EFFECTS OF NITROGEN FERTILIZATION, BURNING, AND GRAZING
ON RESERVE CONSTITUENTS OF BIG BLUESTEM (<u>Andropogon</u> <u>gerardi</u> Vitman)

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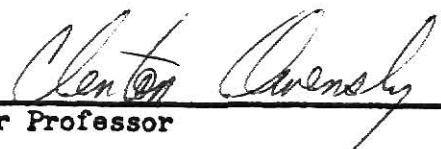
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INTRODUCTION

Major emphasis in range management is toward increased live-stock carrying capacity through increased forage production. Nitrogen fertilization appears to be the key to the greatest increase in production of native tallgrass range, particularly where proper land management techniques are already being employed.

Application of any management practice is centered on maintenance of plant vigor and production. Food reserve quantity and quality are integral factors in plant growth and survival (McKendrick, 1971). Carbohydrate and nitrogen reserve levels depend largely on soil nutrient levels, amount of photosynthetic material available for production, and size or quantity of storage organs. Any process which produces or utilizes energy may affect the amount of food reserve in plants.

In the Kansas Flint Hills, nitrogen, not moisture, was found critically limiting in bluestem range production (Owensby et al., 1970). However, composition shifts from warm-season perennials to cool-season grasses and weeds occurred with fertilization (Mader, 1956; Silker and Wood, 1960; Owensby et al., 1970). Burning, as a management tool, increased forage quality, and reduced population of cool-season grasses, sedges and rushes, and perennial forbs in the True Prairie (Owensby and Smith, 1972).

The effects of nitrogen fertilization, burning, and grazing on nitrogen and carbohydrate reserves of big bluestem (Andropogon gerardi Vitman) were studied.

Materials and Methods

Burning, grazing, and nitrogen fertilization were applied to six randomly selected pastures (44-60 acres each) in a native tallgrass prairie at Manhattan, Kansas, in spring, 1972 (Table 1). Previous pasture treatment effects were minimized by late spring burning, stocking with steers (5 acres/AU), 1968-1970. Burned - unburned treatments began in 1971, with stocking rate remaining at 5 acres/AU. Grazing was by yearling steers (initial wt. 400-500 lbs.), May 1-October 1.

Table 1. Study treatments applied

Burning	N-rate (lb N/A)	Stocking rate (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

Nitrogen was applied aerially in early May as prilled urea in 1972 and as prilled ammonium nitrate in 1973. Stocking rates were adjusted to obtain similar percent removal in each pasture. Stocking rates on pastures with 80 lb N/A were lowered in 1973, since estimated forage production was lower than actual in 1972.

Within each of the six pastures, three loamy upland range sites (Anderson and Fly, 1955) with similar grazing use, were selected as plant collection sites. A minimum of 20 big bluestem plants were

collected along and within one yard either side of a 100-yard line at
two-week intervals from May 15-November 1 and at one-month intervals
from December 1-April 15 (May 15, 1972-November 1, 1973) at each site.
Plants were dug to a depth to insure collection of attached rhizomes.
Percent plants grazed was recorded for each sample. Samples were not
collected on May 1 in 1972 or 1973 since burning removed identifiable
top growth. Soil, roots, and dead organic material were removed from
samples by cold-water washing and hand clipping. Elongated culms were
removed two in. above the uppermost basal node. Cleaned samples were
oven-dried for five days at 70° C, ground in a Wiley mill (40-mesh
screen), and stored in sealed glass bottles in the dark. Total non-
structural 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 sub-classes was
used to test grazing effects on samples from all collection dates (Kemp,
1972). Subsequent analyses of variance, with grazing as a covariate
when significant, were used to test effects of burning and nitrogen
fertilization on collections over two years (growth and storage period:
May 15-November 1) and on collections in one year (dormant period:
December 1-April 15). Means were separated by LSD multiple range tests
when significant ($P < .05$) F-values were found. Both linear and quadratic
effects among fertilizer treatments were compared orthogonally (Cochran
and Cox, 1968).

Results and Discussion

Big Bluestem Total Non Structural Carbohydrate (TNC) Reserves

Grazing (% plants grazed) decreased TNC levels during the grow-ing season ($P < .01$), May 15-November 1, but not in the dormant period ($P < .67$), December 1-April 15. Any situation that interferes with nor-mal growth of the photosynthetic tissue of range plants will restrict development of the roots, normal reserve storage, and may curtail sub-sequent growth (Cook, 1966). Detrimental effects of partial defolia-tion 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. % TNC was higher in burned pastures than in unburned pastures throughout the growth and storage period (Figure 1). TNC dropped in January but rose to stable levels a month later where they remained until initiation of spring growth (Figure 2). That cycle was similar to those reported by Owensby et al. (1970) and McKendrick (1971) for big bluestem. Food reserves are utilized in early growth until the photosynthetic products exceed growth demands and are then stored. TNC level declines in August have been attributed to sexual reproduction. Owensby (unpub.) found only a small fraction of big bluestem plants in tallgrass prairie (<1%) actually initiate seed heads. Root production on new rhizomes of big bluestem in mid-August (McKendrick, 1971) probably caused the decline in reserves at that time. Sampson and McCarty (1930) and Weinmann (1948) report underground development to be most active in

Figure 1. Effect of burning on rhizome, crown, live stem base %
TNC at different dates (May 15-Nov. 1, 1972-73)
averaged over all treatments. 1/Points with common
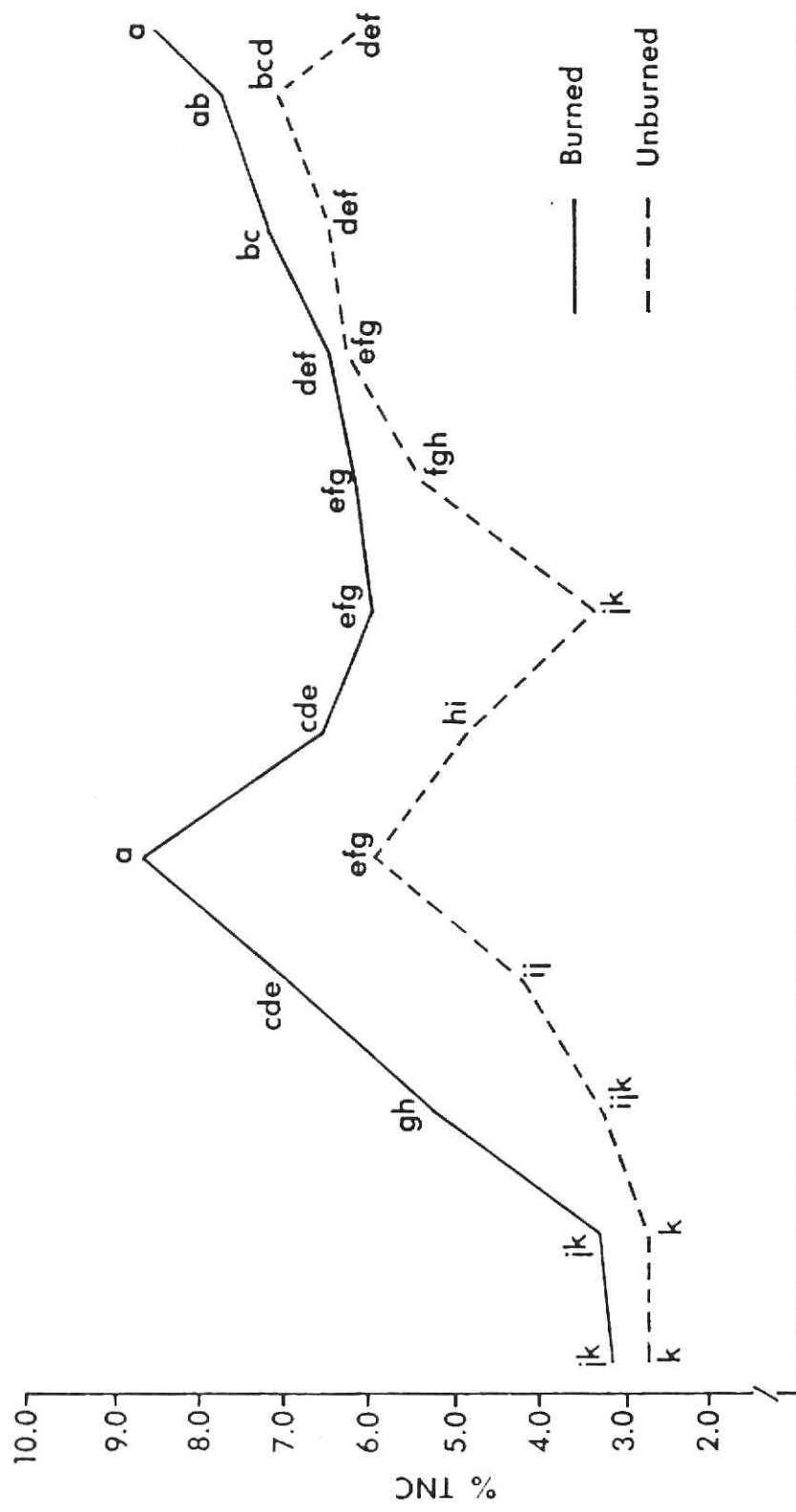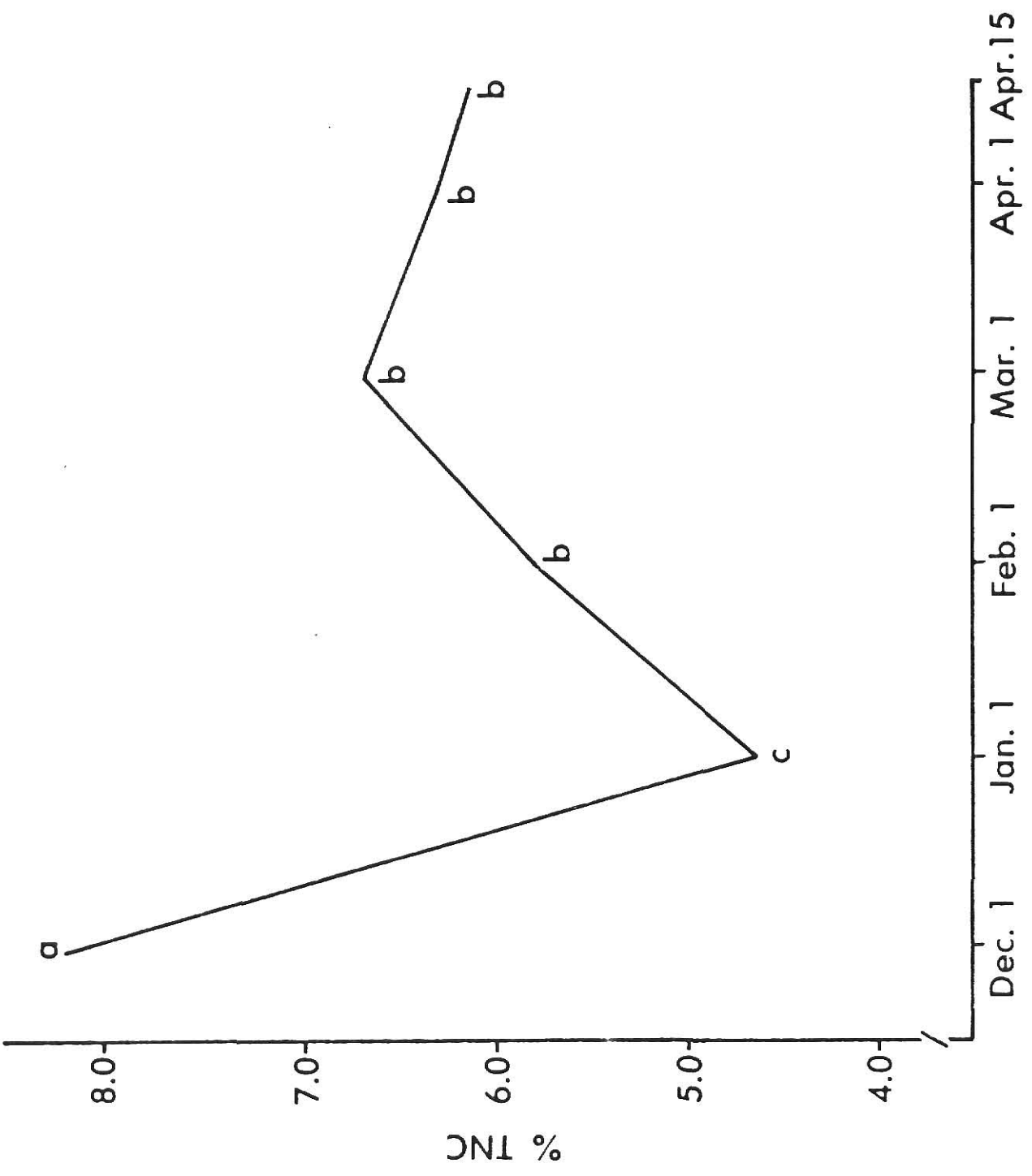letter are not significantly different (P < .05).

Figure 2. Effect rhizome, crown, live stem base % TNC at different
dates (Dec. 1, 1972-April 15, 1973) averaged over all
treatments. 1/Points with common letter are not signifi-
cantly different (P < .05).

the season when herbage growth is at a minimum. Other workers have shown, but have not explained, a drop in mid-winter TNC levels (Sampson and McCarty, 1930; Archbald, 1940; Sonneveld, 1962). Research here was not conclusive; storage compounds may be transfered from one form to another during periods of temperature or moisture stress.

Burning and nitrogen fertilization significantly affected TNC levels during the growing season and dormant period (P < .01). % TNC was highest in burned pastures with no nitrogen and lowest in unburned pastures with 80 lb N/A. Effects were mostly quadratic: TNC levels were higher with 0 and 80 lb N/A than 40 lb N/A in burned pastures but lower with 0 and 80 lb N/A than with 40 lb N/A rate in unburned pastures (Fig. 3 and 4). Ehrenreich (1959) theorized that following burning less mulch and earlier growth would stimulate greater carbohydrate reserves. Pettit and Fagan (1973) showed reduced carbohydrate reserves during the growing season, but nearly equivalent levels at the point of maximum storage with nitrogen fertilization (Fig. 4). The decline in % TNC with fertilization and burning was probably due to increased growth with fertilization.

Big Bluestem Nitrogen (N) reserves:

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

As sampling date changes, the effect of nitrogen fertilization rate on reserve nitrogen levels changes in the growth and storage period (P < .01), but not in the dormant period (P < .15). Reserve levels under 0 lb. and 40 lb. nitrogen fertilization rates declined

Figure 3. Effect of nitrogen fertilization and burning on rhizome,
crown, live stem base % TNC (May 15-Nov. 1, 1972-73)
averaged over all treatments. 1/Points with common
letter are not significantly different (P < .05).
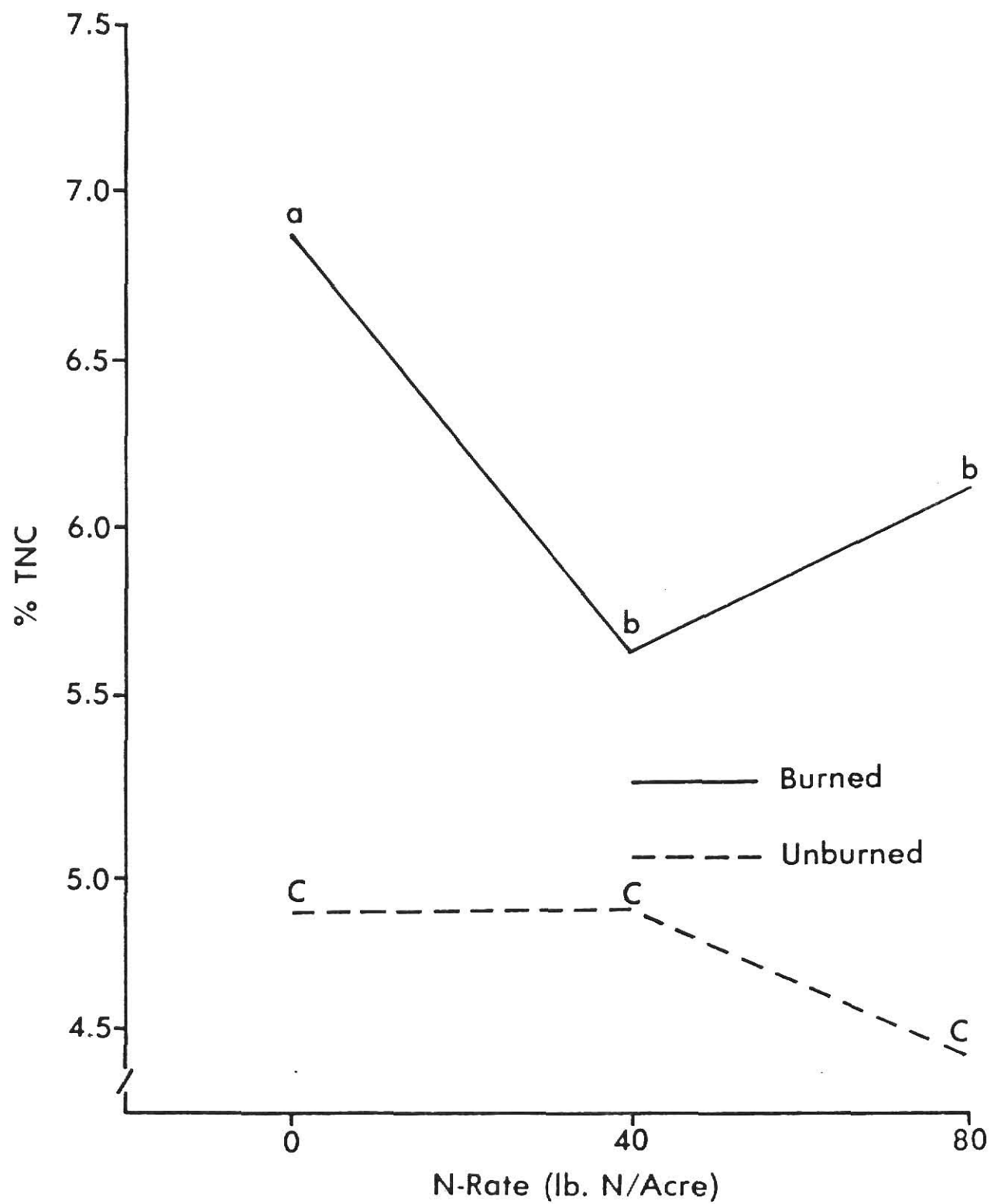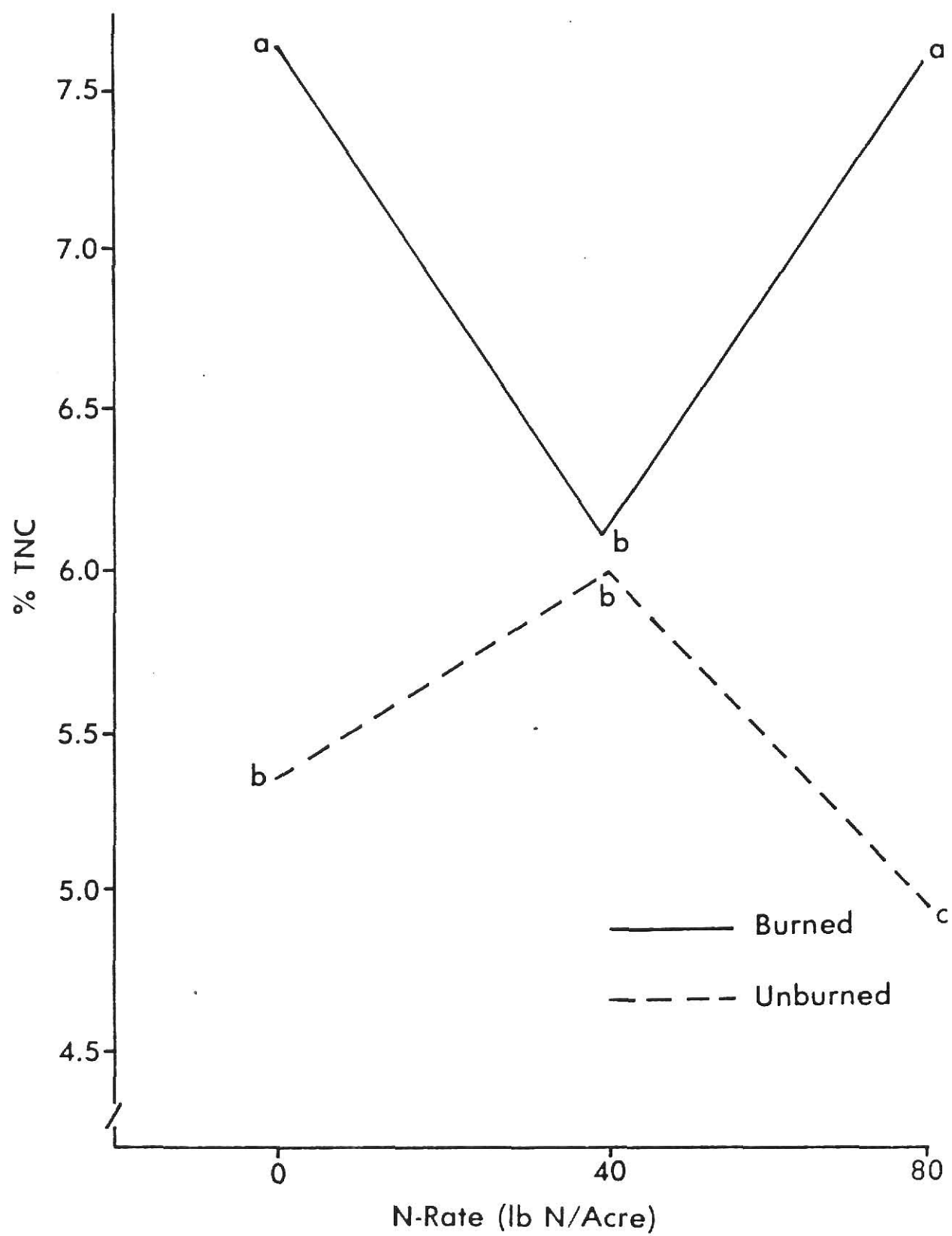
Figure 4. Effect of nitrogen fertilization and burning on rhizome,
          crown, live stem base % TNC (Dec. 1, 1972-Nov. 1, 1973)
          averaged over all treatments. 1/Points with common
          letter are not significantly different (P < .05).

when growth requirements exceeded available nitrogen, remained at lower levels during mid-season, and increased in storage organs when plant requirements no longer exceeded available supply (Fig. 5). Nitrogen reserves were not lowered in mid-August, as were TNC reserves, probably due to sufficient uptake of soil nitrogen by new roots. McKendrick (1971), in earlier work on big bluestem, indicated not only an increase in reserve nitrogen at maturity, but declines in % N with spring growth initiation. Changes in annual N reserve cycling were less noticeable under the 80-lb. N rate indicating high nitrogen uptake throughout the season, with nitrogen reserves not needed to support growth. Nitrogen reserve levels were lowest under 0 lb applied N, higher at the 40-lb rate, and highest at the 80-lb rate. Reserve levels were equal under 0-lb and 40-lb rates at seasons end (Fig. 3). Weinmann (1948) and Power (1972) show positive correlations of increased nitrogen reserve levels with nitrogen fertilization. A positive correlation appeared to exist when available N exceeded plant requirements.

Burning and nitrogen fertilization significantly affected reserve nitrogen levels ($P < .01$) during the growing season. Big bluestem storage organ % N was highest in unburned pastures at the 0 and 40-lb nitrogen rate ($P < .05$) throughout the year (Fig. 6 and 7). Effects of nitrogen fertilization on burned and unburned pastures were linear; % N increased as fertilizer rate increased. Stored nitrogen did not differ ($P < .05$) under the 0-lb and 40-lb rates within burning treatments (Fig. 7) during the dormant period.

Burning removes mulch and darkens the soil surface, increasing soil temperature, resulting in rapid top growth early in the year

Figure 5. Effect of nitrogen fertilization on rhizome, crown,
stem base % N at different dates (May 15-Nov. 1,
1972-73) averaged over all treatments. 1/Points with
common letter are not significantly different (P < .05).
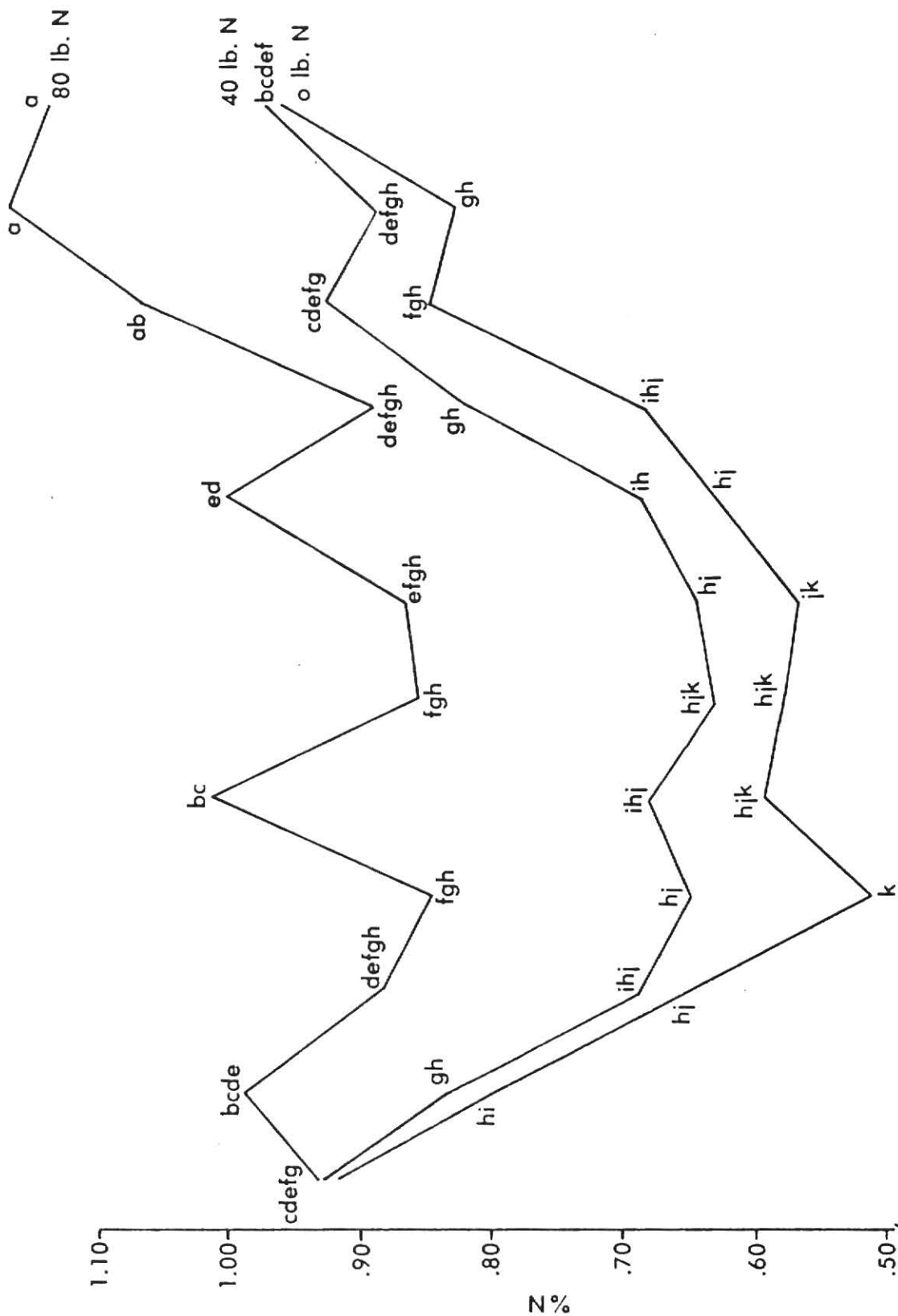
Figure 6.   Effect of nitrogen fertilization and burning on rhizome,
            crown, live stem base % N (May 15-Nov. 1, 1972-73) aver-
            aged over all treatments. 1/Points with common letter
            are not significantly different (P < .05).
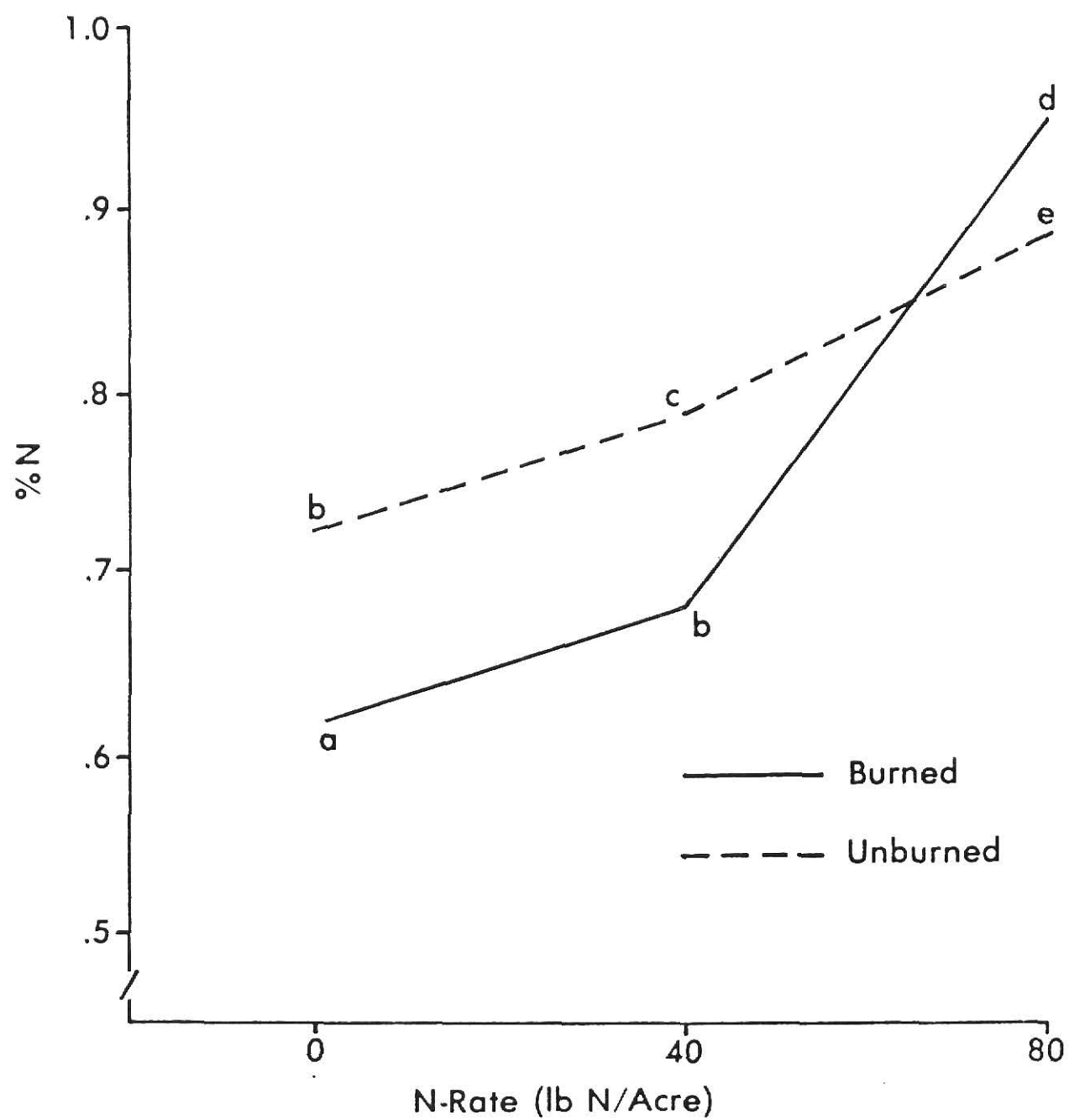
Figure 7. Effect of nitrogen fertilization and burning on rhizome, crown, live stem base % N (Dec. 1, 1972-April 15, 1973) averaged over all treatments. 1/Points with common letter are not significantly different (P < .05).
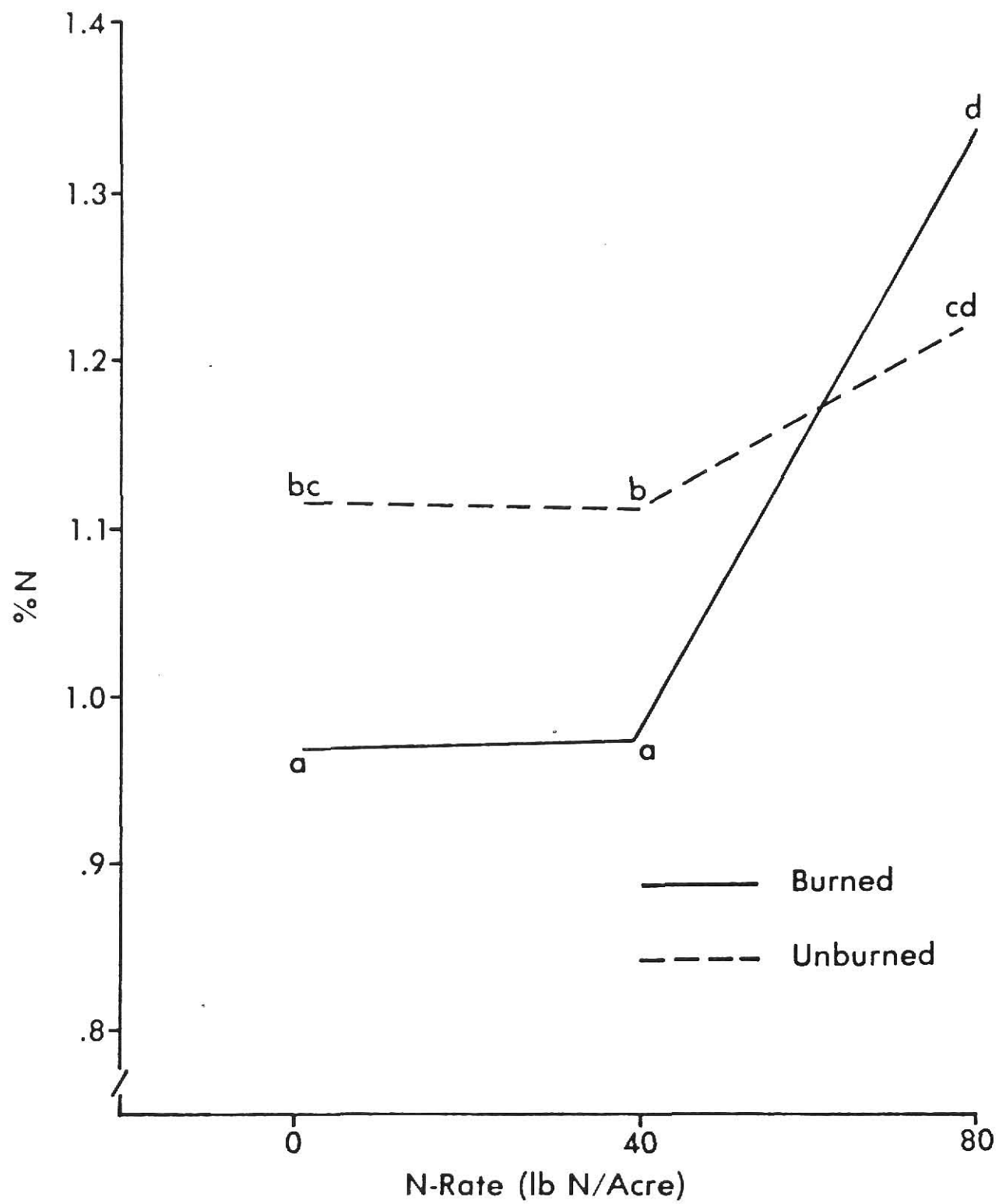
(Owensby and Smith, 1972). Rapid growth causes plant needs to exceed the available soil nitrogen supply and reserve N to be utilized, lowering storage levels.

Storage organ nitrogen levels were similar (P < .05) in 1972 and 1973 under 0-lb and 40-lb applied nitrogen, respectively. % N was higher in 1973 at the 80-lb rate. Apparently, an accumulation of nitrogen occurs in storage organs when excess nitrogen is available (Fig. 8).

Conclusions

TNC and nitrogen levels decreased as growth exceeded available photosynthetic products and soil nutrients. That information may be utilized in determining proper stocking periods. Owensby (unpub.) and Trlica and Cook (1971) state that if defoliation occurs early in the growing season reduction in food reserves at the close of the growing season are not affected nearly so much as if clipping or grazing occurred late in the season.

Higher grazing rate as level of nitrogen fertilization increased had little effect on either TNC or nitrogen reserve levels in big bluestem at senescence. Apparently the rancher could increase cattle numbers with nitrogen fertilization if species composition shifts can be controlled.

Total non-structural carbohydrate reserves were highest, and nitrogen reserves were lowest, under burned conditions with no nitrogen fertilization. Big bluestem TNC levels benefited most with burning, regardless of nitrogen fertilization level. TNC levels during the dormant period were lowest in unburned pastures with heavy fertilization,

Figure 8. Effect of nitrogen fertilization on rhizome, crown, live stem base % N for different years (May 15-Nov. 1, 1972-73) averaged over all treatments. 1/Points with common letter are not significantly different (P < .05).
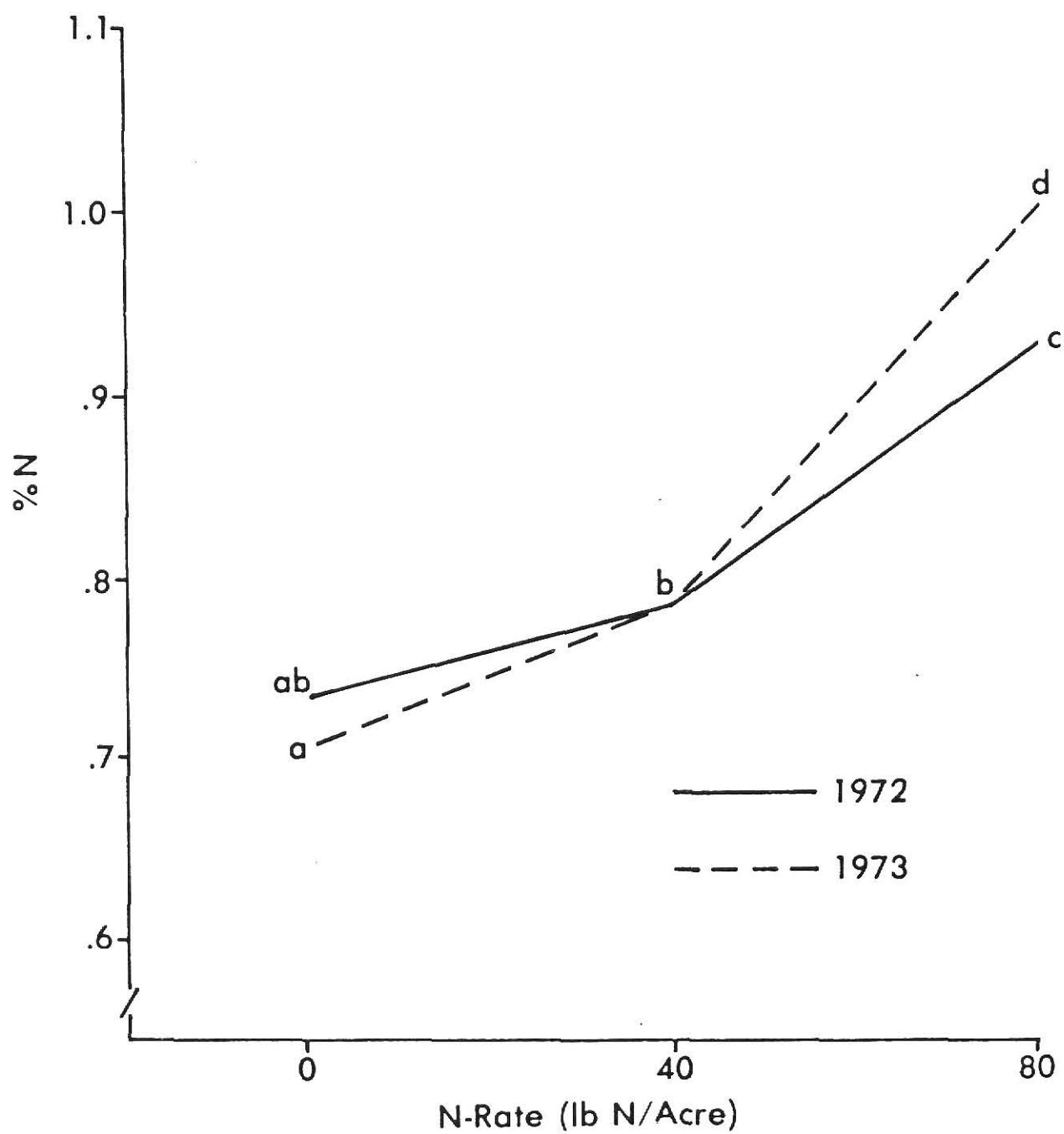
but did not approach the critically low levels of early spring. Continued nitrogen application and lack of burning may lower plant vigor the following year, resulting in lowered big bluestem competitive ability.

Reserve % nitrogen increased linearly as level of nitrogen fertilization increased. Added nitrogen at the 40-lb rate apparently was utilized for increased forage production, but the 80-lb N rate apparently exceeded plant's needs, since accumulation took place over time.

A combination of burning with 0, 40, and 80 lb N/acre did not lower reserve constituent levels below that of unburned, non-fertilized pastures. Plant vigor may be increased in the True Prairie by burning. Nitrogen fertilization with burning, over a two year period, was not detrimental to big bluestem TNC and nitrogen reserve levels.

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Appendix

Reserve substances are typically defined as organic substances produced in one part of the plant and moved to another for storage. Carbohydrate reserves are in a dynamic energy balance system, interrelated to rates of growth and photosynthesis. Soluble carbohydrates form only part of the reserve material needed for herbage regrowth. The proteinaceous compounds may play at least as important a role (Dilz, 1966). Reserve substances are of vital importance in maintaining a stable range resource.

Research correlating various management practices to levels of reserve constituents is lacking. Lowered reserves at critical points in the plants phenology will result in decreased production. A review of literature follows, with particular emphasis given to burning, nitrogen fertilization, and grazing effects on reserve constituents of warm-season perennial grasses. More complete reviews are given by Cook (1966), McIlroy (1967), and White (1973).

Reserve Constituents

Of most importance are the nonstructural carbohydrates stored in vegetative organs of perennial grasses. Weinmann (1947) termed these reserves as "total available carbohydrates", defined as including all those carbohydrates which can be used in the plant body as a source of energy or as building material, either directly or indirectly after having been broken down by enzymes. Smith (1969) offers the term "total nonstructural carbohydrates" as more clearly definable to both plant and animal investigators.

Carbohydrates are defined as polyhydroxy aldehydes or ketones, or as substances that yield one of these compounds on hydrolysis (Conn and Stump, 1972). There are three main groups of carbohydrates: mono-saccharides, oligosaccharides, and polysaccharides. Sucrose functions as a temporary reserve (chiefly in leaves), as a carbohydrate translo-cation form, and as a polysaccharide precursor (Peat, 1946; Porter, 1962). Starch represents a more permanent storage product form, parti-cularly in the warm-season perennial grasses (McKendrick, 1971; White, 1973). Starch granules consist of amylase and amylopectin, present in varying amounts. Structural carbohydrates - hemicellulose (pentosans and hexosans) and cellulose - are not generally considered to be a part of the dynamic system, but do contribute irreversibly to the structure of cells (Weaver, 1946; Porter, 1962; Cook, 1966; Gibbs, 1966; White, 1973).

Reports conflict regarding nitrogenous compounds as reserve con-stituents. Dina and Klikoff (1973), in work with big sagebrush, note accumulation of both sugar and nitrogen in water stressed plants, thereby adapting to adverse conditions for survival. Stoddart and Smith (1955), MacLeod (1965), Davidson and Milthorpe (1965), McKendrick (1971), and Power (1972) note the use of both carbohydrate and nitrogen reserves for root and forage production. With severe defoliation, declines in soluble carbohydrate are insufficient to account for regrowth and respir-ation losses. Other sources such as proteinaceous substances must be involved (McIlroy, 1967). Weinmann (1948) states that nitrogen and other mineral nutrients can't be considered as reserves in the true sense, merely nutrients which enter organic combinations in the plant

body, becoming constituents of reserve materials. White (1973) sum-
mizes that nitrogenous compounds are used in respiration, but are not
alternately stored and utilized as carbohydrate reserves are.

In summary, reserve constituents in warm-season perennial
grasses are comprised primarily of starch granules. Nitrogenous com-
pounds apparently are of lesser importance than carbohydrate reserves
in regrowth and survival. Structural compounds - hemicellulose and
cellulose - are not utilized in significant quantities as food reserves.

Storage Organs

Common storage organs include roots, tubers, rhizomes, stolons,
crowns, and stem bases of herbaceous species and twigs of woody species
(Graber, 1927; Weinmann, 1948; Cook, 1966; Smith and Morton, 1970; White,
1973). Storage may occur temporarily in all portions of the plant
(Bonner and Galston, 1952). McKendrick (1973) states that carbohydrates
retained in aerial portions of big bluestem and indiangrass shoots were
believed important for survival. McIvanie (1942) reported storage in
lower internodes in amounts nearly equal to root reserves.

Roots play a lesser role in storage of carbohydrate fractions
than other specialized storage organs. Marshall and Sagar (1965) found
that nonstructural carbohydrates were not translocated from roots to
shoots following herbage removal. Smith and Morton (1970) report that
carbohydrate initially stored in roots play an active role in regrowth
of shoots, being utilized for structural components retained in the
available state and serving as readily available respiratory substances.

Though lacking supportive research, nitrogenous reserves are likely accumulated in the same regions as the carbohydrates.

In summary, both carbohydrate and nitrogen reserves of grasses are stored primarily in the lower portions of grasses--stem bases, crowns, rhizomes, and possibly roots. These reserves are utilized in the respiration and regrowth of plants.

Reserve Fluctuation

General: Annual fluctuations of total nonstructural carbohydrate and nitrogen levels in storage organs are documented. Cook (1966) defines reserve substances as organic compounds elaborated in photosynthetic tissue and stored for later use in other plant parts. Any process which produces or utilizes energy may affect amounts of reserve constituents in plants.

Reserves are elaborated by aerial parts in excess of current requirements, transferred to roots and rhizomes to be stored, and utilized during new production (Weinmann, 1948). Aldous (1930), McCarty (1935), Weinmann (1940), Weinmann (1942), Rappe (1947), Stoddart (1955), Kinsinger and Hopkins (1961), McKendrick (1971), and Pettit and Fagan (1973) report declines in reserve carbohydrate levels with the initiation of growth. They agree on two other phenologic point fluctuations: declines when seed set occurs and a rise in carbohydrate levels with approaching maturity. Stoddart (1955) states roughly 75% of the food reserves are used in spring to develop 10% of herbage growth, with subsequent growth dependent on current food produced. Dodd and Hopkins (1958) conclude that increases in total nonstructural carbohydrates in

the underground parts vary inversely with rates of growth. Significant increases in foliage starch concentration correspond to periods of maximum tuber growth and maximum foliage photosynthetic area; concentrations of root and culm base starch follow similar trends (Smith and Lienweber, 1973).

Fewer data are available on fluctuation in reserve nitrogen constituents. Remy (1923), Richardson et al. (1932), and Weinmann (1940, 1942) report increased N %'s in storage organs at maturity. Arny (1941) and McKendrick (1971) indicate increases in reserve nitrogen at maturity and N % declines that exceed the % TNC decline with spring growth initiation.

McKendrick (1971) found the decline in reserve food levels during seed set coincides with the phenologic point of root production on new rhizomes. He notes increases in root production at seed set may be a major factor in reserve declines during this period. Sampson and McCarty (1930), in work on Stipa pulchra, found active root growth occurred when herbage growth had practically ceased. Weinmann (1948) reports underground development is most active in the season when herbage growth is at a minimum.

Carbohydrates are for plant respiration and slight growth in winter (Cook, 1966). Food is used in essential life processes during winter as soluble sugars and serves to protect living protoplasm from low temperatures (Norris, 1963). Concentrations of sugar in basal organs are associated with resistance to low temperature, essential to winter survival of plants (McCarty, 1938). Storage products, including carbohydrates and proteins, are associated with plant ability to survive

adverse conditions (Jameson, 1964). Starch granule size may be related to warm-season grass winter hardiness (McKendrick and Anderson, 1971).

Sampson and McCarty (1930), Archbald (1940), and Sonneveld (1962) report a rapid drop and subsequent rise in reserve constituent level in mid-winter. No explanation attempt is made.

In summary, reserve constituent levels of warm-season perennials decline rapidly with growth initiation, increase when photosynthetic production exceed growth demand, decline with root growth on new rhizomes, and reach maximum levels prior to dormancy. TNC levels may drop in mid-winter, but is not explained. Concentrations of reserve materials are related to cold hardiness and winter survival.

Burning: Nature and Man have used burning in grassland management for hundreds of years. Burning is both accepted and condemned by managers. Burning is generally accepted in the tallgrass prairie.

Burning effectiveness is dependent upon time of spring growth initiation and food reserves movement (Aldous, 1934).

Decreases in root system biomass result from thinning stands and lessening foliage area initiated by litter accumulation in absence of burning in tallgrass prairie (Kucera and Dahlman, 1967). These researchers recommend a three-year interval between fires as the maximum period in effectively maintaining vigorous big bluestem stands. Plots subjected to annual fire have more roots and rhizomes than those burned with less frequency (Hadley and Kieckhefer, 1963; Kucera and Dahlman, 1968).

Reports show decreases in yield of tall grasses with use of fire, even when properly timed (Aldous, 1934). However, Hensel (1923)

notes that increases in yield on unburned plots are probably due to previous year's growth. Increases in herbage yield with burning are indicated by several authors (Anderson, 1954; Ehrenreich and Aikman, 1963; Gay and Dwyer, 1965).

Burned range may initiate growth two-three weeks earlier than unburned range, depending on date of burning, but matures earlier (Ehrenreich and Aikman, 1963). Greater amounts of vegetative growth of earlier growing plants may allow the plant to produce more carbohydrates. Ehrenreich (1959) theorizes that less mulch and earlier growth produced greater carbohydrate reserves. Iwanami and Sato (1970), in work on Miscanthus sinensis in Japan, found burning resulted in the rapid depletion of stored carbohydrates in rhizomes due to regrowth; recovery was slower than in unburned plants, especially after late burning. Carbohydrate content of both culms and rhizomes reach the same level as unburned plants by season's end (Iwanami and Sato, 1970).

Anderson (1954) suggests reductions in carbohydrate reserves could follow intensive grazing encouraged by burning; burned plots did not recover to store as much carbohydrate by seasons end when clipped as unburned plots. Pressures of moderate grazing reduce vegetative density the least with late spring burning on native Flint Hills rangeland (Herbel, 1954).

Burning is an effective tool in controlling cool season grasses, weeds, and some brushy species in the tallgrass prairie (Owensby and Smith, 1972).

In summary, burning is an effective tool for managers in the Flint Hills area of Kansas. Burning increases root-rhizome biomass,

providing increased food storage organ quantity. Carbohydrate levels of unburned and burned areas equalize by season's end. Carbohydrate reserves may be lowered by increased grazing pressure in burned areas. This could be controlled by separating burned and non-burned areas, using proper burning time, and adjusting stocking rates.

N Fertilizer: Nitrogen, not moisture, is the most critically limiting factor in bluestem range production (Owensby, et al., 1970). Under nitrogen fertilization composition shifts from warm season perennials to cool season grasses and weeds have been reported (Mader, 1956; Silker and Wood, 1960; Owensby et al., 1970). Burning and fertilization together may greatly increase forage production and control invasion of cool season grasses and weeds.

Fertilizer treatments generally stimulate top growth more than root growth (Weinmann, 1948). He reports N abundance may, especially under conditions of severe defoliation, produce an actual reduction in root weight.

By adding nitrogen, mobilization of stored carbohydrate reserves takes place, leading to significant decreases in percentage of reserve substances in plants (Benedict and Brown, 1944; Sprague and Sullivan, 1950). Under protection, such decreases are of short duration; leaf area increases, hence total photosynthetic activity through addition of nutrients may result in increased accumulation of carbohydrate reserves and higher weights (Weinmann, 1952). Fertilizer treatments and carbohydrate reserve relationships are clearly governed by the law of limiting factors: where carbohydrate accumulation is impaired by accessive defoliation, the beneficial effect of fertilizer on root and herbage growth is greatly reduced (Weinmann, 1952).

Effect of fertilizer on carbohydrate reserves of grasses vary.
Benedict and Brown (1944), Humpheys and Robinson (1966), Schirman and
Buchholtz (1966), Pettit and Fagan (1973), and Stroehlien (1973) report
lowered carbohydrate reserves, particularly during periods of initial
growth, when nitrogen fertilizer is applied. Norman (1939), Griffith
et al. (1964), Bryant (1965), Griffith and Teel (1965), MacLeod (1965),
Bryant (1966), Colby et al. (1966), Waite (1966), and Hojjati et al.
(1968) found similar results in cool season grasses and other perennial
forage plants with varying applications of nitrogen. Most authors
assume that higher total available carbohydrate percentages under low
nitrogen application rates are due to non-utilization in plant growth
and decreases in protein synthesis.

Nitrogen fertilization stimulates utilization of soluble carbo-
hydrate in temperate region grasses, but has little effect on the
reserve carbohydrate content of tropical grasses (McIlroy, 1967).
Balaska and Smith (1971) report total nonstructural carbohydrate percen-
tages of the herbage, stubble, and rhizomes of switchgrass at anthesis
were not affected by temperature or nitrogen fertilization.

Leukel et al. (1934), Adegbola (1966), and Bommer (1966) agree
that nitrogen fertilization at low to moderate levels stimulates leaf
area expansion and chlorophyll development, enhancing photosynthetic
capability and increasing amounts of carbohydrate produced.

Positive correlation exist between increasing nitrogen reserve
levels in grass roots and nitrogen fertilization (Remy, 1923; Weinmann,
1948; and Power, 1972).

In summary, even single fertilization salts have many effects on plant and soil; it is difficult to predict response to added nutrients (May, 1960). Lower levels of carbohydrate reserves and a higher level of nitrogen in storage organs with nitrogen fertilization occur. It appears difficult to obtain combinations of higher yields with high carbohydrate reserves. Accumulations of carbohydrates may indicate yield potentials are not realized (Blaser et al., 1966). Applications of nitrogen are of little use in subsequent growth unless plants have available supplies of carbohydrates or are capable of manufacturing them (Harrison, 1931).

Grazing & Clipping: Crider (1955) reports root growth stoppage for a period of time when half or more of the foliage of grasses is removed simultaneously during the growing season. Tiller formation also stops immediately following cutting (Alberda, 1957). Recovery time in both cases depends on severity of foliage removal and number of defoliations. Both authors agree that growth is reinitiated at the expense of carbohydrate reserves, when they remain available.

Loss of root biomass can be a serious matter in grassland maintenance. Weaver (1950) surmises that root amounts present are a direct measure of plant vigor; they are important in water and nutrient absorption and for continual survival. Storage organs quantity and quality reductions occur with frequent defoliation (Owensby, unpub.). Sampson and McCarty (1930), Owensby (unpub.), Drawe et al. (1972), and Trlica and Cook (1972) argue that if defoliation occurs early in the growing season reductions in food reserves at the close of the growing season are not affected nearly so much as if clipping occurred late in the season. Underground development is most active in the growing season when

herbage growth is at a minimum (Weinmann, 1948). Depletion of reserves caused by excessive defoliation result in reduced vigor and herbage growth, death, and botanical composition changes.

Detrimental effects of partial defoliation increase when frequency or degree of defoliation increase. Total protein yield of herbage is greater in plots harvested more than once; seed yield, root weight, root growth, amount of nutrients taken up, reserve constituents are all reduced by increased clipping and grazing. (Biswell and Weaver, 1933; Bukey and Weaver, 1939; Albertson et al., 1953; Jameson and Huss, 1959; Barnes, 1961; Kinsinger and Hopkins, 1961; Jameson, 1964; McKell et al., 1966; Bartholomew and Booysen, 1969; McDonough, 1969; Reynolds, 1971; and Owensby et al., 1974).

Though grazing and clipping effects parallel each other, they are not exactly the same (Owensby, unpub.; McKendrick, 1971). Grazing intensely may be less detrimental than clipping, provided grazing leaves ungrazed tillers while removing others, allowing for transfer of carbohydrates (White, 1973). Data from a few years of overstocking may lead to false conclusions about stocking rates. Any good range will produce more animal gain for a time, perhaps a number of years, if overgrazed, but will break down eventually, because food reserves and plant vigor are depleted (Owensby, unpub.).

Accumulated food reserves under moderate versus heavy grazing are tied to drought and heat resistance, as well as over-winter survival. Julander (1945) states that heat resistance is a measure of drought resistance and a large accumulation of colloidal carbohydrates is associated with drought resistance.

Decreased reserve levels under intensive grazing may be one factor in plant composition shift. Carbohydrate reserves in the heavily grazed plants are gradually reduced while less palatable species have optimum reserves.

Any situation that interferes with normal growth of the photosynthetic tissue of range plants will restrict development of the roots, normal reserve storage, and curtail subsequent growth (Hanson and Stoddart, 1940; Cook, 1966; Dodd and Hopkins, 1968; and Welch, 1968.

Effects of herbage removal may be compounded by addition of nitrogen fertilizer. Bonner (1966), testing carbohydrate reserves five days after cutting, reported reductions in carbohydrate level immediately after clipping were more pronounced with nitrogen application.

In summary, root growth, rhizome growth, and food reserve accumulation appear adversely affected by increased herbage removal. Clipping may be more detrimental than grazing, plant vigor decreases with increased frequency of both. Nitrogen fertilization compounds effects on removal of food reserve levels. When sufficient photosynthetic material is unavailable to supply needed food for regrowth, regrowth will be at the expense of reserves.

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Table A-1. Analysis of variance for effect of grazing (% plants grazed) on % N (May 15, 1972–November 1, 1973)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	18	12.73654677	0.70758593	28.167	0.0000
Year	1	0.02802367	0.02802367	1.116	0.2909
Burn	1	0.31764841	0.31764835	12.645	0.0004
Fert.	2	5.63892129	2.81945992	112.237	0.0000
Rep.	2	0.01462092	0.00731046	0.291	0.7477
Burn X Fert.	2	0.99159290	0.49579644	19.737	0.0000
Year X Fert.	2	0.26313334	0.13156664	5.237	0.0056
Year X Burn	1	0.10298040	0.10298038	4.099	0.0434
Year X Burn X Fert.	2	0.40590828	0.20295411	8.079	0.0004
% Graze	1	0.01534876	0.01534875	0.611	0.4348
Residual	509	12.78643417	0.02512069		
Total	541	35.36289978			

Table A-2. Analysis of variance for effect of grazing (% plants grazed) on % TNC (May 1-November 1, 1972-73)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	11	1012.68261641	92.06204224	35.048	0.0000
Year	1	40.00911770	40.00910950	15.232	0.0001
Burn	1	243.67070587	243.67070007	92.767	0.0000
Fert.	2	30.33606835	15.16803360	5.775	0.0034
Rep.	2	1.16285483	0.58142740	0.221	0.8016
Burn X Fert.	2	30.54099372	15.27049637	5.814	0.0033
Date X Burn	11	86.80731468	7.89157391	3.004	0.0007
Date X Burn X Fert.	22	81.36893235	3.69858742	1.408	0.1057
Year X Fert.	2	0.15746147	0.07873070	0.030	0.9705
% Graze X Fert.	2	11.18110677	5.59055328	2.128	0.1205
% Graze	1	17.23852496	17.23851013	6.563	0.0108
Residual	374	982.38842773	2.62670612		
Total	431				

Table A-3. Analysis of variance for rhizome, crown, live stem base % TNC (May 15–Nov. 1, 1972–73)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	11	1025.849375000	93.259933472	35.309890747	0.00000
Year	1	44.280761719	44.280761719	16.765487671	0.00005
Burn	1	241.769042969	241.769042969	91.538131714	0.00000
Fert.	2	33.854736328	16.927368164	6.409007072	0.00184
Rep.	2	1.093261719	0.546630859	0.206964314	0.81314
Burn X Fert.	2	30.157470703	15.078735352	5.709081650	0.00363
Date X Burn	11	87.855712891	7.986882210	3.023977280	0.00071
Date X Fert.	22	58.581542969	2.662796974	1.008182526	0.45296
Date X Burn X Fert.	22	78.281982422	3.558271408	1.347225189	0.13763
Year X Fert.	2	0.492187500	0.246093750	0.093175530	0.91106
Residual	354	934.979248047	2.641183853		

Table A-4. Analysis of variance for rhizome, crown, live stem base % N (May 15-Nov. 1, 1972-73)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	11	5.716859818	0.519714475	21.918746948	0.00000
Year	1	0.046253365	0.046253365	1.950717926	0.16335
Burn	1	0.235669553	0.235669553	9.939272881	0.00176
Fert.	2	5.032514572	2.516257286	106.122177124	0.00000
Rep.	2	0.008917991	0.004458994	0.188056350	0.82866
Burn X Fert.	2	0.739092052	0.369545996	15.585460663	0.00000
Year X Fert.	2	0.279958248	0.139979124	5.903565407	0.00300
Date X Fert.	22	1.027152061	0.046688728	1.969079018	0.00624
Date X Burn	11	0.205230117	0.018657282	0.786863744	0.65337
Date X Burn X Fert.	22	0.356060982	0.016184587	0.682578743	0.85715
Residual	355	8.417385101	0.023710944		
Total	431	22.065109253			

Table A-5. Analysis of variance for effect of grazing (% plants grazed) on % TNC (Sept. 1-Nov. 1, 1972-73)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	4	96.16758517	24.04188538	7.985	0.0000
Year	1	88.63202330	88.63201904	29.436	0.0000
Burn	1	51.95130760	51.95129395	17.254	0.0001
Fert.	2	2.81184116	1.40592003	0.467	0.6279
Rep.	2	2.20755806	1.10377884	0.367	0.6938
Burn X Fert.	2	4.54514641	2.27257252	0.755	0.4720
Date X Fert.	8	14.75426798	1.84428310	0.613	0.7662
Date X Burn	4	25.45476476	6.36369038	2.113	0.0822
Date X Burn X Fert.	8	33.26130387	4.15766239	1.381	0.2098
Year X Fert.	2	0.58133002	0.29066497	0.097	0.9080
% Graze X Fert.	2	5.46917620	2.73458767	0.908	0.4056
% Graze	1	1.13549826	1.13549805	0.377	0.5401
Residual	142	427.56298828	3.01100636		
Total	179	769.39453125			

Table A-6. Analysis of variance for rhizome, crown, live stem base % TNC (Sept. 1-Nov. 1, 1972-73)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	4	96.733551025	24.183380127	8.072512627	0.00001
Burn	1	53.814025879	53.814025879	17.963333130	0.00004
Fert.	2	4.105102539	2.052551270	0.685150146	0.50572
Rep.	2	2.461362839	1.230681419	0.410806537	0.66393
Burn X Fert.	2	5.120216370	2.560108185	0.854574740	0.42768
Date X Fert.	8	15.681632996	1.960204124	0.654324234	0.73081
Date X Burn	4	23.714721680	5.928680420	1.979017258	0.10075
Date X Burn X Fert.	8	32.386062622	4.048257828	1.351325035	0.22293
Year	1	100.830200195	100.830200195	33.657531738	0.00000
Year X Fert.	2	0.143688619	0.071844280	0.023981918	0.97631
Residual	145	434.386474609	2.995768547		
Total	179	769.378173828			

Table A-7. Analysis of variance for rhizome, crown, live stem base % N (Sept. 1-Nov. 1, 1972-73)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	4	1.715808868	0.428952217	18.852767944	0.00000
Burn	1	0.310838163	0.310838163	13.661577225	0.00031
Fert.	2	2.183732033	1.091865540	47.988327026	0.00000
Rep.	2	0.031857826	0.015928913	0.700088024	0.49828
Burn X Fert.	2	0.530247688	0.265123844	11.652397156	0.00002
Date X Fert.	8	0.325435996	0.040679500	1.787895203	0.08388
Date X Burn	4	0.026247900	0.006561972	0.288403749	0.88515
Date X Burn X Fert.	8	0.042851977	0.005356494	0.235422015	0.98366
Year	1	0.121680200	0.121680200	5.347938538	0.02215
Year X Fert.	2	0.090463340	0.045231670	1.987966537	0.14065
Residual	145	3.299145699	0.022752728		
Total	179	8.678312302			

Table A-8. Analysis of variance for effect of grazing (% plants grazed) on % TNC (Dec. 1, 1972-April 15, 1973)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	5	91.25502021	18.25099182	8.180	0.0000
Burn	1	73.87284578	73.87283325	33.109	0.0000
Fert.	2	0.73516357	0.36758178	0.165	0.8485
Rep.	2	0.83771539	0.41885769	0.188	0.8293
Burn X Fert.	2	33.43514783	16.71755981	7.493	0.0012
Date X Fert.	10	12.54650522	1.25465012	0.562	0.8386
Date X Burn	5	21.82302995	4.36460590	1.956	0.0966
Date X Burn X Fert.	10	45.39137440	4.53913689	2.034	0.0430
% Graze X Fert.	2	3.45509024	1.72754478	0.774	0.4651
% Graze	1	0.39854641	0.39854640	0.179	0.6739
Residual	67	149.49142456	2.23121452		
Total	107	471.13623047			

Table A-9. Analysis of variance for rhizome, crown, live stem base % TNC (Dec. 1, 1972-April 15, 1973)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	5	125.768444604	25.153762817	11.283016205	0.00000
Burn	1	76.137252808	76.137252808	34.152252197	0.00000
Fert.	2	3.672132492	1.836066246	0.823589146	0.44306
Rep.	2	1.030356407	0.515178204	0.231089234	0.79427
Burn X Fert.	2	33.941574097	16.970779419	7.612442970	0.00102
Date X Fert.	10	13.824617386	1.382461548	0.620119393	0.79172
Date X Burn	5	18.823699951	3.764739990	1.688717842	0.14870
Date X Burn X Fert.	10	41.874282837	4.187427521	1.878319740	0.06289
Residual	70	156.054367065	2.229347229		
Total	107	471.127685547			

Table A-10. Analysis of variance for rhizome, crown, live stem base % N (Dec. 1, 1972-April 15, 1973)

Source	D.F.	Sums of Squares	Mean Squares	F-Ratio	Prob.
Date	5	0.311460137	0.062292024	2.095230103	0.07616
Burn	1	0.076799810	0.076799810	2.583209038	0.11249
Fert.	2	1.376098633	0.688049316	23.142959595	0.00000
Rep.	2	0.063834429	0.031917214	1.073554993	0.34732
Burn X Fert.	2	0.370465457	0.185232699	6.230416298	0.00323
Date X Fert.	10	0.452377796	0.045237780	1.521600723	0.15008
Date X Burn	5	0.158042729	0.031608544	1.063172340	0.38820
Date X Burn X Fert.	10	0.311253011	0.031125300	1.046917915	0.41454
Residual	70	2.081127167	0.029730387		
Total	107	5.201462746			

Table A-11. Effect of nitrogen fertilization and burning on rhizome, crown, live stem base % N (Sept. 1-Nov. 1, 1972-73) averaged over all treatments

| | N Fertilizer Levels (lbs. actual N/acre) | | |
	0	40#	80#
Late spring burned	.722 a[1]/	.773 a	1.088 cd
Unburned	.866 b	.948 c	1.019 d

[1]/ Points with common letter are not significantly different (P< .05).

Figure A-1. Rhizome, crown, live stem base % TNC at different dates
(Sept. 1-Nov. 1, 1972-73), averaged over all treatments.
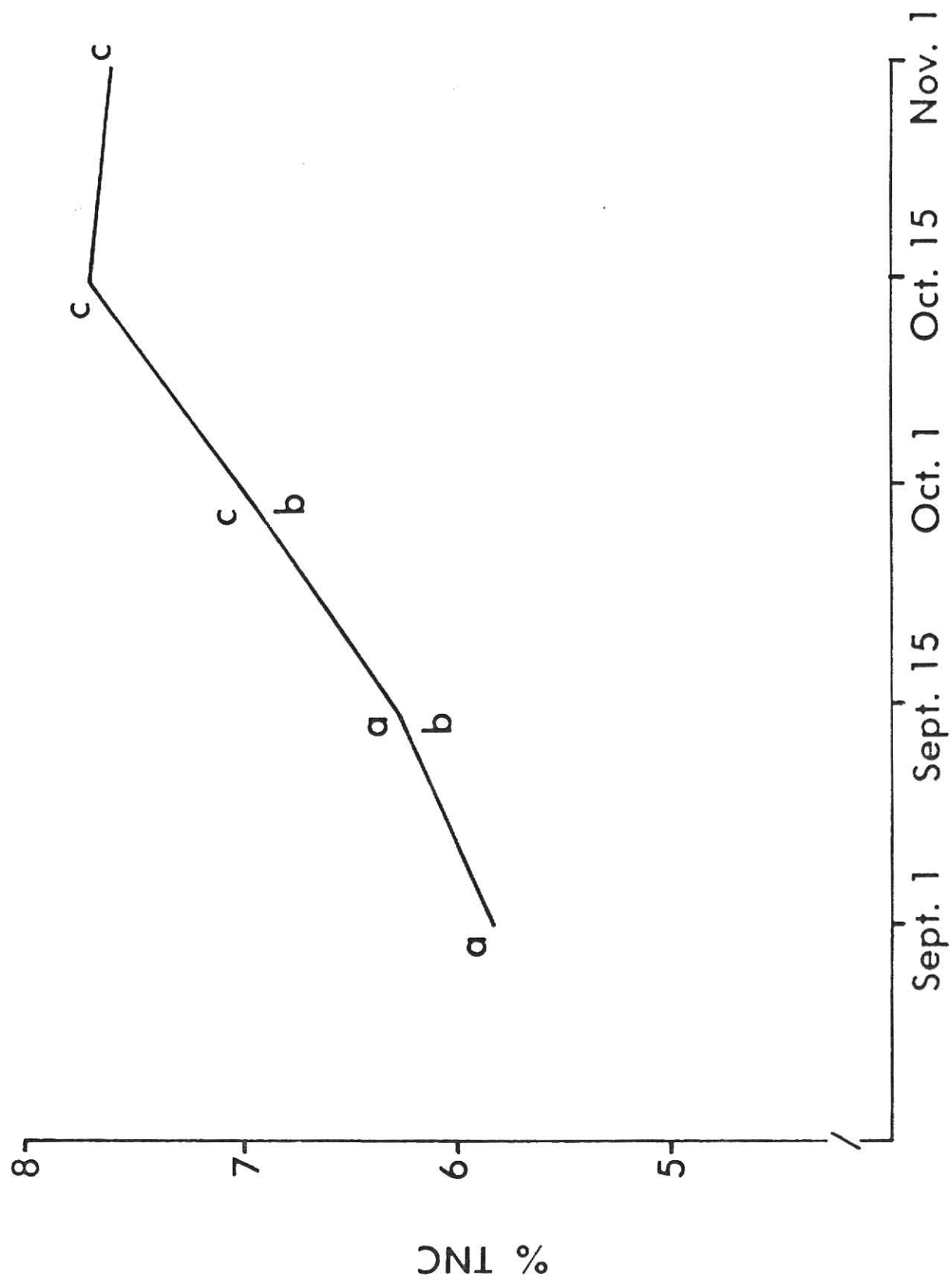1/Points with common letter are not significantly dif-
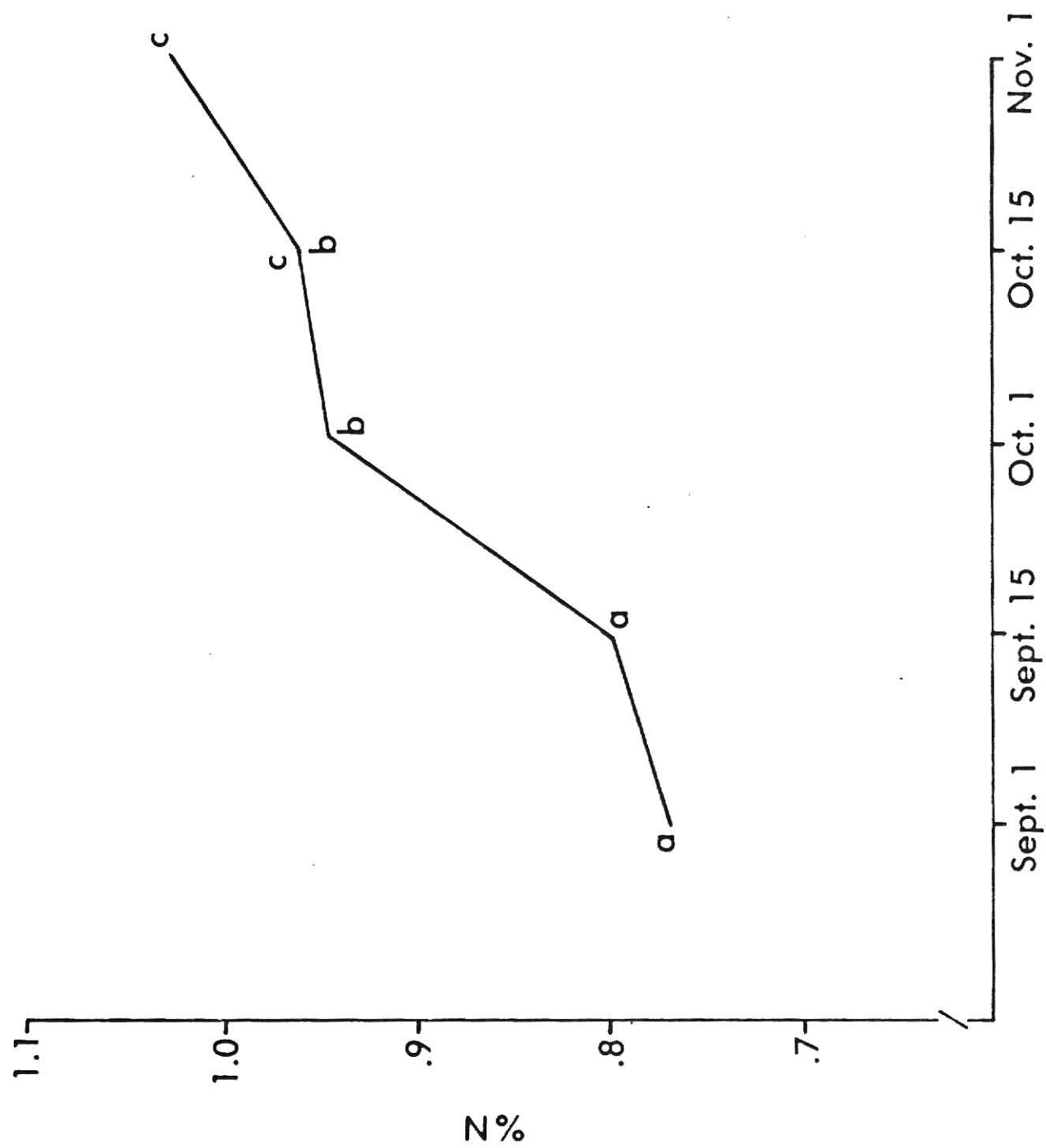ferent (P < .05).

Figure A-2. Rhizome, crown, live stem base % N at different dates
(Sept. 1-Nov. 1, 1972-73) averaged over all treatments.
1/Points with common letter are not significantly dif-
ferent (P < .05).

EFFECTS OF NITROGEN FERTILIZATION, BURNING, AND GRAZING
ON RESERVE CONSTITUENTS OF BIG BLUESTEM (Andropogon gerardi Vitman)

by

JERRY R. RAINS

B. S., Northwest Missouri State College, 1971

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

Effects of nitrogen fertilization, burning, and grazing on nitrogen and carbohydrate reserves of big bluestem (<u>Andropogon gerardi</u> Vitman) were studied. Nitrogen was applied aerially to burned and unburned pastures at 0, 40, 80 lb N/acre. Grazing was by yearling steers, with rates adjusted to obtain similar percent herbage removal from each pasture. Big bluestem storage organs (rhizome, crown, live stem base) were collected every two weeks May 15-Nov. 1, and monthly Dec. 1-April 15. Total nonstructural carbohydrate (TNC) % and Kjeldahl N % were determined for each sample.

TNC and nitrogen levels decreased as growth exceeded photosynthetic production and soil nutrient assimilation. Increased grazing rate had little effect on either reserve TNC or nitrogen levels at senescence as level of nitrogen fertilization increased. TNC reserves were highest, and nitrogen reserves were lowest, with no nitrogen fertilization. Big bluestem % TNC benefited more from burning than from the other treatments, regardless of nitrogen fertilization rate. TNC levels during the dormant period were lowest in unburned pastures with heavy fertilization, but did not approach the critically low levels of early spring. Storage organ nitrogen level increased linearly as nitrogen fertilization rate increased.

Burning alone or combined with fertilization did not lower reserve % TNC levels below that of unburned, unfertilized pastures during the year, indicating vigor may be increased in the True Prairie by burning.