Effects of Nitrogen Fertilization, Burning, and Grazing on Reserve Constituents of Big Bluestem

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Highlight: *During 1972 and 1973, the effects of nitrogen fertilization, burning, and grazing on total nonstructural carbohydrate (TNC) and nitrogen reserves of big bluestem (*Andropogon gerardi *Vitman) were studied in the Kansas Flint Hills. TNC and nitrogen reserves were lowered when growth exceeded photosynthetic production and nutrient assimilation. TNC reserves were lowest in unburned, heavily fertilized, pastures; nitrogen in storage organs increased linearly as nitrogen fertilization was increased. TNC was higher in burned than in unburned pastures, regardless of fertilization rate. Increasing the grazing rate when nitrogen fertilization was increased had little effect on reserves at senescence.*

Increasing livestock carrying capacity by increasing forage production is receiving a major emphasis in range management. Nitrogen fertilization appears to be a key in increasing forage production on native tallgrass ranges, particularly where proper land management techniques are already being used.

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Any management practice centers on maintaining plant vigor and production. Food-reserve quantity and quality are integral factors in plant growth and survival (McKendrick, 1971). Carbohydrate and nitrogen reserves depend largely on soil nutrient levels, amount of photosynthetic material available for production, and size or quantity of storage organs. Any process that produces or uses energy may affect the amount of food reserves in plants.

In Kansas Flint Hills nitrogen, not moisture, was found to be the critically limiting factor in bluestem range production (Owensby et al., 1970). When Flint Hills range was fertilized, composition shifted from warm-season perennials to cool-season grasses and weeds, species which are not dependable forage under the limited rainfall of the area (Mader, 1956; Silker and Wood, 1960; Owensby et al., 1970). Burning, as a management tool, increased forage quality and reduced the population of cool-season grasses, sedges and rushes, and perennial forbs in the True Prairie (Owensby and Smith, 1972).

In light of demand for increased range production, burning, combined with nitrogen fertilization, appears a method of increasing stocking rate without adverse effects of fertilization alone. The effects of nitrogen fertilization, burning, and grazing on nitrogen and carbohydrate reserves of big bluestem (*Andropogon gerardi* Vitman) were studied.

Materials and Methods

In the spring of 1971 burned-unburned treatments, followed by grazing and nitrogen fertilization treatments in 1972, were applied to six randomly selected pastures (44-60 acres each) in a native tallgrass prairie near Manhattan, Kans. (Table 1).

Table 1. Treatments in a native tallgrass prairie pasture, Manhattan, Kansas.

Burning	N-rate (lb N/acre)	Stocking rate, steers (acres/AU) 1972	1973
Burned			
April 25†27	0	5	5
	40	3.3	3.3
	80	2.17	2.79
Unburned	0	5	5
	40	3.3	3.3
	80	2.17	2.79

Previous pasture treatment effects were minimized, and range condition equalized, with late spring burning and stocking with steers (5 acres/AU), 1968-1970. Stocking rate remained at 5 acres/AU when burning treatments began in 1971. Nitrogen (N) was applied aerially in early May as prilled urea in 1972 and as prilled ammonium nitrate in 1973. Stocking rates were adjusted to obtain a similar percentage removal of forage in each pasture. Stocking rates on pastures with 80 lb N/acre were lowered in 1973 because estimated forage production in 1972 was less than actual.

Within each of six pastures, three loamy upland range sites (Anderson and Fly, 1955) with similar grazing use were selected as plant collection sites. Every 2 weeks from May 15 to November 1 and once a month from December 1 to April 15 at each site a minimum of 20 big bluestem plants were selected at random along and within 1 yard either side of a 100-yard line. Plants were dug deep enough to insure collection of rhizomes. Percentage of plants grazed was recorded for plants collected. Samples were not taken on May 1 in 1972 or 1973 because burning had removed identifiable top growth. Soil, roots, and dead organic material were removed from samples by cold-water washing and hand clipping. Elongated culms 2 inches above the uppermost basal node were removed. Though differences in carbohydrate and organic nitrogen concentrations within grass parts have been reported, rhizomes, crowns, and stem bases are all major areas of storage in *Andropogon*, from which the plant can potentially draw stored reserves (McKendrick, 1971; Perry and Moser, 1974). Cleaned samples of rhizome, crown, and live stem bases were oven dried for 5 days at 70°C, ground in a Wiley mill (40-mesh screen), and stored in sealed glass bottles in the dark (Owensby et al., 1970). Total nonstructural carbohydrates (TNC) were determined by enzyme extraction with "Clarase 900" (takadiastase) and copperiodometric titration (Smith, 1969). Kjeldahl nitrogen was determined for each sample.

Least-squares analysis of variance for unequal subclasses was used to test effects of percent plants grazed on stored N and TNC reserves on all samples from all collection dates (Kemp, 1972). Subsequent analyses of variance or covariance, with grazing as a covariate when significant, were used to test effects of burning and nitrogen fertilization on collections over 2 years (growth-and-storage period: May 15 to November 1) and on collections in 1 year (dormant period: December 1 to April 15). Means were separated by LSD when significant ($P<.05$) F-values were found. Both linear and quadratic effects of fertilizer treatments were measured (Cochran and Cox, 1968).

Results and Discussion

Total Nonstructural Carbohydrate (TNC) Reserves

Grazing (percent plants grazed) decreased TNC levels during the growing season ($P<.01$), but not during the dormant period ($P<.67$). Any situation that interferes with normal growth of the photosynthetic tissue of range plants will restrict root development and normal reserve storage and may curtail subsequent growth (Cook, 1966). Detrimental effects on plant growth increase when frequency or degree of defoliation is increased (Jameson, 1964).

TNC was lowest in May, reached a summer maximum by July 15, declined in mid-August, and reached a yearly high by October 15 in unburned pastures and November 1 in burned pastures. TNC was higher in burned than in unburned pastures throughout the growth-and-storage period (Fig. 1A). Plants use food reserves in early growth until the photosynthetic products exceed growth demands, then they store reserves. Though late season TNC decline in several grasses has been attributed to sexual reproduction (Coyne and Cook, 1970; McKendrick, 1971; Pettit et al., 1973; Rappe, 1947), Owensby (unpublished) found that <1% of the big bluestem plants in tallgrass prairie initiated seedheads. Root production on new rhizomes of big bluestem in mid-August (McKendrick, 1971) probably caused reserves to decline at that time (Fig. 2). Sampson and McCarty (1930) and Weinmann (1948) reported that underground development is most active when herbage growth is minimal. Differences between burned and unburned pasture TNC levels over sampling date were not significant during the dormant period (<.19). TNC dropped in January but stabilized a month later and remained stable until spring growth began (Fig. 1B). That cycle was similar to those reported by Owensby et al. (1970) and McKendrick (1971) for big bluestem. Other workers have shown TNC drops

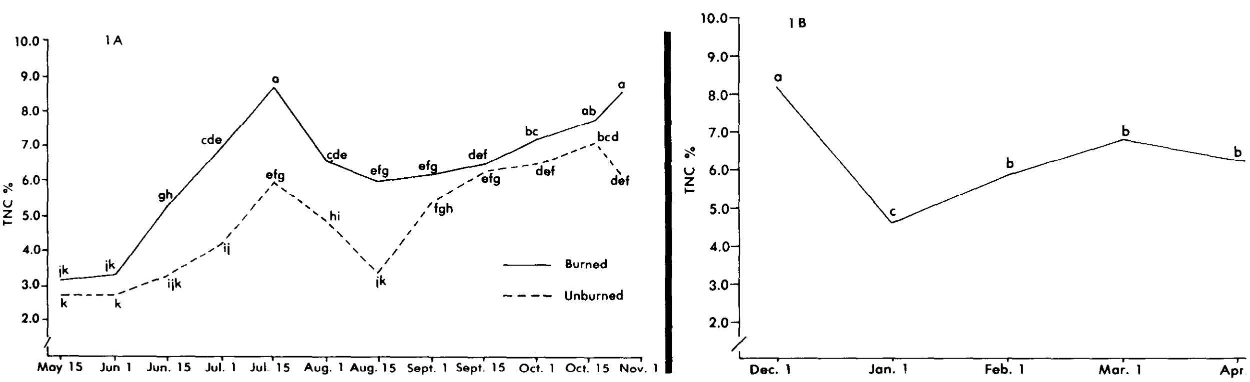

Fig. 1. *Effect of burning on TNC in big bluestem storage organs: (A) May 15 to Nov. 1, 1972; (B) Dec. 1, 1972 to Apr. 15, 1973. Averaged over all treatments. TNC levels with a common letter are not significantly different (P<.05).*

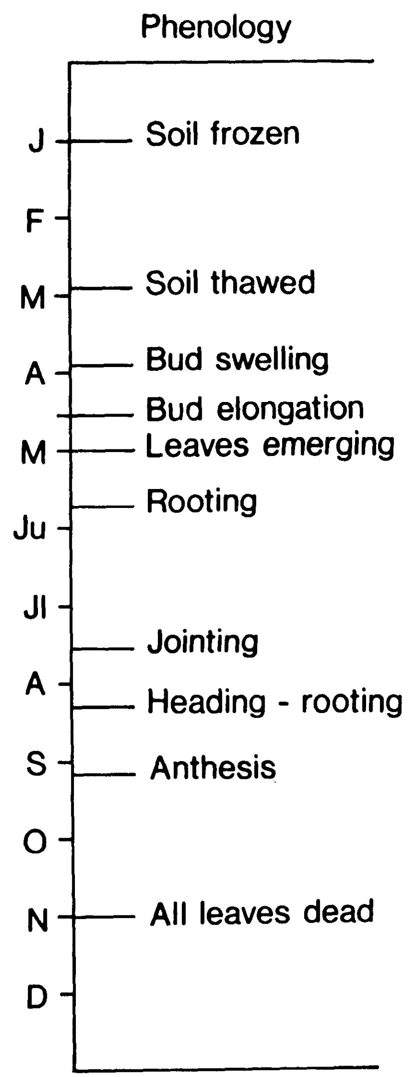

Fig 2. *Phenology of big bluestem (adapted from McKendrick, 1971).*

in mid-winter with no explanation offered (Sampson and McCarty, 1930; Archbald, 1940; Sonneveld, 1962). Research was not conclusive; perhaps storage compounds transferred from one form to another during periods of temperature or moisture stress. Phenologic data (Fig. 2) showed that the soil is usually frozen during January and February in the Flint Hills.

Burning and nitrogen fertilization significantly affected TNC during both growth and dormant periods ($P<.01$); effects were mostly quadratic. TNC was highest in burned nonfertilized pastures, and lowest in unburned pastures regardless of fertilizer rate, during growth and storage periods (Fig. 3A). TNC in burned pastures was highest when rates were 0 and 80 lb N/acre and lowest with 80-lb N/acre in unburned pastures during the dormant period (Fig. 3B). Ehrenreich (1959) theorized that burning removed most mulch, which encouraged early growth and stimulated production of carbohydrate reserves. Pettit and Fagan (1973) reported that for buffalograss (*Buchloë dactyloides*) carbohydrate reserves during the growing season were reduced but were nearly equivalent at the point of maximum storage with nitrogen fertilization. Fertilizing and burning the pasture increased plant growth, which in turn probably resulted in a decline of TNC.

Nitrogen (N) Reserves

Grazing (percent plants grazed) did not significantly affect N reserves in big bluestem. Nitrogen reserves may not be used as readily in regrowth as are carbohydrate reserves.

On different sampling dates, the effect of nitrogen fertilization rate on reserve nitrogen was different during the growth-and-storage period ($P<.01$), but not during the dormant period ($P<.15$). Reserves declined, under 0-lb and 40-lb nitrogen fertilization rates, when growth requirements exceeded available nitrogen (May 15 to July 1). They remained low during mid-season and increased in the fall when plant requirements no longer exceeded the available supply (Fig. 4). Nitrogen reserves were not significantly lowered in mid-August, as were TNC reserves, probably because of sufficient uptake of soil nitrogen by new roots. McKendrick (1971), in earlier work on big bluestem, indicated that reserve nitrogen increased at maturity and that N declined when spring growth was initiated. Changes in annual N-reserve cycling were less under the 80-lb N rate, indicating high nitrogen uptake throughout the season and less need for nitrogen reserves to support growth. Though trends indicated a positive correlation of increased N reserves and fertilizer rate, differences at particular dates were not always significant (Fig. 4). At season's end reserves were equal under 0-lb and 40-lb rates. Weinmann (1948) and

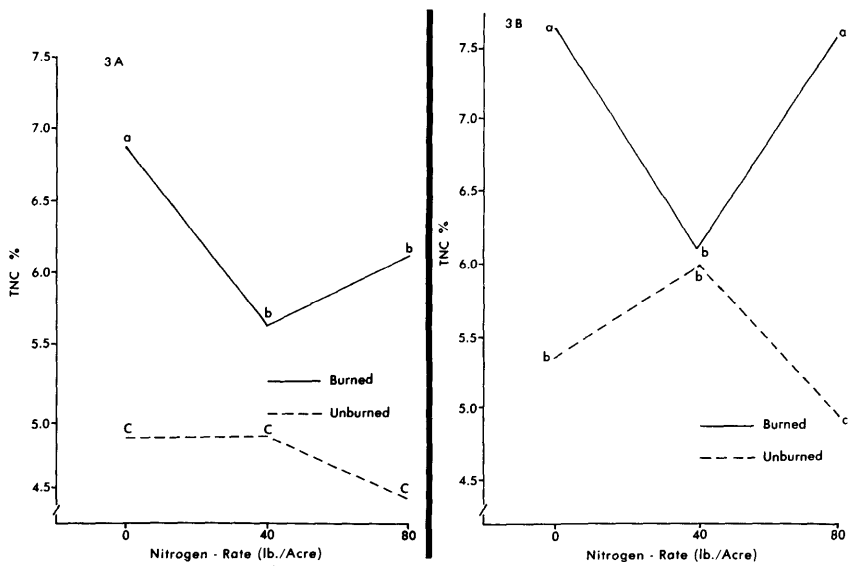

Fig. 3. *Effect of nitrogen fertilization and burning on TNC content in big bluestem storage organs: (A) May 15 to Nov. 1, 1972 and 1973; (B) Dec. 1, 1972 to Nov. 1, 1973. Averaged over all treatments. TNC levels with a common letter are not significantly different (*P<.05*).*

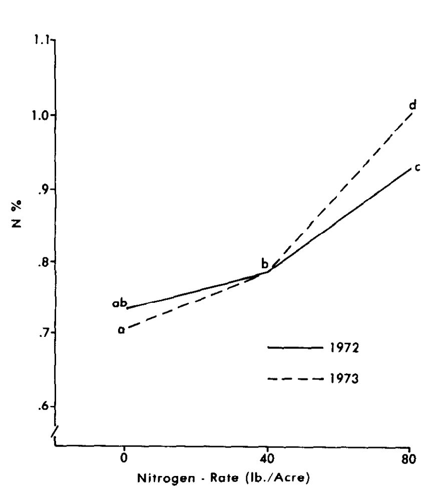

Fig. 4. *Effect of nitrogen fertilization on nitrogen content in big bluestem storage organs (May 15 to Nov. 1, 1972 and 1973). Averaged over all treatments. Nitrogen levels with a common letter are not significantly different (*P<.05*).*

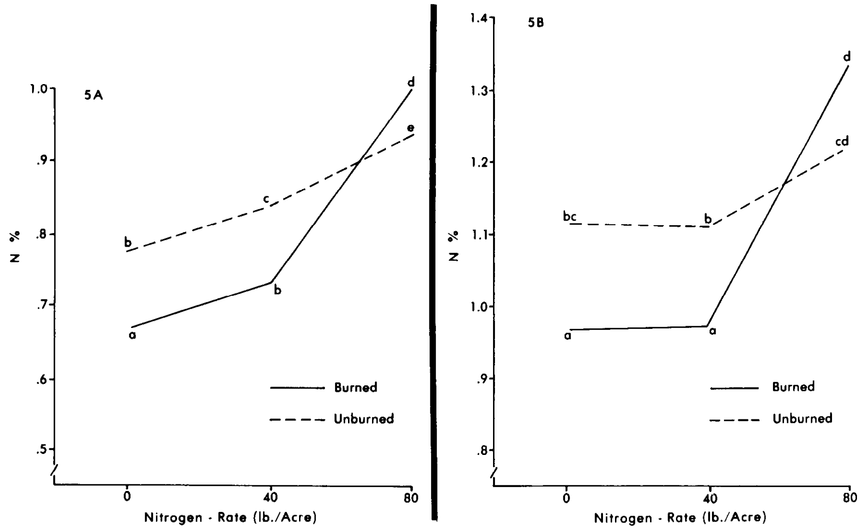

Fig. 5. *Effect of nitrogen fertilization and burning on nitrogen content of big bluestem storage organs: (A) May 15 to Nov. 1, 1972 and 1973; (B) Dec. 1, 1972 to Nov. 1, 1973. Nitrogen levels with a common letter are not significantly different (*P<.05*).*

Power (1972) also showed that a positive correlation apparently existed when available N exceeded plant requirements.

Burning and nitrogen fertilization significantly affected reserve nitrogen during the growing season (P<.01). Throughout the year nitrogen in big bluestem storage organs was higher in unburned than in burned pastures at the 0 and 40-lb nitrogen rate (P<.05) (Figs. 5A and 5B). Nitrogen fertilization affected burned and unburned pastures linearly during the growing season; N increased with fertilizer rate. Under the 0-lb and 40-lb rates stored nitrogen did not differ (P<.05) within burning treatments during the dormant period (Fig. 5B).

Burning removes mulch, darkens the soil surface, increases the soil temperature, and causes rapid top growth of grasses early in the year (Owensby and Smith, 1972). Apparently, when a plant grows rapidly its needs exceed available soil nitrogen supply; hence it uses reserve N, which lowers stored reserves.

Stored nitrogen was similar (P<.05) in 1972 and 1973, under 0-lb and 40-lb applied nitrogen, respectively. At the 80-lb rate, N was higher in 1973. Apparently, nitrogen accumulates in storage organs when excess nitrogen is available (Fig. 6).

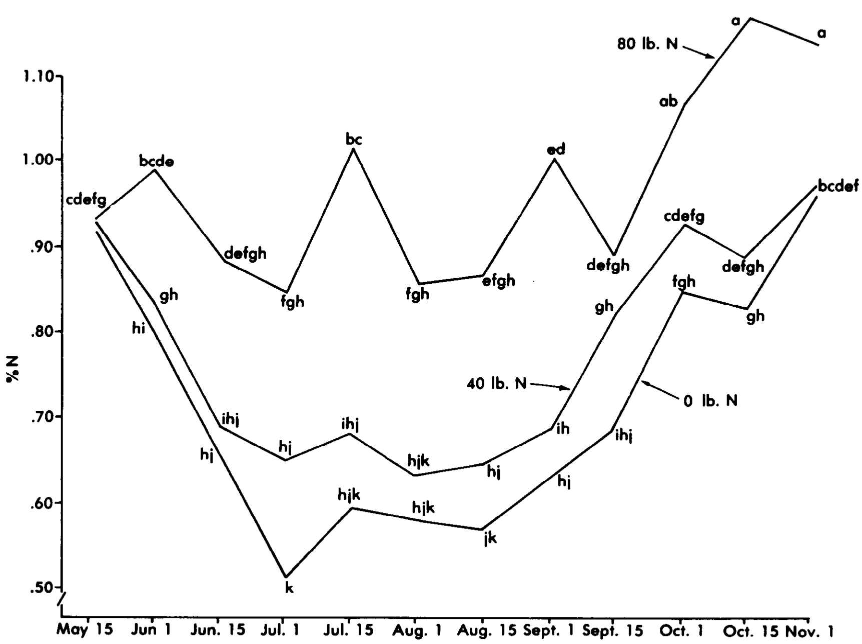

Fig. 6. *Effect of nitrogen fertilization on storage organ N for different years (May 15 to Nov. 1, 1972 and 1973). Averaged over all treatments. Nitrogen levels with a common letter are not significantly different (*P<.05*).*

Conclusions

TNC and nitrogen decreased as growth exceeded available photosynthetic products and soil nutrients. That information may be used in determining proper stocking periods. Owensby (unpublished) and Trlica and Cook (1971) state that if a plant is defoliated early in the growing season, its food reserves at the close of the growing season are not reduced nearly so much as they would be if clipping or grazing had occurred late in the season.

Increasing grazing rate when nitrogen fertilization was increased had little effect on either TNC or nitrogen reserves in big bluestem at senescence. Apparently a rancher could increase cattle numbers on a pasture by applying nitrogen fertilizer provided he could control shifts in plant species composition.

Total nonstructural carbohydrate reserves were highest, and nitrogen reserves were lowest, under burned conditions when there was no nitrogen fertilization during growth and storage periods. Big bluestem TNC benefited most with burning, regardless of nitrogen fertilization rate. During the dormant period, TNC was lowest in unburned, heavily fertilized pastures, but did not approach the critically low levels of early spring. Applying nitrogen in the spring and not burning may lower plant vigor the following year, resulting in lowered big bluestem competitive ability.

Trends in reserve N were linear with increased rate of nitrogen fertilization. Nitrogen added at the 40-lb rate apparently was used to increase forage production, but the 80-lb N rate apparently exceeded the plants' needs, because over time the nitrogen accumulated.

A combination of burning and adding 0, 40, or 80 lb N/acre did not lower constituent reserves below those of unburned, nonfertilized pastures. Plant vigor may be increased in the True Prairie by burning. Nitrogen fertilization plus burning, over a 2-year period, did not adversely affect big bluestem TNC and nitrogen reserves.

Literature Cited

Anderson, K. L., and C. L. Fly. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Manage. 8:163-169.

Archbald, H. K. 1940. Fructosans in the monocotyledons: A review. New Phytol. 39:185-219.

Cochran, William G., and Gertrude M. Cox. 1968. Experimental Designs. 2nd Ed. John Wiley & Sons, Inc.

Cook, C. Wayne. 1966. The role of carbohydrate reserves in managing range plants. Utah Agr. Exp. Sta. Mimeo. Series 499. 11 p.

Coyne, Patrick I., and C. Wayne Cook. 1970. Seasonal carbohydrate reserve cycles in eight desert range species. J. Range Manage. 23:438-444.

Ehrenreich, J. A. 1959. Effect of burning and clipping on growth of native prairie in Iowa. J. Range Manage. 12:133-137.

Jameson, Donald A. 1964. Effects of defoliation of forage plant physiology. p. 67-80. *In:* Keller, Wesley and T. A. Ronningen (eds.) Forage Plant physiology and soil relationships. Amer. Soc. Agron. Spec. Pub. No. 5.

Kemp, Kenneth E. 1972. Least squares analysis of variances, a procedure, a program, and examples of their use. Kansas Agr. Exp. Sta. Res. Pap. 7. Manhattan, Kans.

Mader, E. L. 1956. The influence of certain fertilizer treatments on the native vegetation of Kansas prairies. PhD Diss., Univ. of Nebraska.

McKendrick, J. D. 1971. Big bluestem and Indiangrass vegetative reproduction and critical levels of reserve carbohydrates and nitrogen. PhD Diss., Kansas State Univ.

Owensby, C. E. Unpublished. Range Management I class notes. Kansas State Univ., Manhattan.

Owensby, C. E., Gary M. Paulsen, and J. D. McKendrick. 1970. Effect of burning and clipping on big bluestem reserve carbohydrates. J. Range Manage. 23:356-362.

Owensby, C. E., and Ed. F. Smith. 1972. Burning true prairie. Third Midwest Prairie Conf. Proc., Kansas State Univ., Manhattan. p. 91.

Perry, L. S., Jr., and Lowell E. Moser. 1974. Carbohydrate and organic nitrogen concentrations within range grass parts at maturity. J. Range Manage. 27:276-278.

Pettit, Russ, and Richard E. Fagan. 1973. Carbohydrate reserves in buffalograss crowns and roots as affected by nitrogen. Annual Meeting Abstracts, Soc. for Range Manage. p. 26.

Power, J. F. 1972. Rate of fertilizer nitrogen applied to a northern Great Plains rangeland ecosystem. J. Range Manage. 25:267-371.

Rappe, K. E. 1947. Carbohydrate metabolism of Johnsongrass. J. Amer. Soc. Agron. 39:869-873.

Sampson, A. W., and E. C. McCarty. 1930. The carbohydrate metabolism of *Stipa pulchra*. Hilgardia. 5:60-100.

Silker, T. H., and J. A. Wood. 1960. Fertilized and seeded grazed firebreaks. The Agr. and Mech. College of Texas. Texas Agr. Exp. Sta., MP-451. 10 p.

Smith, Dale. 1969. Removing and analyzing TNC from plant tissue. Univ. of Wisconsin. Res. Rep. No. 41. 11 p.

Sonneveld, A. 1962. Distribution and redistribution of dry matter in perennial fodder crops. Neth. J. Agr. Sci. 10:427-447.

Trlica, G. J., Jr., and Wayne C. Cook. 1971. Defoliation effects on carbohydrate reserves of desert species. J. Range Manage. 24:418-424.

Weinmann, H. 1948. Underground development and reserves of grasses: A review. J. Brit. Grassl. Soc. 3:115-140.