Influence of Nitrogen and Irrigation on Carbohydrate Reserves of Buffalograss

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Highlight: *Five rates (0, 30, 60, 90, and 120 kg of N/ha) of nitrogen fertilizer were applied in April, 1971, to a deep hardland range site where buffalograss (*Buchloe dactyloides *Nutt.) predominated. The influence of these nitrogen applications on the carbohydrate reserve (TAC) concentration of irrigated and nonirrigated buffalograss roots and crowns was evaluated. In 1971 the TAC reserve concentration of the storage tissues varied inversely with rate of nitrogen application until the past ripe phenological stage. After this date, TAC's accumulated more rapidly in the heavier N treatments. In 1972, insignificantly more TAC were found in the control and 30 kg N/ha treatments at the hard seed stage. On all sampling dates buffalograss crowns contained more reserve carbohydrates than did the roots. Similarly, stolons contained 19% more TAC than did the crowns. Water applications reduced the carbohydrate reserves of this grass from 15 to 36%. Irrigation increased female spikelet yield by 44 kg/ha while stolon yield was similar regardless of water regime.*

Buffalograss (*Buchloe dactyloides* Nutt.) is a low-growing, usually dioecious and stoloniferous sod-forming grass found on many deep hardland and clay upland range sites in the shortgrass prairie. Although this grass is important on these range sites, few studies on its physiology have been conducted.

The importance of keeping an adequate level of carbohydrate reserves in grasses has long been known. Ward and Blazer (1961) pointed out that anything which influenced or altered the normal carbohydrate accumulation pattern of grasses should be of interest to grassland managers. A knowledge of carbohydrate depletion and accumulation patterns of important range plants can assist the manager in making the best decision on how and when to graze rangelands.

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This paper reports on work supported in part by National Science Foundation Grant GB-31862X2 to the Grassland Biome, U.S. International Biological Program for "Analysis of Structure, Function, and Utilization of Grassland Ecosystems."

Manuscript received July 11, 1973.

Carbohydrate reserves as influenced by fertilizer applications vary among species, type of fertilizer, and carbohydrate analyzed. Adegbola and McKell (1966) found that after mowing Bermudagrass (*Cynodon dactylon* L.) and applying nitrogen at rates of 0, 100, and 250 lb/acre at 6-week intervals, the concentration of reducing (glucose and fructose) and nonreducing (sucrose) sugars in the leaves increased with increasing rates of nitrogen. In the stems, stolons, roots and rhizomes the percentage of sucrose and fructose in the dry matter was lowest at the highest nitrogen rate.

Waite (1958) applied a complete fertilizer at rates of 100, 200, and 400 lb/acre to four perennial cool-season grass species. His results indicated that higher fertilizer rates decreased the soluble carbohydrate content. In contrast to nitrogen fertilization stimulating the utilization of soluble carbohydrates, Leukel et al. (1934), found that nitrogen fertilization had little effect on the carbohydrate content of certain tropical grasses. Weinman's (1943) study confirmed that fertilization had little effect on reserve carbohydrates.

Little agreement has been reached on the effect of water additions on plant carbohydrate reserves (White, 1973). The grass species being studied under differing environmental conditions may cause differential carbohydrate accumulation and depletion patterns.

Past research on carbohydrate reserves of grasses was often inadequate, as root and crown (stem base) tissues were usually composited prior to analysis. Our pilot studies provided data showing that the crown tissue is quite dynamic in a grassland ecosystem. Crown biomass reaches two maxima, one prior to spring growth and the second at the flowering stage of development. At other growth stages little difference in crown weight is noted.

This research was designed to test the effects of five nitrogen rates on the reserve carbohydrate content (TAC) of irrigated and nonirrigated buffalograss.

Methods and Procedures

Study Area

This study was conducted at the Texas Tech University Center located 24 km northeast of Amarillo, Texas. The plots were located on a level, continuously-past overgrazed, shortgrass prairie. This grazing intensity characterizes much of the Northern Texas High Plains.

The soil of the study area is a Pullman silty clay loam, which is the soil type of about four-fifths of the county and 12 million acres in Northwest Texas (Coover et al., 1953). It is deep and slowly permeable to downward water movement.

Climate of the area is one of extremes. Most precipitation is derived from thunderstorms which occur between April and September. Average annual precipitation is 56 cm but has varied from 14 to 107 cm. The average frost free season is 197 days.

Field Methods

On April 3, 1971, pelleted ammonium nitrate was broadcast with a "whirlwind" seeder onto a nearly pure stand of buffalograss. Treatments used were 0, 30, 60, 90, and 120 kg/ha of nitrogen. Plots were in a completely random grid with three replications of each treatment. Each plot was 10 m^2 with a 2 1/2 m border between plots.

Due to the effects of low (14 cm) precipitation in 1970, the early 1971 and 1972 rainfall was periodically supplemented by sprinkler irrigation to stimulate maximum grass growth. A total of 28.7 and 19.1 cm of water was added to the irrigated block in 1971 and 1972, respectively. Irrigation was done at night when possible to minimize evaporation losses. Contiguous to the irrigated block the same nitrogen treatments were also applied to a dryland block. Since no growth occurred in the dryland block until late June, 1971, no samples were taken until May, 1972.

Vegetation samples for carbohydrate reserves were taken at the following phenological stages in 1971: (a) 3rd leaf, (b) male flowering, (c) late anthesis, (d) early seed, (e) hard seed, (f) past ripe, and (g) quiescence. In 1972 vegetation from both the irrigated and nonirrigated blocks was sampled at the following growth stages: (a) 3-5 leaf, (b) flowering, (c) early seed, and (d) hard seed.

On all dates vegetation samples for carbohydrate content were taken with a "sharp-shooter" shovel to a 10 to 15 cm depth at three randomly selected locations within each plot. After compositing the three samples, they were placed into a preheated (100°C) oven for 12 hours to minimize enzyme activity. After the samples had dried, soil was carefully washed from the plant material. The remaining plant materials were then oven dried at 70°C for 48 hours. After removing the leaf material, the crowns (restricted to 1 cm above roots) were excised from the roots. Any crown or root that appeared nonliving was removed from the sample. After samples were ground to pass through a 40-mesh screen, the root and crown materials were placed in air-tight containers and stored until they could be analyzed.

Herbage yields from the irrigated block treatments were taken at six dates in 1971, while all irrigated and nonirrigated plots were harvested in early August, 1972. All aboveground herbage was clipped from six .1-m^2 plots/treatment. Yield data are not presented in this paper except as needed to discuss carbohydrate partitioning.

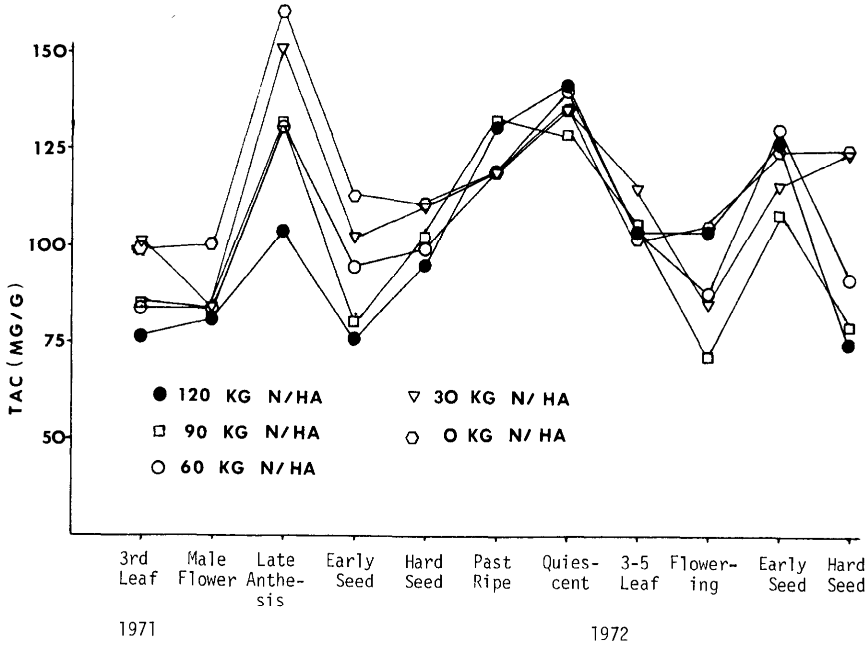

Fig. 1. *Average total available carbohydrate concentration in reserve tissue (crowns and roots) of buffalograss as affected by differential nitrogen applications and supplemental water.*

To evaluate the cumulative effects of water and nitrogen additions upon stolon and female spikelet yield, nine .1-m^2 plots in each treatment were harvested in March, 1973. Care was taken to remove all seed from the soil surface.

Laboratory Methods

Total available carbohydrates (TAC) were extracted according to the method of Smith et al. (1964) with the exception that a .2 normal HCl solution was used. Quantitative determination of TAC was made using the anthrone reagent (Murphy, 1958). Carbohydrates, determined in this manner, are assumed to be readily usable as a source of energy for the plant. We also assumed that this technique did not account for structural carbohydrates such as cellulose and some hemicellulose.

To determine the seed and stolon yield from all treatments, each sample was carefully hand separated into each plant part. All seed found in the plots were collected then weighed. We assumed that differential seed yields would reflect only treatment effects. In addition we assumed that consumption and decomposition of seeds were random throughout all plots.

Similarly all leaf materials were removed from the stolon; thus only the nodal and internodal portions were weighed.

These data were analyzed as a split-plot factorial and mean differences were compared ($P<.05$) using Duncan's Multiple Range Test (Steel and Torrie, 1960). Data from each year were analyzed separately.

Results and Discussion

The TAC in the reserve tissues of irrigated buffalograss decreased with increased rates of nitrogen application (Fig. 1). When considering the 2-year average carbohydrate concentration, 99 mg/g dry weight of TAC were found in the highest fertilizer treatment. Similarly, 120 mg/g dry weight were found in the control treatment. Nonstructural carbohydrates in the 60, 90, and 120 kg of N/ha treatments were not different.

No differences were found in the 30, 60, and 90 kg of N/ha or the 0 and 30 kg of N/ha treatments.

The TAC concentration in the crowns and roots were different from each other at every sampling date, with the crown material consistently higher regardless of nitrogen rate (Fig. 2). The magnitude of this difference, however, varied from 82 mg/g at quiescence to a low of 15 mg/g in the early seed stage of development. In 1971 at the third leaf, male flowering, and early seed stage, no difference in TAC content of the plant tissue was obtained. The late anthesis and quiescent stage, likewise, contained similar TAC concentrations. All other growth stages had significantly different carbohydrate contents.

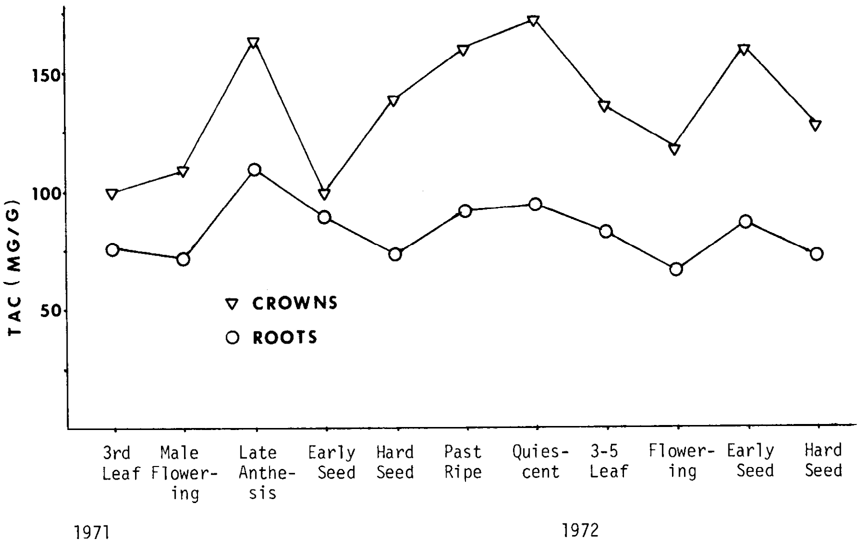

Fig. 2. *Total available carbohydrate accumulation in reserve tissues of irrigated buffalograss. Each datum point represents the average TAC of all nitrogen treatments on a specific sampling date.*

During the growing season, peak carbohydrate reserves correspond to the late anthesis developmented stage (Fig. 2). Reserves then declined rapidly until seed was formed. By mid-September reserves were being accumulated in the roots and crowns once more, though rate of recharge was less than after the male flowering stage. TAC concentration within the storage tissues varied inversely with nitrogen rate in 1971 for all development stages until seed was ripe. After this date, grasses treated with the higher nitrogen levels replenished root and crown reserves more rapidly than do those grasses with lower applications.

Yield samples taken in September showed the 120 kg of N/ha treatment to outyield the 0 kg of N/ha treatment 2787 kg/ha to 812 kg/ha, respectively. The yields from the 30, 60, and 90 kg of N/ha treatments were 1419, 1824, and 1787 kg/ha, respectively. Comparing these data with Fig. 1, it appears that increased N additions to buffalograss have promoted large herbage increases early in the season (until mid-September); then carbohydrates are translocated and accumulated quite rapidly in the grass crowns.

The importance of maintaining adequate carbohydrate reserve levels in range grasses is not a new concept in range management. However, if nitrogen additions severely reduce the energy sources which are needed for regrowth, proper use of our rangeland forages becomes critical. In the heavier-fertilized buffalograss, for instance, a larger percentage of the aboveground herbage could be harvested by herbivores than in non-fertilized stands. Without judiciously controlling grazing use, it is possible to harvest excessive amounts of forage from this species. If the photosynthetic tissue remained "out-of-balance" with energy reserves, we could expect grazing to weaken the plants substantially.

On all sampling dates the average carbohydrate reserves in nonirrigated buffalograss exceeded reserves in the irrigated plots (Table 1). Nitrogen fertilization incorporated with irrigation treatments substantially reduced the TAC. At the irrigated 90 and 120 kg/ha of N treatment, TAC were decreased 36 and 30%, respectively as compared to similarly treated dryland plots. In the control treatment (0 N), irrigation reduced root carbohydrates 20% while crown carbohydrates were reduced 10%. The 30 and 60 kg/ha of N treatments showed intermediate responses to irrigation and fertilizer treatments.

Under irrigation, roots contained 62% as much TAC as did the crowns. Similarly, roots from the dryland plots contained 58% as much nonstructural carbohydrates as the crowns. This demonstrates that even though irrigation and fertilization changed the carbohydrate reserve content of buffalograss, the proportional change of root to crown TAC was similar.

Table 1. Average total available carbohydrate concentration (mg TAC/g) of irrigated and nonirrigated buffalograss reserve tissues sampled at four phenological stages in 1972.

Water and fertilizer[1] treatments	Plant[2] part	Phenological growth stage: 3-5 Leaf	Flowering	Early seed	Hard seed
Irrigated					
0	R	68[3]	72	81	92
	C	135^{a}[4]	140^{bc}	168^{def}	158^{d}
30	R	95	59	74	95
	C	139^{abc}	107	156^{f}	154^{cd}
60	R	76	69	92	73
	C	133^{d}	105^{abc}	167^{bcdef}	113^{e}
90	R	83	47	78	44
	C	133^{ac}	95^{a}	142^{f}	114^{e}
120	R	83	80	92	56
	C	133^{ac}	136^{c}	162^{cdef}	92^{e}
Nonirrigated					
0	R	110	80	108	93
	C	161^{b}	151^{c}	193^{abc}	159^{bcd}
30	R	110	86	104	103
	C	161^{bc}	151^{c}	193^{abcde}	159^{abc}
60	R	94	77	107	84
	C	153^{bc}	135^{bc}	200^{a}	169^{bcd}
90	R	102	83	118	129
	C	180^{b}	130^{bc}	186^{ab}	174^{a}
120	R	116	90	102	139
	C	158^{b}	131^{bc}	197^{abcd}	172^{a}

[1] Kg/ha of nitrogen applied in April, 1971.
[2] R designates root and C is crown tissue.
[3] Concentration of total available carbohydrates expressed as mg TAC/g of dry plant tissue.
[4] Averaged plant part carbohydrate reserves followed by same letter in each column are not different at the 0.05 level of significance.

Table 2. Average weights (kg/ha) of buffalograss female spikelet (seed), stolon, and above-ground biomass from fertilized and nonfertilized plots. Total available carbohydrates (mg TAC/g) in stolon and other reserve tissues are also given.

Water and fertilizer[1] treatments	TAC concentration[2] Roots	Crowns	Stolons	Seed weight[3]	Stolon weight[3]	Total above-ground biomass
Irrigated						
0	92.1	157.6	152.9	133 ± 57[4]	23 ± 9[4]	2742[5]
30	95.0	153.9	159.1	162 ± 47	123 ± 60	3653
60	73.0	112.8	124.0	348 ± 116	158 ± 36	5653
90	43.9	113.5	150.0	325 ± 114	348 ± 83	5131
120	55.9	91.5	158.0	196 ± 89	210 ± 34	5454
Nonirrigated						
0	93.4	159.1	186.1	190 ± 81	58 ± 24	3783
30	102.6	169.4	190.0	250 ± 65	187 ± 49	4259
60	83.9	168.5	193.0	237 ± 77	201 ± 40	5214
90	129.1	173.5	189.2	153 ± 54	252 ± 41	5676
120	139.4	172.2	216.0	113 ± 51	209 ± 69	6293

[1] Kg/ha of nitrogen applied in April, 1971.
[2] Total available carbohydrates determinations were taken when plants were at the ripe seed stage of development. Data expressed as mg TAC/g of dry plant material.
[3] Biomass estimates were determined from 9, .1 m^2 plots in each treatment.
[4] Standard error of the mean.
[5] Litter biomass is included in these estimates.

In the nonirrigated plots, differential nitrogen applications caused no significant differences in buffalograss crown carbohydrate reserves. At the early seed stage of development, carbohydrate reserves in the two heaviest nitrogen and irrigation treatments, were less than half the reserve found in the dryland.

To obtain an estimate of stolon and female spikelet (seed) production as related to nitrogen and water additions, plots were harvested at the termination of this research. Maximum seed production was found in the irrigated - 60 kg of N treatment (Table 2). In the nonirrigated plots most seed was present in the 30 kg of N treatment. This treatment, however, did not produce significantly more seed than the 60 kg of N dryland treatment. These data indicate that heavy nitrogen (120 kg of N/ha) additions are not desirable to produce a large buffalograss seed crop.

Most stolon growth was found in the 90 kg of N plots while least stolon production was consistently recorded in the nonfertilized plots. As was observed for seed production, stolon yield was less at the 120 kg of N/ha rate than at the 90 kg of N/ha rate. When stolons were analyzed for TAC, data from 47 of 50 samples showed that stolons contained more TAC than did the grass crowns. The averaged TAC analyses of roots, crowns, and stolons revealed a concentration of 89, 159, and 190 mg/g dry matter, respectively. These data and that presented in Table 1 and Figure 2 indicate that carbohydrate translocation from buffalograss leaves to the root system is not as active a physiological process as translocation into crown and stolon tissue. Further research needs to test this hypothesis.

Management Implications

Although buffalograss does not produce as much forage as blue grama (*Bouteloua gracilis* [H. B. K.] Lag. ex Steud) or tall grass species which could be grown under irrigation, it is desirable for year-long grazing. Lehman et al. (1968) found heavily fertilized (224 kg of N/ha) and irrigated blue grama yielded 4417 kg of forage/ha/year. These researchers remarked that blue grama was a relatively inefficient user of soil water and nitrogen in comparison to introduced plant varieties. Our study showed buffalograss to produce 2800 kg/ha when irrigated and fertilized with 120 kg/ha of N. This yield, at peak biomass, could be substantially increased with increased N applications as evidenced by buffalograss growth in plot borders where fertilizer was occasionally spilled in weighing procedures.

Several questions must be raised concerning the feasibility of fertilizing and irrigating native unimproved forages. First, what is a kilogram of forage worth to the rancher? Second, what alternatives to provide forage for livestock are available in below average precipitation years? Third, what are the costs involved in fertilizing and irrigating rangeland? Fourth, are management data available to show how to properly manage these forages after treatment? Fifth, what is improved forage quality worth to ranchmen? Other questions can be raised; however, the decision concerning feasibility of water and nitrogen additions to improve forage quality and quantity must lie with the grazier.

Our results show that the need for judicious grazing would be much more critical on irrigated than nonirrigated pasturage. Under heavy nitrogen with water applications, appreciable energy reserves were used for stolon and seed development. Similarly, the proportion of vegetative to generative shoots appeared higher when nonirrigated.

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