EFFECT OF STOCKING RATE ON THE LOCATION OF STORAGE CARBOHYDRATES IN THE STUBBLE OF TROPICAL GRASSES

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ABSTRACT

Yearling steers (240 kg initial liveweight) were rotationally grazed (2 wk grazing, 4 wk rest) at 3 stocking rates (SR) of 7.5 (low), 10 (medium) and 15 (high) head/ha, on 3 stargrasses: 'UF-5' and 'McCaleb' (Cynodon aethiopicus *Clayton and Harlan) and 'Ona'* Cynodon nlemfuensis *Vanderyst var.* nlemfuensis); *and at the medium SR only on 'Transvala' digitgrass* (Digitaria decembens *Stent.*) *and 'Pensacola' bahiagrass* (Paspalum notatum *Flugge*). *Grazing commenced in early June 1976 and 1977 and continued for 168 days each year at the University of Florida Agricultural Research and Education Center, Ona, Florida on the sandy siliceous hypermethic family of aeric Haploquods. Total non-structural carbohydrate (TNC) concentration was monitored weekly during summer and autumn in 3 stubble regions; roots/crown (5 cm root + 2.5 cm crown), lower stubble (2.5 cm–10 cm) and upper stubble (> 10 cm).*

The region of highest TNC concentration depended mostly on species. The TNC in stargrasses was 5.0, 3.5 and 3.2% of DM for roots/crown, lower, and upper stubble regions, respectively. Bahiagrass roots/crown had 12.2% TNC compared to 3.6% in other regions. Concentration of TNC in Transvala from root to 10 cm stubble averaged 6.2% and the upper stubble averaged 4.7%. The TNC in roots/crown and lower stubble of stargrasses was linearly reduced by increased SR. These data suggest the need for varied grazing management of the tropical grasses in order to maintain a long-term productive stand. Transvala digitgrass should not be grazed below a stubble height of 17 cm to conserve stored TNC whereas bahiagrass could withstand close grazing. Medium to heavy grazing pressure could be imposed on stargrasses during summer but a more lenient pressure may be desirable in the autumn.

RESUMEN

Novillos de un año (240 kg peso vivo al entrar al experimento) pastorearon rotacionalmente (2 semanas pastoreo, 4 semanas descanso) a 3 cargas animales (SR) de 7.5 (baja), 10 (media) y 15 (alta) cabezas/ha en 3 cultivares de pasto estrella: "UF-5" y "McCaleb" (Cynodon aethiopicus *Clayton and Harlan) y "Ona"* Cynodon nlemfuensis *Vanderyst var.* nlemfuensis) *y con solamente la mitad de la carga animal en "Transvala"* (Digitaria decumbens *Stent.*) *y "Pensacola" bahiagrass* (Paspalum notatum *Flugge*). *El pastoreo empezó a principios de Junio de 1976 y 1977, continuando por 168 dias cada año, en el Centro de Investigación y Enseñanza Agricola, de la Universidad de Florida, en Ona, Florida, sobre un suelo arenoso siliceo hipermético de la familia aeric Haploquods. La concentración total de carbohidratos no estructurales (TNC) fué evaluada semanalmente durante el verano y el otoño en 3 regiones de las plantas después del pastoreo: raíces/corona (5 cm de raíz + 2.5 cm de corona) parte aérea baja (2.5 cm-10 cm) y parte aérea alta (> 10 cm).*

La región de mas alta concentración de TNC depende mayormente de la especie. La TNC en pasto estrella fué 5.0, 3.5 y 3.2% de MS para raíces/corona, parte aérea baja y alta, respectivamente. Las raíces/corona del pasto bahia (Bahiagrass) raíces/coronas tuvo 12.2% de concentración de TNC, comparada con el 3.6% en otras regiones. La TNC en Transvala, desde la raíz hasta 10 cm de residuo tuvo un promedio de 6.2% y el residuo superior tenía un promedio de 4.7%. La TNC en raíces/corona y residuo aéreo inferior de los estrellas, se redujo linealmente con el aumento de la carga animal. Estos datos indican la necesidad de un manejo del pastoreo diferente de las gramíneas tropicales, con el fin de mantener las pasturas productivas a largo plazo. Las gramíneas *digitaria Transvala, no deben de ser pastoreadas por debajo de una altura de residuo de 10-17 cm para conservar los TNC almacenados; mientras que el pasto bahía puede tolerar el pastoreo más intenso. Durante el verano, se podría imponer una presión de pastoreo mediana a alta a los pastos estrella, pero una presión más leve sería deseable en el otoño.*

INTRODUCTION

Pasture regrowth in a favourable environment is a function of energy from photosynthetic tissue and carbohydrate reserves in herbage tissues. Though non-structural carbohydrates may be stored temporarily in all plant parts, many scientists have identified roots (Weinmann 1948; Troughton 1957) and stem bases including stolons, corms and short rhizomes (Sullivan and Sprague 1943; Baker and Garwood 1961) as the major storage regions. Pasture management practices such as season of use and degree of utilization are partially based upon how they affect carbohydrate reserves in grasses (National Research Council 1962).

Many review articles and reports have emphasized the function of carbohydrate reserves during regrowth (Graber *et al.* 1927; May 1960, Trlica and Cook 1971, 1972; Menke 1973; Bokhari and Dyer 1974). Recent studies using labelled carbon-14 have provided direct evidence of the role of carbohydrate reserves in the regrowth of many plants (Ehara *et al.* 1966; Pearce *et al.* 1969; Smith and Martin 1970; Kobhari, 1977). Exhaustion of reserves as a result of excessive defoliation has generally been associated with reduction in vigour and ultimately pasture deterioration. Hence, characterization of reserves in storage organs can aid in detecting early symptoms of pasture deterioration before yield or persistence is seriously reduced. However, this subject is still controversial since several other workers on temperate grasses (Stoddart *et al.* 1975; Caldwell *et al.* 1981; Richards and Caldwell, 1985) have reported no correlation between regrowth and crown non-structural carbohydrate concentrations, total pools nor amounts utilized during regrowth. Most of the controversy on the importance of carbohydrate reserves in controlling regrowth rate was attributed to a number of factors (White 1973) such as variation in amount of photosynthetic tissue remaining after herbage removal; sampling for reserves too late after defoliation when the reserves have already been restored; and sampling wrong plant parts. Cook (1966) cautioned that proper management does not necessarily imply maintenance of maximum levels of carbohydrate reserves but that such reserves should not fall below a critical level at which tillers would die. Perennial ryegrass grown in growth chambers was unable to use carbohydrate reserves below 6% of dry weight and at this level, reserves inadequately supported the existing tiller population (Alberda 1966). Davies (1965) speculated that the critical level of carbohydrate reserves can be different among grass varieties and species and is affected by fertility, management, environment and season.

The increasing use of intensively managed tropical grasses for beef cattle production in Florida has stimulated research of factors influencing their productivity and persistence. Preliminary investigation during grazing trials has revealed that stargrasses retain higher concentrations of total non-structural carbohydrates (TNC) in their roots than above ground stubble (Adjei *et al.* 1985). The current experiment examined TNC concentration in 3 vertical stratifications of the stubble of 5 tropical pasture grasses and the effect of stocking rate (SR) on TNC storage location.

MATERIALS AND METHODS

The carbohydrate experiment was part of a grazing trial conducted on 7.8 ha of a sandy siliceous hyperthermic family of aeric Haploquods (Immokalee series) at the University of Florida Agricultural Research and Education Centre, Ona, Florida in 1976 and 1977. The Centre is located at 27°25′ North latitude, 81°55′ West longitude and an elevation of 26 m. The cultural practices, forage yield, quality and animal performance data was reported by Adjei *et al.* (1980). Three SR of 7.5 (low), 10 (medium), and 15 (high) yearling steers/ha were imposed on 3 stargrass pastures: 'UF-5' and 'McCaleb' (*Cynodon aethiopicus* Clayton and Harlan) and 'Ona' (*Cynodon nlemfuensis* Vanderyst var. *nlemfuensis*) forming a 3 × 3 factorial combination in a split plot arrangement with pasture as whole plots and SR as sub-plots. Additionally, the medium SR was imposed on 'Transvala' digitgrass (*Digitaria decumbens* Stent.) and 'Pensacola' bahiagrass (*Paspalum notatum* Flugge.) pastures in 2 field replicates each. Each pasture replicate consisted of 3 paddocks of equal size grazed in rotation, allowing for 2 weeks of grazing and 4 weeks of rest (regrowth) periods. Six yearling steers were assigned to each replicate and paddock size for the stargrasses was 0.26, 0.20 and 0.13 ha to obtain low, medium and high SR, respectively.

Starting in mid July 1976 and 1977, sampling of plant parts for total non-structural carbohydrate (TNC) analysis was conducted on each of the 3 paddocks in a rotation. Sampling began on the first day of the grazing period and continued weekly throughout the 6-week grazing cycle on each paddock. The procedure was repeated in the autumn, beginning in mid September. At each sampling, 6 cores (10 cm in diameter) were randomly removed from a paddock to a rooting depth of 5 cm and composited into 2 replicates (3 cores/replicate). Core stubble was cut back to a height similar to that of residue remaining after grazing for the respective grass and SR combination (Table 1). These stubble heights were established in the field following the initial grazing cycle of the season prior to sampling for TNC.

TABLE 1

Grass stubble heights[1] of cores sampled for TNC, following grazing at 3 stocking rates.

Stocking rate	UF-5	Ona	McCaleb	Digitgrass	Bahiagrass
(Steers/ha)			(cm)		
7.5	17.5	25.0	22.0		
10	15.0	20.0	22.5	17.5	12.5
15	12.0	12.5	17.5		

[1]Stubble heights were established after the first grazing cycle in spring prior to sampling for TNC.

Samples were immediately washed to remove soil and debris, heated at 100°C for 60 minutes to denature respiratory enzymes and subsequently dried at 60°C in a forced-draft oven. Dried tissue was separated into roots/crown (5 cm root + 2.5 cm above ground stubble), lower stubble (2.5-10 cm) and upper stubble (> 10 cm; ranging between 2 cm and 15 cm of herbage) components, ground to pass through a 1 mm mesh, sealed in plastic bags and stored in a freezer with silica-gel dessicant. Extraction of TNC from ground tissue followed the enzymatic procedure modified after Smith (1981). The extract was analyzed for reducing sugars using Nelson's (1944) colourimetric adaptation of Somogy's (1945) copper reduction method and glucose standards.

RESULTS AND DISCUSSION

Total non-structural carbohydrates measured in stubble regions of the 3 stargrasses at 3 stocking rates (SR) are presented in Table 2. The effect of SR on TNC concentration in McCaleb stargrass was independent of stubble fraction. Consequently, mean TNC values computed over factors are indicated for that grass (Table 2). For the remaining 2 stargrasses, response of TNC to SR depended on stubble region, resulting in significant interaction ($P < 0.05$) between these 2 factors. The nature of SR effect for each stubble fraction is therefore indicated in the last column for Ona and UF-5 stargrasses (Table 2).

TABLE 2

Total non-structural carbohydrate concentration in stubble regions of 3 stargrasses at 3 stocking rates (SR).

Year	Stubble Region	Stocking Rate (steers/ha) 7.5	10	15	Mean	Stocking rate effect[2]
			(%)			
McCaleb						
	roots/crown	6.4	6.2	5.7	6.1 a[1]	
1976	lower	5.1	4.4	4.0	4.5 b	
	upper	4.7	3.9	3.7	4.1 b	
	roots/crown	4.3	4.4	3.9	4.2 a	
1977	lower	3.0	3.1	2.6	2.9 b	
	upper	2.6	2.4	1.9	2.3 b	
	Stocking Rate Mean	4.4	4.1	3.6		L
Ona						
	roots/crown	6.8 a[1]	6.4 a	5.8 a		L
1976	lower	5.3 b	4.5 b	4.5 b		L Q
	upper	4.8 c	4.7 b	4.6 b		NS
	roots/crown	4.2 a	4.6 a	3.8 a		L
1977	lower	3.3 b	2.8 b	2.6 b		L
	upper	2.8 c	2.4 c	2.5 b		L Q
UF-5						
	roots/crown	5.2 a[1]	4.9 a	4.6 a		L
1976	lower	3.6 b	3.2 b	2.9 b		L
	upper	3.2 b	3.3 b	3.1 b		NS
	roots/crown	4.1 a	4.1 a	3.8 a		NS
1977	lower	2.7 b	2.6 b	2.3 b		NS
	upper	1.8 c	2.2 b	2.7 b		L
2 yr average					Stocking Rate Equation	r^2
All cultivars	roots/crown	5.3	5.1	4.6	5.97–0.09SR	0.92
All cultivars	lower	3.8	3.4	3.1	4.44–0.09SR	0.86
McCaleb	upper	3.6	3.2	2.8	4.39–0.11SR	0.91
Ona	upper	3.8	3.5	3.6		NS
UF-5	upper	2.5	2.8	2.9	2.20+0.05SR	0.75

[1]Means in a column for each year (McCaleb) or values within a column under each year and stocking rate (Ona and UF-5) followed by different letters are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test.

[2]L, Q: significant ($P < 0.05$) linear and quadratic SR effects. NS: no significant SR effect.

Stubble region effect on stargrass TNC

The roots/crown section was a major carbohydrate storage location for all 3 stargrasses (Table 2). There is evidence (Adjei *et al.* 1985) to suggest that the roots could be a major contributing factor to the high roots/crown TNC levels in stargrasses. Maintenance of high carbohydrate reserves close to the ground (crown region) by stargrasses would enable them to withstand moderate to heavy grazing. The lower and upper stubble regions of McCaleb stargrass maintained similar TNC concentration each year (Table 2). Reserves within the lower stubble were higher than within the upper stubble regions at the low and medium stocking rates for Ona stargrass and only at the lowest SR in 1977 for UF-5 stargrass (Table 2). Variable differences in TNC between the stubble regions of stargrasses may be explained on the basis of grass morphology. McCaleb stargrass forms a moderately open sod with coarse erect stems as much as 5 mm in diameter and 50 to 70 cm in height (Hodges *et al.* 1975). Much of the culm base of McCaleb (including both lower and upper stubbles) was refused by cattle because of its uniform, extreme coarseness. UF-5 stargrass produces slender stems whereas Ona produces numerous coarse stolons. The lower and upper stubble regions of these 2 stoloniferous grasses contained varying proportions of leaf and stem.

Stocking rate effect on stargrass TNC

Increased SR consistently reduced TNC concentration in both roots/crown and lower stubble except for UF-5 (in 1977), as greater demands were made on the sward's reserves for regrowth. Regression equations for these responses using the combined 2-year analyses were estimated to be linear in each case (Table 2). A number of reports on the effects of defoliation on carbohydrate reserves have established that heavy or frequent grazing or defoliation (exceeding removal of 50% of current season's growth) resulted in declining vigor of vegetation (Hedrick 1958; White 1973). The effect of SR on TNC within the upper stubble depended on the stargrass cultivar (Table 2). No significant relationship was found for Ona, a decreasing relationship for McCaleb and an increasing one for UF-5. Morphological basis for these differences in response have already been provided.

Comparison of 5 tropical grasses at the medium SR

Significant differences in TNC storage location was found among the types (genera) of tropical grasses studied. There was about twice as much TNC concentrated in the roots/crown region of bahiagrass compared with the same stubble region of the other grasses (Table 3). This is due to dense short stolons at the base of the bahiagrass sward. The concentration of TNC within the lower stubble was highest for Transvala digitgrass. UF-5 stargrass generally maintained the lowest TNC concentrations.

TABLE 3

The distribution of total non-structural carbohydrate among stubble regions of 5 tropical grasses at the stocking rate of 10 steers/ha.

Grass	1976			1977		
	Roots/ crown	Lower	Upper	Roots/ crown	Lower	Upper
		(%)			(%)	
McCaleb	6.2 b[1]	4.4 b	3.9 ab	4.4 b	3.1 ab	2.4 a
Ona	6.4 b	4.5 b	4.7 a	4.6 b	2.8 b	2.4 a
UF-5	4.9 c	3.2 c	3.3 b	4.0 b	2.6 b	2.2 a
Penascola	12.1 a	4.4 b	3.2 b	12.3 a	4.2 a	2.6 a
Transvala	6.1 b	6.2 a	4.7 a	—	—	—

[1]Values in same column followed by different letters are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test.

A significant ($P < 0.05$) interaction between grass type and season was observed in 1976 (Table 4). The TNC in roots/crown on Transvala digitgrass during summer was higher ($P < 0.05$) than concentrations in the same region of the 3 stargrass cultivars. Summer TNC concentrations found in the lower and upper stubble were highest for Transvala ($P < 0.05$) when compared with all other grasses (Table 4). However, concentrations of TNC found in all stubble regions of Transvala in the autumn were among the lowest of all grasses.

The 5 tropical grasses behaved similarly in reduced growth (Adjei *et al.* 1980), and reduced TNC concentrations (Table 4) between summer and autumn. Studies conducted by West (1971) and Boyd *et al.* (1973) indicated reduced photosynthetic rates and carbohydrate translocation by tropical grasses during the cool season. However the decrease in TNC concentration during autumn varied considerably among the 5 grasses. Transvala was the most susceptible to cold, recording about 4.4 (53%), 5.7 (63%), and 3.8 (58%) units drop in roots/crown, lower and upper stubble TNC levels, respectively between summer and autumn (Table 4). Corresponding decreases in TNC between summer and autumn for stargrasses were 0.7 (11%), 1.3 (28%) and 1.1 (25%) units and for bahiagrass, 1.5 (12%), 1.6 (31%) and 0.3 (9%) units for roots/crown, lower and upper stubbles, respectively.

TABLE 4

The effect of season on TNC within 3 stubble regions of 5 tropical grasses at SR of 10 steers/ha (1976).

Stubble region	Season	Grass				
		McCaleb	Ona	UF-5	Penascola	Transvala
Roots/crown	Summer	6.5 c[1]	6.7 c	5.2 d	12.8 a	8.3 b
	Autumn	5.8 b	6.0 b	4.6 c	11.3 a	3.9 c
		NS[2]	NS	NS	*	*
Lower	Summer	5.0 b	5.3 b	3.8 c	5.2 b	9.1 a
	Autumn	3.9 a	3.6 ab	2.6 b	3.6 a	3.4 ab
		*	*	*	*	*
Upper	Summer	4.6 bc	5.2 b	3.8 cd	3.4 d	6.6 a
	Autumn	3.3 ab	4.1 a	2.8 b	3.1 b	2.8 b
		*	*	NS	NS	*

[1]Values in same row followed by different letters are significantly different ($P < 0.05$).
[2]* = Difference between seasons significant at $P < 0.05$; NS = no significant season effect.

The data did not indicate good correlation between TNC concentration and forage yield. Apparently the different types of tropical grasses thrived at varying levels of carbohydrate reserves, as suggested by Davis (1965), and with varying critical minimum levels (Cook 1966). These important points have been ignored in most work where TNC levels were not successfully related to forage yield. Two attributes of Transvala digitgrass made it most vulnerable to heavy grazing. The first was the storage of TNC high up the stubble (up to lower stubble; Table 4) early in the season where it was easily removed under close grazing. The second was its extreme cold susceptibility in the autumn. In this study Transvala pastures weakened by the combined effect of severe grazing (10 steers/ha) and cool temperatures were lost to bermudagrass (*Cynodon dactylon* (L.) Pers) encroachment at the end of 1976 grazing season. The critical minimum of TNC required for survival of Transvala needs to be determined in future greenhouse experiments.

CONCLUSIONS

Under the rotational grazing schedule (2 wk grazing and 4 wk rest) of this study, the location of stored carbohydrate depended mostly on the type of grass. Bahiagrass stored 240% more TNC in the dense stolons of the crown relative to the other 2 higher stubble regions. Comparatively, stargrasses stored 45% more TNC in the roots/crown as against other regions at the medium SR. Transvala retained the same TNC concentration from the crown up to 10 cm stubble (ie. roots/crown + lower stubble) and TNC decreased by only 24% in the upper stubble. Transvala TNC was also most susceptible to cold. Stargrass grazed at 15 steers/ha SR had 20% less TNC than stargrass grazed at 7.5 steers/ha. These data on TNC offer some explanation for the ability of bahiagrass to withstand close grazing. The data also suggests that Transvala pastures should be grazed leniently, allowing a 20 cm stubble especially during autumn season to maintain stand persistence. Medium to heavy grazing pressure could be imposed on stargrass during summer without reducing plant vigour but more lenient pressure may be desirable in the autumn.

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