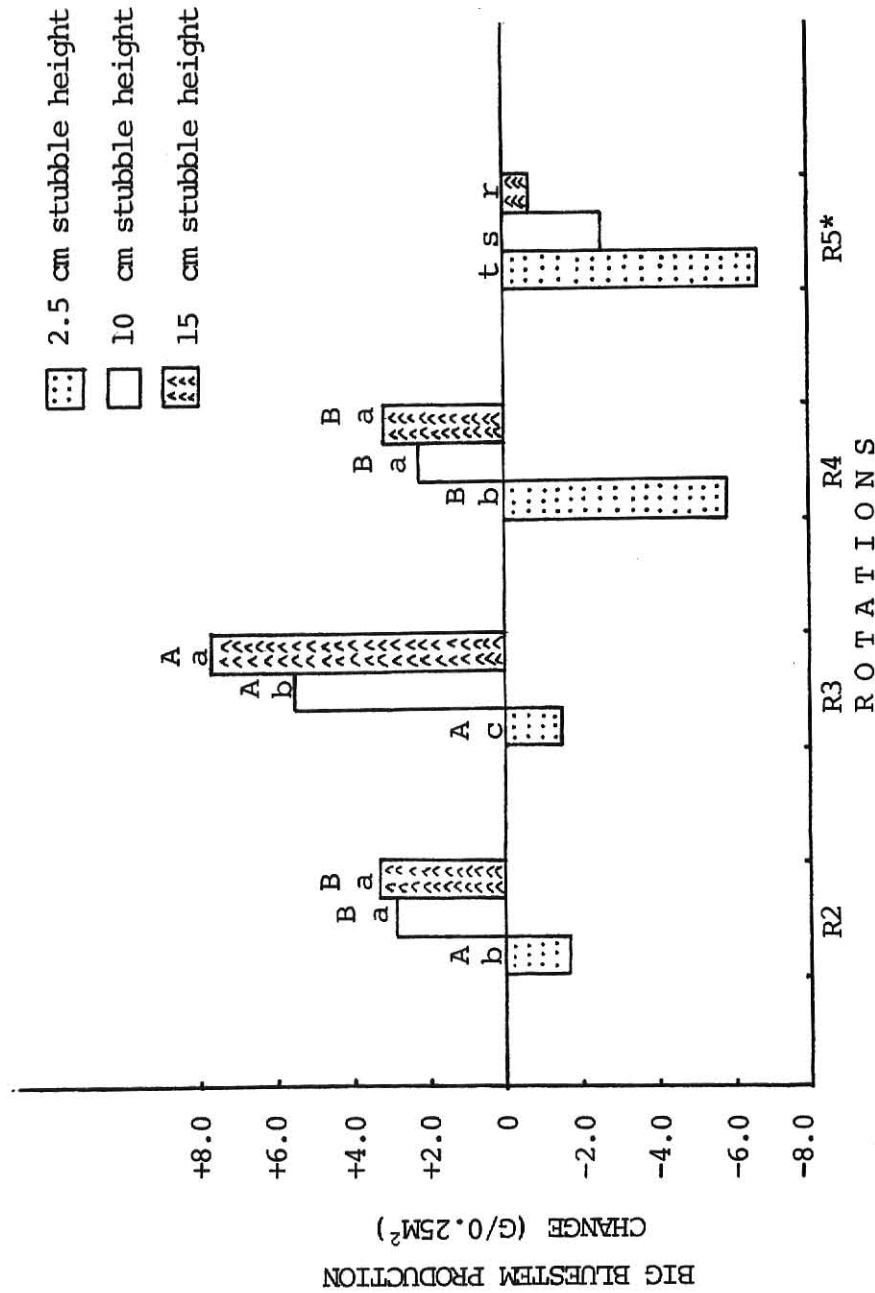


Fig. 9. Change in big bluestem herbage production at different rotations using R1 yield as a covariate as affected by three clipping heights. Averaged over pastures and clipping frequency regimes. Bars of a given rotation with same lowercase letter are not significantly different ( $LSD_{0.05}=1.56$ ). Bars of a given cutting height with same uppercase letter are not significantly different ( $LSD_{0.05}=1.30$ ). \*Analyzed separately using Duncan's multiple range test ( $P<0.05$ ).

Ben Mansoura (1983) confirmed this carry-over mechanism since he found that by the spring following the defoliations, big bluestem plants clipped at 2.5 cm from the ground in the eighth pasture of an 8-pasture SDG system had significantly less carbohydrate reserves in their rhizomes compared to those cut at 10 or 15 cm stubble height. Fig. 9 showed also, that early in the season there was no statistical difference in big bluestem herbage production when subjected to either 10 or 15 cm stubble height (R2). However, Ben Mansoura (1983) reported that big bluestem plants subjected to the 15 cm cutting height had at R2 significantly more carbohydrate reserves in their rhizomes than those subjected to the 10 cm defoliation height. Thus, when comparing the effects of different clipping heights, herbage yield alone may not be a safe criterion. During the accelerated phase of big bluestem regrowth at R3, there was an indication that the lower photosynthetic area left at the 10 cm stubble height was limiting compared to that left at the 15 cm cutting height since the change in big bluestem herbage production was significantly lower at 10 cm than at 15 cm stubble height. Although there was no significant difference in the late season (R4) between the change in big bluestem herbage production when subjected to 10 or 15 cm defoliation height, a subtle clarification should be made. Indeed Fig. 7 confirmed this result but only under the less severe CFR2.

A fifth cut under CFR1 (analyzed separately) resulted in further depression of big bluestem herbage yields under all cutting heights (negative change values). The more severe the cutting height was, the more accentuated the depression.

## Total vegetation responses

### Pasture effect

The regular clipping sequence of pastures 1 thru 8 throughout the growing season significantly affected ( $P < 0.01$ ) the cumulated change in total vegetation production summed over rotations and averaged over clipping frequency regimes and heights, using R1 yield as a covariate (Fig. 10). Each pasture was subjected to nine clipping dates (five under CFR1 and four under CFR2). Pastures 1, 2 and 3 had six clipping dates that occurred during the first half of the season from May 4 to July 15, whereas pastures 4 thru 8 had only four clippings that occurred during the same period. The remaining five clipping dates took place during the second half of the season (Table 2). Although July 15 may not be a clear cut division between two deliberate halves of the season, the environmental conditions usually deteriorate in the Flint Hills during the later part of the season (higher summer temperatures and less soil moisture). Thus, under short duration grazing, the earlier a pasture is used, the better its vegetation performance would be. Earlier, Smith and Owensby (1978) found that with intensive early use from May 1 to July 15 at twice the recommended stocking rate the yield of perennial grasses as well as animal weight gains/ha were higher than under continuous year-long use at the normal stocking density.

The declining trend in total vegetation production as one moved from one pasture to the next in Fig. 10 was even more accentuated than with big bluestem alone (Fig. 1).

After deletion of R5 observations, the analysis of variance showed a significant ( $P < 0.01$ ) pasture x rotation interaction. Fig. 11

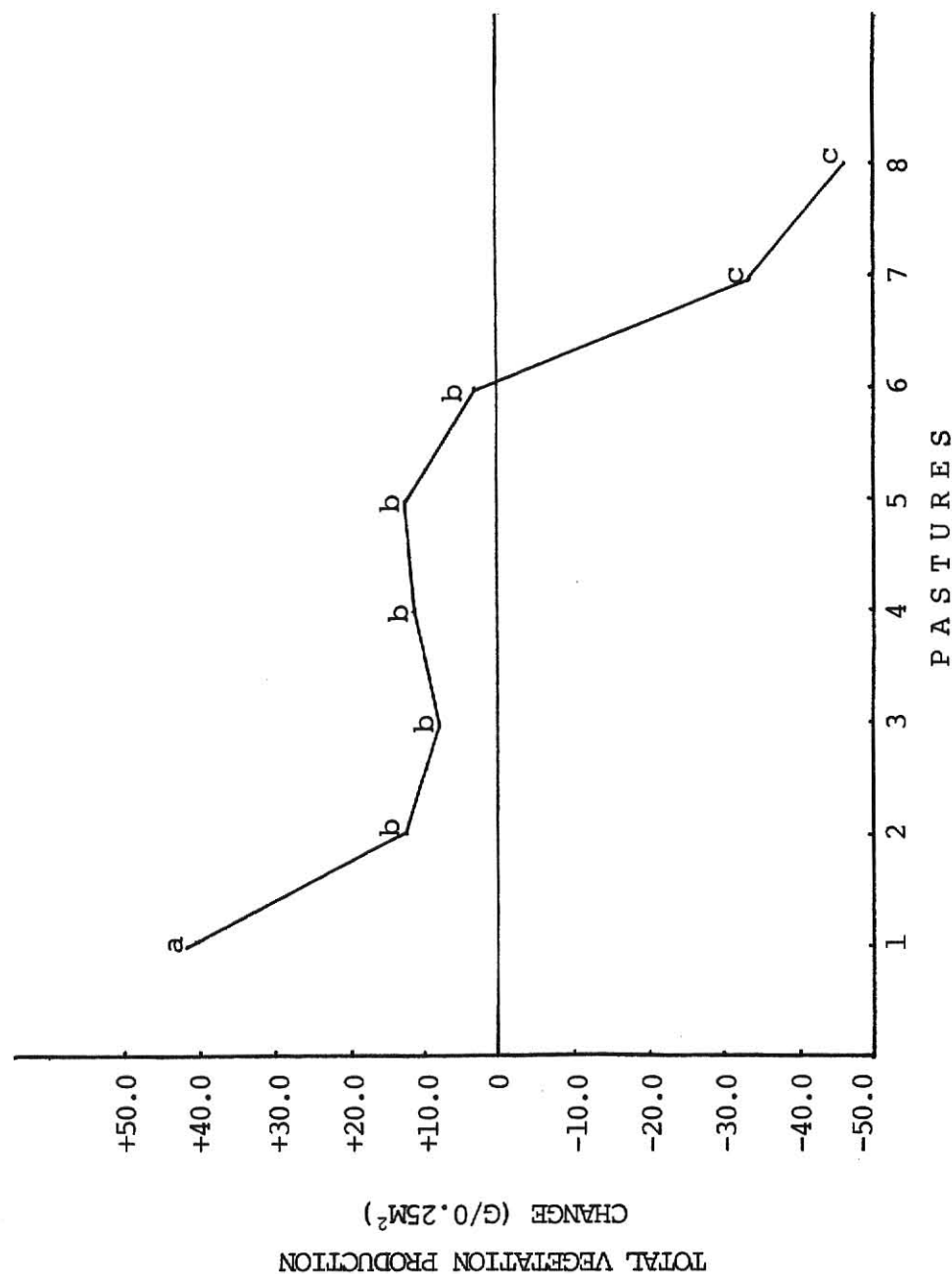


Fig. 10. Change in total vegetation herbage production across a simulated 8-pasture SDG system over the growing season (summed over rotations) using R1 yield as a covariate. Averaged across clipping frequency regimes and heights. Means with same letter are not significantly different according to Duncan's multiple range test ( $P < 0.05$ ).

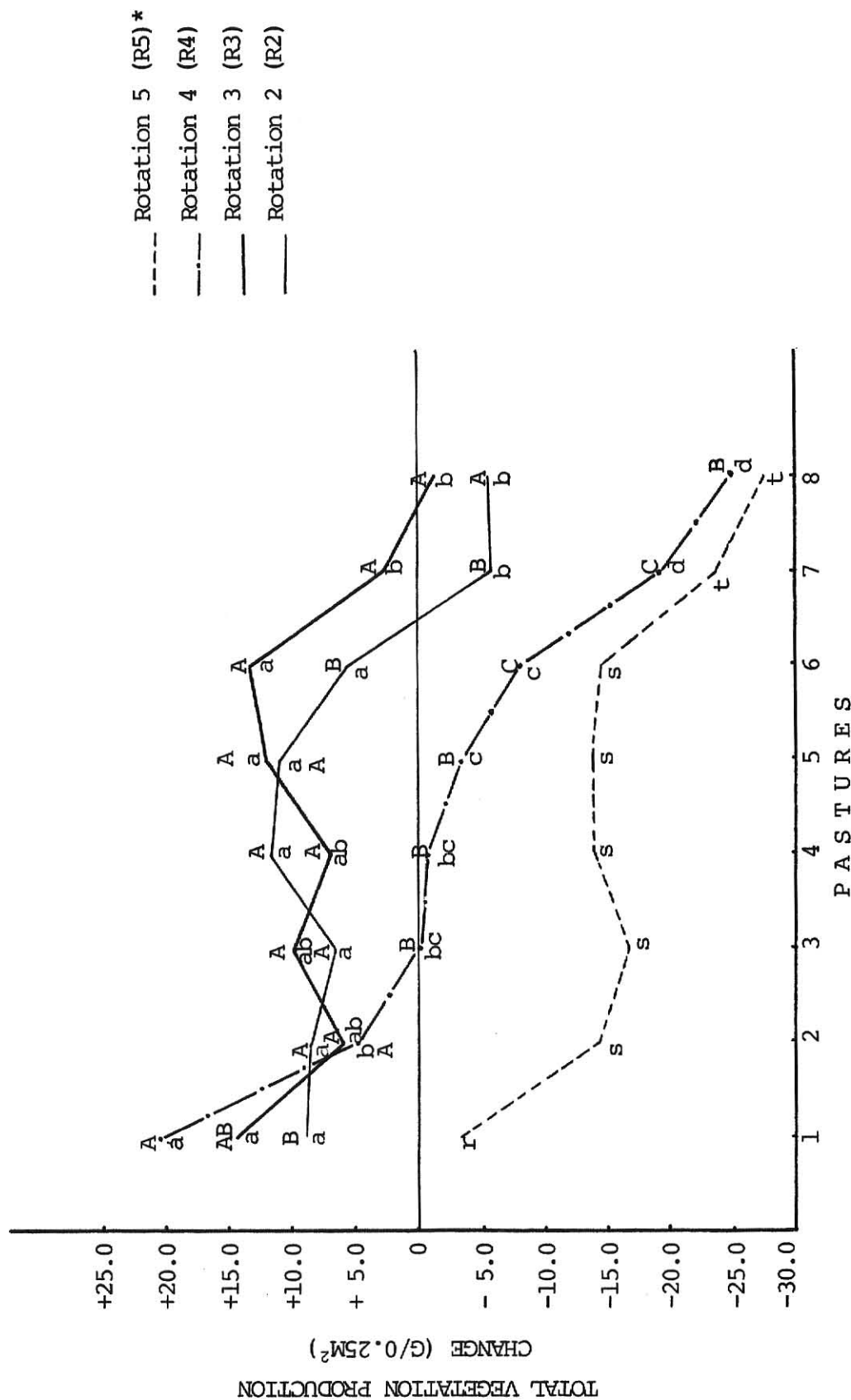


Fig. 11. Change in total vegetation herbage production across a simulated 8-pasture SDG system at different rotations using R1 yield as a covariate. Averaged over clipping frequency regimes and heights. Means of a given rotation with same lowercase letter are not significantly different ( $LSD_{0.05}=8.84$ ). Means of a given pasture with same uppercase letter are not significantly different ( $LSD_{0.05}=6.03$ ). \*Analyzed separately. Pasture means with same letter are not significantly different ( $DMRT_{0.05}$ ).

showed the deleterious effects of successive clippings particularly late in the season (Aldous 1930, Owensby et al. 1974), since at the fourth and fifth clippings, the change in total vegetation production was mostly negative and had a decreasing trend particularly at R4 (Fig. 11). Early in the season however, only the later pastures were affected. Indeed, all pastures yielded equally well except pastures 7 and 8 whose production was depressed at the second and third cuts compared to the previous ones. There was also no difference between the pasture yields at R2 or R3 except for pastures 6 and 7 which yielded significantly less at R2 than at R3.

#### Clipping frequency regime effect

Clipping frequency regime (1), which consisted of five successive defoliations at regular intervals, significantly ( $P < 0.01$ ) depressed the production of big bluestem and its associated species compared to only four clippings at increased rest periods during the second half of the season. Because of the negative change (Fig. 12), the cumulative effects of CFR1 were more drastic on the total vegetation production than on that of big bluestem alone (Fig. 3).

#### Clipping height effect

When summed over rotations and averaged over pastures and clipping frequency regimes, the defoliation intensity had a significant ( $P < 0.01$ ) effect upon the change in total vegetation production using R1 yield as a covariate. As the clipping height increased, the total vegetation yield significantly increased (Fig. 13). The severe clipping height of 2.5 cm from the ground had a pronounced detrimental effect upon the total vegetation as the variable "change" was on the negative

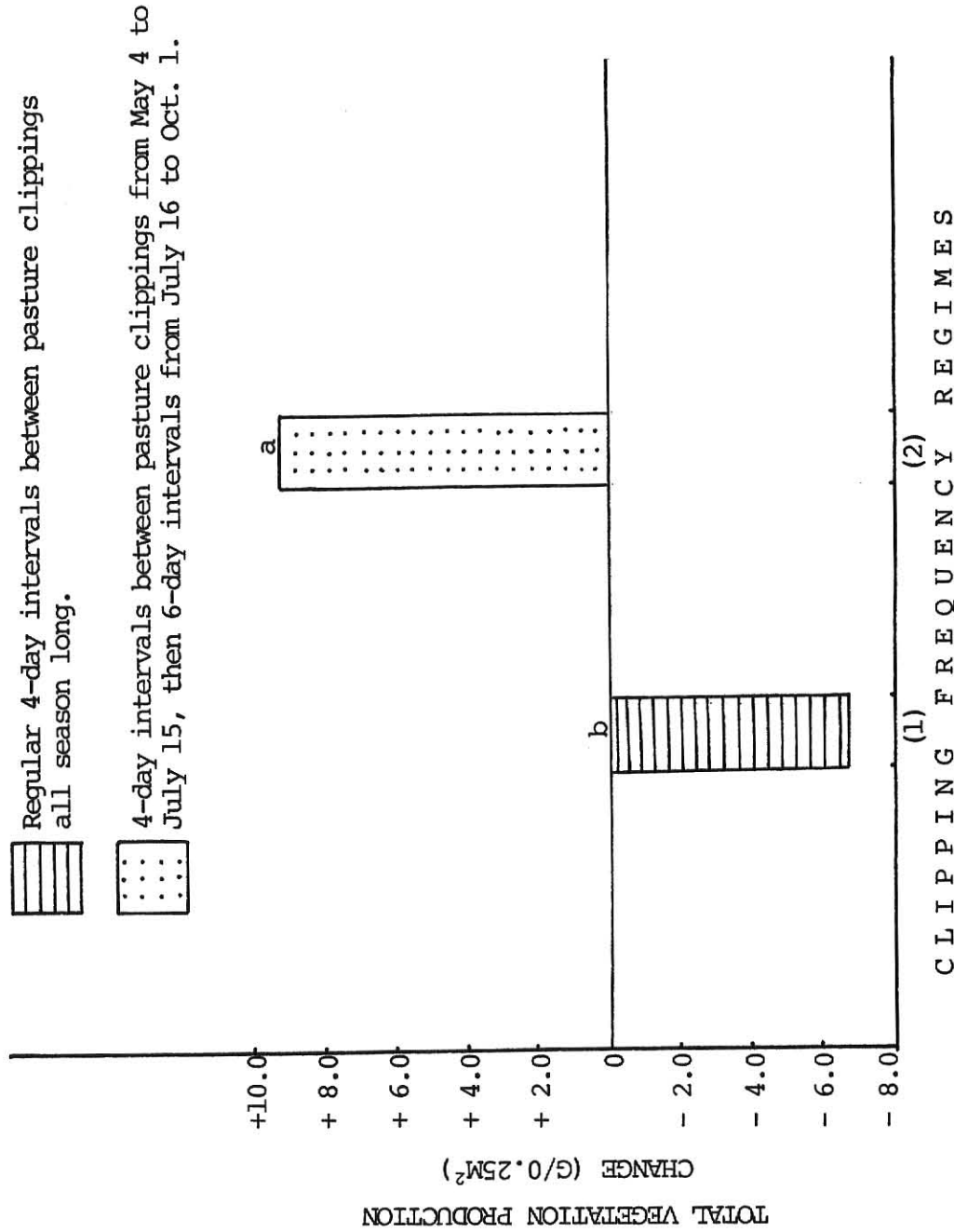


Fig. 12. Change in total vegetation production over the season (summed over rotations) using R1 yield as a covariate, as affected by two different clipping frequency regimes. Averaged across pastures and clipping heights. Bars with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ).



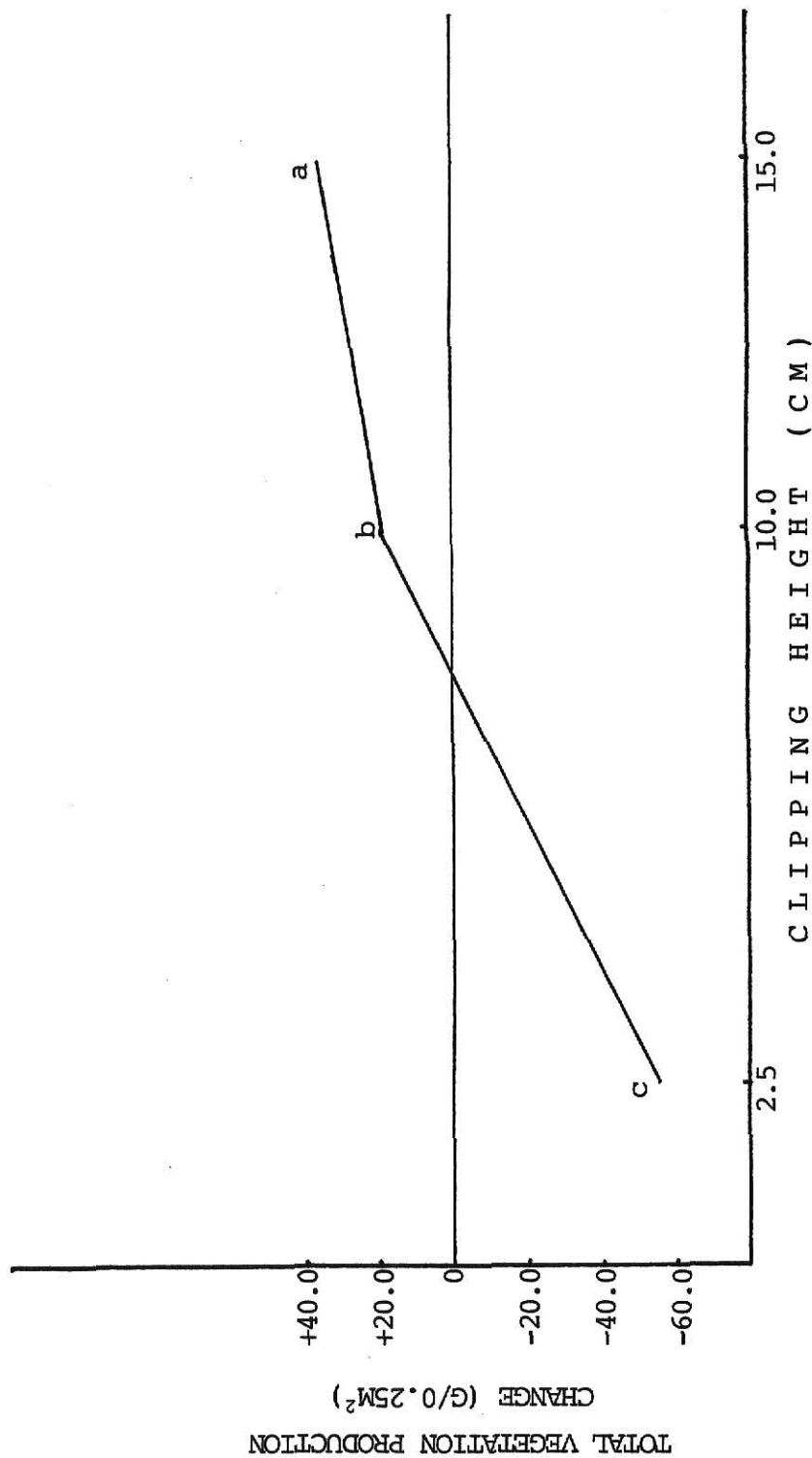


Fig. 13. Change in total vegetation herbage production over the season (summed over rotations) using RL yield as a covariate, as affected by three clipping heights. Averaged across pastures and clipping frequency regimes. Means with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ).

side (Fig. 13) as was the case with big bluestem alone (Fig. 5). Furthermore, this cutting height deeply affected the overall response of the total vegetation production (similarly to big bluestem alone) since the yield pattern due to the 2.5 cm defoliation height in Fig. 14 was remarkably similar to that in Fig. 10 which depicted the significant ( $P < 0.01$ ) height x pasture interaction effect.

The last pastures (7 and 8) were most adversely affected at the 2.5 cm cutting height. The increase in clipping height to 15 cm partially removed the effect of pastures since there was no significant difference among pastures clipped at 15 cm (Fig. 14). With the earliest pasture use (Pasture 1), the "change" variable was on the positive side even under the most severe clipping height. In contrast, the last pastures 7 and 8 had a negative "change" not only at 2.5 cm but also at the 10 cm stubble height, a fact that did not occur for the other pastures. Besides, only pasture 8 yielded significantly less at 10 cm than at the 15 cm cutting height. All these observations supported the conclusion that earlier pasture use under an SDG scheme may result in better vegetation herbage yields. Later pasture use, on the other hand, may call for some concern not only in regard to herbage production but also towards vegetation persistence and survival particularly with increased use intensity.

Height x clipping frequency regime interaction was significant ( $P < 0.01$ ). At the 15 cm cutting height, there was no significant ( $P < 0.05$ ) difference between the total vegetation yields under either clipping frequency regime (Fig. 15). The same result was observed at the 10 cm cutting height which however resulted in yields comparable to those at the 15 cm stubble height when the vegetation was allowed more

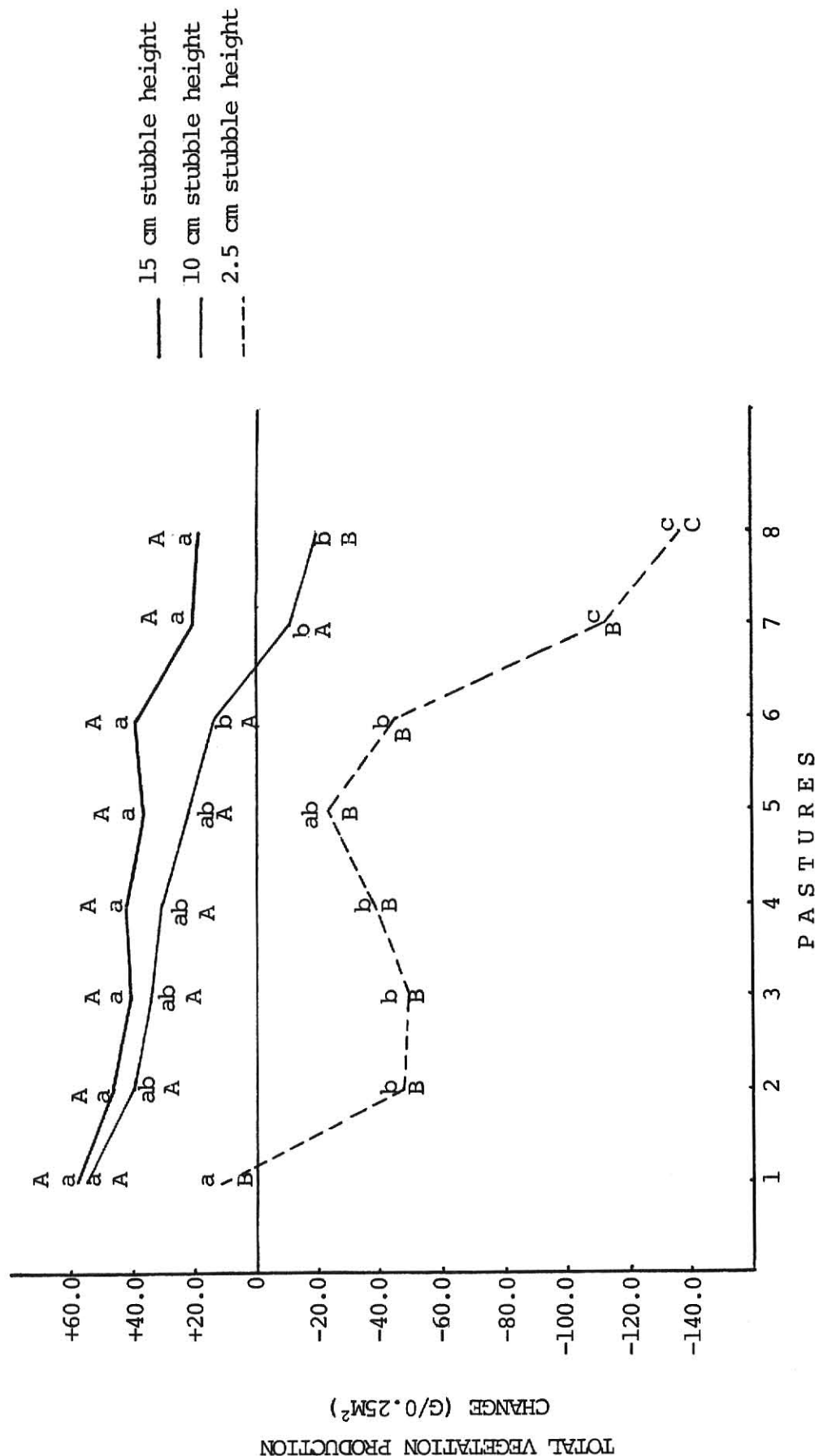


Fig. 14. Change in total vegetation herbage production over the growing season (summed over rotations) using RL yield as a covariate, at different pastures as affected by three clipping heights. Averaged over clipping frequency regimes. Means of a given cutting height with same lowercase letter are not significantly different ( $LSD_{0.05} = 38.56$ ). Means of a given pasture with same uppercase letter are not significantly different ( $LSD_{0.05} = 34.81$ ).

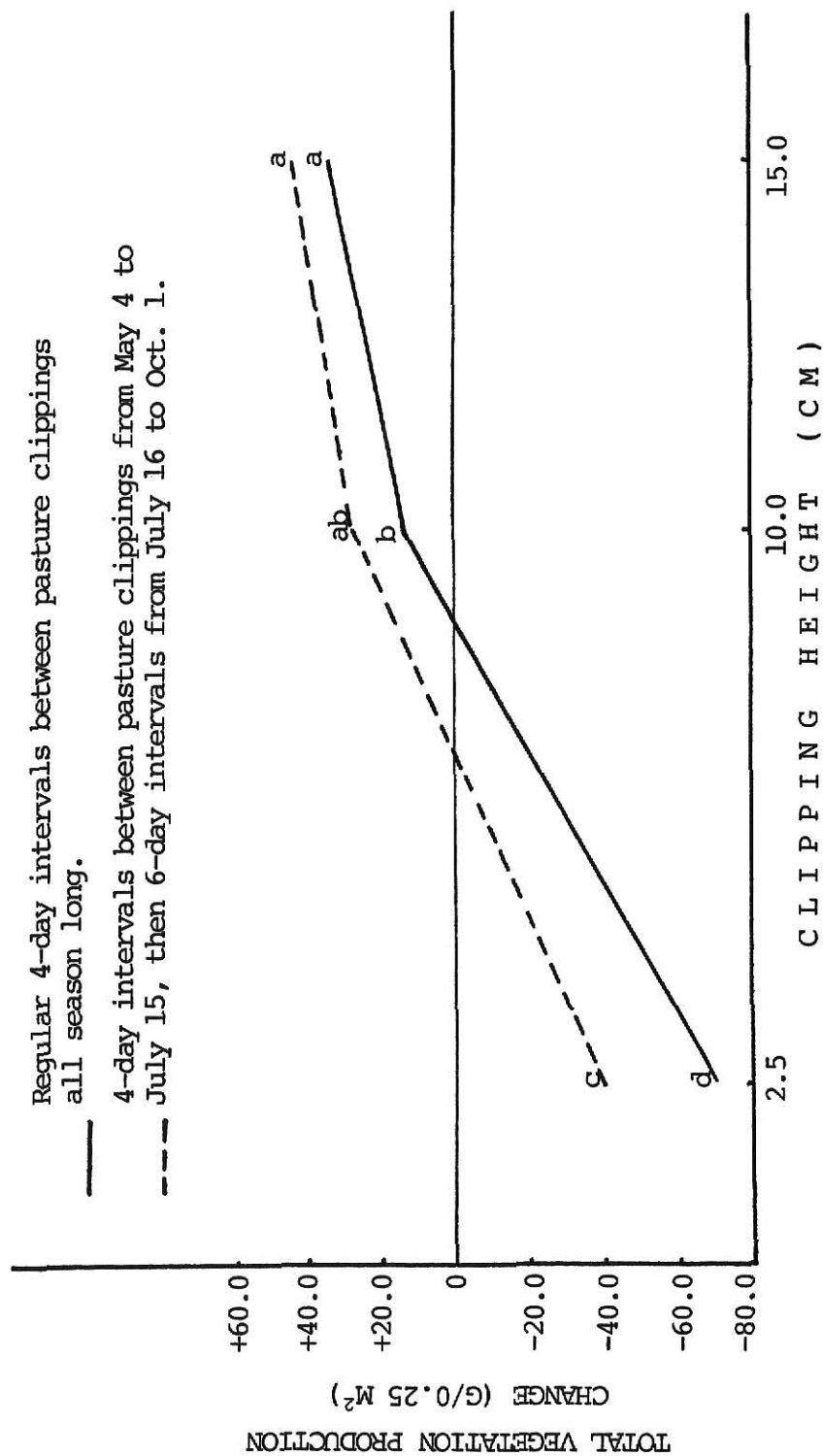


Fig. 15. Change in total vegetation herbage production over the growing season (summed over rotations) using RL yield as a covariate, as affected by two clipping frequency regimes and three cutting heights. Averaged over pastures. Means with same letter are not significantly different ( $LSD_{0.05} = 17.13$ ).

regrowth time late in the season and saved from a fifth cut under CFR2. At the 2.5 cm cutting height (Fig. 15) four cuts at increased regrowth time during the second half of the season resulted in significantly higher production of big bluestem and its associated species than under five regularly spaced cuts. Nevertheless, clipping bluestem vegetation at 2.5 cm from the ground was detrimental under both clipping frequency regimes because of negative ordinates in Fig. 15 which did not occur under the two other clipping heights. The grass stands subjected to this heavy defoliation were by the season's end remarkably reduced compared to those subjected to lesser defoliation intensities. Aldous (1930), clipping Kansas Flint Hills vegetation yearly at either 30 or 42-day intervals found that by the third year, the vegetation green weights decreased by about 80% compared to the first year clipping yields. Thus repeated heavy defoliations on bluestem vegetation may be detrimental to Tallgrass Prairie vegetation particularly when no late season rest was provided (Owensby et al. 1974).

#### Rotation effect

A significant ( $P < 0.01$ ) rotation effect upon the total vegetation production was found. Increasingly higher vegetation growth rates occurred during early and mid-season with peak production of the total vegetation in early to mid-August by R3 (Fig. 16). After that, negative yields (compared to those of the initial clipping) were recorded at R4 as well as at R5. Kothmann et al. (1983) experimenting a 16-pasture SDG system in Texas reported that grasses and forbs had negative net growth rates after an August peak in standing crop. This suggested that more rapid movement from one pasture to the next during accelerated growth phases at R2 and R3 could probably be advantageous in terms of vegetation

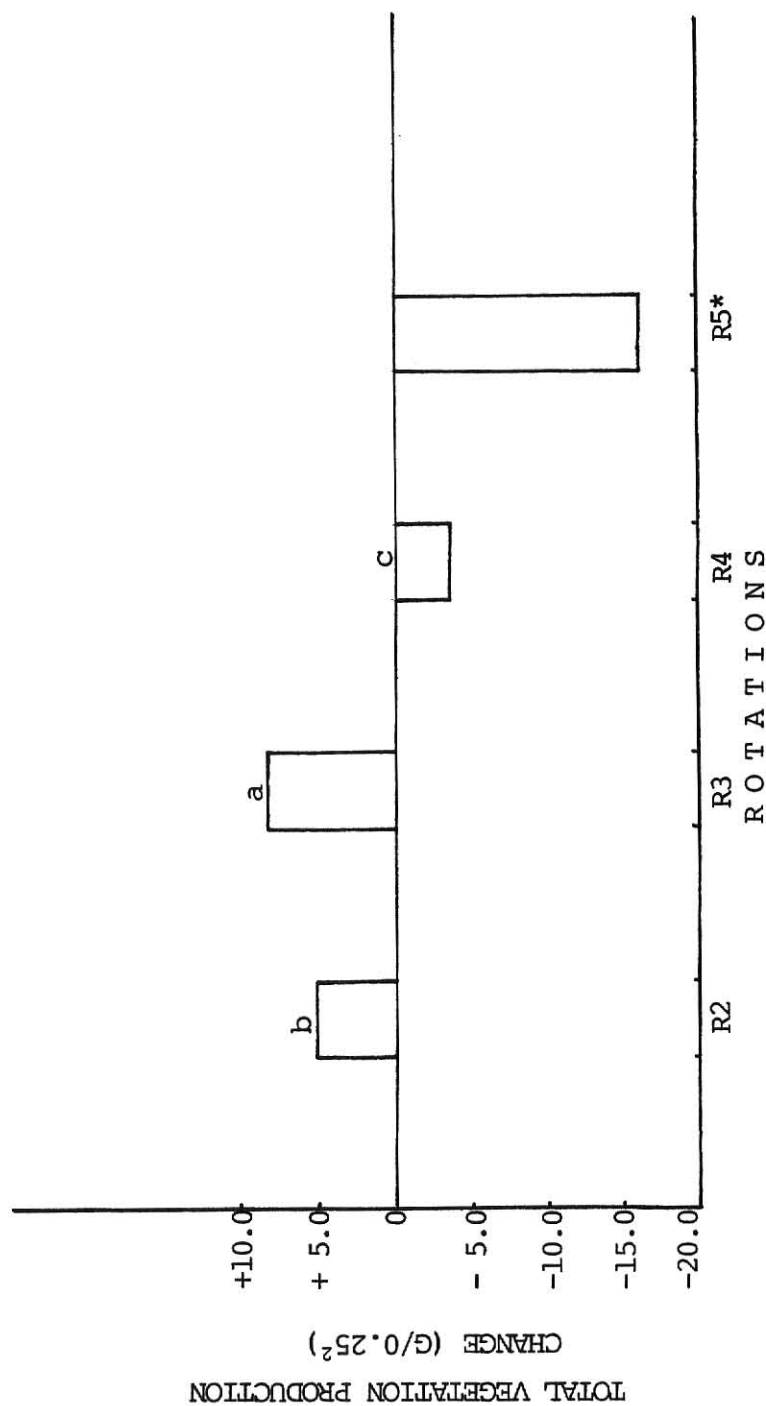


Fig. 16. Change in total vegetation herbage production at different rotations using R1 yield as a covariate. Averaged over pastures, clipping frequency regimes and heights. Bars with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ).  
\*R5 analyzed separately.

production and may help reduce plant senescence losses which were found to be important even early in the season (Brown and Stuth 1983).

A significant interaction effect between rotation and clipping height ( $P < 0.01$ ) is depicted in Fig. 17. Under the 2.5 cm clipping height, the total vegetation production worsened from one rotation to the next and was significantly lower than that at any of the two other cutting heights at all rotations excluding the first clipping. A comparison between Fig. 16 and Fig. 17 at R4 illustrated how deeply the severe 2.5 cm clipping height affected the overall response of the vegetation. In fact, even at R4, plots subjected to either 10 or 15 cm clipping height continued to exhibit positive changes in production (Fig. 17). Moreover, at the 15 cm clipping height there was no significant difference between the vegetation growth rates at R2 or R4. Although the difference in production change between 10 and 15 cm cutting height treatments was not significant at any given rotation, the growth rate late in the season (R4) was significantly lower than that in early season (R2) contrary to the 15 cm clipping height treatment. Thus, the 10 cm clipping height treatment could be labelled as critical.

A fifth cut adversely affected the total vegetation production (Fig. 17). A further worsening trend occurred within R5 as the defoliation intensity increased.

Rotation by pasture by clipping frequency regime and rotation by pasture by cutting height interactions were significant ( $P < 0.01$ ). This was primarily due to the declining trend in pasture yields (Fig. 10), the cubic response of the vegetation to rotation effect (Fig. 16) and the overriding effect of the 2.5 cm clipping height compared to the effects of 10 and 15 cm stubble height treatments.

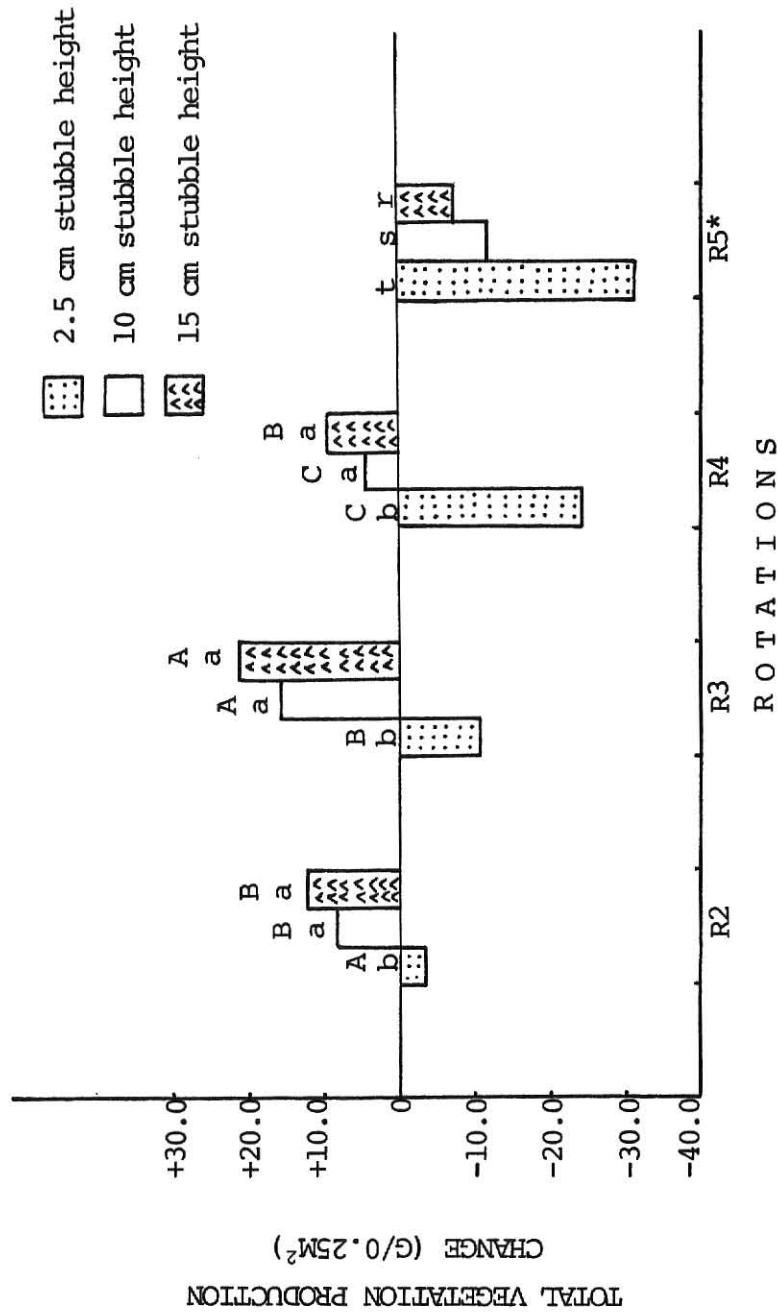


Fig. 17. Change in total vegetation herbage production at different rotations using R1 yield as a covariate, as affected by three clipping heights. Averaged over pastures and clipping frequency regimes. Bars of a given rotation with same lowercase letter are not significantly different ( $LSD_{0.05} = 7.72$ ). Bars of a given cutting height with same uppercase letter are not significantly different ( $LSD_{0.05} = 3.69$ ). \*Analyzed separately according to Duncan's multiple range test ( $P < 0.05$ ).



### Conclusions and Management Implications

Under a simulated 8-pasture SDG system there was an indication that the production of big bluestem and its associated species was reduced in at least the last three pastures. Vegetation production in the first pasture was significantly higher than any of the others.

An increased growth rate was observed in the first three rotations which suggested that a more rapid movement from pasture to pasture in early to mid-season might be advantageous. After an early August peak in standing crop, the production diminished appreciably by late season but was still satisfactory at the fourth clipping particularly at the optimum 15 cm stubble height treatment. A fifth rotation resulted in yields lower than those obtained at the initial clipping at all cutting height treatments.

A clipping frequency regime based on regular 4-day intervals between pastures throughout the growing season resulting in five rotations was not significantly different from that consisting of the same 4-day intervals between pasture clippings during the first half of the season, then shifted to 6-day intervals in the second part of the season resulting in only four rotations, when the clipping height was 15 cm. At the lower cutting heights of 10 and 2.5 cm from the ground herbage production of both big bluestem and total vegetation were significantly favored by the four rotation clipping frequency regimes which in addition to a lesser number of defoliations provided increased rest periods late in the season.

Big bluestem and associated species had their production drastically depressed when subjected to a 2.5 cm cutting height and showed a worsening trend over rotations. The overall response of big bluestem and the total vegetation to the different treatments applied tended to be masked by the pronounced effect of such a heavy defoliation treatment.

Therefore, at an optimum stocking rate, yet to be determined by further grazing studies, a more rapid rotation over the pastures during the first half of the season should be insured in order to take advantage of higher growth rates and higher nutritional quality as well as to minimize early season leaf senescence (Brown and Stuth 1983). Late in the season, as also recommended by Voisin (1959), increased rest periods between pastures and/or lighter stocking rates ought to be the key factors to be balanced. These recommendations are not different from those outlined by Owensby et al. (1977) and Smith and Owensby (1978) for intensive early use. From a ranching point of view, a comparison between these two methods of grazing might be in favor of intensive early use given the sophisticated managerial ability and investment (fencing and water development) required under SDG, particularly when the objectives sought (higher herbage and animal production while improving the range conditions) are fulfilled under intensive early use.

At a stocking density equivalent to the defoliation intensity of 15 cm stubble height, an 8-pasture SDG system may be satisfactorily implemented using a regular pasture occupancy time (4 days) and a regular pasture rest period (32 days) throughout the season. A shift to a 6-day grazing period by pasture in the late season resulting in increased pasture rest periods, may allow greater forage removal by increasing the stocking density to the equivalent of 10 cm stubble height defoliation intensity, and yet maintain herbage production at satisfactory levels.

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II - Simulated Short Duration Grazing System: Effects on Acid  
Detergent Fiber and Crude Protein Content of Big Bluestem

## Introduction

Big bluestem (Andropogon gerardi Vitman), one of the key dominant grasses in the True Prairie, was reported by Rao et al. (1973) and Angell (1978) to show a declining trend in digestibility and crude protein (CP) content with advance in the growing season. At the same time, the acid detergent fiber (ADF) content showed an increasing trend reducing the plant forage quality status.

Early in the season however, a relatively higher plant growth rate was responsible for maintaining better forage quality and as a result, animal performance was not adversely affected even under increased stocking rates (Launchbaugh 1957, Smith and Owensby 1978).

Kilcher (1981) recommended increased stocking rates to draw maximum benefits from forage quality such that ". . . the crop, so to speak, does not get too far ahead of the animals."

Beaty and Engel (1980) proposed frequent harvesting near the plant growing points as a management tool to reduce the shading of the older leaves by the newly developed ones, and prevent the build-up of dead tissue; processes that occur during achievement of plant maturation.

By keeping the plants in younger stages of development, greener and less stemmy, frequent defoliations could reduce the forage quality deterioration through the season (Osman, 1979).

Savory and Parsons (1980) adopted these basic principles of frequent defoliations and increased stocking densities in a short duration grazing (SDG) system they called the Savory Grazing Method, which was reported earlier by Goodloe (1969).

Heitschmidt et al. (1982) found that a properly managed SDG system increased the average quality of forage if the rate of rotation of animals kept up with that of plant leaf senescence.

Although animal grazing is not identical to hand clipping, significant information may be gained when testing the effects of a particular treatment or grazing system upon the quality components of plant species (White 1973).

The present study monitored the changes in CP and ADF in big blue-stem under an 8-pasture SDG system at three levels of cutting intensities: 2.5, 10 and 15 cm stubble height. The following two clipping frequencies were studied: 4 days between pastures throughout the growing season; and a 4-day interval between pastures during the first half of the season with a 6-day interval between pastures in the second half of the season.

### Study area and methods

The study area and the experimental design were described by Ben Mansoura (1983a). The clipped big bluestem samples were, after drying at 60 C for 2 days and weighing, ground in a Wiley mill to pass through a 1 mm screen. They were then stored in glass vials under dark conditions until needed for ADF and CP analyses. At each clipping date and treatment the most advanced developmental stage achieved by big bluestem was recorded.

#### Acid detergent fiber

Duplicate ADF analyses were run on each sample in the laboratory (Goering and Van Soest 1970). The sample size was reduced to 0.5 g instead of 1.0 g, due to small samples.

#### Crude protein

Total nitrogen  $\times 6.25$ , was determined by a reagent grade sulfuric acid digestion of the samples (Isaac and Johnson 1976). Duplicate aliquots were taken from each sample to read the concentration of the ammonia-salicylate complex through a Bausch and Lomb spectrophotometer set at 660 nanometers (Anonymous 1976).

For rotation 5, the first three pastures in rotation 1, and the last two pastures of rotation 4, there was little material left to conduct CP analyses because the samples were initially small and ADF was run first. For this reason, the partial data relative to those samples was disregarded.

Standard analysis of variance was made using pastures as whole plots, rest periods as sub-plots, cutting heights as sub-sub-plots, and finally rotations as sub-sub-sub-plots.



## Results and discussion

### Acid detergent fiber

The overall analysis of variance showed a significant pasture and rotation effect on the ADF component of big bluestem herbage ( $P < 0.01$ ). There was no significant difference in ADF due to clipping frequency regimes ( $P < 0.40$ ) or heights ( $P < 0.17$ ). Table 3 showed the ADF content of big bluestem in each of the eight pastures at the different rotations when averaged over the clipping frequency regimes and heights. In the first two rotations the pastures clipped last, mainly 5, 7, and 8, had consistently higher ADF levels, while pastures 2 and 3 had significantly lower levels. In the last two rotations however, the trend was reversed. The early clipped pastures 1, 2 and 3 ended up with higher ADF content in their herbage at R4 than pastures 6 or 8. In the pasture means (Table 3) the ADF content was significantly lower, in the first sequentially clipped pastures 2 and 3, and highest in 5, 7, and 8.

There was a statistically significant ( $P < 0.05$ ) increasing trend in the ADF fraction from rotation 1 (R1) to rotation 3 (R3) (Table 3). Kamstra et al. (1966) working with Kikuyugrass (Pennisetum clandestinum Hochst. ex chiov.) reported similar crude fiber increases in plant regrowth with time after the last applied clipping. However at the fourth cutting (R4), the ADF component levels did not statistically differ from those of the third clipping except in pasture 8 (Table 3). The fourth rotation occurred between August 8 and September 5 using clipping frequency regime (1) (CFR1), and between August 15 and October 1 using clipping frequency regime (2) (CFR2). The observed peak of the ADF fraction in pastures 1, 2, and 3 at R4 which started occurring in early August is in agreement

Table 3. Percent ADF in big bluestem herbage as affected by pasture and rotation sequence.

Averaged over clipping frequency regimes and heights.

| Rotation <sup>2</sup> | Pastures <sup>1</sup> |              |              |               |              |              |               |               | Rotation Means |
|-----------------------|-----------------------|--------------|--------------|---------------|--------------|--------------|---------------|---------------|----------------|
|                       | 1                     | 2            | 3            | 4             | 5            | 6            | 7             | 8             |                |
| R1                    | C<br>36.14bc          | C<br>34.67c  | C<br>36.36b  | C<br>37.37b   | C<br>39.71a  | C<br>36.76b  | B<br>39.90a   | C<br>41.00a   | C<br>37.74     |
| R2                    | B<br>43.16ab          | B<br>41.04cd | B<br>40.04d  | B<br>43.13ab  | B<br>43.31ab | B<br>42.10bc | A<br>44.44a   | AB<br>43.96ab | B<br>42.65     |
| R3                    | A<br>47.02a           | A<br>45.17bc | A<br>44.78bc | A<br>45.67abc | A<br>46.25ab | A<br>43.96c  | A<br>45.47abc | A<br>45.84ab  | A<br>45.52     |
| R4                    | A<br>48.00a           | A<br>46.41ab | A<br>46.18ab | A<br>45.63b   | A<br>45.62b  | AB<br>42.80d | A<br>45.02bc  | B<br>43.45cd  | A<br>45.39     |
| Pasture Means         | 43.58a                | 41.82b       | 41.84b       | 42.95a        | 43.72a       | 41.40b       | 43.71a        | 43.56a        |                |

<sup>1</sup>Pastures connected with the same lowercase letter in a given row are not significantly different (P<0.05) according to Duncan's multiple range test.

<sup>2</sup>Rotations connected with the same uppercase letter in a given column are not significantly different (P<0.05) according to Duncan's multiple range test.

with Allen et al. (1976) who reported a similar trend in composite under-foliated bluestem samples. However, Angell (1978) found a continued increase in ADF content of hand-clipped big bluestem samples throughout the season with rotation late-season rest or continuous grazing.

Separate analyses of the ADF determinations by rotation showed that as expected there no statistical difference between the two clipping frequency regimes at R1 and R2 since they were the same (Fig. 18). But at R3, the plants subjected to CFR2 accumulated significantly more structural lignocellulosic material than those under CFR1 (Fig. 18). That corroborates the results of Kamstra et al. (1966) since the time period allowed for the third regrowth was increasingly greater in the last five pastures under clipping frequency regime (2) than (1). However, the observed difference in ADF content at R3 (45.21% under CFR1 versus 45.83% under CFR2) is not likely to affect animal performance. In contrast, at the last clipping (R4) (Fig. 18) the increased time allowed for regrowth under CFR2 did not result in higher ADF levels ( $P < 0.39$ ) compared to those under CFR1, even though the developmental stages of the plants were more advanced under CFR2 when subjected to the same cutting height (Table 4).

The similarity in the ADF fraction levels between R3 and R4 as well as between the two clipping frequency regimes within R4 could be due to downward translocation of photosynthates, primarily nonstructural carbohydrates in response to root growth demands particularly at the higher cutting heights of 10 and 15 cm. Consequently, the remaining herbage would primarily consist of fibrous material. According to earlier phenological studies on big bluestem by Neiland and Curtis (1956) and McKendrick (1971) the time period of the fourth cut (R4) in this study

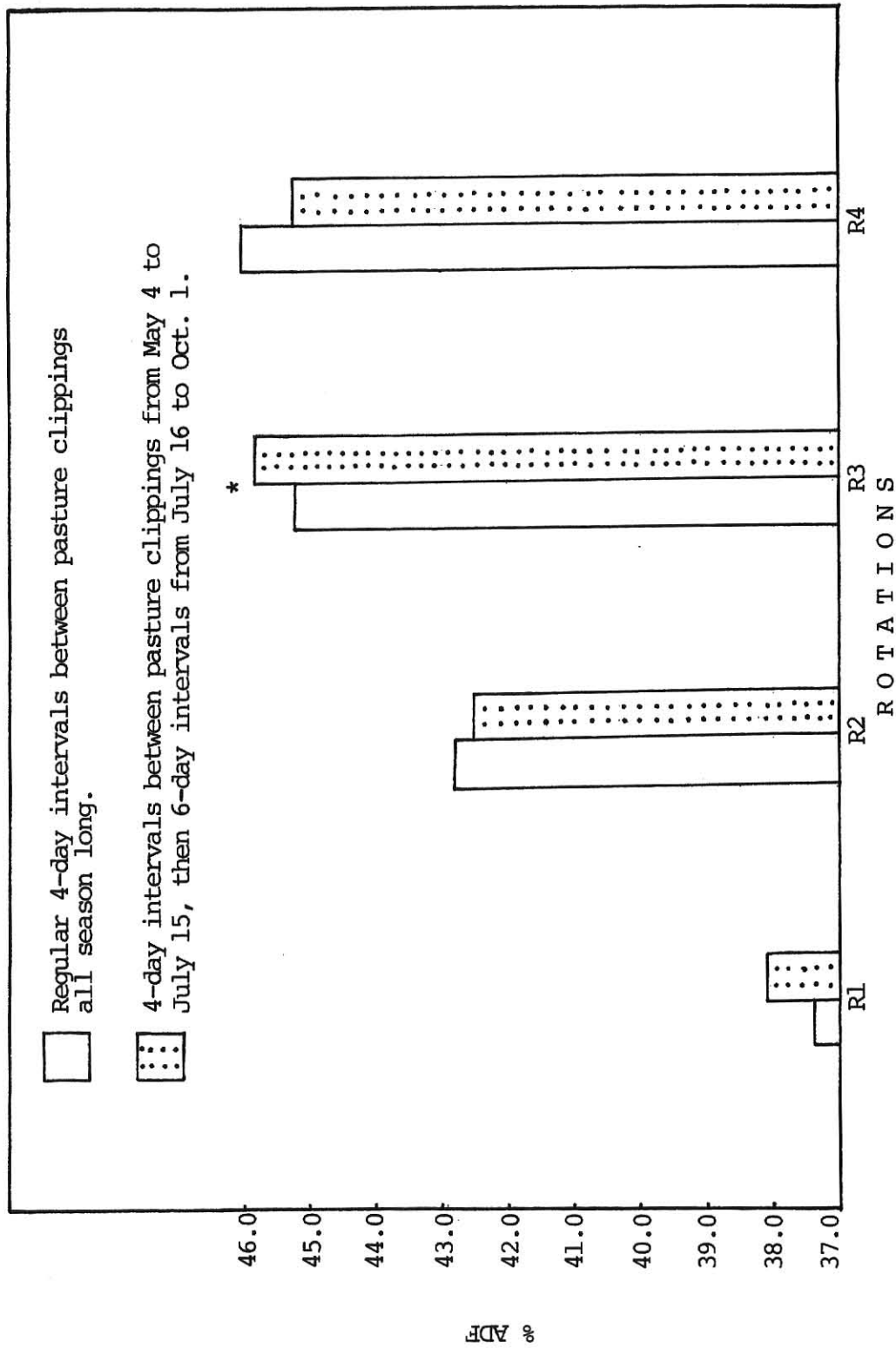


Fig. 18. Percent ADF in big bluestem herbage at four different rotations of an 8-pasture SDG system as affected by two clipping frequency regimes. Averaged over pastures and clipping heights. Asterisk above bars of a given rotation indicates significant difference ( $P < 0.05$ ) between clipping frequency regimes according to Duncan's multiple range test.

Table 4. Most advanced developmental stages achieved by big bluestem plants at the fourth rotation (R4) under a simulated 8-pasture SDG system as affected by clipping frequency regimes and heights.

| Pastures | Clipping frequency regimes                             |            |           |  |       |            |
|----------|--|------------|-----------|--|-------|------------|
|          | (1)<br>4-day interval between pastures all season long |            |           | (2)<br>4-day interval from May 4 to July 15, then 6-day interval from July 16 to Oct 1 |       |            |
|          | Clipping height (cm)                                   |            |           | Clipping height (cm)   |       |            |
|          | 2.5  | 10         | 15        | 2.5  | 10    | 15         |
| 1        | 5 LPE <sup>1</sup>                                     | boot       | late boot | early boot   | boot  | late boot  |
| 2        | 5 LPE  | early boot | boot      | boot   | head  | head       |
| 3        | boot   | 5 LPE      | 5 LPE     | 5 LPE  | head  | head       |
| 4        | 5 LPE  | head       | head      | boot   | head  | head       |
| 5        | 3 LPE  | head       | boot      | 3 LPE  | 4 LPE | head       |
| 6        | boot   | 5 LPE      | head      | 3 LPE  | head  | early boot |
| 7        | 4 LPE  | head       | head      | 4 LPE  | 4 LPE | 5 LPE      |
| 8        | 2 LPE  | 4 LPE      | head      | 3 LPE  | 5 LPE | 4 LPE      |

<sup>1</sup>LPE: Leaf pre-elongation.

corresponded to that of the development of new roots. Furthermore, Owensby et al. (1977) found that the carbohydrate and nitrogen reserve build-up in big bluestem rhizomes to occur during the same time period corresponding to R4.

In the early season (R1), big bluestem herbage clipped at 2.5 cm from the ground contained a significantly ( $P < 0.05$ ) higher fraction of lignocellulose than herbage clipped at either 10 or 15 cm from the soil surface (Fig. 19). This is consistent with the fact that plant tips and growing shoot apices are generally more palatable and of higher quality than whole tillers. As a result, a significantly lower structural material in the herbage cut at 10 or 15 cm compared to that cut at 2.5 cm was expected. Almost the same relationship between cutting height and percent ADF was observed at the second cut (R2) (Fig. 19) apart from the fact that plants clipped at 15 cm had ADF levels comparable to those of plants cut at 2.5 and 10 cm.

The closely clipped plants (2.5 cm) in R3 had significantly ( $P < 0.10$ ) more ADF material than those subjected to the 15 cm clipping height. This result could not be explained apart from the fact that continued old age and senescence rate in the heavily defoliated tillers could have accounted for higher ADF levels. In R4, ADF increased significantly ( $P < 0.10$ ) as the cutting height increased (Fig. 19). One plausible explanation lies in an increased stem to leaf ratio at the higher cutting height of 15 cm which predominated over the ratio of young to old tillers in the closely clipped plants (2.5 cm). Thus the stem to leaf ratio could have become the overriding factor by mid to late season in determining big bluestem ADF content and subsequently its overall quality. Because of the extreme importance of this ratio, Beaty and Engel (1980), in a review and critique of forage quality measurements, suggested that whenever "grasses high in stem content are harvested, percent stem would be a useful data in evaluating nutritional quality of the forage."

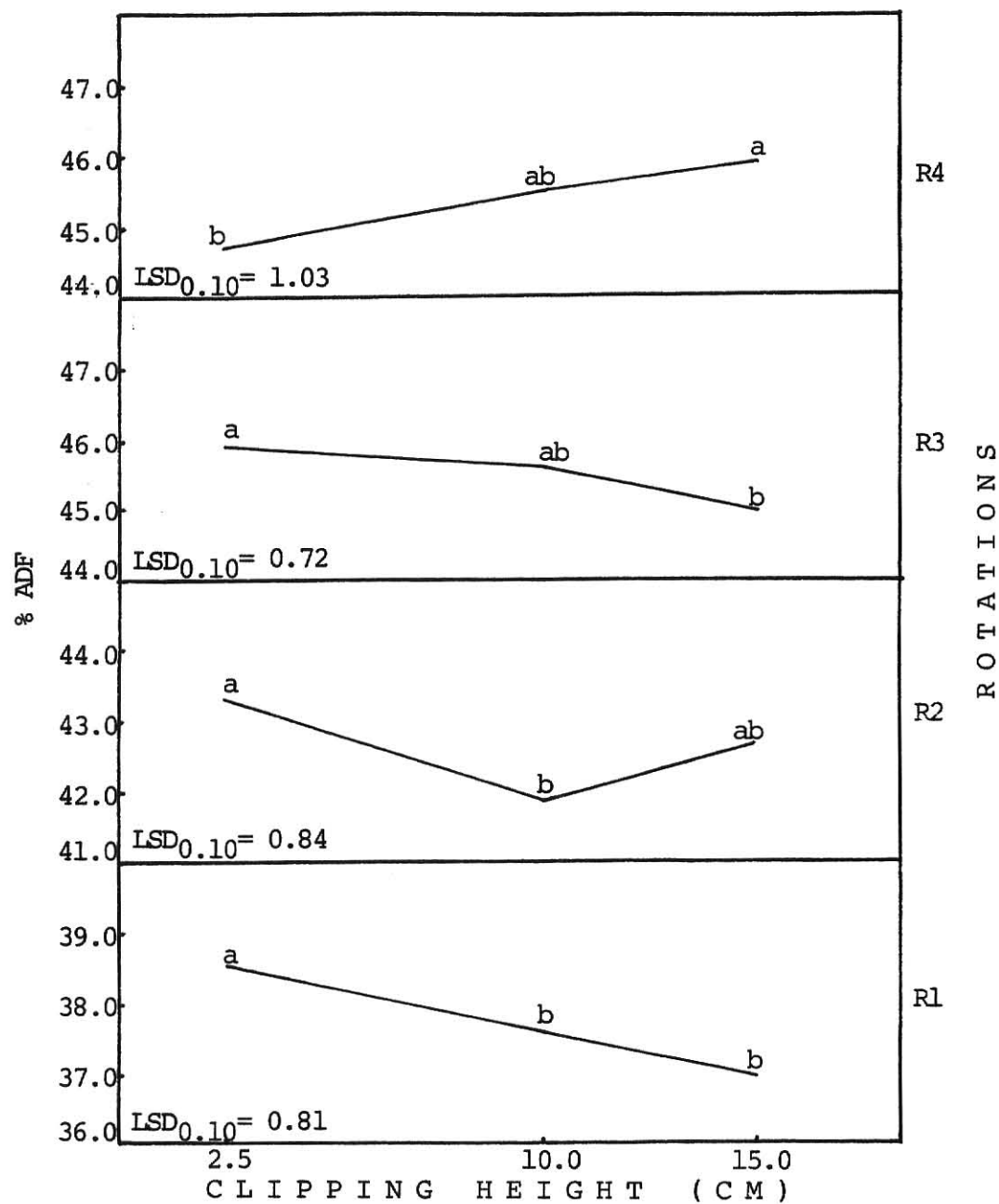


Fig. 19. Percent ADF in big bluestem herbage as affected by clipping height at different rotations over an 8-pasture SDG system. Averaged over pastures and clipping frequency regimes. Means of a given rotation with same letter are not significantly different ( $P < 0.10$ ).

### Crude protein

The overall analysis of variance of the data showed significant differences in percent CP content of big bluestem ( $P < 0.05$ ) due to pastures, clipping frequency regimes and rotations. Table 5 showed a significant declining trend ( $P < 0.05$ ) in the CP fraction of big bluestem herbage between rotations within individual pastures. Angell (1978) studying the effects of rotation of late-season rest and season-long grazing reported a similar progressive drop in CP content of hand-clipped big bluestem samples with advance of the season. Thus, it may be assumed that lowered CP levels in big bluestem through the season was unavoidable even under a simulated 8-pasture SDG system that is based on frequent defoliations which were thought to maintain forage quality (Savory 1978). The separation of the pasture means within each of R2 and R3 (Table 5) showed that the first clipped pastures 1, 2, 3, and 4 were consistently ranked higher in CP levels than the last ones: 5, 6, 7, and 8.

The two clipping frequency regimes did not differ within each of the first two rotations R1 and R2, because the interval of clipping from pasture to pasture was the same (4 days) (Fig. 20). However at R3 and R4, separate analyses indicated that the uniform 4-day clipping interval between pastures throughout the season resulted in significantly ( $P < 0.05$ ) higher crude protein content in big bluestem herbage than under the frequency regime where there was a shift from 4 to 6 days of interval between pasture clippings during the second half of the season (Fig. 20). That is in agreement with Burton et al. (1963) who proposed shorter cutting intervals in order to keep the plants and plant parts in younger stages of development and consequently maintain



Table 5. Percent crude protein in big bluestem herbage as affected by pasture and rotation sequence. Averaged over clipping frequency regimes and heights.

| Rotation <sup>2</sup> | Pastures <sup>1</sup> |              |             |             |             |             |             |             |
|-----------------------|-----------------------|--------------|-------------|-------------|-------------|-------------|-------------|-------------|
|                       | 1                     | 2            | 3           | 4           | 5           | 6           | 7           | 8           |
| R1                    |                       |              |             | A<br>10.24a | A<br>9.53bc | A<br>9.39bc | A<br>9.69b  | A<br>9.08c  |
| R2                    | A<br>8.65a            | A<br>8.24abc | A<br>8.41ab | B<br>7.94bc | B<br>7.11de | B<br>7.20de | B<br>7.64cd | B<br>6.97e  |
| R3                    | B<br>6.69ab           | B<br>6.71ab  | B<br>6.84a  | C<br>6.86a  | C<br>6.01c  | C<br>5.90c  | C<br>6.05c  | C<br>6.30ab |
| R4                    | C<br>5.38c            | C<br>6.04b   | B<br>6.59a  | D<br>5.94b  | C<br>6.00b  | C<br>5.82b  |             |             |

<sup>1</sup>Pastures connected with the same lowercase letter in a given row are not significantly different ( $P < 0.05$ ) according to Duncan's multiple range test.

<sup>2</sup>Rotations connected with the same uppercase letter in a given column are not significantly different ( $P < 0.05$ ) according to Duncan's multiple range test.

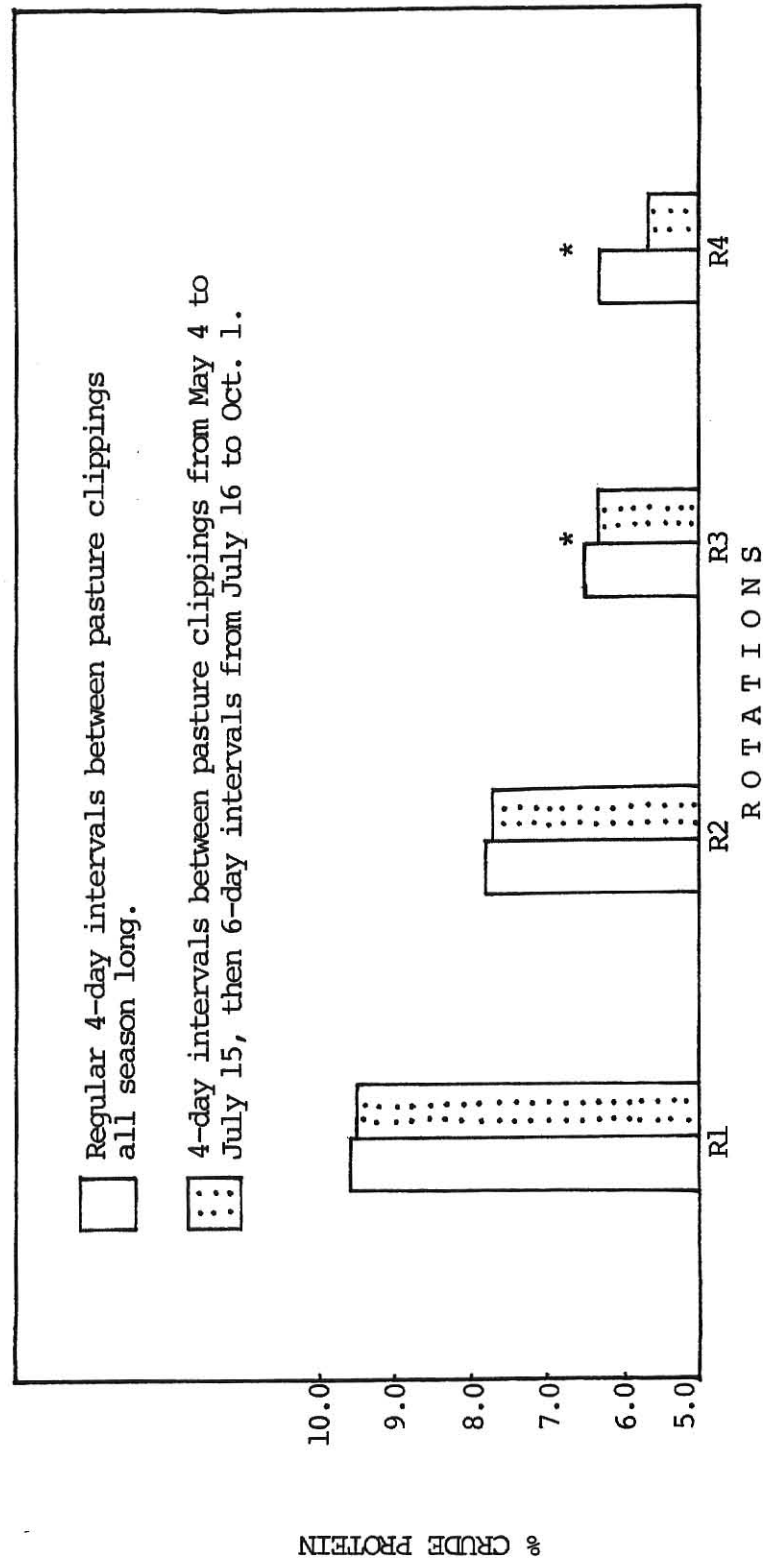


Fig. 20. Crude protein content in big bluestem herbage at four different rotations over an 8-pasture SDG system as affected by two clipping frequency regimes. Averaged over pastures and clipping heights. Asterisk above bars of a given rotation indicates significant differences ( $P < 0.05$ ) between clipping frequency regimes according to Duncan's multiple range test.

higher forage quality. Table 4 where the most advanced developmental stages achieved by big bluestem plants at R4 are shown supports this in general, since the plants under CFR1 had a less advanced stage of maturity than those under CFR2, when compared at the same cutting height. In the case of R3, the difference in CP content between CFR1 (6.49%) and CFR2 (6.35%) may not cause a noticeable difference in animal weight gains. However at R4, the difference in CP content of big bluestem herbage between CFR1 (6.29%) and CFR2 (5.64%) became greater, and as a result animal performance would most likely reflect this difference.

The overall analysis showed no significant effect attributable to the three different clipping heights ( $P < 0.41$ ). However, analyses within each rotation showed that the crude protein content in big bluestem herbage varied significantly ( $P < 0.05$ ) at R1 and R4 (Fig. 21). At R1, the highest cutting height of 15 cm contained more protein than herbage removed at the 2.5 and 10 cm heights. This was probably due to the fact that the leafier shoot apices made up a higher proportion of the aboveground material of big bluestem plants at the 15 cm cutting height than at the other lower cutting heights. At the second and third cut (R2 and R3), the different cutting heights failed to exhibit any significant effect upon the crude protein component. This could have resulted from a compensation between increased stemminess at the cutting heights of 10 and 15 cm on one hand, and an increased senescence rate in the mostly vegetative herbage clipped at 2.5 cm on the other hand. At the fourth regrowth however, big bluestem plants previously clipped at 2.5 cm from the ground showed significantly higher crude protein content than those clipped at either 10 or 15 cm stubble height. The reason lies in an overriding percent stem factor which according to Table 4 was

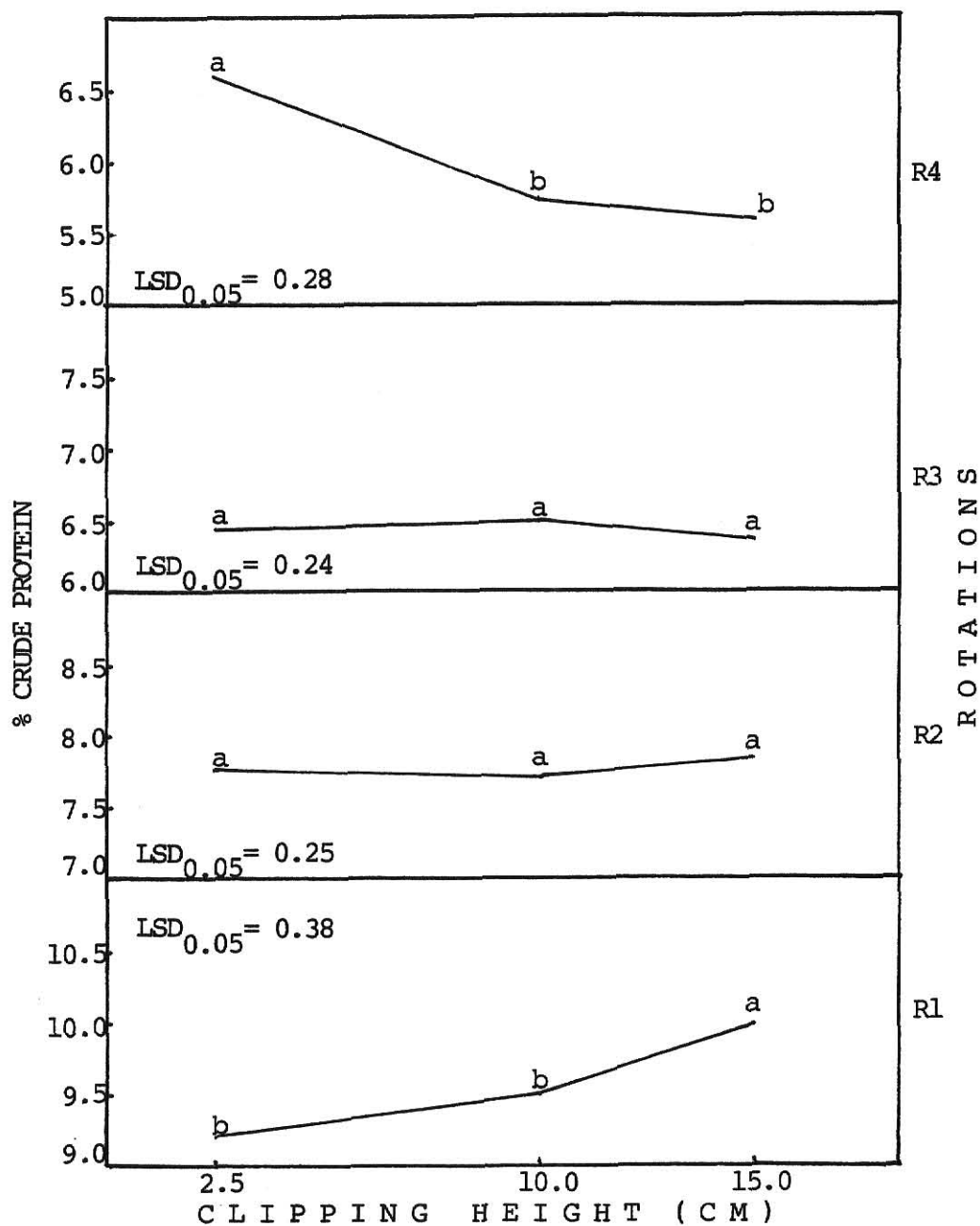


Fig. 21. Percent crude protein in big bluestem herbage as affected by clipping height at different rotations over an 8-pasture SDG system. Averaged over pastures and clipping frequency regimes. Means of a given rotation with same letter are not significantly different ( $P < 0.05$ ).

predominant in the fourth rotation at the higher cutting heights. The 2.5 cm cutting height apparently helped maintain significantly higher crude protein content and also a lower ADF by mid to late season (R4 occurred from August 8 to September 5 under CFR1 and from August 20 to October 1 under CFR2). This is in agreement with Kilcher (1981) who proposed increased stocking intensities in order to benefit from better forage quality.

### Conclusions and Management Implications

There was a significant declining trend in big bluestem herbage quality from one rotation to the next under a simulated 8-pasture SDG system. This decline was analogous to that described by Angell (1978) comparing rotation of late-season rest and continuous season-long use, except that the ADF fraction levelled off in August through the end of the season, an observation that was also reported by Allen et al. (1976) working with undefoliated plants of bluestems. This might be tied to belowground translocation of total nonstructural carbohydrates particularly at the higher cutting heights of 10 and 15 cm (Ben Mansoura 1983b).

Increased interval of use from pasture to pasture, resulting in longer regrowth time during the second half of the season decreased big bluestem forage quality compared to a uniform interval of use particularly in the mid season (R3) when the ADF component continued to show an increasing trend. Late in the season (R4), although the ADF fraction levelled off, the CP content continued to decrease with increased regrowth time, confirming thereby that more frequent defoliations help maintain an improved nutritional quality in forages. Nevertheless, because of the unavoidable drop of big bluestem herbage quality with the advance of the season regardless of the management practice, intensive early use might be the best management option in the Flint Hills, since it was shown by Smith and Owensby (1978) to provide better animal performance as well as a preserved plant vigor (Owensby et al. 1977).

Although the clipping height or degree of use did not have a significant effect upon the ADF and CP measurements in the overall data analysis

there was a significant effect within individual rotations. The height effects were closely tied to phenological stages achieved by plants subjected to different clipping heights as well as to the compensation of the stem ratio in plants cut at 10 and 15 cm from the ground with the age and senescence rate in the plants cut at 2.5 cm from the soil surface which generally remained vegetative and had thinner stands by the close of the season. But in the early season (R1), although the closely clipped plants (2.5 cm) had a lower nutritive value (higher ADF and lower CP) than those cut at 10 or 15 cm, forage quality was still high enough to justify increased degree of use in the early season and probably a more intensive frequency regime of defoliation than those tested.

It would, however, be detrimental to continue the intensive use in the second part of the season as this was shown to lower plant carbohydrate reserves and may endanger their survival (Owensby et al. 1977, Smith and Owensby 1978). Besides little advantage in higher crude protein levels was gained in plants clipped at 2.5 cm compared to plants clipped at 10 and 15 cm by the end of the season (R4) to justify close use as a remedy to increased stemminess and thereby a lowered quality in the second half of the season.

Apart from the fact that the results of this study are clearly in favor of the intensive early use proposed by Smith and Owensby (1978) as the best management practice to maximize the returns from the Flint Hills rangeland and preserve the vigor of the desirable key species; there remains some lack of evidence on whether a short duration grazing system over the entire growing season such as tested here would have an advantage or not over intensive early use because animals have the

ability to upgrade the composition of their diet compared to the chemical composition of the available grasses (Launchbaugh and Owensby 1978), as well as to shift their preference from one species or group of species to others as different species become more palatable at different times of the season (Rosiere et al. 1975).



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III - Simulated Short Duration Grazing System: Effects on Total  
Nonstructural Carbohydrate Reserves of Big Bluestem Rhizomes

## Introduction

McKendrick (1971) stated that quality and quantity of reserve carbohydrates in the storage organs of grasses constitute critical factors in plant regrowth and its survival. Range grasses store carbohydrate reserves primarily in roots, rhizomes and stem bases (Graber et al. 1927, Weinmann 1948). Changes in carbohydrate reserve cycles throughout the growing season have been well documented for range grasses by several authors (Aldous 1930, McCarty 1935, Graber et al. 1927).

By reducing the photosynthetic area of plants, grazing or cutting can lower carbohydrate reserves (Thaine 1964, Owensby et al. 1974). Frequent clipping, particularly during the second half of the growing season may drastically reduce plant food reserves (Owensby et al. 1970, Trlica and Cook 1972), while clipping early in the season followed by subsequent rest may be beneficial to warm-season plant communities (Owensby et al. 1970).

Singh and Mall (1976) and Trlica and Cook (1972) showed that the carbohydrate reserve build-up before the onset of dormancy was directly affected by the time allowed for photosynthesis between the last clipping applied and the onset of dormancy. However, Owensby et al. (1974) suggested that the effects of intensive clipping on carbohydrate reserves apparently carry over into the next growing season and consequently he warns against intensive use particularly during the second half of the season.

Alberda (1957) found that tillers did not form after clipping for some time due to root and rhizome growth inhibition and that recovery

periods varied with conditions and plant species. Crider (1955) and Jameson and Huss (1959) noted similar responses to clipping.

The present study investigated the total nonstructural carbohydrate (TNC) reserve fluctuations in big bluestem (Andropogon gerardi Vitman) rhizomes in the eighth pasture of an 8-pasture short duration grazing (SDG) system throughout the growing season and shortly before the initiation of new growth the next spring. This pasture had the least time to continue growth between the last applied clipping and the onset of dormancy.

## Study area and methods

### Study area

The study area was located on a clay upland range site of the Tall-grass Prairie, 7 miles northwest of Manhattan, Kansas. The major dominant species were big bluestem, Indiangrass (Sorghastrum Nutans (L.) Nash) and little bluestem (Andropogon scoparius Michx.). Anderson and Fly (1955) studied in further detail the soil-vegetation relationships in the Flint Hills.

### Experimental design

The experimental design consisted of a split-plot design with one of the following two mowing frequencies being the whole plot treatment:

(1) Mowing each 32 days throughout the entire growing season of 1981 (June 1, July 3, August 4, September 5, and October 7), resulting in five rotations.

(2) Mowing each 32 days during the first half of the season (June 1 and July 3), and mowing thereafter at an increased rest period of 42 days (August 14) and then 48 days (October 1 of the same year), resulting in only four rotations. The mowing dates correspond to those of the last sequentially defoliated pasture under an 8-pasture SDG system (Table 6).

On March 18 of the following year (1982), before growth initiation took place, all experimental units were again sampled. This was labelled a late dormant season sample.

The sub-plot treatments were three mowing intensities of 2.5, 10 and 15 cm from the ground surface.

All treatments were replicated three times in adjacent blocks along a gentle slope gradient. The experimental units were 9 x 9 m in size.

Table 6. Mowing and TNC sampling dates.

| Rotations               | R1    | R2    | R3     | R4    | R5             | LDSS <sup>1</sup> |
|-------------------------|-------|-------|--------|-------|----------------|-------------------|
| Mowing<br>frequency (1) | Jun 1 | Jul 3 | Aug 4  | Sep 5 | Oct 7          | Mar 18            |
| Mowing<br>frequency (2) | Jun 1 | Jul 3 | Aug 14 | Oct 1 | - <sup>2</sup> | Mar 18            |

<sup>1</sup>LDSS: late dormant season sample. No mowing, only TNC sampling.

<sup>2</sup>No mowing and no TNC sampling.

### Sampling

For all the sampling dates (Table 6) except on June 1, big bluestem rhizomes were dug by hand from within the experimental units at a depth of approximately 15 cm. All holes were refilled and mowing took place thereafter at the assigned stubble height, by means of a gas-propelled mower equipped with an adjustable sickle cutting bar of 0.9 m width. On June 1 however, the first sampling date, the vegetation was still undisturbed and was consequently supposed to be uniform as to the status of the TNC reserves for a given species. For this reason, and in order to ensure minimal disturbance within the experimental units; sampling for big bluestem rhizomes on that date (June 1) was made from the surrounding vegetation.

On all sampling dates, the most advanced developmental stage achieved by big bluestem plants under a given treatment was recorded.

While in the field, the samples were stored in properly labelled paper sacks that were placed in a dark nylon bag. In the laboratory, they were washed with tap water to remove soil, roots and dead organic material. Careful hand plucking was also used during the cleaning process.

The rhizome samples were oven-dried at 60 C for 48 hours, ground in a Wiley mill to 1 mm size, and stored in glass vials under dark conditions until needed for chemical analyses.

Duplicate sub-samples of 500 mg each were used to determine the TNC content by use of an enzyme extraction (mycolase) and copperiodometric titration (Smith 1969). Sample TNC content was expressed as an average of the duplicates on a percent dry matter basis.

### Statistical analyses

Although the June 1 samples were informative in regard to the initial TNC reserves of the plants, they were considered as statistically invalid and thus were disregarded.



In order to add another split over time and include rotations, two different stages of analysis of variance were undertaken. The first was an analysis of variance of a split-split-plot design by omitting the fifth rotation, thereby making a balanced design for this purpose. The second stage was a split-plot analysis of variance within each of the whole plot treatments. The statistical classes were: mowing height, rotation, and their interaction.

## Results and discussion

The initial TNC content of big bluestem rhizomes at the first rotation (R1) on June 1, before any mowing took place, was 3.85%. This relatively low level of carbohydrate reserves could be explained by an upward translocation in response to growth demands early in the season which usually starts in late April to early May (Launchbaugh and Owensby 1978).

### Mowing frequency

The analysis of variance of the subsequent observations, except those of the fifth rotation (R5), showed that the TNC content was significantly affected by the mowing frequency ( $P < 0.07$ ) when they were averaged across the cutting heights and the different rotations. The mowing frequency that allowed plants greater rest during the second half of the season permitted higher TNC reserve accumulations. This was expected since more frequent clipping was shown to lower herbage yield, vigor and carbohydrate reserves of plants (Aldous 1930, Singh and Mall 1976); especially late in the season (Owensby et al. 1974, Trlica and Cook 1971).

Fig. 22 showed the TNC variation between the two mowing frequencies used, across the different rotations after averaging over the mowing heights. At the second rotation (R2), the two TNC levels were the same since the plots in both cases rested 32 days after the previous initial clipping. However at the third rotation (R3), the plots under mowing

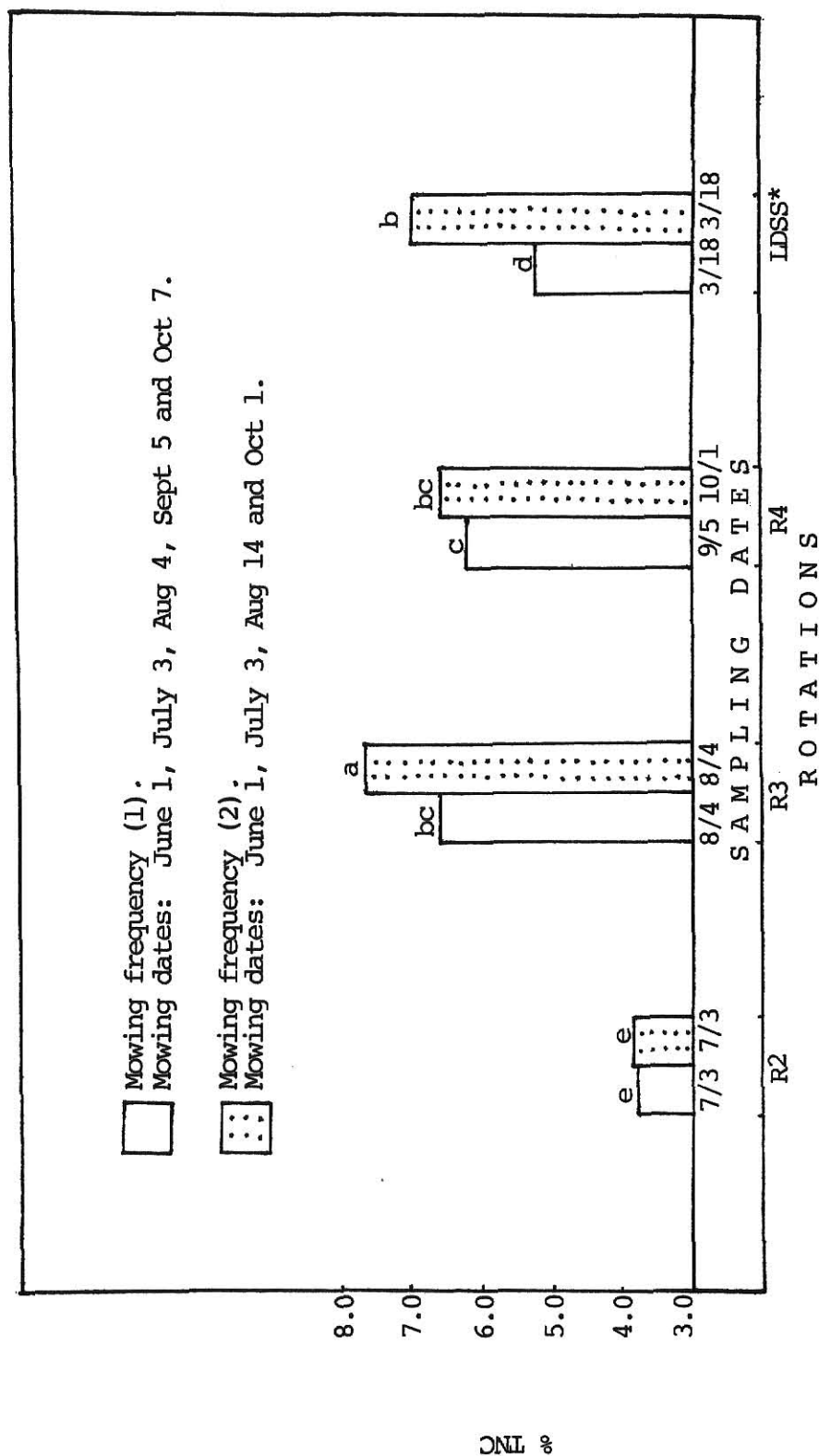


Fig. 22. Percent total nonstructural carbohydrates (%TNC) in big bluestem rhizomes at four sampling dates as affected by mowing frequency. Averaged across three mowing heights. Rotation 5 deleted. Bars with same letter are not significantly different ( $LSD_{0.05} = 0.66$ ). \*LDSS: late dormant season sample.

frequency (2) had 42 days of rest compared to 32 days only for those under mowing frequency (1). The 10 additional days of rest had a significant beneficial effect upon big bluestem growth that subsequently made significantly more photosynthates available for belowground storage. At the fourth rotation (R4), although the plots under mowing frequency (2) had 48 days of rest, while those under frequency (1) continued to receive the uniform 32-day rest period, there was no significant advantage upon the carbohydrate reserve build-up ( $P < 0.32$ ).

It has been established that carbohydrate translocation is tied to a "dynamic source-sink relationship" (Moser 1977, Trlica 1977); therefore, the mentioned failure could be explained by the development of strong sinks such as during root growth initiation, particularly at the higher cutting heights of 10 and 15 cm, since the severe 2.5 cm stubble height may result in root growth inhibition and eventually in plant death (Alberda 1957, Biswell and Weaver 1933, Crider 1955). Table 7 showed that big bluestem plants subjected to the severe 2.5 cm cutting height were mainly vegetative by the season's end (R4) as a result of depressed tillering capability. Those mowed at the higher cutting heights reached generally more advanced stages of development at R4 under mowing frequency (2) than under mowing frequency (1) (Table 7). Phenological studies on big bluestem (Neiland and Curtis 1956, McKendrick 1971) showed that root growth processes occur during the interval of time allowed between R3 and R4 under the two mowing frequencies.

Differences in root growth could have occurred between plants subjected to different frequencies and intensities of clipping. If so, a measurement of the TNC content in varying weights of storage organs could have explained the response of the species to an increased rest

Table 7. Most advanced developmental stages achieved by big bluestem plants subjected to two mowing frequencies and three cutting heights at four different rotations.

| Rotations | Mowing frequencies                                    |       |       |   |       |      |
|-----------|---|-------|-------|---|-------|------|
|           | (1)<br>Regular 32-day intervals<br>between rotations. |       |       | (2)<br>Mowing intervals of 32 days<br>(R1 and R2), then 42 days<br>(R3), and 48 days (R4) |       |      |
|           | Mowing height (cm)                                    |       |       | Mowing height (cm)  |       |      |
|           | 2.5   | 10    | 15    | 2.5   | 10    | 15   |
| R2        | 4 LPE <sup>1</sup>                                    | 5 LPE | 5 LPE | 4 LPE   | 4 LPE | boot |
| R3        | 5 LPE   | 6 LPE | boot  | boot  | head  | head |
| R4        | 2 LPE   | 4 LPE | head  | 3 LPE   | 4 LPE | head |
| R5        | 2 LPE   | 4 LPE | 5 LPE |   |       |      |

<sup>1</sup>LPE: Leaf pre-elongation

period during the second half of the season better than the simple % TNC measurement.

On March 18 of the following year, the final sampling date, the plots under mowing frequency (1) showed a significant decrease in TNC levels of big bluestem rhizomes (Fig. 22), because of a fifth cut (R5) that occurred on October 7 a date between R4 and the late dormant season sample (LDSS). Under mowing frequency (2) there was no change in TNC content of big bluestem rhizomes between R4 (October 1) and LDSS (March 18). A comparison of the TNC levels between the two mowing frequencies at LDSS (Fig. 22) indicated a definite advantage to big bluestem vigor due to increased rest periods between defoliations given in the late season ( $P < 0.05$ ). Earlier research work by Trlica and Cook (1971) confirmed the necessity for less intensive use at the close of the growing season in order to preserve plant vigor.

In the Flint Hills, Smith and Owensby (1978) found that doubling the stocking rate during the first half of the season followed by nonuse during the second half significantly favored a big bluestem dominated botanical composition compared to a continuous season-long grazing system at the normal stocking rate.

#### Mowing height

Significant differences in carbohydrate reserves of big bluestem were found ( $P < 0.01$ ) due to the effect of mowing height (Fig. 23). The lowest cutting height (2.5 cm) caused the lowest TNC reserves when averaged over the mowing frequencies and rotations. As the defoliation heights increased, the TNC reserves in big bluestem rhizomes significantly increased. Neiland and Curtis (1956) reported a similar trend.

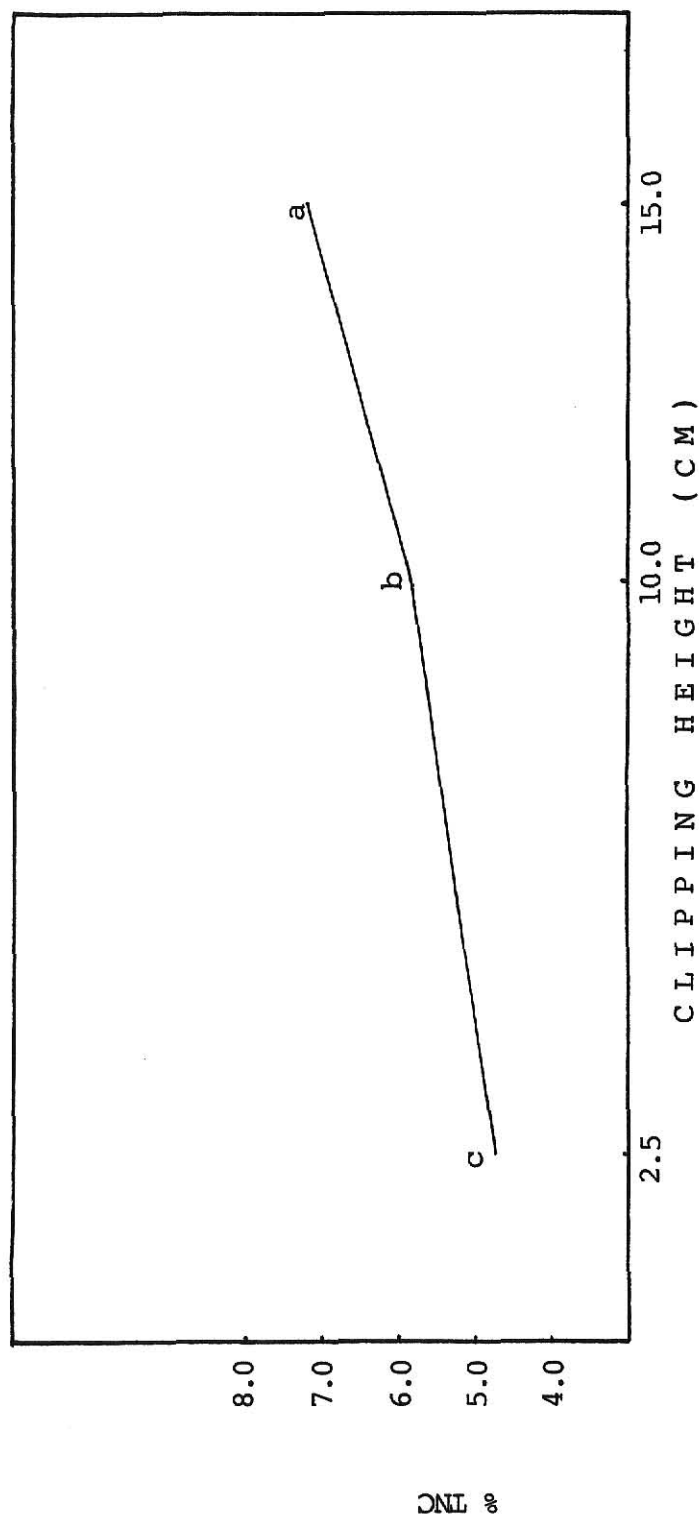


Fig. 23. Percent total nonstructural carbohydrate (%TNC) reserves in big bluestem rhizomes as affected by three mowing heights. Averaged across mowing frequencies and rotations. Rotation 5 deleted. Means with different letters are significantly different according to Duncan's multiple range test ( $P < 0.05$ ).

Thus, photosynthetic processes and the resulting food material available for downward translocation were correlated with the remaining photosynthetic areas left at the different clipping heights.

Fig. 24 showed that the TNC levels increased significantly ( $P < 0.05$ ) from R2 to R3 under each one of the three cutting heights. At R3, the TNC reserves in big bluestem plants subjected to either 2.5 or 10 cm mowing heights did not significantly differ. This corroborates the tolerance of big bluestem plants to higher clipping or grazing pressure in early and mid-season (Owensby et al. 1977, Smith and Owensby 1978). At R4, there was a drop in TNC reserves at the cutting height of 15 cm ( $P < 0.05$ ) due to root growth processes; while at the lower cutting heights of 2.5 and 10 cm, the TNC levels remained unchanged from those at R3.

At the final sampling date of March 18 (LDSS), the carbohydrate reserves of plants subjected to the severe 2.5 cm mowing height, were drastically reduced (Fig. 24). Those under the 10 cm mowing height remained unchanged from the previous rotation; whereas the plants subjected to the 15 cm cutting height showed a significant increase in TNC reserves which could be explained by a continued downward translocation through the fall period before respiratory losses began (Rains et al. 1975) or by a conversion of storage materials from other forms to nonstructural carbohydrates.

A second stage of analysis of variance where the observations within each mowing frequency were analyzed separately (Fig. 25 and 26) showed that by July 3 (R2), the TNC levels were comparable for the respective heights under both mowing frequencies. That is, TNC levels were greatest under the 15 cm clipping height regime and equal for the 2.5 and 10 cm cutting height treatments. This was expected since the two mowing frequency regimes were the same at R2 (32 days of rest).



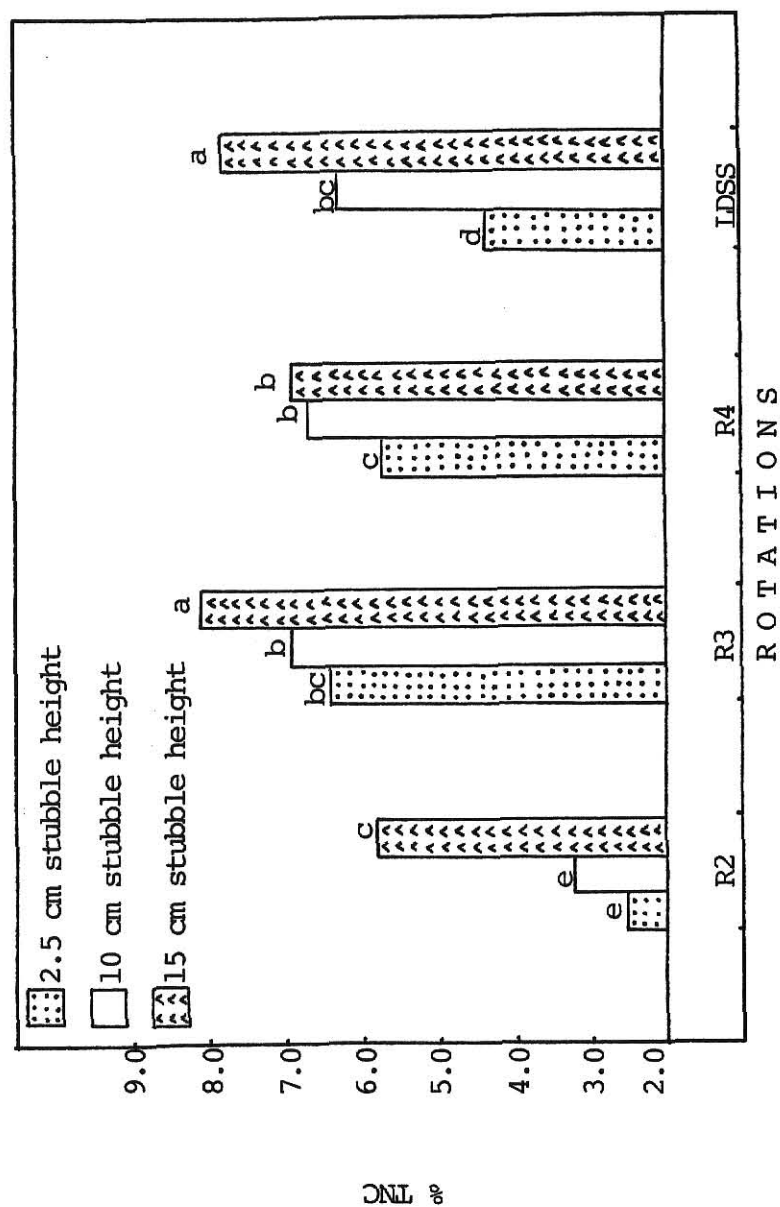


Fig. 24. Percent total nonstructural carbohydrates (%TNC) in big bluestem rhizomes at different rotations and at the late dormant season sampling (LDSS), as affected by three mowing heights and averaged over two mowing frequencies. Bars with similar letters are not significantly different ( $LSD_{0.05} = 0.82$ ).

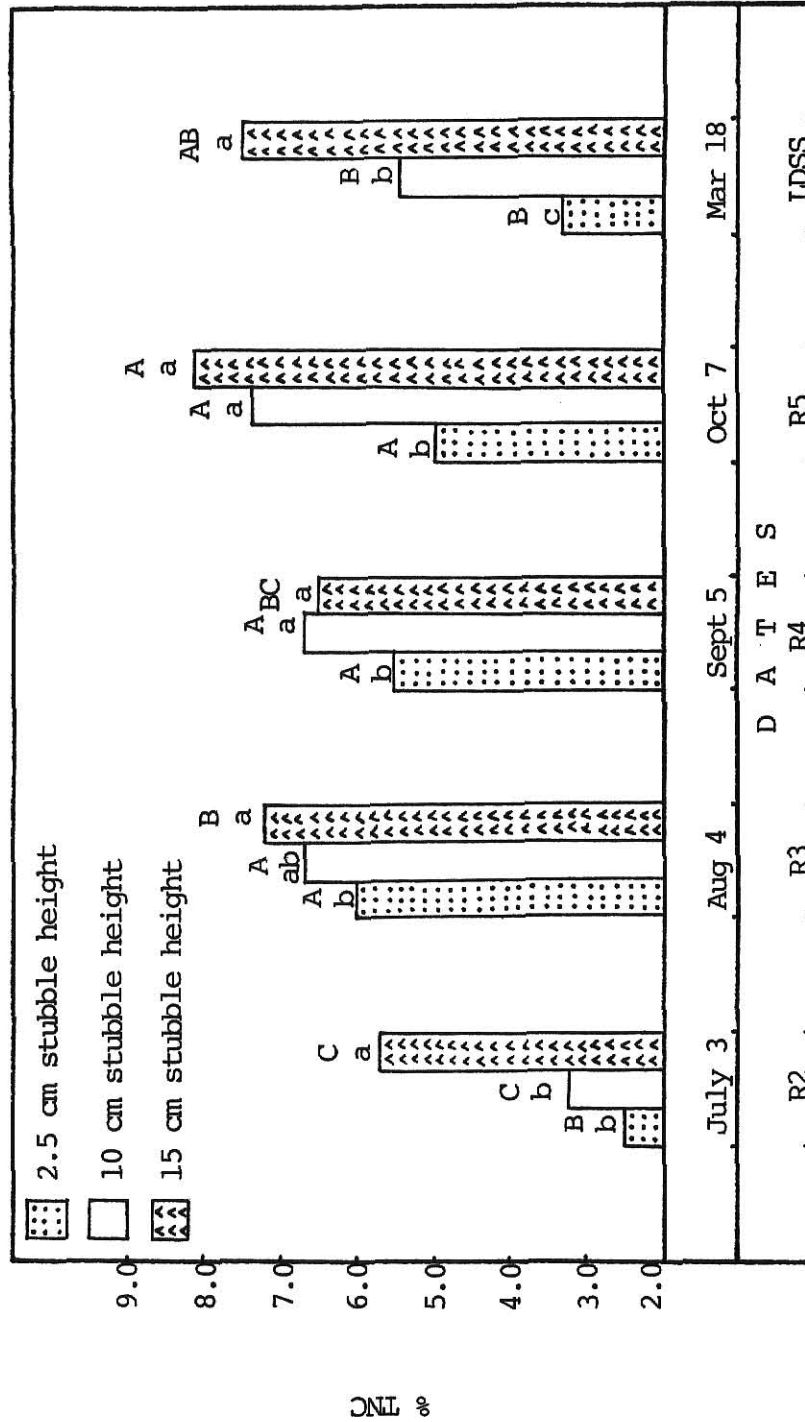


Fig. 25. Percent total nonstructural carbohydrates (%TNC) in big bluestem rhizomes on different dates and rotations following mowing at three heights at uniform 32-day intervals beginning on June 1, 1981. Bars of different dates at the same mowing height are statistically non-significant if associated with the same uppercase letters ( $LS D_{0.05} = 0.92$ ). Bars of a given date at different mowing heights are statistically non-significant if associated with the same lowercase letters ( $LS D_{0.05} = 1.01$ ).

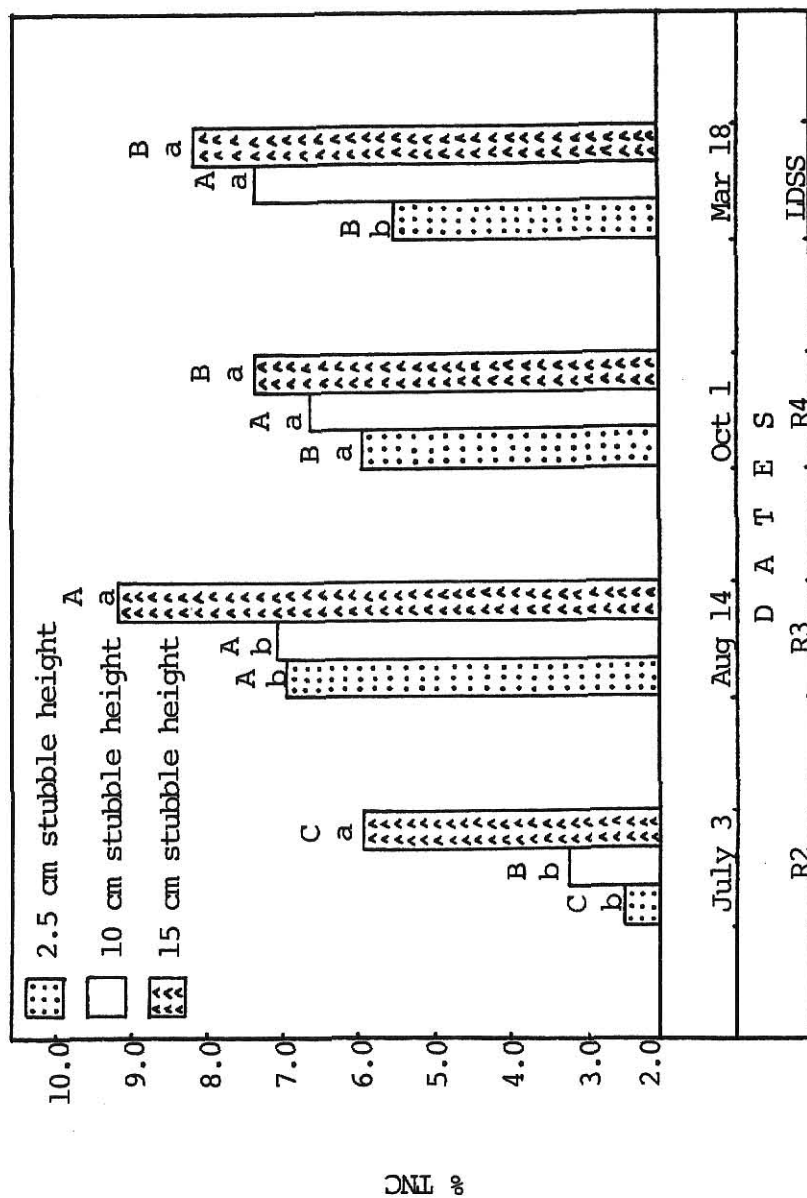


Fig. 26. Percent total nonstructural carbohydrates (%TNC) in big bluestem rhizomes on different dates and rotations following mowing at three heights on June 1, July 3, August 14 and October 1, 1981. Bars of different dates at the same mowing heights are statistically non-significant if associated with the same uppercase letter ( $LSD_{0.05} = 0.88$ ). Bars of a given date at different mowing heights are statistically non-significant if associated with the same lowercase letter ( $LSD_{0.05} = 1.52$ ).

By early October, at the season's end, big bluestem plants cut at 2.5 cm from the ground under mowing frequency (1) (Fig. 25) had significantly less TNC reserves in their rhizomes than those cut at either 10 or 15 cm; whereas under mowing frequency (2) (Fig. 26), plants of big bluestem that were subjected to only four cuttings at 2.5 cm from the soil surface had their TNC reserves comparable to those subjected to 10 or 15 cm stubble height. This is in agreement with the findings of Perry and Chapman (1976) who found that the survival of basin wildrye (*Elymus cinereus* Scribn and Merr.) plants clipped at the lowest height of 15 cm was proportional to clipping frequency, while those clipped at 30 and 45 cm from the soil surface did not have their survival affected by the defoliation frequency.

At the last sampling date (LDSS), the TNC levels were not significantly different from those of the last cutting (R4) at the respective heights under mowing frequency (2) (Fig. 26). This was not the case under mowing frequency (1) (Fig. 25) where the two lower cutting heights of 2.5 and 10 cm caused their respective TNC levels to drop significantly from R5 to LDSS. Thus, under the more frequent defoliation regime, only the highest cutting height of 15 cm did not cause the TNC reserves of big bluestem to drop from the last defoliation (R5) to LDSS. Furthermore, within mowing frequency (1) (Fig. 25) only the plants that were subjected to the lowest defoliation intensity of 15 cm stubble height benefited at R5 and showed significantly higher TNC content compared to the previous rotation. The other two cutting heights caused the carbohydrate reserves to remain unchanged at R5.

This suggested that the 15 cm stubble height may represent the critical amount of leaf area necessary in order not to hinder carbohydrate reserve build-up in big bluestem rhizomes during the late summer (between September 5 and October 7) (Fig. 25).

### Conclusions and Management Implications

A regime of four consecutive defoliations with progressively increased rest periods in the second half of the season was consistently more beneficial to big bluestem TNC reserves than that consisting of five successive defoliations at regular intervals throughout the season.

The lowest defoliation intensity of 15 cm stubble height maintained higher TNC reserves in big bluestem rhizomes through the next fall and winter particularly under the more frequent mowing regime.

Under close use (2.5 cm height), the carbohydrate reserves in big bluestem rhizomes declined significantly under both mowing frequency regimes. Although this intensity appeared tolerable early in the season; nearly all big bluestem plants subjected to this cutting height remained vegetative because of reduced tillering activity that was reflected by thinner stands in the plots corresponding to this treatment.

Grazing systems based on continued heavy defoliations throughout the entire growing season should be avoided on bluestem range (Owensby et al. 1974), as this may result in the destruction of the desirable plant species over a period of a few years (Kinsinger and Hopkins 1961, Bukey and Weaver 1939).

In the Flint Hills, early season defoliations of big bluestem was found to promote secondary shoot production (McKendrick et al. 1975), since the removal of the plant growing points overcomes apical dominance and promotes lateral bud development. Accordingly, intensive early use (Owensby et al. 1977, Smith and Owensby 1978) could be satisfactorily implemented, as this practice was shown to be compatible with animal production as well as with plant growth and survival.

Similarly, short duration grazing systems, ought to be practiced with these concepts in mind in order to preserve the vital quantity and quality of carbohydrate reserves (Cook 1966, McKendrick 1971) of the desirable range species, particularly big bluestem.

Under an 8-pasture short duration grazing system, increased rest periods late in the season may be qualified as mandatory in the Flint Hills because of reduced tillering capability (McKendrick et al. 1975). However, early in the season, there was some evidence that more frequent defoliations could be given at the proper intensity without harming plant vigor if followed by appropriate rest periods late in the summer. Future research work ought to clarify this.

At uniform pasture rest periods throughout the season, a stocking density equivalent to the 15 cm stubble height could be implemented without hurting big bluestem carbohydrate reserves and its recovery. Under increased pasture rest periods during the second half of the season, a higher stocking density equivalent to the defoliation intensity of 10 cm stubble height, could be allowed without sacrificing big bluestem reserve carbohydrates.

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## APPENDIX

## REVIEW OF LITERATURE

In the past, the low value of range led to abuse by overstocking in an attempt to increase returns from the land. With the introduction of cattle into the United States and the advent of commercial ranching, the initial equilibrium that previously existed between range resources and various wild herbivory species was upset (Angell 1978). This led early researchers to warn against overgrazing. They proposed grazing systems to improve the quality, vigor, and seed fertility of forage grasses (Smith 1895, Sampson 1913, Sarvis 1923). Sims (1970) defined grazing management systems as being the control of the grazing animals in time and space by proper changes of stocking rate, season of use, and kind of animal, as well as an even distribution and frequency of use.

Lewis (1981) classified the major kinds of grazing systems and their respective procedures including the Short Duration Grazing (S.D.G.) system.

### The Short Duration Grazing System

S.D.G. bears the concept of "High Performance Grazing" which would require the division of the range into a large number of pastures with a high stocking rate to achieve uniform grazing distribution and utilization of high proportion (virtually all) of the tillers (Lewis 1981).

The S.D.G system was earlier implemented in Zimbabwe and later reported in the United States by Goodloe (1969) who gave an account of its major principles.

The period of occupation under S.D.G. must be short enough in order to avoid regrazing of individual tillers (Voisin 1959, 1960; Savory 1978, 1981) because regrazing of recent regrowth is detrimental and retards recovery (George 1981). The period of nonuse, on the other hand, should be long enough so that regrowth can take place (George 1981). Voisin (1959) suggested that this rest period varies with the growth rate of the vegetation. He found that the optimum nonuse period in France to be about 18 days in May and 36 days in August. Savory (1978) recommends a minimum nonuse period of 30 days and a maximum of 60 days even in the desert.

In order to minimize animal disturbance, labor and cost, Voisin and LeComte (1962) proposed the development of a central watering and working area from which the pastures called "paddocks" would radiate outwardly. Williams (1962) developed relatively inexpensive fencing designs for usage around rotationally grazed paddocks for different kinds of animals or herd combinations. Savory (1979) proposed other improved fencing designs with solar electrification.

Savory (1981) affirmed that every area of range in the United States he visited is suffering from understocking. He suggested to double or more than double the usually recommended stocking rate, as this results in tiller stimulation and increased productivity (Heitschmidt et al. 1982a); break the soil surface crusting by the hoof action of a larger herd size as well as to lay litter into the soil which will improve water infiltration into the soil and provide mulching that can enhance seed germination (George 1981). Double stocking would also result in an improved animal distribution; but individual

animal gains may be lowered due to the non selective utilization of both palatable and unpalatable species (Taylor et al. 1980) unless supplementary feeding is provided from outside the system (Corbett 1978). Heitschmidt et al. (1982b) found no significant differences in average daily gain of growing heifers under continuous and S.D.G. systems; but the animal production per hectare was significantly higher under S.D.G., concluding thereby that a properly managed S.D.G. system may support greater stocking rates satisfactorily.

In the context of holistic range management, Savory recommends the use of the flexible "Savory Grazing Method" instead of the inflexible "S.D.G. system." This flexibility concerns the day to day management decisions as well as the possibility of a desirable increased paddocking level depending on the managerial ability and the adequacy of cash flow (Savory and Parsons 1980).

However, Kothmann (1980) stated that " . . . no quantitative, statistically sound data evaluating the animal production responses to S.D.G. under a range of stocking rates." In an "exclusive report" Livestock magazine (1979) raised the question whether the Savory Grazing Method will work in the United States or not. This question remains largely unanswered. Lewis (1981) stressed the need for further research in the next several years so that reliable guidelines be provided for the management of this system.

#### Clipping Versus Grazing

Clipping removes uniformly the same amount of material between and within different plants. Removal of photosynthetic material by grazing may not be uniform between and within plants. Hormay and

Talbot (1961) found that when the average utilization of Idaho fescue (Festuca idahoensis Elmer) was 43%; 15% of the plants remained totally ungrazed; 3% were grazed to 10.2 cm stubble height or taller; 13% to 7.6 cm; 29% to 5.1 cm; and 40% to 2.5 cm.

When selective grazing is allowed, particularly with continuous grazing systems or understocking, recurrent defoliation by grazing on new growth of previously grazed plants would be detrimental to overall plant vigor resulting in patchy thinned stands of grass although it is beneficial to animal weight gains. Likewise, selective grazing could be more severe to plant vigor than a single clipping at the same degree of herbage removal. On the other hand, clipping may result in more severe injury to the grasses than defoliation by grazing (Whitman et al. 1961). Because of animal selectivity, the ungrazed vegetation would have a competitive advantage over the clipped plants for nutrient and water uptake (Mueggler 1970).

Marshall and Sagar (1965) reported the translocation of labelled carbon products to the defoliated tillers from a remaining single undefoliated tiller within the same plant. Fick and Moser (1978) found that the translocation of carbon compounds from tiller to tiller was limited to less than 6% of the initially applied tagged carbon. The most independent tillers were those already elongated. Marshall and Sagar (1965 1968) observed that most of the tagged carbon was transferred to the roots and that the older tillers were the most independent ones. They also found that the transfer of assimilates from undefoliated tillers to the defoliated sister tillers did not occur beyond the third day following defoliation.

Crider (1955) found that partial clipping of a group of tillers of Weeping lovegrass (Eragrostis curvula (Scrad.) Nees) resulted in

stopped root growth for the defoliated tillers only. Under grazing situations, leaving undefoliated tillers resulted in an increased net primary production not only due to the transfer of carbohydrates, but also because of more photosynthetic area left, and consequently more reserves could be manufactured and subsequently stored (White 1973).

Thus, the effect of grazing on plant vigor can be more or less harmful than that of clipping depending on the circumstances.

Mechanical clipping or mowing removes virtually all of the nutrients contained in the forage from the ecosystem. By grazing, however; about 75% to 96% of the nitrogen and phosphorus and 90% of the potassium contained in the forage grazed by animals was returned to the range in the form of feces (Peterson et al. 1956, Sears 1951).

Vittoria and Rendina (1960) suggested that the grazing animal caused a stimulation of plant regrowth by deposition of saliva during grazing. This was later verified by Reardon et al. (1972) who showed that animal saliva contained thiamine (Vitamin B<sub>1</sub>) at concentrations reported earlier by Bonner and Greene (1939) to stimulate growth of some grass plants. Reardon et al. (1972) found that sideoats grama (Bouteloua curtipendula (Michx.) Torr.) plants which were treated by bovine saliva after clipping had significantly higher top and root growth.

However, Johnson and Bailey (1972), in a similar experiment, reported that the addition of bovine saliva to clipped plants of Festuca scabrella Torr. and Festuca idahoensis Elmer did not stimulate regrowth. The latter authors collected the saliva directly from the rumen. This procedure was criticized by Reardon et al. (1974) arguing that rumen-saliva could be contaminated by bacterial enzymes and rumen microflora.

Using saliva collected from the animals' mouth, Reardon et al. (1974) observed a growth stimulation only with the low clipping intensity

of 15 cm stubble height. Promotion of regrowth did not occur when the intensity of defoliation was excessive (7.5 cm stubble height) at either 3 or 6 week interval between clippings.

Jameson (1964) suggested the need for further research on the effect of thiamine upon the regrowth of defoliated plants. This is still valid today because of the lack of definite evidence on whether the deposition of saliva is effective or not in plant growth stimulation.

Robinson et al. (1937) and Stapledon and Jones (1927) suggest that although plant responses to clipping and grazing are similar, it may not always be wise to consider that one would substitute for the other. White (1973) reviewing the same subject matter of clipping versus grazing, stated that both are similar but not identical.

Sarvis (1923) noted that simulating grazing by clipping does indeed provide a considerable amount of information by studying the responses of plant species to defoliations.

#### Effect of Clipping Frequency and Intensity on Plant Productivity

The effect of photosynthetic tissue removal upon the growth of plant tops has been well documented by numerous authors. Aldous (1930) found that the vegetation yield varied inversely with the frequency of cutting. He also found that the vegetation density decreased about 60% in three seasons under a two-week clipping interval treatment. Clipping at three-week intervals resulted in only a 13% reduction.

Graber et al. (1927) showed that the productivity of bluegrass (Poa pratensis L.) was reduced after two years of frequent cuttings to less than one-fourth of adjacent bluegrass cut only once at maturity.

Owensby et al. (1974) found that with increased clipping frequency during one growing season, the herbage yields of big bluestem (Andropogon gerardi Vitman) declined linearly the following year.

Multiple defoliation studies showed that, in general, as the intensity of cutting increased, the herbage yield, vigor, and total nonstructural carbohydrate (T.N.C.) reserve levels of plants were greatly reduced (Trlica and Cook 1971 1972, Owensby et al. 1974).

Welch (1968) reported similar plant responses to varying grazing intensities.

Branson (1953) pointed out the importance of the position of the apical meristem in the response of a grass to defoliation. Indeed, heavy clipping treatments may injure or remove the plant growing points, resulting in reduced tillering capability. McKendrick and Sharp (1970) found a high correlation between tiller density and herbage production. Owensby et al. (1974) reported identical results.

Biswell and Weaver (1933), Crider (1955), and Alberda (1957) found that repeated intensive defoliations resulted in an inhibition of underground stem growth and sometimes led to the death of the pre-existing roots and rhizomes.

Trlica (1977) documented how renewed plant regrowth was directly linked to the underground stored food reserves. Repeated defoliations may cause the depletion of the reserve carbohydrates. Thus, regrowth can no longer occur and as a consequence yields get depressed, particularly when the intervals between defoliations are not long enough to allow the replenishment of the storage organs in reserve substances.

Laycock and Conrad (1969) found that foliage removal during periods of active growth was less detrimental than when plants were flowering



or fruiting. Herbage yields were also greater in early and mid season, than in late season. Cook (1966) found that late season clipping resulted in lowered yield and vigor of warm-season grasses. The lowered herbage production in late season was attributed to the less favorable environmental factors for photosynthesis such as moisture (Bukey and Weaver 1939) and higher temperatures (Owensby et al. 1970a). Trlica et al. (1977) reported that after a rest period of 26 months, the root T.N.C. levels of previously defoliated blue grama plants had been restored to those of the control ones. Nevertheless, the same rest period was insufficient for the recovery of herbage yield. They attributed this to the reduction of the underground biomass that resulted from the previous intensive defoliations.

Cook and Child (1971) predicted that more than 7 years of nonuse was required to allow several salt desert species to rebuild normal vigor after cessation of various defoliation treatments.

Grazing, similarly to clipping, does result in lowered carbohydrate reserves. Rains et al. (1975) found that grazed big bluestem had lower T.N.C. levels during the growing season. Lowered food reserves could have detrimental effects on subsequent plant growth (Jameson 1964).

Under grazing situations, animals usually select palatable plant parts and nutritious forage species first. As animals continue to graze the same plants over and over, they place additional stress on those species (Angell 1978); resulting in a decrease of the desirable range species and an increase of the undesirable ones (Aldous 1930). This is likely to occur under the grazing systems that allow continued selectivity to the animals (Smith and Owensby 1978).

## Forage Quality

A primary role of forages in the diet of animals is to provide energy (Reid et al. 1959). Several plant factors as well as animal factors intervene in the determination of digestible energy which is of utmost importance in terms of forage conversion to animal product, along with the environmental factors. Among the plant factors we would list chemical composition, cell wall constituents, protein content, stage of maturity, leaf to stem ratio, green to dead ratio, to name a few.

Hanna et al. (1976) suggested that plant stems reduce both animal intake and forage digestibility because of their secondary thickened and lignified cells; as well as their lower protein content (Aldous 1930) especially with advanced maturity.

Kilcher and Troelsen (1973) monitored the change of crude protein (C.P.) and cell wall lignin in bromegrass (Bromus inermis Leyss.) from the juvenile stage to full maturity. The C.P. content declined from 25% to 8% while the lignin content increased from 45% to 60% in leaves, and from 55% to 70% in stems over the same period, thereby lowering the energy digestibility of both leaves and stems.

Lewis et al. (1975) showed that the C.P. content of several blue-stems in the pine-wiregrass range, declined from 10.2% in April to 3.2% in October. In vitro dry matter digestibility fell from 54.0% to 34.0% over the same period.

Frequent defoliations had been suggested as a means to prevent shading of the older leaves by the newly developed leaves and tillers. The collected herbage would in consequence be greener, with younger

forage, less stems, and a higher green to dead leaf ratio. As a result, higher nutritional quality would be expected (Beaty and Engel 1980).

McKendrick et al. (1975) found that when big bluestem plants were subjected to grazing, the secondary shoots failed to joint. Thus stemminess could be avoided by defoliation. However, the same authors found no tertiary shoots which meant that big bluestem forage quality may depend on leaf senescence rate that could also be controlled to some extent by frequency of defoliation.

Owensby et al. (1970a) found that the nitrogen content in big bluestem herbage declined in each successive month such that by September 1 the nitrogen content was one-third of that found on June 1.

Murneek (1932) suggested another reason for the herbage nitrogen decline. He found increased amounts of nitrogen reserves stored in the roots and rhizomes with advancing maturity. Owensby et al. (1977) confirmed this by their finding that the build-up of belowground nitrogen reserves in big bluestem occurred between mid-August to late season when roots were growing and new rhizomes being formed. The nitrogen reserves decreased in the early season with the initiation of growth in the aboveground material.

Although Prates et al. (1975) found that C.P. levels remained fairly constant throughout the season, there was an ascendant trend in lignin content which significantly reduced the digestibility of bahiagrass (Paspalum notatum Flugge). Kamstra (1973) found the same increasing trend in fiber, lignin and cuticular material in some important range species in South Dakota with advancing maturity.

Other aspects associated with lower quality forage in the summer have been found. Smith (1977) noted a decrease in the levels of soluble

carbohydrates, whereas Bush et al. (1972) found increased alkaloid concentrations. Eck et al. (1975) found that although the levels of some important mineral constituents (nitrogen, phosphorus, potassium, and magnesium) remained quite constant during the growing season, there was a declining trend in the concentration of these elements with aging and weathered forage. The relative constancy in element concentration was primarily maintained by the more frequent defoliation treatments.

In the late season, not only plant maturation is of concern, but also unfavorable environmental factors may contribute to lower forage quality. Kaiser et al. (1974) and Smith (1977) found that summer temperatures reduced the growth rate and resulted in lowered quality herbage because high temperatures cause protein denaturation and disruption of protoplasmic structure. Haferkamp (1982) found that very dry and hot periods would enhance maturation of forage and reduce regrowth of defoliated plants. However, in the spring and early summer when moisture was adequate and temperatures were not excessive, forage quality was not affected.

Owensby et al. (1970b) showed that nitrogen fertilization increased water use efficiency and C.P. content of big bluestem except in the late season because of less favorable weather conditions.

Burton et al. (1963) proposed the imposition of shorter cutting intervals to maintain high forage quality throughout the season by keeping plants and plant parts in a younger stage of development. This was substantiated by Osman (1979) who found that with a six-week clipping interval, the C.P. content of some tropical grasses was reduced by 50% or more, depending on the species, compared to the protein levels of bi-weekly cut herbage.

Kilcher (1981) suggested another management practice in order to benefit from maximum forage quality. He recommended increased stocking rates so that, in his words ". . . the crop, so to speak, does not get too far ahead of the animals."

Both increased defoliation frequency and stocking rate constitute the primary management tools of S.D.G. systems. Heitschmidt et al. (1982c) found that the C.P. content of live herbage remained relatively constant throughout the season. However, Taylor et al. (1980) found that under S.D.G., forage digestibility was lowered in the late season, and so were intake and overall nutritional quality, resulting in lower animal gains (Corbett 1978).

#### Carbohydrate Reserves

Range grasses store carbohydrates primarily in the stems including rhizomes and stolons (Sampson and McCarty 1930, White 1973) during favorable periods of surplus photosynthates. They are translocated from the leaves where they are manufactured to the storage organs in a "dynamic source-sink relationship" (Moser 1977, Trlica 1977). These substances are mobilized and retranslocated during periods of regrowth following a period of dormancy, periods of stress when normal photosynthesis processes are hindered such as after a severe reduction in leaf area, drought, or winter respiration; and finally during periods when the need for these carbohydrates exceed its productivity and/or its availability particularly with the development of strong sinks such as during production of roots on new rhizomes (McKendrick 1971).

Although Graber et al. (1927) included nitrogenous compounds in plant reserve constituents; most researchers investigate only carbohydrates,

because they are the most important substances in supporting regrowth (White 1973). Smith (1969) suggested the term of total nonstructural carbohydrates (T.N.C.) to designate the readily available carbohydrate energy to the plant. Structural carbohydrates, hemicellulose, cellulose and pentosans, are thought to be less important reserve constituents (Weinmann 1948).

De Cugnac (1931) distinguished two groups of grasses. Those of tropical or subtropical regions, or "sacchariferes"; and the others of temperate regions or "levuliferes". The former accumulate their reserve carbohydrates essentially as starch; the latter as fructosans (Smith 1968).

The main form of carbohydrate translocated is as sucrose molecules (Smith and Leinweber 1973) by symplastic movement along with water in the phloem (Moser 1977).

Several authors monitored the fluctuations of T.N.C. reserves on a daily basis (White 1973). Although some slight variations occur from one species to another, the trend of daily fluctuations is primarily the same (Holt and Hilst 1969). The highest T.N.C. concentrations in the aerial plant parts occurred about 6 pm. By contrast, the lowest values occurred at 6 am.

The annual cycle of carbohydrate reserve levels in the storage organs of plants follow what Trlica (1977) termed as a V- or U-shaped curve. In both cases, the cycle starts by an upward translocation in response to growth initiation demands. McCarty and Price (1942) found that the first 10% of the annual growth consumed about 75% of the root reserves. Then, with the V-shaped curve species a rapid build-up of the reserves occur; whereas with the U-shaped pattern, the build-up occurs later when the plant approaches maturity.

Environmental factors and defoliations can affect seriously the dynamic source-sink relationship. For instance, by hindering photosynthesis, water stress would decrease T.N.C. accumulation levels (Bukey and Weaver 1939). Brown and Blaser (1970) reported increased T.N.C. levels following a drought. This was due to a breakdown of the carbon-containing nitrogenous compounds into carbohydrates.

Owensby et al. (1970a) showed that clipping in the late season was detrimental to carbohydrate reserve replenishment before the onset of dormancy. Trlica and Cook (1972) made similar observations about late season clipping. They found that the expected amount of growth from the defoliated plants was positively correlated with the time remaining for favorable photosynthesis processes in late season.

Reardon and Merrill (1974) reported that grazed cane bluestem (Bothriochloa barbinodis Lag.) plants exhibited better vigor than ungrazed plants. Late in the season, the grazed plants benefited from adequate moisture and temperature to make some growth resulting in increased T.N.C. reserves. The undefoliated plants, however, failed to do so, because of an already achieved maturity.

Under intensive early stocking (E.I.S.), the T.N.C. reserves of big bluestem were, by the end of the growing season, comparable to those under continuous season long stocking (C.S.L.S.). The rest period during the second half of the season provided under E.I.S. allowed the species to regain vigor despite the double stocking rate in the early season (Owensby et al. 1977).

Buwai and Trlica (1977) proposed 5- and 6-pasture rest rotation grazing systems in order to allow the key range species to regain vigor by giving them sufficient rest periods following late season utilization.



Repeated defoliations on plants would cause a repeated drawdown of the T.N.C. reserves during primarily the first few days of subsequent regrowth (White 1973). Depending on the intensity of defoliation and the length of the rest period, subsequent T.N.C. storage replenishment will be affected by the amount of regrowth achieved or in other words amount of leaf area left. Donart and Cook (1970) and Trlica and Cook (1971) found that plants that were allowed to make 20% of the total anticipated growth had higher T.N.C. reserves than those allowed to make 10% only.

Nevertheless, severe clipping intensities are likely to injure plant meristems, thereby delaying the production of new tillers resulting in lowered yields and plant food reserves (Daubenmire 1947, Singh and Mall 1976).

Neiland and Curtis (1956) found that regardless of defoliation intensity, the number of total shoots produced by big bluestem were significantly reduced when it was subjected to clipping. They related the species decrease to the removal of the dormant buds by defoliation. This decline was shown by Owensby et al. (1974) to be carried over in subsequent years in the case of continued clipping or grazing. Thus a prolonged reduction in photosynthetic area will eventually be accompanied by impaired root production and lowered food reserves. McKendrick (1971) reported that no teritary shoots developed on big bluestem plants that were intensively defoliated. This reduced tiller formation was attributed to an inhibition of root and rhizome growth over the subsequent years, following intensive multiple defoliations (Alberda 1957, Crider 1955, Biswell and Weaver 1933).

Owensby et al. (1974) made similar observations, and found that even after one year rest; big bluestem plants did not recover from



previous intensive clipping treatments. It was then concluded that intensive use on bluestem range should be avoided even if it was over only one season, because of a carry-over mechanism of lowered vigor into the following years as a result of intensive defoliation given earlier; thus resulting in big bluestem plant destruction over a period of a few years (Kinsinger and Hopkins 1961, Bukey and Weaver 1939).

Quantity and quality of carbohydrate reserves that are necessary for plant growth and survival (McKendrick 1971), should be the cornerstone of any grazing system or management practice in order to maintain "critical levels" of carbohydrate reserves (Cook 1966) so that persistence of the key range species is guaranteed.

To do so, knowledge of both top and belowground plant parts' behavior pattern is needed. Any use should be based upon the minimum photosynthetic leaf area necessary in order not to hinder the light energy interception and conversion processes. Intensity and frequency of use should also take account of the environmental conditions that prevail at any time of the season; as well as tiller production and root growth periods of the key range species.

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Table A.1 Analysis of variance on the cumulated change in big bluestem herbage production (summed over rotations), using R1 yield as covariate. (May - October, 1981).

| Source of Variation          | D.F. | Sum of Squares  | F-Value              | Probability<br>of Greater F |
|------------------------------|------|-----------------|----------------------|-----------------------------|
| MODEL                        | 79   | 31477.01596597  | 4.95                 | 0.0001                      |
| ERROR                        | 64   | 5151.00900000   | R-SQUARE = 0.859370  |                             |
| CORRECTED TOTAL              | 143  | 36628.02496597  | CHANGE MEAN = 3.6367 |                             |
|                              |      | C.V. = 246.6859 | STD DEV = 8.9713     |                             |
| Pasture                      | 7    | 4178.40331597   | 4.12                 | 0.0090                      |
| Block (pasture)              | 16   | 2317.02303333   |                      |                             |
| Frequency                    | 1    | 739.88533403    | 8.12                 | 0.0116                      |
| Frequency x pasture          | 7    | 760.96064931    | 1.19                 | 0.3609                      |
| Frequency x block (pasture)  | 16   | 1458.48536667   |                      |                             |
| Height                       | 2    | 18952.40417639  | 117.74               | 0.0001                      |
| Height x frequency           | 2    | 177.14588472    | 1.10                 | 0.3389                      |
| Height x pasture             | 14   | 2206.28295694   | 1.96                 | 0.0361                      |
| Height x frequency x pasture | 14   | 686.42524861    | 0.61                 | 0.8477                      |

Table A.2 Analysis of variance on the change in big bluestem herbage production, using R1 yield as covariate. Rotation 5 deleted. (May - October, 1981).

| Source of Variation                  | D.F. | Sum of Squares  | F-Value              | Probability<br>of Greater F |
|--------------------------------------|------|-----------------|----------------------|-----------------------------|
| MODEL                                | 239  | 13810.96277199  | 5.45                 | 0.0001                      |
| ERROR                                | 192  | 2036.00000000   | R-SQUARE = 0.871521  |                             |
| CORRECTED TOTAL                      | 431  | 15846.96277199  | CHANGE MEAN = 1.7640 |                             |
|                                      |      | C.V. = 184.6029 | STD DEV = 3.2564     |                             |
| Pasture                              | 7    | 1130.64513310   | 3.52                 | 0.0177                      |
| Block (pasture)                      | 16   | 735.18694444    |                      |                             |
| Frequency                            | 1    | 17.94630208     | 0.63                 | 0.4375                      |
| Frequency x pasture                  | 7    | 306.71041088    | 1.55                 | 0.2212                      |
| Frequency x block (pasture)          | 16   | 452.71064815    |                      |                             |
| Height                               | 2    | 5007.63056713   | 102.54               | 0.0001                      |
| Height x frequency                   | 2    | 147.60107639    | 3.02                 | 0.0557                      |
| Height x pasture                     | 14   | 600.81193287    | 1.76                 | 0.0656                      |
| Height x frequency x pasture         | 14   | 238.37068287    | 0.70                 | 0.7686                      |
| Height x frequency x pasture x block | 64   | 1562.67740741   |                      |                             |
| Rotation                             | 2    | 1176.78695602   | 55.49                | 0.0001                      |
| Rotation x pasture                   | 14   | 1142.24554398   | 7.69                 | 0.0001                      |
| Rotation x frequency                 | 2    | 11.81107639     | 0.56                 | 0.5739                      |
| Rotation x frequency x pasture       | 14   | 316.94401620    | 2.13                 | 0.0117                      |
| Rotation x height                    | 4    | 322.04988426    | 7.59                 | 0.0001                      |
| Rotation x height x frequency        | 4    | 19.98118056     | 0.47                 | 0.7569                      |
| Rotation x height x pasture          | 28   | 393.17733796    | 1.32                 | 0.1392                      |
| Rotation x height x pasture x freq.  | 28   | 227.67567130    | 0.77                 | 0.7949                      |

Table A.3 Analysis of variance on the cumulated change in total vegetation herbage production (summed over rotations), using R1 yield as covariate. (May - October, 1981).

| Source of Variation          | D.F. | Sum of Squares   | F-Value              | Probability<br>of Greater F |
|------------------------------|------|------------------|----------------------|-----------------------------|
| MODEL                        | 79   | 1166125.51946108 | 15.68                | 0.0001                      |
| ERROR                        | 352  | 331275.96187588  | R-SQUARE = 0.778766  |                             |
| CORRECTED TOTAL              | 431  | 1497401.48133696 | CHANGE MEAN = 1.3835 |                             |
|                              |      | C.V. = 2223.7846 | STD DEV = 30.7653    |                             |
| Pasture                      | 7    | 295209.59980948  | 30.89                | 0.0001                      |
| Block (pasture)              | 16   | 21843.10924547   |                      |                             |
| Frequency                    | 1    | 27609.67837666   | 37.63                | 0.0001                      |
| Frequency x pasture          | 7    | 5664.26995113    | 1.10                 | 0.4072                      |
| Frequency x block (pasture)  | 16   | 11739.53191674   |                      |                             |
| Height                       | 2    | 697289.93161642  | 370.46               | 0.0001                      |
| Height x frequency           | 2    | 9622.68432481    | 5.11                 | 0.0067                      |
| Height x pasture             | 14   | 85832.77653399   | 6.51                 | 0.0001                      |
| Height x frequency x pasture | 14   | 11313.93768639   | 0.86                 | 0.6100                      |

Table A.4 Analysis of variance on the change in total vegetation herbage production, using R1 yield as covariate. Rotation 5 deleted. (May - October, 1981).

| Source of Variation                  | D.F. | Sum of Squares  | F-Value              | Probability<br>of Greater F |
|--------------------------------------|------|-----------------|----------------------|-----------------------------|
| MODEL                                | 239  | 390429.39018701 | 19.31                | 0.0001                      |
| ERROR                                | 1056 | 89320.95309523  | R-SQUARE = 0.813818  |                             |
| CORRECTED TOTAL                      | 1295 | 479750.34328224 | CHANGE MEAN = 3.1336 |                             |
|                                      |      | C.V. = 294.3337 | STD DEV = 9.2232     |                             |
| Pasture                              | 7    | 75386.86178536  | 33.14                | 0.0001                      |
| Block (pasture)                      | 16   | 5199.09273948   |                      |                             |
| Frequency                            | 1    | 0.24870544      | 0.00                 | 0.9716                      |
| Frequency x pasture                  | 7    | 1870.71036517   | 1.41                 | 0.2693                      |
| Frequency x block (pasture)          | 16   | 3040.60524466   |                      |                             |
| Height                               | 2    | 175724.43210027 | 335.28               | 0.0001                      |
| Height x frequency                   | 2    | 184.23513070    | 0.35                 | 0.7050                      |
| Height x frequency x pasture         | 14   | 21023.87827348  | 5.73                 | 0.0001                      |
| Height x frequency x pasture x block | 64   | 16771.72937776  |                      |                             |
| Rotation                             | 2    | 32658.24696760  | 193.05               | 0.0001                      |
| Rotation x pasture                   | 14   | 28968.56926540  | 24.46                | 0.0001                      |
| Rotation x frequency                 | 2    | 133.97551983    | 0.79                 | 0.4553                      |
| Rotation x frequency x pasture       | 14   | 2608.19295492   | 2.20                 | 0.0067                      |
| Rotation x height                    | 4    | 16266.00805268  | 48.08                | 0.0001                      |
| Rotation x height x frequency        | 4    | 330.09305125    | 0.97                 | 0.4229                      |
| Rotation x height x pasture          | 28   | 5748.24920830   | 2.43                 | 0.0001                      |
| Rotation x height x pasture x freq.  | 28   | 1496.03301812   | 0.63                 | 0.9345                      |

Table A.5 Analysis of variance on acid detergent fiber (A.D.F.) determinations  
(January - April, 1982).

| Source of Variation                  | D.F. | Sum of Squares | F-Value               | Probability<br>of greater F |
|--------------------------------------|------|----------------|-----------------------|-----------------------------|
| MODEL                                | 287  | 8730.28339724  | 4.89                  | 0.0001                      |
| ERROR                                | 288  | 1789.75744166  | R-SQUARE = 0.829872   |                             |
| CORRECTED TOTAL                      | 575  | 10520.04083890 | A.D.F. MEAN = 42.8226 |                             |
|                                      |      | C.V. = 5.8214  | STD DEV = 2.4929      |                             |
| Pasture                              | 7    | 482.98359099   | 9.77                  | 0.0001                      |
| Block (pasture)                      | 16   | 113.04582083   |                       |                             |
| Frequency                            | 1    | 4.31254445     | 0.76                  | 0.3971                      |
| Frequency x pasture                  | 7    | 44.92030069    | 1.13                  | 0.3944                      |
| Frequency x block (pasture)          | 16   | 91.12366944    |                       |                             |
| Height                               | 2    | 24.70900895    | 1.83                  | 0.1690                      |
| Height x frequency                   | 2    | 0.61240218     | 0.05                  | 0.9557                      |
| Height x pasture                     | 14   | 154.94927022   | 1.64                  | 0.0929                      |
| Height x frequency x pasture         | 14   | 53.85277560    | 0.57                  | 0.8790                      |
| Height x frequency x pasture x block | 64   | 432.50881806   |                       |                             |
| Rotation                             | 3    | 5719.61601494  | 306.79                | 0.0001                      |
| Rotation x pasture                   | 21   | 866.18189409   | 6.64                  | 0.0001                      |
| Rotation x frequency                 | 3    | 37.36888368    | 2.00                  | 0.1118                      |
| Rotation x frequency x pasture       | 21   | 66.74397118    | 0.51                  | 0.9647                      |
| Rotation x height                    | 6    | 138.40458273   | 3.71                  | 0.0014                      |
| Rotation x height x frequency        | 6    | 29.98209365    | 0.80                  | 0.5674                      |
| Rotation x height x pasture          | 42   | 206.73015200   | 0.79                  | 0.8184                      |
| Rotation x height x pasture x freq.  | 42   | 262.23760357   | 1.00                  | 0.4688                      |

Table A.6 Analysis of variance on acid detergent fiber (A.D.F.) determinations of rotation 1 (R1)  
(January - April, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value       | Probability<br>of greater F |
|------------------------------|------|----------------|---------------|-----------------------------|
| MODEL                        | 79   | 1155.65431042  | 2.51          | 0.0001                      |
| ERROR                        | 64   | 373.55843889   | R-SQUARE =    | 0.755718                    |
| CORRECTED TOTAL              | 143  | 1529.21274931  | A.D.F. MEAN = | 37.7387                     |
|                              |      | C.V. = 6.4018  | STD DEV =     | 2.4159                      |
| Pasture                      | 7    | 615.25562153   | 18.33         | 0.0001                      |
| Block (pasture)              | 16   | 76.71815278    |               |                             |
| Frequency                    | 1    | 19.47015625    | 2.84          | 0.1115                      |
| Frequency x pasture          | 7    | 64.56461042    | 1.34          | 0.2934                      |
| Frequency x block (pasture)  | 16   | 109.79422500   |               |                             |
| Height                       | 2    | 63.39990243    | 5.43          | 0.0066                      |
| Height x frequency           | 2    | 11.82390312    | 1.01          | 0.3689                      |
| Height x pasture             | 14   | 141.52974201   | 1.73          | 0.0708                      |
| Height x frequency x pasture | 14   | 53.09699688    | 0.65          | 0.8128                      |

Table A.7 Analysis of variance on acid detergent fiber (A.D.F.) determinations of rotation 2 (R2)  
(January - April, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value       | Probability<br>of greater F |
|------------------------------|------|----------------|---------------|-----------------------------|
| MODEL                        | 79   | 776.05466667   | 1.55          | 0.0345                      |
| ERROR                        | 64   | 404.44563333   | R-SQUARE =    | 0.657395                    |
| CORRECTED TOTAL              | 143  | 1180.50030000  | A.D.F. MEAN = | 42.6467                     |
|                              |      | C.V. = 5.8946  | STD DEV =     | 2.5138                      |
| Pasture                      | 7    | 280.10742222   | 6.24          | 0.0012                      |
| Block (pasture)              | 16   | 102.64808611   |               |                             |
| Frequency                    | 1    | 3.92370070     | 0.46          | 0.5057                      |
| Frequency x pasture          | 7    | 16.74364375    | 0.28          | 0.9516                      |
| Frequency x block (pasture)  | 16   | 135.43359722   |               |                             |
| Height                       | 2    | 44.55444479    | 3.53          | 0.0353                      |
| Height x frequency           | 2    | 1.16292326     | 0.09          | 0.9122                      |
| Height x pasture             | 14   | 94.93714132    | 1.07          | 0.3980                      |
| Height x frequency x pasture | 14   | 96.54370729    | 1.09          | 0.3825                      |

Table A.8 Analysis of variance on acid detergent fiber (A.D.F.) determinations of rotation 3 (R3)  
(January - April, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value               | Probability<br>of greater F |
|------------------------------|------|----------------|-----------------------|-----------------------------|
| MODEL                        | 79   | 400.19090677   | 1.10                  | 0.3434                      |
| ERROR                        | 64   | 293.82302222   | R-SQUARE = 0.576632   |                             |
| CORRECTED TOTAL              | 143  | 694.01392899   | A.D.F. MEAN = 45.5179 |                             |
|                              |      | C.V. = 4.7073  | STD DEV = 2.1427      |                             |
| Pasture                      | 7    | 108.20982761   | 2.99                  | 0.0331                      |
| Block (pasture)              | 16   | 82.80204722    |                       |                             |
| Frequency                    | 1    | 14.13446684    | 4.57                  | 0.0483                      |
| Frequency x pasture          | 7    | 11.40127344    | 0.53                  | 0.8016                      |
| Frequency x block (pasture)  | 16   | 49.45621389    |                       |                             |
| Height                       | 2    | 17.77498368    | 1.94                  | 0.1527                      |
| Height x frequency           | 2    | 7.68578368     | 0.84                  | 0.4377                      |
| Height x pasture             | 14   | 50.92159687    | 0.79                  | 0.6737                      |
| Height x frequency x pasture | 14   | 57.80471354    | 0.90                  | 0.5634                      |



Table A.9 Analysis of variance on acid detergent fiber (A.D.F.) determinations of rotation 4 (R4)  
(January - April, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value               | Probability<br>of greater F |
|------------------------------|------|----------------|-----------------------|-----------------------------|
| MODEL                        | 79   | 792.91201233   | 1.06                  | 0.4009                      |
| ERROR                        | 64   | 603.78583333   | R-SQUARE = 0.567705   |                             |
| CORRECTED TOTAL              | 143  | 1396.69784566  | A.D.F. MEAN = 45.3873 |                             |
|                              |      | C.V. = 6.7673  | STD DEV = 3.0715      |                             |
| Pasture                      | 7    | 345.59261372   | 7.22                  | 0.0005                      |
| Block (pasture)              | 16   | 109.45064444   |                       |                             |
| Frequency                    | 1    | 4.15310434     | 0.79                  | 0.3884                      |
| Frequency x pasture          | 7    | 18.95474427    | 0.51                  | 0.8120                      |
| Frequency x block (pasture)  | 16   | 84.51885556    |                       |                             |
| Height                       | 2    | 37.38426077    | 1.98                  | 0.1463                      |
| Height x frequency           | 2    | 9.92188576     | 0.53                  | 0.5936                      |
| Height x pasture             | 14   | 74.29094201    | 0.56                  | 0.8839                      |
| Height x frequency x pasture | 14   | 108.64496146   | 0.82                  | 0.6424                      |

Table A.10 Analysis of variance on crude protein (C.P.) determinations . Pastures 1, 2 and 3 of rotation 1; and pastures 7 and 8 of rotation 4 are missing. (April - May, 1982).

| Source of Variation                  | D.F. | Sum of Squares | F-Value             | Probability of greater F |
|--------------------------------------|------|----------------|---------------------|--------------------------|
| MODEL                                | 257  | 1092.01132593  | 10.45               | 0.0001                   |
| ERROR                                | 228  | 92.71917222    | R-SQUARE = 0.921738 |                          |
| CORRECTED TOTAL                      | 485  | 1184.73049815  | C.P. MEAN = 7.3033  |                          |
|                                      |      | C.V. = 8.7317  | STD DEV = 0.6377    |                          |
| Pasture                              | 7    | 47.35253287    | 10.77               | 0.0001                   |
| Block (pasture)                      | 16   | 10.05308889    |                     |                          |
| Frequency                            | 1    | 6.23107181     | 7.47                | 0.0147                   |
| Frequency x pasture                  | 7    | 3.45199624     | 0.59                | 0.7538                   |
| Frequency x block (pasture)          | 16   | 13.34150000    |                     |                          |
| Height                               | 2    | 1.19726790     | 0.93                | 0.4017                   |
| Height x frequency                   | 2    | 0.83603251     | 0.65                | 0.5275                   |
| Height x pasture                     | 14   | 8.95157377     | 0.99                | 0.4755                   |
| Height x frequency x pasture         | 14   | 13.09062027    | 1.45                | 0.1589                   |
| Height x frequency x pasture x block | 64   | 41.40923889    |                     |                          |
| Rotation                             | 3    | 802.03164046   | 657.41              | 0.0001                   |
| Rotation x pasture                   | 16   | 51.24168593    | 7.88                | 0.0001                   |
| Rotation x frequency                 | 3    | 6.49964050     | 5.33                | 0.0016                   |
| Rotation x frequency x pasture       | 16   | 7.52635255     | 1.16                | 0.3047                   |
| Rotation x height                    | 6    | 31.41205117    | 12.87               | 0.0001                   |
| Rotation x height x frequency        | 6    | 6.03790767     | 2.47                | 0.0244                   |
| Rotation x height x pasture          | 32   | 25.25206272    | 1.94                | 0.0029                   |
| Rotation x height x pasture x freq.  | 32   | 16.09506177    | 1.24                | 0.1888                   |

Table A.11 Analysis of variance on crude protein (C.P.) determinations of rotation 1 (R1).

Pastures 1, 2 and 3 are missing. (April - May, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|------------------------------|------|----------------|---------------------|-----------------------------|
| MODEL                        | 49   | 65.87791556    | 1.50                | 0.0929                      |
| ERROR                        | 40   | 35.75453333    | R-SQUARE = 0.648198 |                             |
| CORRECTED TOTAL              | 89   | 101.63244889   | C.P. MEAN = 9.5751  |                             |
|                              |      | C.V. = 9.8740  | STD DEV = 0.9454    |                             |
| Pasture                      | 4    | 13.81221556    | 6.22                | 0.0088                      |
| Block (pasture)              | 10   | 5.55080000     |                     |                             |
| Frequency                    | 1    | 0.19787111     | 0.12                | 0.7324                      |
| Frequency x pasture          | 4    | 0.31456222     | 0.05                | 0.9947                      |
| Frequency x block (pasture)  | 10   | 15.99860000    |                     |                             |
| Height                       | 2    | 11.44427556    | 6.40                | 0.0039                      |
| Height x frequency           | 2    | 1.76976889     | 0.99                | 0.3805                      |
| Height x pasture             | 8    | 7.49222444     | 1.05                | 0.4180                      |
| Height x frequency x pasture | 8    | 9.29759778     | 1.30                | 0.2712                      |

Table A.12 Analysis of variance on crude protein (C.P.) determinations of rotation 2 (R2)  
(April - May, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|------------------------------|------|----------------|---------------------|-----------------------------|
| MODEL                        | 79   | 94.51589375    | 3.01                | 0.0001                      |
| ERROR                        | 64   | 25.40108889    | R-SQUARE = 0.788178 |                             |
| CORRECTED TOTAL              | 143  | 119.91698264   | C.P. MEAN = 7.7709  |                             |
|                              |      | C.V. = 8.1071  | STD DEV = 0.6299    |                             |
| Pasture                      | 7    | 50.84993264    | 10.09               | 0.0001                      |
| Block (pasture)              | 16   | 11.51996667    |                     |                             |
| Frequency                    | 1    | 0.16605625     | 0.42                | 0.5285                      |
| Frequency x pasture          | 7    | 4.42228264     | 1.58                | 0.2118                      |
| Frequency x block (pasture)  | 16   | 6.39854444     |                     |                             |
| Height                       | 2    | 0.46615139     | 0.59                | 0.5588                      |
| Height x frequency           | 2    | 1.20240417     | 1.51                | 0.2276                      |
| Height x pasture             | 14   | 13.85771528    | 2.49                | 0.0069                      |
| Height x frequency x pasture | 14   | 5.63284028     | 1.01                | 0.4514                      |

Table A.13 Analysis of variance on crude protein (C.P.) determinations of rotation 3 (R3)  
(April - May, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|------------------------------|------|----------------|---------------------|-----------------------------|
| MODEL                        | 79   | 46.94923819    | 1.64                | 0.0207                      |
| ERROR                        | 64   | 23.16884444    | R-SQUARE = 0.669574 |                             |
| CORRECTED TOTAL              | 143  | 70.11808264    | C.P. MEAN = 6.4203  |                             |
|                              |      | C.V. = 9.3714  | STD DEV = 0.6017    |                             |
| Pasture                      | 7    | 20.19734375    | 9.20                | 0.0001                      |
| Block (pasture)              | 16   | 5.01728889     |                     |                             |
| Frequency                    | 1    | 0.77000625     | 4.88                | 0.0422                      |
| Frequency x pasture          | 7    | 4.96411042     | 4.49                | 0.0061                      |
| Frequency x block (pasture)  | 16   | 2.52680000     |                     |                             |
| Height                       | 2    | 0.48383472     | 0.67                | 0.5161                      |
| Height x frequency           | 2    | 1.08745417     | 1.50                | 0.2304                      |
| Height x pasture             | 14   | 5.38548750     | 1.06                | 0.4072                      |
| Height x frequency x pasture | 14   | 6.51691250     | 1.29                | 0.2410                      |

Table A.14 Analysis of variance on crude protein (C.P.) determinations of rotation 4 (R4).

Pastures 7 and 8 are missing. (April - May, 1982).

| Source of Variation          | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|------------------------------|------|----------------|---------------------|-----------------------------|
| MODEL                        | 59   | 72.69045463    | 3.22                | 0.0001                      |
| ERROR                        | 48   | 18.34088889    | R-SQUARE = 0.798521 |                             |
| CORRECTED TOTAL              | 107  | 91.03134352    | C.P. MEAN = 5.9638  |                             |
|                              |      | C.V. = 10.3649 | STD DEV = 0.6181    |                             |
| Pasture                      | 5    | 13.73472685    | 8.39                | 0.0013                      |
| Block (pasture)              | 12   | 3.93076667     |                     |                             |
| Frequency                    | 1    | 11.59677870    | 35.55               | 0.0001                      |
| Frequency x pasture          | 5    | 1.27739352     | 0.78                | 0.5809                      |
| Frequency x block (pasture)  | 12   | 3.91487778     |                     |                             |
| Height                       | 2    | 20.21505741    | 26.45               | 0.0001                      |
| Height x frequency           | 2    | 2.81431296     | 3.68                | 0.0325                      |
| Height x pasture             | 10   | 7.46820926     | 1.95                | 0.0603                      |
| Height x frequency x pasture | 10   | 7.73833148     | 2.03                | 0.0511                      |

Table A.15 Analysis of variance on T.N.C. content of big bluestem rhizomes. Rotation 5 deleted.  
(May - July, 1982).

| Source of Variation           | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|-------------------------------|------|----------------|---------------------|-----------------------------|
| MODEL                         | 35   | 227.88521632   | 20.40               | 0.0001                      |
| ERROR                         | 36   | 11.48790833    | R-SQUARE = 0.952008 | T.N.C. MEAN = 5.8951        |
| CORRECTED TOTAL               | 71   | 239.37312465   | C.V. = 9.5825       | STD DEV = 0.5648            |
| Block                         | 2    | 0.41809144     |                     |                             |
| Frequency                     | 1    | 9.89754201     | 12.82               | 0.0699                      |
| Block x frequency             | 2    | 1.54458611     |                     |                             |
| Height                        | 2    | 70.52695903    | 42.32               | 0.0001                      |
| Height x frequency            | 2    | 0.55884653     | 0.34                | 0.7247                      |
| Block x height x frequency    | 8    | 6.66585278     |                     |                             |
| Rotation                      | 3    | 111.90732326   | 116.90              | 0.0001                      |
| Rotation x height             | 6    | 16.05773819    | 8.39                | 0.0001                      |
| Rotation x frequency          | 3    | 6.11347049     | 6.39                | 0.0014                      |
| Rotation x height x frequency | 6    | 4.19487847     | 2.19                | 0.0066                      |

Table A.16 Analysis of variance on T.N.C. content of big bluestem rhizomes collected from plots subjected to the uniform mowing frequency regime (1). Rotation 5 included.  
(May - July, 1982).

| Source of Variation | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|---------------------|------|----------------|---------------------|-----------------------------|
| MODEL               | 20   | 120.54190444   | 20.31               | 0.0001                      |
| ERROR               | 24   | 7.12139333     | R-SQUARE = 0.944217 | T.N.C. MEAN = 9.4093        |
| CORRECTED TOTAL     | 44   | 127.66329778   | C.V. = 9.4093       | STD DEV = 0.5447            |
| Block               | 2    | 0.34884111     |                     |                             |
| Height              | 2    | 48.69219111    | 68.12               | 0.0008                      |
| Block x height      | 4    | 1.42961556     |                     |                             |
| Rotation            | 4    | 55.32107000    | 46.60               | 0.0001                      |
| Rotation x height   | 8    | 14.75018667    | 6.21                | 0.0002                      |



Table A.17 Analysis of variance on T.N.C. content of big bluestem rhizomes collected from plots subjected to the mowing frequency regime (2) with varying rest periods.  
(May - July, 1982).

| Source of Variation | D.F. | Sum of Squares | F-Value             | Probability<br>of greater F |
|---------------------|------|----------------|---------------------|-----------------------------|
| MODEL               | 17   | 125.66437083   | 28.36               | 0.0001                      |
| ERROR               | 18   | 4.69125417     | R-SQUARE = 0.964012 | T.N.C. MEAN = 6.2658        |
| CORRECTED TOTAL     | 35   | 130.35562500   | C.V. = 8.1476       | STD DEV = 0.5105            |
| Block               | 2    | 1.42286667     |                     |                             |
| Height              | 2    | 36.35666250    | 13.11               | 0.0175                      |
| Block x height      | 4    | 5.54594583     |                     |                             |
| Rotation            | 3    | 75.33227500    | 96.35               | 0.0001                      |
| Rotation x height   | 6    | 7.00662083     | 4.48                | 0.0060                      |

- I - SIMULATED SHORT DURATION GRAZING SYSTEM: EFFECTS ON PRODUCTION OF BIG BLUESTEM AND ASSOCIATED SPECIES,
- II - SIMULATED SHORT DURATION GRAZING SYSTEM: EFFECTS ON ACID DETERGENT FIBER AND CRUDE PROTEIN CONTENT OF BIG BLUESTEM,
- III - SIMULATED SHORT DURATION GRAZING SYSTEM: EFFECTS ON TOTAL NONSTRUCTURAL CARBOHYDRATE RESERVES OF BIG BLUESTEM RHIZOMES

by

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Diplôme d'Ingénieur d'Application des Eaux et Forêts,  
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AN ABSTRACT OF A MASTER'S THESIS

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## ABSTRACT

A clipping study was conducted to simulate an 8-pasture SDG system. Big bluestem and associated species were subjected to 2.5, 10 and 15 cm clipping heights. Two clipping frequency regimes were used. The first consisted of 4-day intervals between pasture clippings season long. The second consisted of the same 4-day intervals from May 4 to July 15, then of 6-day intervals from July 16 to October 1. Production of big bluestem and total vegetation was assessed by using initial clipped yield of the first rotation as a covariate. Clipped big bluestem samples were analyzed for ADF and crude protein contents. Big bluestem rhizomes were sampled at dates corresponding to those of the eighth pasture clippings and the following spring, for total nonstructural carbohydrate (TNC) determinations.

A decreasing trend in production was observed due to the pasture sequence effect. Yields were lower in the last three pastures. Because of less defoliations and increased rest periods in late-season under the second clipping frequency regime, big bluestem and associated species produced more herbage than under the first clipping frequency regime. Production was greatest at 15 cm stubble height and was comparable to that obtained at 10 cm clipping height under the second frequency regime. Clipping at 2.5 cm was detrimental to herbage production. Maximum standing crop occurred in August, then decreased thereafter. At the fifth rotation, production was severely depressed at all defoliation intensities.

ADF increased with the season advance, peaked by August and levelled off thereafter. Crude protein decreased steadily throughout the season. Increased rest periods in late-season adversely affected forage quality.

Higher forage quality was obtained from herbage cut at 15 cm in early-season. Late in the season however, higher crude protein and lower ADF were found in herbage clipped at 2.5 cm.

Less defoliations and increased rest periods in late-season resulted in more carbohydrate reserve storage. Greatest TNC build-up occurred at the least defoliation intensity. Clipping at 2.5 cm resulted in depressed TNC levels the following spring.