Nonstructural Carbohydrates in Grazed and Ungrazed Cane Bluestem

PATRICK O. REARDON AND LEO B. MERRILL

Highlight: *Trend of carbohydrate reserves, major storage carbohydrates, and primary storage locations were determined in grazed and ungrazed cane bluestem plants. Sucrose was usually the major reserve carbohydrate, and the largest concentration of reserve carbohydrates was in the crown portion of the plant. The total nonstructural carbohydrate (TNC) levels were higher in grazed than in ungrazed plants. The ungrazed plants matured earlier, as indicated by an earlier TNC peak and had lower winter TNC levels. Results indicate that maximum plant vigor can be maintained with a periodic June to November grazing deferment followed by moderate foliage removal.*

The study of production and accumulation of total nonstructural carbohydrates (TNC) in plants is often utilized for gaining insights into maintenance of plant vigor and forage yields. The seasonal trends of carbohydrate reserves are similar but not always the same for most native range plants. Species differences and environmental conditions make it difficult to draw general conclusions concerning management of all important range plants. Therefore, repetitive research is necessary to gain information pertaining to all important range plants under varying environmental influences (White, 1973). Merrill and Reardon (1966) reported that cane bluestem (*Bothriochloa barbinodis* Lag.), among other herbaceous plants, remained in a low state of vigor in an area deferred from livestock and wildlife grazing for over 20 years. The same plant species in an adjacent area managed under a 4-pasture deferred rotation system was in a high state of vigor and highly productive. Plants in the grazed area had a faster spring growth rate and produced more foliage than plants in the ungrazed area. Carbohydrate levels may have played an important role in causing these differences. Higher carbohydrate reserve levels preceding winter conditions could explain the accelerated spring growth rate in grazed plants.

This study was undertaken to gain information concerning seasonal reserve carbohydrate trends, major nonstructural carbohydrate reserves and primary storage areas in cane bluestem. Results will be useful in designing grazing systems to maintain plant vigor and production in cane bluestem.

Study Areas and Procedures

Samples of cane bluestem were taken from two experimental pastures within the Texas A&M University Agricultural Research Station at Sonora. One pasture has not been grazed by domestic livestock or deer since 1949. The other is one of four pastures in a deferred-rotation system. This pasture was grazed at the rate of 32 animal units per section with cattle, sheep, and goats from 1949 until 1959 and with 43 animal units per section from 1960 until 1970. These two pastures provided properly utilized plants and unutilized plants, so that the difference in carbohydrate concentrations based on degree of defoliation could be determined.

Cane bluestem plants with similar basal diameters and from the same range site were selected and staked at the beginning of the study. Three replications of individual plants were collected monthly from each pasture. Samples were taken at a set time during the day to reduce errors resulting from daily carbohydrate fluctuations (Waite and Boyd, 1953). Plants were removed to a depth of 6 to 8 inches in a manner similar to that described by Williams and Baker (1957), The collected material was separated in the field into two categories: basal crown, including the lower 3/4 inch of the culms; and roots. After collection, the material was frozen immediately in dry ice to arrest enzymatic activity and stored in a deep freeze until chemical analyses were made.

Prior to chemical analyses, the plant material was freeze-dried and ground through a Wiley mill to pass a 40-mesh screen. Quantitative analyses were made for reducing sugars, sucrose, and starch.

Plant material was extracted with 90% ethanol (Waite, 1957). The filtrate was cleared with cadmium hydroxide (Laidlaw and Reid, 1952). Quantity of reducing sugars and sucrose in the filtrate was determined by a modification of the ferricyanide reduction method (Furuholmen et al., 1964). Residue from a water extract was utilized for quantitative determination of starch by the perchloric acid extraction method as described by Pucher et al., (1948). All chemical analyses were expressed as a percentage on a dry weight basis. These data were analyzed by Student's *t*-Distribution procedures, as outlined by Li (1957), using monthly observations from the grazed and ungrazed plants in a paired analysis.

Table 1. Individual and TNC concentrations (%) from cane bluestem roots collected from grazed and ungrazed areas.

	Grazed				Ungrazed			
Month	Reducing sugars	Sucrose	Starch	TNC	Reducing sugars	Sucrose	Starch	TNC
Feb.	2.7	2.8	0.8	6.3	2.2	3.4	0.4	6.0
Apr.	1.4	2.3	0.1	3.8	1.2	1.0	0.1	2.3
May	1.6	3.4	0.1	5.1	2.0	3.4	0.0	5.4
June	2.1	0.2	1.6	3.9	1.0	0.4	0.1	1.5
July	2.3	7.9	0.3	10.5	2.3	6.0	0.2	8.5
Aug.	1.2	5.5	0.6	7.3	2.6	4.4	0.4	7.4
Sept.	1.6	4.0	3.3	8.9	1.2	2.8	1.9	5.9
Oct.	2.1	5.2	2.1	9.4	1.4	1.5	1.6	4.5
Nov.	1.9	2.8	0.1	4.8	1.9	3.7	0.1	5.7
Dec.	4.3	3.9	0.5	8.7	1.4	3.2	0.5	5.1
Jan.	1.8	4.6	0.1	6.5	1.4	2.3	0.0	3.7
Average	2.09	3.87	0.88	6.84	1.69	2.92	0.48	5.09

The authors are assistant professor and associate professor in charge of Texas A&M University Agricultural Research Station, Sonora.

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All field data were collected that the Texas A&M University Agricultural Research Station at Sonora. Chemical analyses were done at the Range Science Departmental Laboratory at Texas A&M University, College Station.

Results and Discussion

Levels of TNC in the roots of grazed plants were significantly higher ($P < .05$) than in ungrazed plants. The seasonal trend of TNC reserves in the roots (Fig. 1) follows the general trend as previously established by several other workers (McCarty, 1938; McCarty and Price, 1942). In both the grazed and ungrazed plants, the seasonal low was in June and the peak in July. After July, TNC in the ungrazed plants began a gradual decline, indicating plant maturity. In grazed plants, TNC levels were again high at the October and December sampling dates, indicating carbohydrate synthesis and storage following the July peak. This extra synthesis and storage was probably due to additional growth following heavy fall rains and warm days which occurred until December. TNC reserves in the roots of the grazed plants at the last sampling date were about 76% higher than from the ungrazed plants. The ungrazed plants must not have been able to utilize the warm, moist fall weather conditions for synthesis or storage. Higher TNC levels could explain why the grazed plants have a greater spring growth rate than the ungrazed plants.

The seasonal trend of TNC levels in the crown of grazed and ungrazed plants followed similar patterns (Fig. 2). Both had a low TNC level in April and a high TNC level in September or October. Ungrazed plants had a TNC peak about a month earlier than the grazed plants, indicating earlier maturity. After this peak, TNC levels declined. However, the high December TNC level in grazed plants indicates TNC synthesis and more storage after the October peak. The TNC level in the grazed plant crown was 167% higher on the January sampling date than that for the ungrazed plant. As with the roots, mean TNC levels in crowns of grazed plants were significantly ($P < .05$) higher than in the ungrazed plants.

Sucrose was the major reserve carbohydrate in roots of both the grazed and ungrazed plants (Table 1). However, reducing sugars were the major reserve carbohydrates in the crowns of ungrazed plants (Table 2). There was no sizable difference between sucrose and reducing sugar levels in crowns of grazed plants (Table 2). This agrees with previous re-

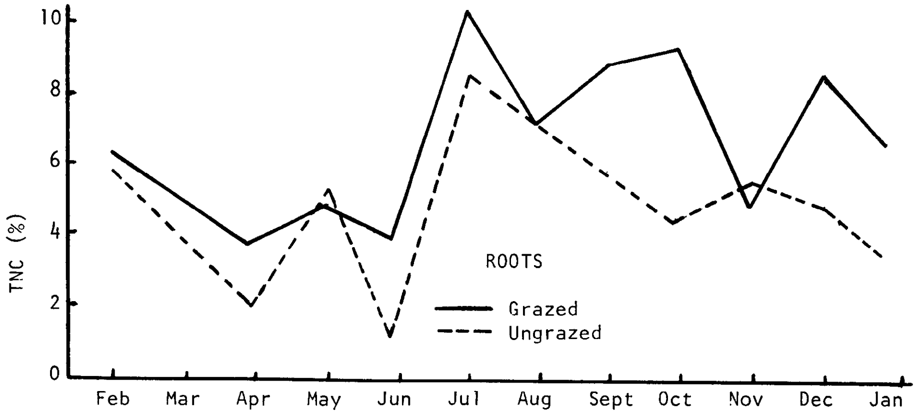

Fig. 1. *Total nonstructural carbohydrate (%) reserves in roots of cane bluestem plants from grazed and ungrazed areas.*

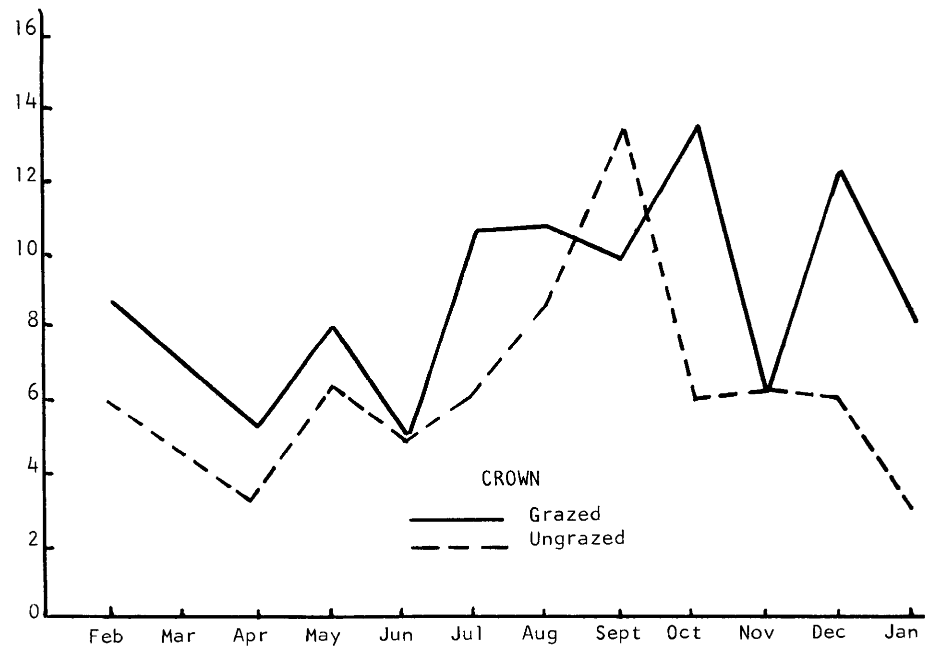

Fig. 2. *Total nonstructural carbohydrate (%) reserves in crown of cane bluestem plants from grazed and ungrazed areas.*

Table 2. Individual and TNC concentrations (%) from cane bluestem crowns collected in the grazed and ungrazed areas.

	Grazed				Ungrazed			
Month	Reducing sugars	Sucrose	Starch	TNC	Reducing sugars	Sucrose	Starch	TNC
Feb.	4.6	2.3	1.8	8.7	3.8	1.6	0.4	5.8
Apr.	2.4	1.7	1.1	5.2	1.8	0.0	1.4	3.2
May	3.1	4.1	0.7	7.9	2.8	2.7	0.7	6.2
June	2.8	0.0	2.2	5.0	2.4	1.3	1.0	4.7
July	3.6	5.1	1.9	10.6	2.4	2.3	1.4	6.1
Aug.	3.2	3.0	4.5	10.7	4.5	1.0	3.1	8.6
Sept.	2.1	2.2	5.6	9.9	2.0	7.4	3.0	13.3
Oct.	3.1	4.3	5.9	13.3	2.3	9.7	2.9	5.9
Nov.	2.0	2.7	1.5	6.2	2.1	2.0	2.2	6.3
Dec.	2.8	5.3	4.1	12.2	3.0	1.0	1.9	5.9
Jan.	2.9	3.7	1.4	8.0	1.9	0.9	0.2	3.0
Average	2.98	3.13	2.79	8.88	2.64	1.89	1.74	6.27

search (Okajima and Smith, 1964; Weinmann, 1952) in that warm season grasses such as cane bluestem accumulate primarily sucrose and starch and cool season grasses store sucrose and fructosans. The low levels of sucrose in the crowns of ungrazed plants can probably be explained by the fact that high sucrose levels are usually associated with accelerated growth which was not evident in the ungrazed plants (Nowakowshi, 1962).

Relative concentrations of reducing sugars, sucrose, and starch varied during the year, (Tables 1 and 2). On some sampling dates the reducing sugar concentration was highest; on other dates, the sucrose or starch. The major storage area for nonstructural carbohydrates within cane bluestem plants is in the crown. The difference in the TNC levels between roots and crown was small. However, during peak periods and winter months, TNC levels were higher in the crown.

Results from this study bring out several important points concerning growth and management of cane bluestem. Because sucrose was usually the major reserve carbohydrate and the crown the major storage area, future carbohydrate analyses could be simplified by analyzing for sucrose found in the crown. The low June TNC level and the high October TNC level indicate that a grazing deferment between June and November would be beneficial in maintaining plant vigor in cane bluestem plants. This deferment would allow the plant to synthesize and accumulate plant foods and go into dormancy with a relatively high reserve TNC level. Moderate grazing after the October TNC peak should not be harmful.

Literature Cited

Furoholmen, A. M., J. D. Winefordner, F. W. Knapp, and R. A. Dennison. 1964. The quantitative analysis of glucose and fructose in potatoes. J. Agr. Food Chem. 12:109-112.

Laidlaw, R. A., and S. G. Reid. 1952. Analytical studies on the carbohydrates of grasses and clovers. 1. Development of methods for the estimation of the free sugar and fructosan contents. J. Sci. Food and Agr. 3:19-25.

Li, J. C. R. 1957. Introduction to statistical inference. Edwards Brothers, Inc., Ann Arbor, Michigan. 568 p.

Merrill, L. B., and P. O. Reardon. 1966. Influence of grazing management systems and vegetation composition and livestock reaction. U. S. Dep. Agr. Coop. State Exp. Sta. Ser. (C. S. E. S. S.) Progr. Rep. Unpubl. 19 p.

McCarty, E. C. 1938. The relation of growth to the varying carbohydrate content of mountain brome. U. S. Dep. Agr. Tech. Bull. 598. 24 p.

McCarty, E. C., and Raymond Price. 1942. Growth and carbohydrate content of important mountain forage plants in Central Utah as affected by clipping and grazing. U. S. Dep. Agr. Tech. Bull. 818 51 p.

Nowakowshi, T. Z. 1962. Effects of nitrogen fertilizers on total nitrogen, soluble nitrogen, and soluble carbohydrate contents of grass. J. Agr. Sci. 59:387-392.

Okajima, H., and D. Smith. 1964. Available carbohydrate fractions in the stem bases and seed of timothy, smooth bromegrass and several other northern grasses. Crop Sci. 4:317-320.

Pucher, G. W., S. C. Leavenworth, and H. B. Vickery. 1948. Determination of starch in plant tissues. Analyt. Chem. 20:850.

Waite, R. 1957. The water soluble carbohydrates of grasses. III. First and second year growth. J. Sci. Food Agr. 8:422-428.

Waite, R., and J. Boyd. 1953. The water soluble carbohydrates of grasses. I. Changes occurring during the normal life cycle. J. Sci. and Food Agr. 4:197-204.

Weinmann, H. 1952. Carbohydrate reserves in grasses. Proc. Sixth Int. Grassland Cong. 1:655-660.

White, L. M. 1973. Carbohydrate reserves of grasses: A review. J. Range Manage. 26:13-18.

Williams, T. E., and H. K. Baker, 1957. Studies on the root development of herbage plants. I. Techniques of herbage root investigations. Brit. Grassland Soc. 12:49-55.