

SEASONAL NITROGEN TRANSLOCATION IN
BIG BLUESTEM, ANDROPOGON GERARDII VITMAN,
IN KANSAS DURING A DROUGHT YEAR

by

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B.S., University of Montana, 1976

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1982

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ACKNOWLEDGEMENTS

Appreciation is expressed to Dr. Lloyd C. Hulbert, major professor, and to the graduate committee members: Dr. Peter Wong, Dr. Dave Kissel, and Dr. Steve Thien, for their support and guidance throughout this study. Thank go to Dr. Peter Wong for the loan of most of the laboratory equipment used in the study. Thanks also go to Tim Seastedt for many impromptu discussions and helpful suggestions, and Craig Freeman for help in the final assemblage process. I am particularly grateful to my husband, Steve, for his unending encouragement and support for this project and his help and companionship during the field work.

PART I

SEASONAL NITROGEN TRANSLOCATION IN BIG BLUESTEM, ANDROPOGON GERARDII VITMAN,
IN KANSAS DURING A DROUGHT YEAR:

TOTAL NITROGEN

ABSTRACT

Seasonal nitrogen translocation in big bluestem in the tallgrass prairie was studied in burned and unburned treatments on two sites within Konza Prairie Research Natural Area, Manhattan, Kansas. Total nitrogen concentrations in the leaves dropped from 1.46% and 1.82% on unburned and burned treatments, respectively, in May 1980 to 0.72% on both treatments in July. Levels further dropped to 0.21% and 0.23% total nitrogen in November 1980 for unburned and burned treatments, respectively. The May to July percentage decrease is believed due to a more rapid increase in plant biomass than in plant total nitrogen. The July to November decrease is assumed to be retranslocation of nitrogen into perennial belowground parts. During the same period rhizomes increased from 0.49% to 0.97% total nitrogen. Roots increased from 0.31% to 0.59% total nitrogen, indicating that roots are also used as storage organs. As 1980 was a dry year, comparisons with other studies indicate that drought stress may reduce the nitrogen content of big bluestem.

Keywords: big bluestem, Andropogon gerardii Vitman, nitrogen burning, retranslocation, tallgrass prairie, drought.

INTRODUCTION

The objective of this study was to follow the movement of total nitrogen in various plant parts of big bluestem, Andropogon gerardii Vitman, a dominant species in the tallgrass prairie. Specific attention was given to the fall decrease in leaf total nitrogen and concurrent increase in rhizome total nitrogen which has been hypothesized to be retranslocation of nitrogen to the perennial plant parts for storage. Retranslocation may be defined as the movement of nitrogen from the annual to the perennial plant parts during senescence. This may be a pathway for internal conservation of nitrogen to regulate losses and maintain a steady state condition.

Extensive data exist on the total nitrogen content of grasses: concurrent measurements of above and belowground parts are rare. Many studies have been conducted in relation to management treatments and their effect on percent nitrogen in forage (i.e. fertilization or grazing: Rains et al. 1975, McIllvanie 1942, Owensby et al. 1977). An increasing number of nitrogen studies have emphasized nitrogen retranslocation and storage in various plant parts of forest systems (Carlisle et al. 1976, Woodwell 1974, Best and Monk 1875) but this approach has not been fully explored for natural grasslands. A few earlier studies evaluated nitrogen content of whole plants (Weinmann 1940, 1942, 1948) and more recent studies have developed grassland nitrogen cycling budgets (Clark 1977, Woodmansee et al. 1978). Computers have aided in developing nitrogen cycling models to describe general systems (Reuss and Innis 1977, Bormann et al. 1977, Risser and Parton 1982). However, when actual data were put into these models two discrepancies were found: 1) the amount of nitrogen in leaf litter was much lower than the amount of nitrogen in the same leaves in early summer, and 2) the amount of yearly nitrogen uptake by the roots was

not enough to satisfy the plant's nitrogen uptake for that year (Clark 1981). To explain these discrepancies, Clark (1977, 1981) hypothesized that there must be another pathway for nitrogen within the plant.

Clark (1977) states that the slow decomposition and mineralization rate of shortgrass prairie, in conjunction with low standing crops of detritus, does not supply the yearly nitrogen uptake requirement for the shortgrass prairie. A similar discrepancy may exist in the tallgrass prairie. Even with a higher decomposition rate due to higher annual precipitation, the high productivity of the tallgrass prairie probably requires more nitrogen inputs than microbial decomposition and mineralization supply. Fire does release nutrients from the standing dead material but Evans and Allen (1971) have found that a majority of the nitrogen is volatilized in the fire. Leaching from living and dead plant material is a possible way to speed up the return of nitrogen to the soil. Carlisle et al. (1977) found inorganic nitrogen from rainfall is absorbed and organic nitrogen is leached by tree leaves. However, the general consensus is that no evidence exists to support leaching as a major explanation of rapid late season nitrogen loss in grasses (Long et al. 1956, Clark 1977). Currently, neither possibility is included in grassland nitrogen models (Reuss and Innis 1977, Woodmansee et al. 1978, Risser and Parton 1982).

Retranslocation of nitrogen to storage organs was suggested by Weinmann (1940, 1942, 1948) as the explanation for rapid loss of nitrogen from living aboveground material of grasses during late summer. Trlica and Singh (1979), Pate (1971) and Perry and Moser (1974) discussed the possibility of nitrogen movement out of senescing parts and into storage organs for reuse in the spring. Removal of nutrients from leaves of woody plants during senescence has been well described (Carlisle et al. 1967, Woodwell 1974, Bormann et al. 1977) so it does not seem illogical to suspect that grasses might do likewise.

Internal conservation of nitrogen would be important to the plant in many ways. It could be critical for survival in a nitrogen limited system (Pate 1971, Switzer and Nelson 1972, Woodmansee et al. 1978). As Bormann et al. (1977) states, retranslocation would maintain a mobile pool of nitrogen unaffected by outside losses and serve to guard against short term vacillations in soil nitrogen availability. Morton (1977) believes that internal conservation of nitrogen could extend the growing range of Molinia into areas of nitrogen deficiency. Trlica and Singh (1979) projected that the plant could be protected from reduced availability of soil nitrogen under drought conditions. Chibnall (1939) says retranslocation may also protect from nutrient loss in low temperature conditions which might begin to kill the plant before senescence is complete.

Recently retranslocation has been incorporated into grassland nutrient cycling models (Reuss and Innis 1977, Woodmansee et al. 1978, Risser and Parton 1982) however, Clark (1977) and Woodmansee et al. (1978) state that no data were available to support this inclusion. There have been attempts to estimate the amount of internal cycling occurring in various systems. Bormann et al. (1977) estimates 33% of the nitrogen utilized during the spring in eastern deciduous forest is from storage tissue. Morton (1977) estimates 75% withdrawal of nitrogen from Molinia grass leaves to storage organs upon senescence. In the shortgrass prairie, Woodmansee et al. (1978) estimates as much as 26% of the following year's nitrogen supply is from storage organs, while Clark (1977) places the estimate closer to 33%. McKendrick et al. (1975) estimates 18% of the spring nitrogen utilized comes from rhizomes, based on one year's observation. Adams (1982) estimates an average 42% export of nitrogen from the leaves of big bluestem and 81% import of nitrogen from all sources to belowground organs during senescence. These estimates describe an important system of nitrogen conservation in perennial prairie grasses. However, Clark (1977) and Woodmansee et al. (1978) state these estimates are only an assump-

tion of retranslocation but do not actively identify the mechanism for nitrogen loss from living aboveground plant material.

SITE DESCRIPTION

The study was conducted at Konza Prairie Research Natural Area (KPRNA) 12 km south of Manhattan, Kansas. KPRNA is 3487 hectares of native tallgrass prairie managed by the Division of Biology, Kansas State University. It is dominated by big bluestem, little bluestem and indiangrass. Two sites were used, at the northwest and southern parts of KPRNA. The north site is on Reading silty loam, a fine mixed, mesic, Typic Argiudall, formed in alluvial sediments. The south site is on Tully silty clay loam, a fine mixed mesic Pachic Argiustoll, formed in colluvial and alluvial sediments.

In 1980, burned and unburned treatments were set up on the two sites with four replicates each for a total of eight 5 by 2 m plots at each site. At the north site burned and unburned treatments were paired, with the burned plot randomly selected. The unburned plots had not been burned for two years. On the south site plots were established in two of the KPRNA management areas, an annual burned area (1C), burned in late April 1980, and in a two year burn area, (2oC), burned in 1979 but not in 1980. They will be referred to as burned and unburned, respectively. Statistical analysis of 1980 results indicated no significant difference in plant total nitrogen between sites so the north site was abandoned in 1981 and the replicates on the south site increased to eight for each treatment.

1980 was a very dry year and the patterns of precipitation were very different from the 29 year average of 1941-1970 (Appendix table 1). On the average, 75% of the yearly precipitation comes from April through September, the big bluestem growing period. In 1980, only 46% of the average for this period was received. This drought must be taken into account in all discussion of the results of this study.

The leaves emerged in mid-April 1981 on the burned and a short time later on the unburned plots. Most of the rapid growth occurs in May and early June. In McKendrick's (1975) study, the leaves gained weight until mid-September and began to turn reddish brown, a sign of senescence, in early October. In this study, growth appeared to have stopped in mid-June 1980 and browning of mature leaf tips was noticed in mid-July 1980.

METHODS

Field Sampling

A soil core (30 cm diam by 29 cm deep) with roots and plant tops intact was collected from each sample plot at two week intervals. The cores were chosen to contain a majority of big bluestem. The soil cores with intact plants were promptly soaked in cold water for at least one hour or until the water had penetrated the root mass. The soil was then washed from the roots and rhizomes by spraying water from a garden hose. The washing was completed within 4 hours of the time of sampling. Only belowground parts attached to a live big bluestem leaf or a recently dead leaf (that year) were retained. Due to some senescence of that year's growth that did not show visually, some dead belowground parts may have been included in the sample. The sample was put on ice and taken back to the laboratory and frozen until it could be further processed (max. 1 month).

Samples were quickly thawed and rinsed with cold water to remove all remaining traces of soil. The sample was separated into three categories: 1) leaves and stems, 2) crown and rhizomes and 3) roots. Seedheads did not develop on the study plots and very few were observed anywhere on KPRNA in 1980. Root samples collected in 1980 were separated into two depth categories, 0 to 10 cm and 10 to 20 cm. Statistical analysis of total nitrogen showed no significant difference due to depth so those roots collected in 1981 were not separated. Since care was taken in both washing procedures to separate the plant parts by hand, many fine roots were saved. The samples were dried at 60 C to a constant weight, ground to 40 mesh in a Wiley mill and stored in the dark in air-tight bottles.

Soil samples from 0 to 10 cm and 10 to 20 cm depths were collected from each plot every two weeks for gravimetric soil moisture analysis. Soil samples used for analysis of NO_3^- and NH_4^+ content were collected in November 1980 and April 1981.

Chemical Analysis

Plant total nitrogen was analyzed using the standard micro-Kjeldhal procedure (Bremmer 1960) using a Pro-Pak catalyst and an Aminco distillation apparatus, then titrated with weak sulfuric acid. Random samples were run on a Technicon auto-analyzer against the USDA orchard leaves standard to obtain correction factors for each time period. All data are reported as percent nitrogen on a dry weight basis ($\text{gN}\cdot\text{g}^{-1}$). Soil analysis for NH_4^+ and NO_3^- was done at the KSU soil testing laboratory.

Statistical Analysis

An analysis of variance test using SAS procedures was conducted on all data. All statistical differences reported are significant at the $P<.05$ level.

RESULTS

Total nitrogen values of roots, rhizomes and leaves were significantly different over time (Tables 1 and 2, Figure 1). The roots average 0.40% nitrogen in May 1980, dropped to a low in late June (0.29%) and reached the high in late September to mid-October (0.59% for burned and 0.67% for unburned). The total nitrogen levels were maintained with little loss over the winter. On both sites, the roots from the unburned plots had significantly higher nitrogen values than those in the burned plots for most dates. North and south site differences in root total nitrogen were significant in the unburned treatment but not in the burned. The site-time interaction on the unburned plots was significant.

Nitrogen trends were similar in rhizomes. Rhizomes in May 1980 averaged 0.54% total nitrogen. Levels decreased to 0.49% in mid-July and subsequently increased to 0.97% in mid-October. There was a significant decrease (approx. 22%) in rhizome total nitrogen over the winter. On the north site, total nitrogen was significantly higher in the unburned than the burned plots for most dates. The unburned plots on the north site were significantly higher in total nitrogen than the unburned plots on the south site for most dates. The site-time interaction on the unburned plots was also significantly different.

In mid-May 1980, the leaves had very high total nitrogen levels (1.64%), declined rapidly until mid-July (0.60%) and decreased slowly into November (0.23%). The leaf total nitrogen content in November did not change over the winter. The same pattern was seen when the leaves emerged in mid-April 1981 with very high total nitrogen levels. Leaf total nitrogen was not significantly different between treatment or between sites. However, the site-time interaction was significant.

Since the summer of 1980 was a drought period with infrequent rains, the soil

Figure 1. Average total nitrogen content for burned and unburned plots during 1980 and 1981. (open symbols = north site, closed symbols = south site; ● = leaves, ▲ = rhizomes, ■ = roots; Line is the average of north and south sites).

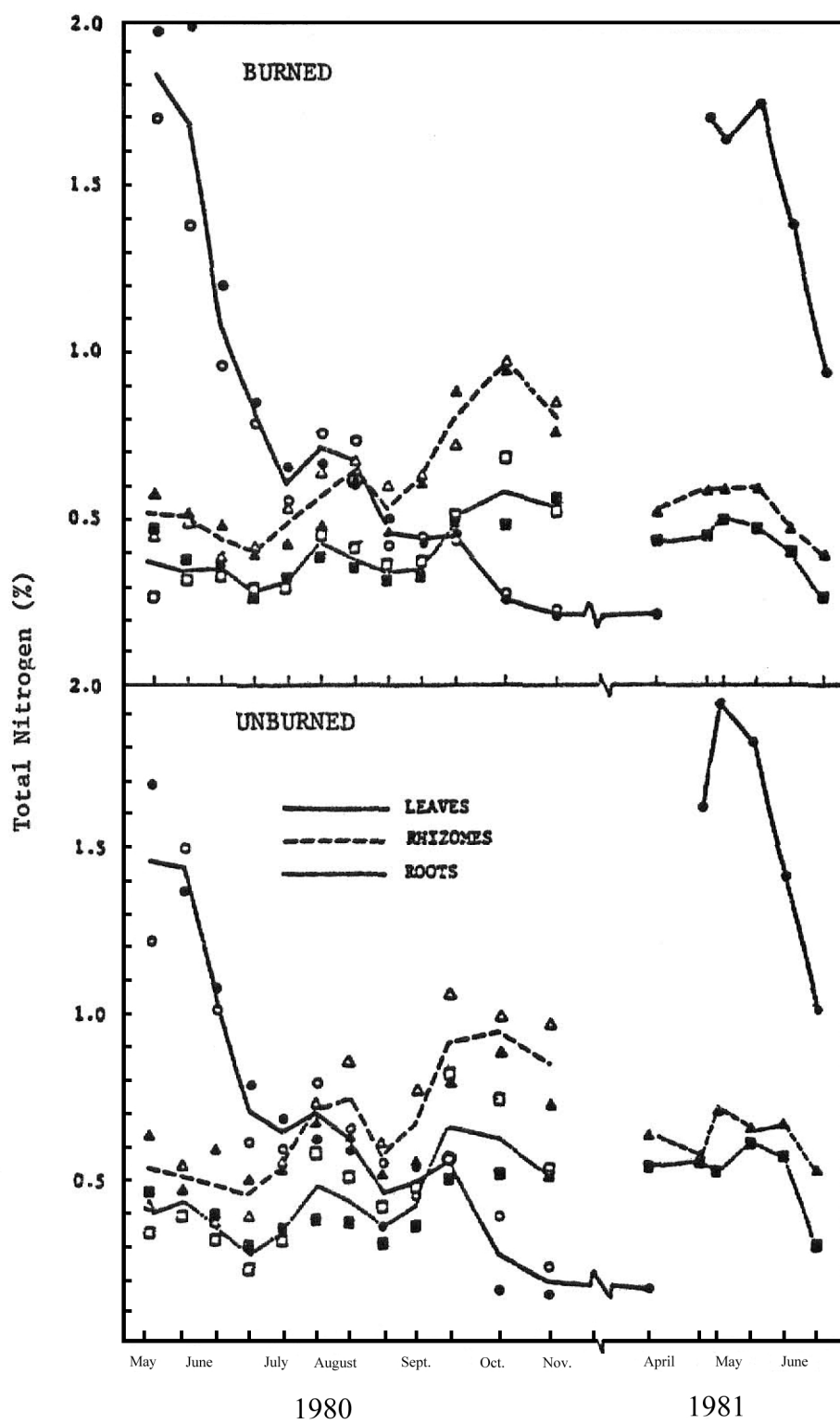


Table 1. Total nitrogen content of roots, rhizomes, and leaves of big bluestem in burned plots during 1980 and 1981. Averages are of 4 replicates for 1980 and 8 replicates for 1981. LSD = least significant difference.

	ROOTS			RHIZOMES			LEAVES		
	NORTH SITE	SOUTH SITE	AV.	NORTH SITE	SOUTH SITE	AV.	NORTH SITE	SOUTH SITE	AV.
<hr/>									
	<hr/>								
	----- % -----								
1980 / LSD	0.06	0.06	0.04	0.07	0.07	0.05	0.13	0.13	0.09
May 19	0.27	0.47	0.37	0.46	0.57	0.52	1.70	1.96	1.83
June 1	0.32	0.37	0.35	0.49	0.52	0.51	1.38	1.98	1.68
June 15	0.33	0.37	0.35	0.38	0.49	0.44	0.96	1.20	1.08
June 29	0.30	0.27	0.29	0.42	0.40	0.41	0.70	0.85	0.82
July 13	0.30	0.32	0.31	0.54	0.43	0.49	0.56	0.64	0.60
July 27	0.46	0.39	0.43	0.65	0.48	0.57	0.76	0.67	0.72
Aug. 10	0.42	0.36	0.39	0.68	0.61	0.65	0.74	0.61	0.68
Aug. 24	0.37	0.32	0.35	0.61	0.47	0.54	0.43	0.51	0.47
Sept. 7	0.38	0.33	0.36	0.64	0.62	0.63	0.46	0.44	0.45
Sept. 21	0.51	0.50	0.51	0.73	0.89	0.81	0.45	0.46	0.46
Oct. 12	0.69	0.49	0.59	0.98	0.95	0.97	0.27	0.26	0.27
Nov. 2	0.53	0.57	0.55	0.86	0.77	0.82	0.23	0.22	0.23
1981 / LSD		0.03			0.03			0.07	
April 4	----	0.44	----	----	0.53	----	----	0.22	----
April 26	----	0.46	----	----	0.60	----	----	1.71	----
May 3	----	0.51	----	----	0.60	----	----	1.64	----
May 17	----	0.48	----	----	0.60	----	----	1.75	----
June 3	----	0.41	----	----	0.48	----	----	1.39	----
June 18	----	0.27	----	----	0.40	----	----	0.95	----

Table 2. Total nitrogen content of roots, rhizomes, and leaves of big bluestem in unburned plots during 1980 and 1981. Averages are of 4 replicates for 1980 and 8 replicates for 1981. LSD = least significant difference.

	ROOTS			RHIZOMES			LEAVES		
	NORTH SITE	SOUTH SITE	AV.	NORTH SITE	SOUTH SITE	AV.	NORTH SITE	SOUTH SITE	AV.
----- % -----									
1980 / LSD	0.06	0.06	0.04	0.07	0.07	0.05	0.13	0.13	0.09
May 19	0.35	0.47	0.41	0.43	0.64	0.54	1.22	1.69	1.46
June 1	0.40	0.47	0.44	0.55	0.48	0.52	1.50	1.37	1.44
June 15	0.33	0.40	0.37	0.38	0.60	0.49	1.01	1.08	1.04
June 29	0.24	0.31	0.28	0.40	0.51	0.46	0.62	0.79	0.71
July 13	0.33	0.36	0.35	0.56	0.54	0.55	0.60	0.69	0.65
July 27	0.59	0.39	0.49	0.74	0.68	0.71	0.80	0.63	0.72
Aug. 10	0.52	0.38	0.45	0.86	0.64	0.75	0.66	0.60	0.63
Aug. 24	0.43	0.32	0.38	0.63	0.53	0.58	0.56	0.37	0.47
Sept. 7	0.49	0.37	0.43	0.78	0.57	0.68	0.46	0.55	0.50
Sept. 21	0.82	0.51	0.67	1.07	0.80	0.92	0.57	0.57	0.57
Oct. 12	0.75	0.53	0.64	1.00	0.89	0.95	0.40	0.18	0.29
Nov. 2	0.54	0.52	0.53	0.98	0.74	0.86	0.25	0.17	0.21
1981 / LSD		0.03			0.04			0.07	
April 4	----	0.55	----	----	0.65	----	----	0.18	----
April 26	----	0.56	----	----	0.59	----	----	1.63	----
May 3	----	0.54	----	----	0.72	----	----	1.94	----
May 17	----	0.63	----	----	0.67	----	----	1.82	----
June 3	----	0.58	----	----	0.68	----	----	1.42	----
June 18	----	0.32	----	----	0.54	----	----	1.02	----

moisture levels in the topsoil varied sharply (Appendix tables 2 and 3, figure 1). The upper soil levels (0 to 10 cm) had an average moisture content of 32% in mid-May 1980. The levels generally decreased over the summer with sharp spikes after a rainfall event. The lowest values reached were on the burned plots, with 8.9% on the north site and 12.8% on the south site in mid-August 1981. The soil moisture content generally increased after August as more rain was received and temperatures declined. The soil moisture content greatly increased over the winter and stayed at higher levels during 1981. Both burned and unburned plots soil moisture content were significantly higher in the north site than in the south site. The soil moisture content in the burned plots was significantly higher than in the unburned plots on the north site.

The 10 to 20 cm soil level followed the same trend beginning May 1980 at 29%. Moisture content decreased to a low of 9.7% on the north site and 12.8% on the south site in August 1980. Soils at the south site had significantly higher soil moisture in both the burned and unburned treatments. The unburned plots were significantly higher in soil moisture than the burned plots on both the north and south sites.

There was no significant difference between treatments or soil depth for NH_4^+ in the soil (Appendix table 4). The soil at the south site for both soil depths in the unburned plots and the 10 to 20 cm soil depth on the burned plot were significantly higher than the soils at the north site. The soil NH_4^+ content was significantly higher in the spring than the fall in the lower depths but not in the upper depth. Soil NO_3^- showed no significant difference between treatments, sites or dates (Appendix table 5).

DISCUSSION

The total nitrogen content in big bluestem observed in this study generally agree with previous findings. Plant total nitrogen was lower than McKendrick (1975) found in the Kansas Flint Hills and Adams (1982) and Risser and Parton (1982) found in Oklahoma. The severe drought encountered in 1980 is a possible cause for this difference. The high leaf nitrogen levels in the spring are due to the high rate of protein synthesis of emerging leaves. Total nitrogen percentage dropped as the foliage matured, as would be expected from the reduced ratio of protein to other cell constituents as cells matured. Concurrently nitrogen levels in roots and rhizomes dropped as they were being depleted of stored nitrogen to support the rapid leaf growth. Early spring root uptake of nitrogen alone did not keep pace with such rapid growth. This trend is supported by other grassland studies (Woodmansee et al. 198, Risser and Parton 1982, Adams 1982).

After the June low, rhizomes and roots increased in nitrogen concentration until late July, then dropped and subsequently increased through October. Reuss and Innis (1977) predicted such a midsummer trend in roots in the ELM Grassland Model but knew of no data at that time to substantiate the prediction.

This study showed that leaf height reached maximum and growth stopped during mid-June to early July 1980. Clark (1940) noted that even with a 30 mm rain up to 70% may be intercepted by big bluestem leaves and litter and not reach the soil. Seastedt (unpublished data) in a KPRNA study has revised this estimate downward to 35 to 50% due to stemflow. So of the 182 mm received during June-August, as little as 61 mm may be available for root uptake. All new blades initiated after the early August rain had died, no new roots were being initiated and mature leaf tips were brown. The general trend in leaf nitrogen decreased after late July while biomass remained steady with a concurrent increase in rhizome

and root nitrogen concentration. These changes are believed to be the result of retranslocation of nitrogen from the dying leaves to storage in the belowground organs. The similarity of root and rhizome trends indicate that the roots are also storing nitrogen. Rhizome and root nitrogen content reached a peak in mid-October when 80% of the aboveground parts had died.

Burning Effects

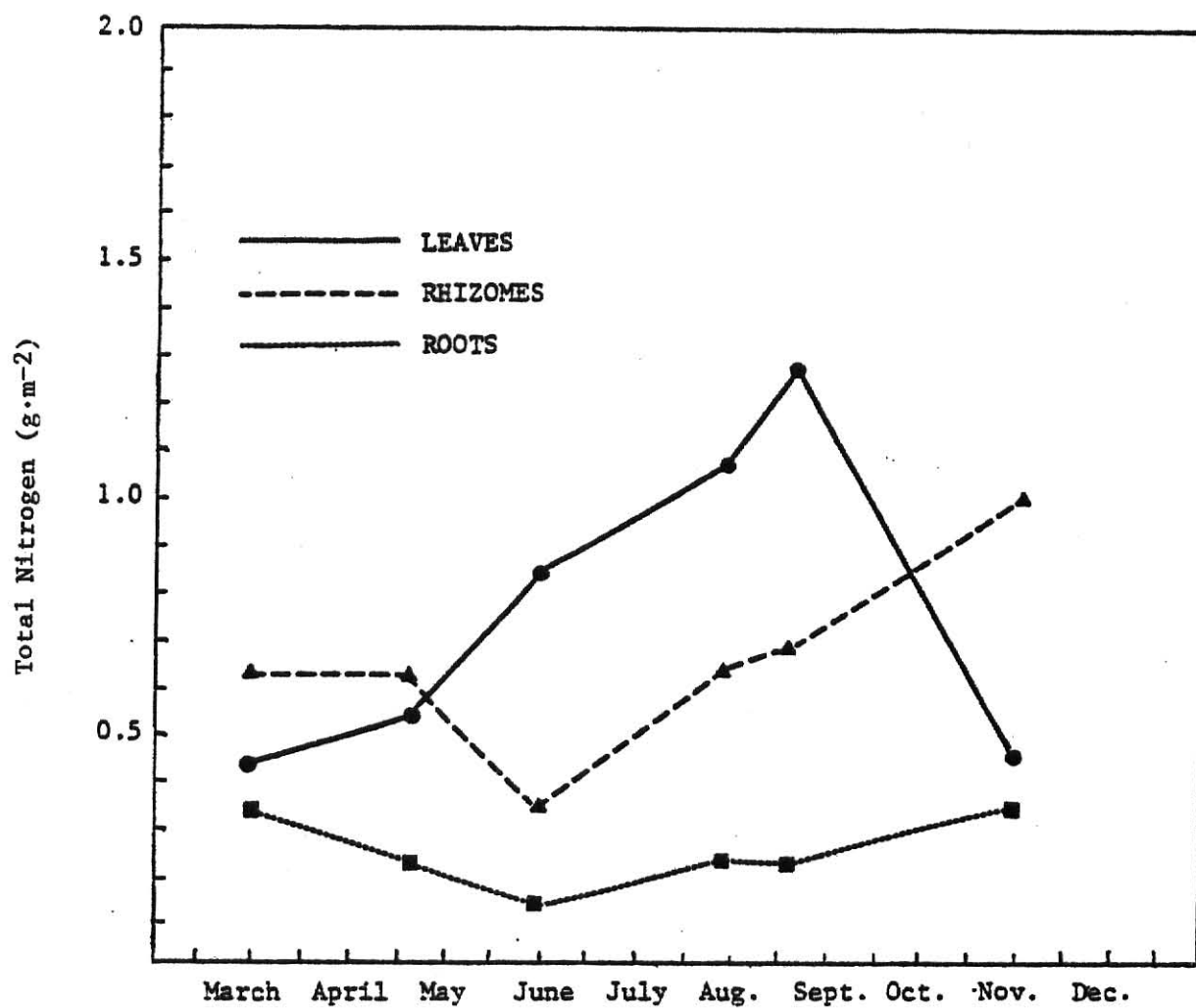
The burned treatment during the drought significantly lowered the nitrogen concentration of belowground plant parts. By removing the litter layer, the soil was exposed to maximum evaporation from the top 10 cm which was not balanced by average precipitation. During years with adequate precipitation, the litter removal would help the plant by warming the soil earlier in the season (Hulbert 1969). This allows more rapid leaf production and increased photosynthesis. Garwood and Williams (1967) found that some poor growth attributed to drought was actually due to nitrogen deficiency. As the upper soil layers dry out, the rate of nitrogen mineralization decreased with a corresponding decrease in available soil nitrogen (Russell 1973). The plant obtains water from the deeper soil which is low in nitrogen due to the low leaching of the tallgrass prairie soils. Thus the plants on the burned plots may be able to reach enough moisture to survive, but cannot get an adequate nitrogen supply. Unlike the rhizomes the leaves showed no difference in total nitrogen content between treatments which suggests that the plant is not sending any excess nitrogen to the leaves.

Nitrogen Use Efficiency

Biomass of leaves, rhizomes and roots is necessary to convert nitrogen concentrations to amounts in the various components of the plants. Aboveground biomass was obtained, but it was not feasible in this study to get belowground biomass. To get a preliminary evaluation of efficiency of nitrogen conservation, biomass values were sought from other studies. Adams (1982) made his data available from

a study in Osage County, Oklahoma, for 1980-1981. In 1980 both the Oklahoma and KPRNA sites had a severe drought. Although Adams' plots were 28% big bluestem compared to 80% in this study, it seems reasonable to assume that the ratio of biomass between plant parts is similar for both sites. When the nitrogen concentrations are converted to $\text{gN}\cdot\text{m}^{-2}$, using Adams' biomass data, the trend of retranslocation becomes much clearer (Figure 2). The ratio of the amount of nitrogen stored from a year's growth and available for reuse the following year divided by the total amount used per year may be considered the efficiency of nitrogen conservation. There are several methods of determining this efficiency. Woodmansee et al. (1978) and Clark (1977) use the difference between peak leaf nitrogen and low leaf nitrogen in the fall to achieve the amount of nitrogen exported from the leaves. Using this procedure, the big bluestem efficiency for this study would be 58%. This does not take into account leaching or NH_4^+ volatilization from the leaves during senescence, which would decrease the actual efficiency. While Clark (1977) and Woodmansee et al. (1978) do not feel this is a significant loss, Farquhar et al. (1979) has found volatilization from maize leaves that, while not accounting for the majority of late season nitrogen loss in grain crops, is large enough that it must be considered. This calculation does not consider the addition of inorganic nitrogen from precipitation. KPRNA data (Seastedt personal communication) on burned plots shows that the leaf acts as a nitrogen sink for inorganic nitrogen from precipitation at least through September. Seastedt's data also show that there is a leaching loss of organic nitrogen during senescence but these losses are more than offset by the total nitrogen input to the plant from precipitation during the growing season. This factor would tend to make the above calculation a minimum estimate of conservation efficiency since the plant is retranslocating the nitrogen transported up from the roots and rhizomes in the spring as well as the nitrogen absorbed by the leaves from rainfall during the growing season.

Figure 2. Biomass nitrogen content during the 1980 growing season for roots, rhizomes and leaves of big bluestem (Biomass data from Adams 1982).



McKendrick et al. (1975) calculated conservation efficiency as the amount of nitrogen lost from the rhizomes during the spring growth divided by the peak rhizome nitrogen. This efficiency would be 46% for rhizomes and 58% for roots in this study. This calculation does not take into account the nitrogen going into rapidly growing rhizomes and roots, when biomass is increasing faster than nitrogen uptake in early May and June, nor the nitrogen loss through root exudates (Hale et al. 1971). It does not consider the nitrogen uptake from the soil occurring in June and July. These may be offsetting factors since the underground growth would decrease the June value and thereby cause a higher apparent efficiency. The soil nitrogen uptake would increase the June concentration of nitrogen thereby causing a lower apparent efficiency. Clearly no one has measured all processes involved in nitrogen conservation efficiency. Each of the above methods measures only part of the several processes involved. Studies to date are a first approximation. Their value depends on whether the assumptions are correct that processes not measured are either minor or cancel each other.

Comparison with the shortgrass prairie

The soil of the tallgrass prairie is often at field capacity following snow-melt and spring rains, during which evapotranspiration is relatively low. Even though most of the precipitation comes during the growing season, the soil moisture regularly decreases during the summer because evapotranspiration soon exceeds precipitation. The dominant prairie grasses seem attuned to growth through much of the summer. Leaf growth may stop growth earlier than usual if drought is severe, as it was in 1980, but they regularly grow little after August, regardless of the weather.

The shortgrass prairie is very different in its reaction to limited summer precipitation. Available soil moisture is much less predictable than in tallgrass prairie. As a response the plants seem able to go dormant yet remain able to resume growth quickly when rains come. Sala and Laurenroth (1982) showed

that even very small rainfall events (8 to 10 mm) can be ecologically important to shortgrasses. By measuring leaf conductance and leaf water potential, they showed that blue gramma can respond quickly to a small amount of precipitation. They found the response could last up to two days and be extended with many small events close together. Since these parameters can be related to photosynthesis, shortgrasses can react to a small improvement in conditions with increased production (Sala and Laurenroth 1982). Shortgrasses will grow while moisture is available, go dormant when the soil begins to dry out and die-off in an extended drought. When another rainfall event is received, regrowth occurs quickly. Thus the shortgrass prairie retains more nitrogen in the dead aboveground material than the tallgrass prairie for any one year. The values given for the shortgrass prairie in Reuss and Innis' ELM Grassland model (1977), presumable based on actual values, are 3.0% for peak leaf nitrogen concentration vs. 1.74% for this study, and 1.0% in the fall compared to .21% total nitrogen for big bluestem. Many studies of the shortgrass prairie have reported as high as 26% to 33% retranslocation (Clark 1977, Woodmansee et al. 1978). It is possible the energy and time needed to conserve as high a percentage of nitrogen in the leaves as the tallgrass prairie is a high cost compared with the extra photosynthate produced quickly if the drought is broken before the end of the growing season.

Drought Effects

As the nitrogen values reported here are lower than others reported for the tallgrass prairie in average precipitation years, a drought effect must also be considered. Adams' Osage data collected in 1980 and 1981 are higher than those of this study but not significantly so. They were lower than those of Risser and Parton (1982) for 1970 through 1972 on the Osage site. McKendrick's (1975) values (for rhizomes only) were significantly higher than those of this study on similar sites in the Flint Hills. Although Adams did not find a significant difference between nitrogen concentration in 1980 and 1981, his 1980 values were

lower than 1981. Due to the lower than average rainfall in 1980, the question is raised, does drought affect nitrogen content and translocation in tallgrasses? Adams' September leaf nitrogen concentration was 0.32% compared with 0.80% for Risser and Parton (1982). The 1980 peak leaf nitrogen concentration in May was also lower than 1971-1972 (1.30% for Adams' vs. 2.00% for Risser and Parton 1982). Thus both Adams' work and the overall findings of this study show reduced nitrogen concentration during a drought period. These findings are in conflict with the simulated (Risser and Parton 1981) and actual results (Owensby et al. 1970) of irrigation which show decreased plant nitrogen concentration compared to control plots. On the basis of studies in crop plants and weed species, Bannister (1976) stated that in a nitrogen deficiency, as yield increased so did nitrogen concentration. This implies that with the decreased biomass of a drought year there is a decrease in nitrogen concentration. This shows the danger of extrapolating irrigation data into a drought condition.

Due to lower nitrogen concentrations on two separate sites, in two separate studies for 1980, the inclination is to conclude that drought does have an effect on plant nitrogen. Mineralization of unavailable soil nitrogen decreases under drought conditions (Russell 1971). Because mass flow of water is necessary for significant nitrogen movement through the soil, it is possible that root uptake of nitrogen was reduced in early summer, thus lowering the overall nitrogen content of the plant (McKendrick 1975). Because root uptake of minerals decreased during the reproductive stage (Nooden 1977), plants may have been unable to respond to the rains in September and October 1980. If each increment of biomass requires a set increment of nitrogen, it would appear that big bluestem enjoys "luxury consumption" in a year with average precipitation, even though biomass may be increased (Bannister 1976). Another interpretation is that the lower nitrogen concentration in drought years may result from leaves being partially senescent through the summer.

Drought stress may increase nitrogen conservation efficiency. McKendrick (1975) found only 18% efficiency in spring transport of nitrogen from rhizomes to leaves while Adams and this study found 35% and 46%, respectively. For 1980, Adams found a 50% export of nitrogen from the leaves but only a 36% export of nitrogen from the leaves in 1981. This study shows a 58% export of leaf nitrogen during senescence in 1980. Risser and Parton (1982) appeared to show a 22% reduction in leaf nitrogen during senescence ($0.5 \text{ g} \cdot \text{m}^{-2}$ retranslocated vs. $2.27 \text{ g} \cdot \text{m}^{-2}$ left in August 1972). A higher efficiency of nitrogen conservation would indicate a response to drought conditions or a genetic factor whereby the same amount of nitrogen is retranslocated regardless of the nitrogen concentration of the plant. Because 1980 belowground biomass values for the KPRNA site are not available, the latter suggestion is not addressed here.

The findings of this study very strongly support the concept of retranslocation of nitrogen to storage organs and reuse the next year. Results also suggest that roots may act as storage organs as well as rhizomes. Burning during a drought year was found to lower the nitrogen concentration of roots and rhizomes but not of leaves of big bluestem. A higher efficiency of nitrogen conservation than previously reported was found in above- and belowground parts. More years of study would be necessary to ascertain whether this higher efficiency is a result of the drought conditions or a normal trait of the tallgrass prairie.

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PART 2

SEASONAL NITROGEN TRANSLOCATION IN BIG BLUESTEM, ANDROPOGON GERARDII VITMAN,
IN KANSAS DURING A DROUGHT YEAR:

TOTAL AMINO ACIDS

ABSTRACT

Seasonal amino-nitrogen translocation in big bluestem in the tallgrass prairie was studied on burned and unburned treatments within Konza Prairie Research Natural Area, Manhattan, Kansas. Although there was no significant difference in leaf amino acid concentration between treatments over the summer of 1980, the percent of total nitrogen as amino acids increased in the leaves during the summer of 1980 with a dramatic increase from mid-August to October. In April 1981, emerging leaves on the unburned plots were significantly higher in amino acid concentration than those on the burned plots ($805 \text{ ugN}\cdot\text{g}^{-1}$ vs. $631 \text{ ugN}\cdot\text{g}^{-1}$). Rhizome amino acid concentration was significantly higher on the unburned plots, increasing from $207 \text{ ugN}\cdot\text{g}^{-1}$ in May 1980 to $283 \text{ ugN}\cdot\text{g}^{-1}$ and $405 \text{ ugN}\cdot\text{g}^{-1}$ in August 1980 for burned and unburned plots, respectively. Levels dropped sharply in September and subsequently increased in October and over the winter of 1980. The unburned plots were higher in percent total nitrogen as amino acids than burned plots throughout 1980, but the trend reversed in 1981. It is suggested that the high percent of total nitrogen as amino acids in leaves and rhizomes in June and July 1980 is due to early senescence induced by drought stress. The increase in both leaf and rhizome amino acid concentration and percent of total nitrogen as amino acids in September 1980, is due to remobilization of proteins and retranslocation to the belowground parts as storage organs.

Keywords: big bluestem, Andropogon gerardii Vitman, nitrogen amino acids, burning, retranslocation, tallgrass prairie, drought.

INTRODUCTION

When nitrogen enters a plant, usually as NO_3^- or NH_4^+ , it is converted to NH_4^+ if not already in that form. The ammonia is then assimilated into glutamic and aspartic acid or their amide forms. These amino acids can go through transamination reactions into other amino acids or they may be synthesized into protein (Beevers 1976). However, because they are not water soluble, proteins are not translocatable (Weinmann 1942). The nitrogen must be in the form of nitrates, ammonia or amino acids to move to the rapidly growing parts of the plant. Glutamic and aspartic acid and their amides are the principle transport forms in the phloem (Pate 1971, Beevers 1976). High total nitrogen and amino acids levels are detected in the phloem during bud break (Kursanov 1963, Pate 1971). These levels drop after leaf expansion when the amino acids are synthesized into leaf proteins (Kursanov 1963, Pate 1971).

During the life of the leaf there is a continuous cycle of protein synthesis and degradation (Chibnall and Wiltshire 1953, Beevers 1976). With the onset of senescence the cycle shifts toward increased proteolysis, with amino acids as the primary product of this breakdown (Chibnall 1939, Kursanov 1963, Pate 1971, Thimann 1980). The amide residues of glutamine and asparagine seem to dominate the free amino acid pool at this time (Chibnall 1939, Beevers 1976). Storey and Beevers (1977) found glutamine synthetase levels in bean leaves high enough to convert all liberated amino acids into glutamine (Thimann 1980). At this point the amino acids move out of the yellowing leaf into the petioles (Chibnall 1939, Beevers 1976) and down into the perennial portions of the plant. This same phenomenon can occur under drought conditions (Barnett and Naylor 1966). Leaf total nitrogen amino acid levels will drop and stem levels will increase, but the process may reverse with an increase in soil moisture (Koretskaya and Zholkevich 1966, Trlica and Singh 1979).

With true senescence the total nitrogen will concentrate in the stem bases, rhizomes and roots to be stored, possibly in the amino acid form (Weinmann 1942, Perry and Moser 1974) or as protein (Thimann et al. 1974).

This retranslocation and conservation of nitrogen has assumed a new importance with the advent of nutrient cycling studies (i.e. Clark 1977). This stored nitrogen can be very important in nitrogen limited systems (Clark 1977, Woodmansee et al. 1978). Most of the work on amino acid metabolism has been on detached leaves (Chibnall 1939) or laboratory seedlings (Thimann et al. 1974, Stewart et al. 1977, Bauer et al. 1977, Kinraide 1981). Weinmann (1942) studied amino acids in a South African Highveld grass and Dina and Klikoff (1973) analyzed big sagebrush for alcohol soluble and protein nitrogen. No amino acid studies of grasses of the tallgrass prairie were found in the literature. Because big bluestem is a dominant in the tallgrass prairie and an important range forage grass, it was chosen for this look at the chemical form of internal nitrogen cycling in the tallgrass prairie.

SITE DESCRIPTION

The study was conducted at Konza Prairie Research Natural Area (KPRNA), 12 km south of Manhattan, Kansas. KPRNA is 3487 hectares of native tallgrass prairie managed by the Division of Biology, Kansas State University. It is dominated by big bluestem, little bluestem and indiagrass.

The study plots are located on Tully silty clay loam, a fine mixed mesic, Pachic Argiustoll, formed in colluvial and alluvial sediments. The plots were established in two of the KPRNA management areas, an annual burned area (1C), burned in late April 1980, and in a two year burn area (2oC), burned in 1979 but not in 1980. They will be referred to as burned and unburned plots, respectively. Four replicates of 5 by 2 m plots were laid out in each treatment.

1980 was a very dry year and the patterns of precipitation were very different from the 29 year average of 1941-1970 (See Appendix table 1). On the average, 75% of the yearly precipitation comes from April through September, the big bluestem growing period. In 1980, only 46% of the average for this period was received. This drought must be taken into account in all discussion of the results of this study.

The leaves emerged in mid-April 1981 on the burned plots and a short time later on the unburned plots. Most of the rapid growth occurred in May and early June. In McKendrick's (1975) study, the leaves gained weight until mid-September and began to turn red, a sign of senescence, in early October. In this study growth appeared to have stopped in mid-June 1980 and browning of mature leaf tips was noticed in mid-July 1980.

METHODS

Field Sampling

A soil core (30 cm diam by 20 cm deep) with roots and plant tops intact was collected from each sample plot at two week intervals. The cores were chosen to contain a majority of big bluestem. The soil cores with intact plants were promptly soaked in cold water for at least one hour or until the water had penetrated the root mass. The soil was then washed from the roots and rhizomes by spraying water from a garden hose. The washing was completed within 4 hours of the time of sampling. Only belowground parts attached to a live big bluestem leaf or recently dead leaf (that year) were retained. Due to some senescence of that year's growth, some dead belowground parts may have been included in the sample. The sample was put on ice and taken back to the laboratory and frozen until it could be further processed (max. 1 month).

Samples were quickly thawed and rinsed with cold water to remove all remaining traces of soil. The sample was separated into three categories; 1) leaves and stems, 2) crown and rhizomes and 3) roots. No seedheads developed on the study plots and very few were observed anywhere on KPRNA in 1980. The samples were dried at 60 C to a constant weight, ground to 40 mesh in a Wiley and stored in the dark in air-tight bottles.

Soil samples for moisture content at 0 to 10 cm and 10 to 20 cm depths were collected from each plot every two weeks for gravimetric soil moisture analysis (See Appendix tables 2 and 3, figure 1).

Chemical Analysis

Samples of 0.25 g oven dry tissue were extracted by incubating overnight in a water bath shaker at 65 C in 25 ml of 80% ethanol. The solution was filtered and dried to a powder with a roto-evaporator. The sample was rehydrated to a standard volume with glass double distilled deionized water. In the test analysis, it was

determined that extraneous compounds such as organic sugars, etc, did not interfere with the Yemm and Cocking (1955) ninhydrin reaction for total amino acids and a resin column purification was not needed. The methods detects glutamine and asparagine but not tryptophan. Glycine was used for a standard curve and all chemicals were fresh for each assay run. Data are reported as $\mu\text{g amino N}\cdot\text{g}^{-1}$ oven dry plant tissue.

Field sampling, as described, was conducted at two week intervals. Due to the number of samples, the assays were conducted in two groups of every other sampling period to insure uniformity across the season. The first run of samples consisted of those collected during the first two weeks of each month and the second group was samples from the third and fourth weeks of each month. Only the results from the first run of samples are reported here. The runs were three months apart and due to an increase in background atmospheric and water ammonia levels in the laboratory, as measured by the reagent blank, the data from the second period were not considered valid and were discarded. The levels are believed to have increased for several reasons: 1) a colleague broke a bottle of concentrated NH_4OH during the ninhydrin assay of the second run, 2) the janitorial staff was discovered to be cleaning the laboratory counters with full strength ammonia, 3) the deionizing resin column was changed without my knowledge and the water ammonia levels increased for a short time, and 4) the office across the hall was leased by a group of heavy smokers. Total nitrogen values were also determined for the samples and are reported in Part 1.

Statistical Analysis

An analysis of variance test using SAS procedures was run on all data. All statistical differences reported are significant at the $P < .05$ level.

RESULTS

Both leaves and rhizomes showed significant change in amino acid concentration over time (Table 3 and figure 3). The leaves decreased throughout the summer from a mid-May high of $325 \text{ ugN}\cdot\text{g}^{-1}$. By mid-July the values had stabilized at around $180 \text{ ug N}\cdot\text{g}^{-1}$ and remained stable until fall. Old leaf values during the winter decreased to an average of $70 \text{ ugN}\cdot\text{g}^{-1}$. Emerging leaves on the unburned plots were significantly higher in amino acid concentration than burned plots in early May 1981 (805 vs. $621 \text{ ugN}\cdot\text{g}^{-1}$). This is the only date with significant differences in amino acid content between treatments in the leaves. These spring highs dropped very rapidly to an average of $300 \text{ ugN}\cdot\text{g}^{-1}$ in early June.

Rhizomes in unburned plots were significantly higher in free amino nitrogen than the burned plots. Rhizomes in burned and unburned plots increased to a high of $283 \text{ ugN}\cdot\text{g}^{-1}$ and $405 \text{ ugN}\cdot\text{g}^{-1}$, respectively in mid-August 1980. Both treatments sharply declined in concentration to a low in early September with a subsequent increase until October. The levels of free amino nitrogen in the rhizomes increased slightly over the winter and into the spring of 1981.

The percentage of total nitrogen in the form of amino acids was computed for each date (Table 4 and figure 3). The percent amino acid in leaves increased throughout the summer 1980, with the largest increase from mid-August to October. During 1980, rhizome percent amino acid was highest on the unburned plots but the opposite was observed in 1981. The rhizome percent of total nitrogen as amino acid was nearly twice that of the leaves until September and increased over the winter. • June 1981 values of percent of total nitrogen as amino acids in both leaves and rhizomes were higher than June 1980 values.

Figure 3. Amino acid content and percent of total nitrogen as amino acids for leaves and rhizomes on burned and unburned treatments during 1980-1981.

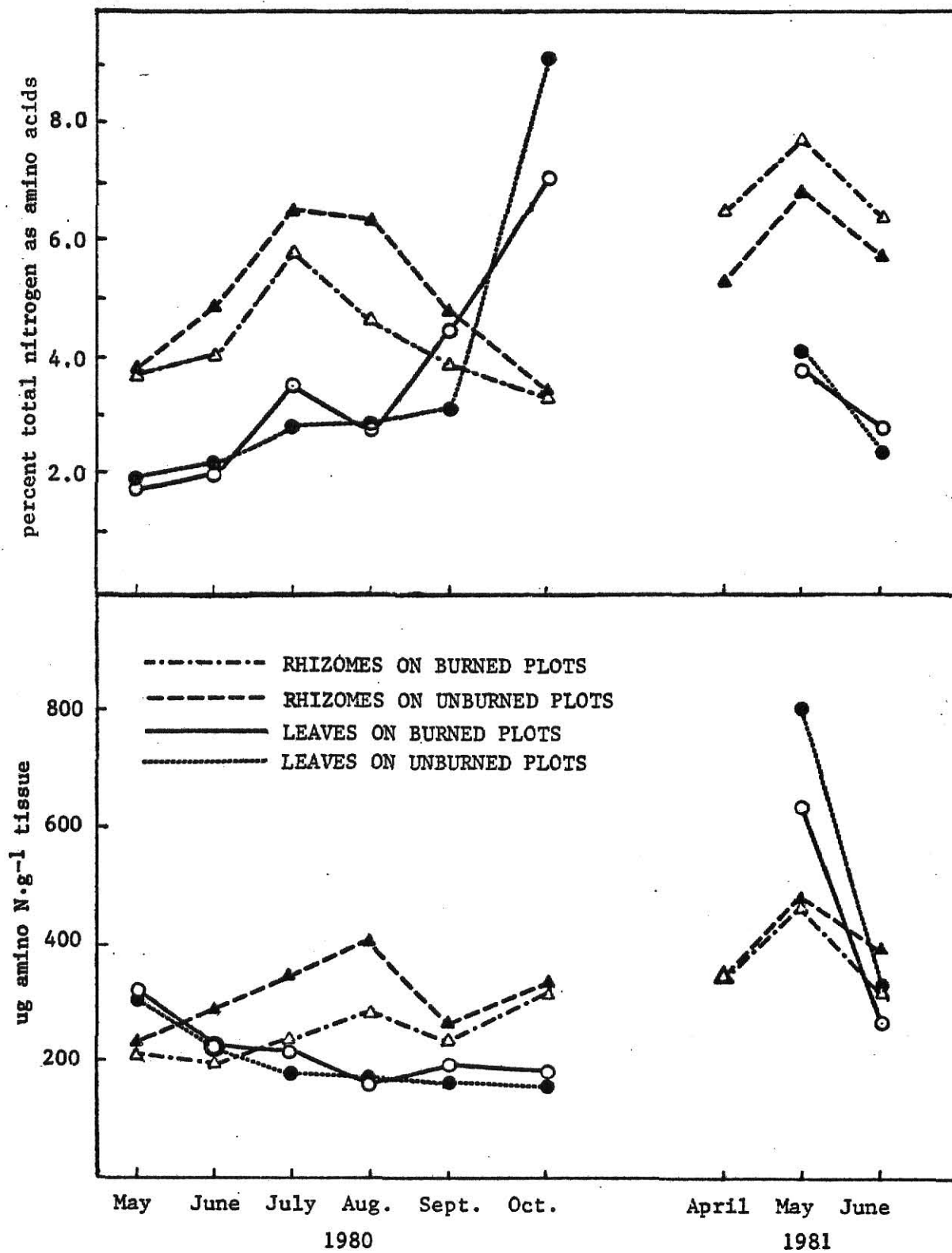


Table 3. Rhizome and leaf amino acid concentration for big bluestem in burned and unburned treatments for 1980 and 1981 (4 replicates). Leaves on April 4, 1981 were old leaves, other leaves were produced that year. Least significant difference (LSD) calculated separately for rhizomes and leaves.

	RHIZOMES		LEAVES	
	BURNED	UNBURNED	BURNED	UNBURNED
	<hr style="border-top: 1px dashed black;"/> <div>----- ugN·g⁻¹ -----</div> <hr style="border-top: 1px dashed black;"/>			
1980 / LSD	36	36	32	32
May 19	207	237	327	318
June 15	195	288	226	226
July 13	245	351	223	186
Aug. 10	283	405	167	176
Sept. 7	239	267	196	170
Oct. 12	313	302	185	165
1981				
April 4	346	344	67	84
May 3	461	487	631	805
June 3	310	391	267	335

Table 4. Rhizome and leaf amino acid content as percent of total nitrogen content in big bluestem in burned and unburned treatments for 1980 and 1981.

	RHIZOMES		LEAVES	
	BURNED	UNBURNED	BURNED	UNBURNED
	----- % -----			
1980				
May 19	3.6	3.7	1.7	1.9
June 15	4.0	4.8	1.9	2.1
July 13	5.7	6.5	3.5	2.7
Aug. 10	4.6	6.3	2.7	2.9
Sept. 7	3.9	4.7	4.5	3.1
Oct. 12	3.3	3.4	7.1	9.2
1981				
April 4	6.5	5.3	3.0	4.6
May 3	7.7	6.8	3.8	4.1
June 3	6.5	5.8	2.8	2.4

DISCUSSION

Most studies of amino acid nitrogen dynamics in plant have been conducted over a period of hours or days on detached leaves or potted laboratory seedlings with senescence induced by water stress. The general pattern was an increase in leaf amino nitrogen with a concurrent root amino nitrogen increase. Likewise in this study, because newly developing leaves are very actively synthesizing protein (Beevers 1976), the free amino acid concentration decreased as the leaf biomass increased. This pattern was found in May of 1980 and April and May of 1981, with concentrations leveling off in June. Due to the findings of studies of detached leaves and seedlings in the laboratory, an increase in leaf amino acids was expected in August, but this was not found in this field study. Although the amount of protein degradation may have increased, the concentration of amino acids in the leaves may have held steady due to transport into perennial plant parts as suggested by Weinmann (1942). This explanation is supported by the increase in percent of total leaf nitrogen as amino acids. This percentage would increase if the amount of amino acids did not change but the amount of protein decreased.

The rhizome amino acid content was much more dynamic throughout the season. The rhizome amino acid concentration increased steadily on the unburned plots from May to August 1980. Since a majority of root nitrogen uptake is expected in the early summer (Weinmann 1948), the amount of amino acids ready for translocation should be high in the spring and decrease as plant growth progresses. A concurrent increase in leaf amino acids would be expected. This was not the case, as discussed earlier, probably due to rapid synthesis of proteins. However, the leaf production seemed to stop in mid-June when the soil moisture levels were decreasing rapidly. It is well documented that water stress will cause a decrease in photosynthesis, nutrient uptake and translocation and in protein synthesis, with an increase in

protease activity (Beevers 1976, Noorden 1980). A decrease in protein synthesis could cause a buildup in rhizome amino acid nitrogen as seen in the increase in percent of total nitrogen as amino acids. The increase could be amplified by increased proteolytic activity in the leaves and export of amino acids to the rhizomes.

In mid-August 1980, the soil moisture content increased to 22% for both burned and unburned plots. The reduction in water stress could have increased the translocation of nitrogen to the leaves and subsequent protein synthesis with a corresponding decrease in rhizome amino acids. Indeed, the percent of total nitrogen as amino acids does decrease during that period but it is doubtful that the amino acids were translocated to the leaves as the total leaf nitrogen continued to decline (Part 1). It is possible that the protein synthesis in the roots increased but this aspect was not measured. The leaf tips were browning in mid-July, indicating that senescence was initiated early in 1980. The increase in soil moisture may have delayed the process for a short time in August but probably did not reverse it. This is indicated by the increase in rhizome amino acid concentration after early September and the continued increase in percent of total nitrogen as amino acids in the leaves. It has been suggested that nitrogen would be stored as water soluble nitrogen in the rhizomes and roots (Weinmann 1942, Perry and Moser 1974) or as protein (Thimann et al. 1974). These findings would indicate protein storage resulting in a decrease in the percent of total nitrogen as amino acids in October with a concurrent increase in root and rhizome total nitrogen (Part 1), even though the amino acid concentration continues to increase over the winter.

In early April 1981, the rhizome amino acid levels increase more dramatically indicating storage nitrogen remobilizing into amino acids (Beevers 1976). This would also imply that protein is the storage medium. The May 1981 decline in rhizome amino acid shows translocation to the leaves is occurring. This is

supported by the April 1981 increase in percent of total nitrogen as amino acids in the rhizomes and the May decline. A concurrent high in amino acids in leaves is seen in May 1981. The level rapidly drops as biomass increase and amino acids are transformed into proteins (Beevers 1976).

Burning Effects

The more rapid decrease in rhizome amino acids on burned than on unburned plots in May 1981 could be due to faster growth on the burned plots. The warmer soil and the greater light intensity for the young leaves results in more rapid early growth in burned than unburned plots. The removal of standing dead vegetation also increases loss of water by evaporation, but that is rarely a problem early in the growing season. The rapid translocation of amino acids to the leaves and synthesis into protein was indicated by the lower percentages of total nitrogen as amino acids in leaves on burned than on unburned plots in 1980 and 1981.

Higher levels of rhizome amino acids were found in the unburned plots than in burned plots in the summers of both 1980 and 1981. This is surprising since amino acid levels increased in water stressed plants (Barnett and Naylor 1966, Thimann et al. 1974, Beevers 1976, Thimann 1980). The soil moisture values were significantly lower in the burned than in unburned plots, implying that the plants on the burned plots were more stress than on the unburned plots. A possible explanation is that in the spring and early summer, the plants on the burned plots had increased transpiration pressures and decreased soil moisture due to a lack of standing dead material. The plants may have decreased their production and initiated early senescence due to the water stress. The rhizomes on the burned plots were always lower in percent of total nitrogen as amino acids and total nitrogen (Part 1). From July through September, the leaves in the burned plot were higher in percent of total nitrogen as amino acids, even though not significantly different from those in unburned plots in total amino acid concentration. This again could indicate that senescence initiated early in 1980 on the burned

plots. It should be noted that at least 30 cm of standing dead vegetation can build up on the tallgrass prairie over a two-year period while the leaves of big bluestem may only be 45 to 55 cm long. With the standing dead material, less of the leaf was exposed to sunlight, while the lower leaf blades were in a high relative humidity in the litter layer. Thus the plant on the unburned plots may not have been stressed enough to senesce in July but did show the stress symptoms. Because of the higher soil moistures, the unburned plots could still have had some nitrogen uptake. This nitrogen would accumulate as free amino acids since protein synthesis and translocation were depressed. This would increase the already accumulated pool of free amino acids from spring root uptake. The rainfall event in mid-August may have equalized the stress on burned and unburned plots, and thus allowed for the rhizome amino acids to be synthesized into storage proteins on both plots.

This is a pioneering study on the physiological effects of burning the tallgrass prairie. The rhizome amino acid concentration in unburned plots was significantly higher than burned plots in 1980. This pattern was repeated in spring of 1981. No significant difference in leaf amino acid concentration was found in 1980. The effect of burning on phenology accounts for the lower amino acid concentration on burned plots in rhizomes in May of 1980 and in leaves in April 1981.

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APPENDIX

Table 1. Mean monthly precipitation for the period 1941-1970 (Source: Kansas Agricultural Experiment Station, KSU, Manhattan, Ks.) and 1980 and 1981 monthly precipitation at the KPRNA headquarters.

	Average 1941-1970	1980	1981
	----- mm -----		
January	21.8	34.7	1.0
February	23.4	25.8	8.4
March	47.0	123.7	26.9
April	76.2	31.0	47.8
May	110.5	36.2	178.3
June	148.0	69.7	136.5
July	111.3	62.5	170.9
August	91.4	49.9	90.2
September	100.6	37.9	22.2
October	69.1	80.4	61.0
November	24.9	1.5	141.1
December	26.9	76.0	12.2
Total	851.4	680.0	896.5

Figure 1. Soil moisture content for 0 to 10 cm and 10 to 20 cm soil depths in burned and unburned plots on the north and south sites for 1980 and 1981.

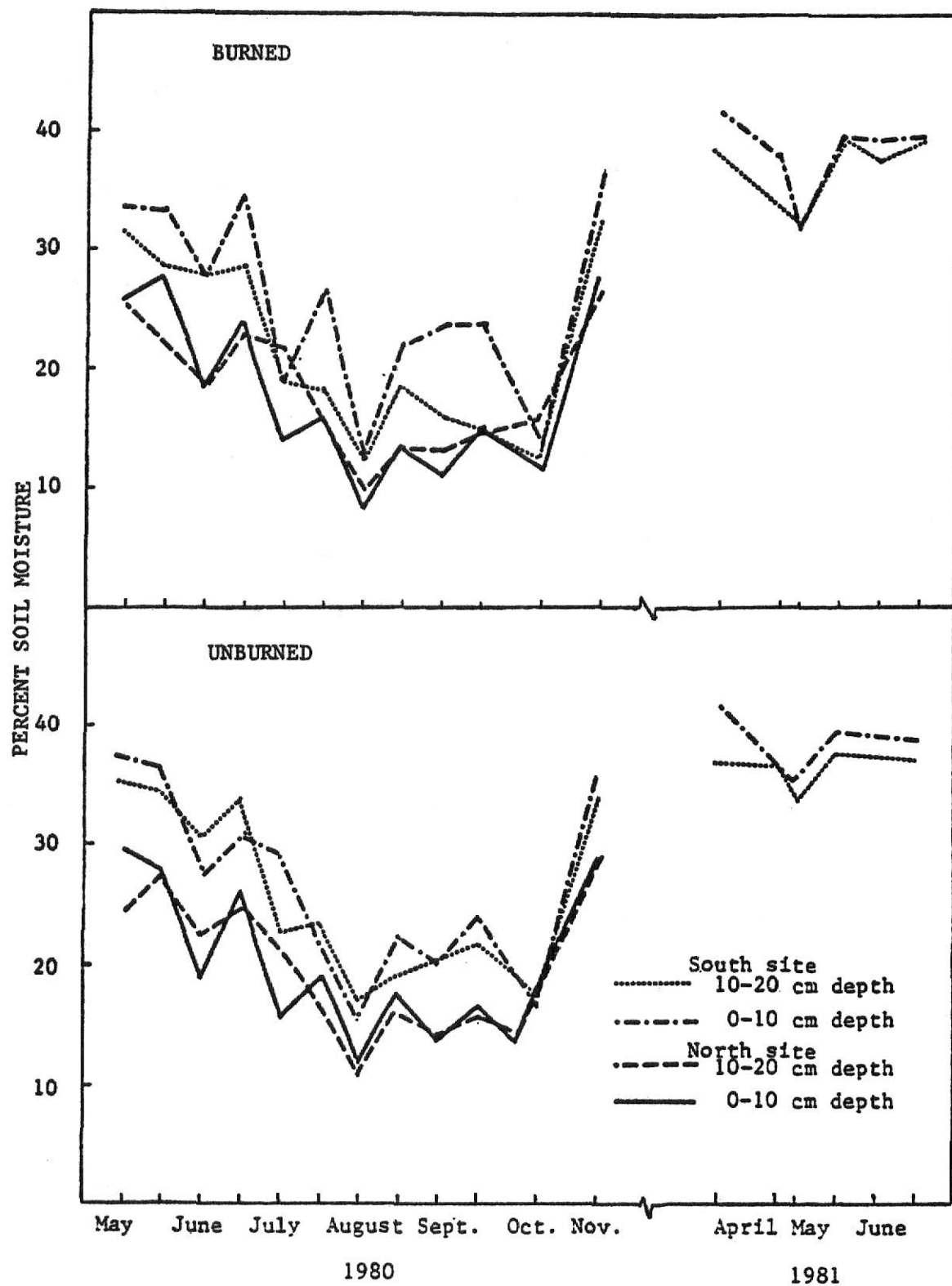


Table 2. Soil moisture content in unburned plots for two soil depths (0 to 10 cm and 10 to 20 cm) during 1980 and 1981. Averages are of 4 replicates in 1980 and 8 replicates in 1981. LSD = least significant difference.

	NORTH SITE		SOUTH SITE	
	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm
	----- % -----			
<u>1980 / LSD</u>	<u>1.97</u>	<u>1.54</u>	<u>1.97</u>	<u>1.54</u>
May 19	29.8	24.1	36.8	35.2
June 1	27.9	27.1	36.3	34.3
June 15	19.0	22.5	27.8	30.4
June 29	26.0	24.7	30.5	33.4
July 13	15.7	22.0	29.3	22.5
July 27	19.1	16.9	21.2	23.4
Aug. 10	12.0	13.1	15.6	16.9
Aug. 24	16.0	16.1	22.2	19.5
Sept. 7	13.5	14.3	20.0	20.4
Sept. 21	16.3	15.6	23.9	21.4
Oct. 12	13.6	14.3	16.4	17.0
Nov. 2	29.0	28.7	36.0	33.5
<u>1981 / LSD</u>			<u>0.98</u>	<u>0.77</u>
April 4	----	----	41.5	37.0
April 26	----	----	36.6	35.5
May 3	----	----	35.1	33.6
May 17	----	----	39.8	37.7
June 3	----	----	39.1	37.4
June 18	----	----	38.0	36.8

Table 3. Soil moisture content on burned plots for two soil depths (0 to 10 and 10 to 20 cm) during 1980 and 1981. Averages are of 4 replicates in 1980 and 8 replicates in 1981. LSD = least significant difference.

	NORTH SITE		SOUTH SITE	
	0 to 10 cm	10 to 20 cm	0 to 10 cm	10 to 20 cm
	----- % -----			
<u>1980 / LSD</u>	<u>1.70</u>	<u>1.36</u>	<u>1.70</u>	<u>1.36</u>
May 19	26.3	24.2	33.9	31.5
June 1	27.9	22.1	33.6	28.5
June 15	18.0	18.8	27.9	27.5
June 29	23.3	22.6	34.6	28.8
July 13	13.8	21.4	18.7	19.0
July 27	15.3	15.1	26.7	18.2
Aug. 10	8.1	9.7	12.8	12.8
Aug. 24	12.8	12.8	22.0	18.2
Sept. 7	10.5	12.8	23.5	16.1
Sept. 21	14.3	13.5	23.8	15.0
Oct. 12	10.9	13.2	13.7	12.8
Nov. 2	27.1	25.6	36.5	32.3
<u>1981 / LSD</u>			<u>0.85</u>	<u>0.68</u>
April 4	----	----	41.4	37.7
April 26	----	----	37.5	34.2
May 3	----	----	31.7	32.0
May 17	----	----	39.7	39.5
June 3	----	----	39.2	37.5
June 18	----	----	39.4	40.0

Table 4. Soil NH_4^+ for burned and unburned treatments on north (N) and south (S) sites at two soil depths (0 to 10 cm and 10 to 20 cm) on October 12, 1980 (4 replicates each) and May 5, 1981 (8 replicates each). (Standard errors are in parentheses).

	0 to 10 cm		10 to 20 cm	
	N	S	N	S
----- ppm -----				
BURNED				
October 12, 1980	10.45 (2.12)	18.23 (7.00)	9.18 (0.46)	15.33 (2.51)
May 5,	-----	37.40 (12.45)	-----	25.50 (2.96)
UNBURNED				
October 12, 1980	10.73 (1.53)	18.30 (2.62)	9.30 (0.85)	15.13 (1.28)
May 5, 1981	-----	31.93 (14.50)	-----	27.55 (5.10)

Table 5. NO_3^- for burned and unburned treatments on north (N) and south (S) sites at two soil depths (0 to 10 cm and 10 to 20 cm) on October 12, 1980 (4 replicates each) and May 5, 1981 (8 replicates each). (Standard errors are in parentheses).

	0 to 10 cm		10 to 20 cm	
	N	S	N	S
	----- ppm -----			
	BURNED			
October 12, 1980	6.23 (0.55)	6.45 (0.83)	6.18 (.67)	6.80 (1.37)
May 5, 1981	----	7.19 (1.26)	----	6.79 (0.97)
	UNBURNED			
October 12, 1980	5.95 (1.00)	6.10 (0.64)	5.75 (1.13)	5.98 (0.38)
May 5, 1981	----	7.35 (1.99)	----	6.75 (0.72)

Table 6b. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. June 1, 1980 (Correction factor = 0.99).

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%-----					
ROOTS					
Plot 1	0.37	0.37	Plot 5	0.38	0.46
Plot 2	0.31	0.47	Plot 6	0.34	0.43
Plot 3	0.35	0.30	Plot 7	0.47	0.45
Plot 4	0.25	0.46	Plot 8	0.30	0.53
Average	0.32	0.40	Average	0.37	0.47
RHIZOMES					
Plot 1	0.43	0.51	Plot 5	0.65	0.63
Plot 2	0.49	0.40	Plot 6	0.47	0.54
Plot 3	0.62	0.44	Plot 7	0.51	0.55
Plot 4	0.41	0.85	Plot 8	0.46	0.21
Average	0.49	0.55	Average	0.52	0.48
LEAVES					
Plot 1	1.36	1.32	Plot 5	1.68	1.44
Plot 2	1.54	1.41	Plot 6	3.38	1.63
Plot 3	1.41	1.27	Plot 7	1.36	1.38
Plot 4	1.20	2.00	Plot 8	1.51	1.04
Average	1.38	1.50	Average	1.98	1.37

Table 6c. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. June 15, 1980 (Correction factor = 0.85).

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%-----					
ROOTS					
Plot 1	0.28	0.23	Plot 5	0.34	0.41
Plot 2	0.22	0.29	Plot 6	0.34	0.34
Plot 3	0.61	0.26	Plot 7	0.42	0.37
Plot 4	0.23	0.54	Plot 8	0.39	0.34
Average	0.33	0.33	Average	0.37	0.40
RHIZOMES					
Plot 1	0.31	0.28	Plot 5	0.49	0.57
Plot 2	0.43	0.39	Plot 6	0.45	0.73
Plot 3	0.44	0.25	Plot 7	0.41	0.66
Plot 4	0.36	0.59	Plot 8	0.49	0.60
Average	0.38	0.38	Average	0.49	0.60
LEAVES					
Plot 1	0.90	1.11	Plot 5	1.18	1.12
Plot 2	0.94	0.88	Plot 6	1.35	1.07
Plot 3	0.93	1.09	Plot 7	1.24	1.12
Plot 4	1.07	0.97	Plot 8	1.04	0.99
Average	0.96	1.01	Average	1.20	1.08

Table 6d. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. June 29, 1980 (Correction factor = 0.90).

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.27	0.37	Plot 5	0.23	0.27
Plot 2	0.36	0.27	Plot 6	0.24	0.26
Plot 3	0.23	----	Plot 7	0.37	0.36
Plot 4	0.35	0.32	Plot 8	0.25	0.34
Average	0.30	0.24	Average	0.27	0.31
RHIZOMES					
Plot 1	0.33	0.73	Plot 5	0.40	0.46
Plot 2	0.45	0.40	Plot 6	0.41	0.47
Plot 3	0.40	----	Plot 7	0.46	0.74
Plot 4	0.47	0.48	Plot 8	0.33	0.38
Average	0.42	0.40	Average	0.40	0.51
LEAVES					
Plot 1	0.77	0.81	Plot 5	0.93	0.72
Plot 2	0.73	0.84	Plot 6	0.99	0.76
Plot 3	0.91	----	Plot 7	0.93	0.84
Plot 4	0.76	0.84	Plot 8	0.56	0.85
Average	0.79	0.62	Average	0.85	0.79

Table 6e. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. July 13, 1980 (Correction factor = 1.00).

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%-----					
ROOTS					
Plot 1	0.22	0.30	Plot 5	0.31	0.25
Plot 2	0.31	0.36	Plot 6	0.27	0.51
Plot 3	0.36	0.30	Plot 7	0.33	0.36
Plot 4	0.31	0.34	Plot 8	0.38	0.32
Average	0.30	0.33	Average	0.32	0.36
RHIZOMES					
Plot 1	0.46	0.51	Plot 5	0.44	0.44
Plot 2	0.43	0.51	Plot 6	0.50	0.65
Plot 3	0.61	0.55	Plot 7	0.39	0.47
Plot 4	0.66	0.67	Plot 8	0.40	0.59
Average	0.54	0.56	Average	0.43	0.54
LEAVES					
Plot 1	0.50	0.58	Plot 5	0.55	0.74
Plot 2	0.47	0.66	Plot 6	0.68	0.81
Plot 3	0.69	0.57	Plot 7	0.61	0.85
Plot 4	0.57	0.59	Plot 8	0.73	0.38
Average	0.56	0.60	Average	0.64	0.69

Table 6f. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. July 27, 1980 (correction factor = 0.80)

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.41	0.79	Plot 5	0.39	0.37
Plot 2	0.37	0.51	Plot 6	0.43	0.37
Plot 3	0.66	0.43	Plot 7	0.41	0.42
Plot 4	0.41	0.61	Plot 8	0.33	0.41
Average	0.46	0.59	Average	0.39	0.39
RHIZOMES					
Plot 1	0.45	0.75	Plot 5	0.34	0.69
Plot 2	0.46	0.74	Plot 6	0.55	0.62
Plot 3	0.84	0.65	Plot 7	0.56	0.70
Plot 4	0.86	0.80	Plot 8	0.48	0.70
Average	0.65	0.74	Average	0.48	0.68
LEAVES					
Plot 1	0.62	0.79	Plot 5	0.58	0.72
Plot 2	0.50	0.94	Plot 6	0.61	0.62
Plot 3	1.33	0.50	Plot 7	0.83	0.45
Plot 4	0.61	0.95	Plot 8	0.66	0.72
Average	0.76	0.80	Average	0.67	0.63

Table 6g. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. August 10, 1980 (correction factor = 0.79)

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.43	0.33	Plot 5	0.36	0.29
Plot 2	0.37	0.54	Plot 6	0.34	0.42
Plot 3	0.45	0.52	Plot 7	0.36	0.43
Plot 4	0.44	0.69	Plot 8	0.38	0.39
Average	0.42	0.52	Average	0.36	0.39
RHIZOMES					
Plot 1	0.57	0.63	Plot 5	0.70	0.59
Plot 2	0.75	0.92	Plot 6	0.47	0.84
Plot 3	0.62	0.95	Plot 7	0.74	0.71
Plot 4	0.79	0.94	Plot 8	0.54	0.41
Average	0.68	0.86	Average	0.61	0.64
LEAVES					
Plot 1	0.63	0.60	Plot 5	0.65	0.75
Plot 2	0.83	0.72	Plot 6	0.55	0.72
Plot 3	0.77	0.68	Plot 7	0.59	0.40
Plot 4	0.75	0.65	Plot 8	0.64	0.54
Average	0.74	0.66	Average	0.61	0.60

Table 6h. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. August 24, 1980 (correction factor = 0.98)

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
<hr/>					
-----%					
ROOTS					
Plot 1	0.26	0.35	Plot 5	0.30	0.34
Plot 2	0.37	0.51	Plot 6	0.50	0.35
Plot 3	0.47	0.39	Plot 7	0.21	0.27
Plot 4	0.38	0.46	Plot 8	0.27	0.31
Average	0.37	0.43	Average	0.32	0.32
RHIZOMES					
Plot 1	0.58	0.43	Plot 5	0.51	0.66
Plot 2	0.52	0.73	Plot 6	0.59	0.45
Plot 3	0.70	0.66	Plot 7	0.34	0.45
Plot 4	0.66	0.70	Plot 8	0.45	0.55
Average	0.61	0.63	Average	0.47	0.53
LEAVES					
Plot 1	0.40	0.54	Plot 5	0.56	0.68
Plot 2	0.33	0.65	Plot 6	0.42	0.16
Plot 3	0.58	0.51	Plot 7	0.53	0.25
Plot 4	0.42	0.54	Plot 8	0.52	0.37
Average	0.43	0.56	Average	0.51	0.37

Table 6i. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. September 7, 1980 (correction factor = 0.90)

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.35	0.29	Plot 5	0.40	0.36
Plot 2	0.35	0.68	Plot 6	0.40	0.42
Plot 3	0.49	0.38	Plot 7	0.16	0.30
Plot 4	0.34	0.58	Plot 8	0.35	0.39
Average	0.38	0.49	Average	0.33	0.37
RHIZOMES					
Plot 1	0.70	0.57	Plot 5	0.81	0.72
Plot 2	0.55	0.83	Plot 6	0.64	0.42
Plot 3	0.64	0.71	Plot 7	0.47	0.53
Plot 4	0.66	1.01	Plot 8	0.56	0.60
Average	0.64	0.78	Average	0.67	0.57
LEAVES					
Plot 1	0.37	0.45	Plot 5	0.40	0.48
Plot 2	0.43	0.57	Plot 6	0.51	0.75
Plot 3	0.51	0.26	Plot 7	0.47	0.43
Plot 4	0.53	0.54	Plot 8	0.39	0.55
Average	0.46	0.46	Average	0.44	0.55

Table 6j. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. September 21, 1980 (correction factor = 0.76)

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
-----%-----					
ROOTS					
Plot 1	0.45	----	Plot 5	0.75	0.63
Plot 2	0.44	0.81	Plot 6	0.46	0.52
Plot 3	0.58	0.75	Plot 7	0.49	0.40
Plot 4	0.57	0.90	Plot 8	0.32	0.48
Average	0.51	0.82	Average	0.50	0.51
RHIZOMES					
Plot 1	0.51	----	Plot 5	1.29	0.88
Plot 2	0.71	1.07	Plot 6	0.70	0.78
Plot 3	0.73	1.18	Plot 7	0.80	0.72
Plot 4	0.96	0.97	Plot 8	0.75	0.84
Average	0.73	1.07	Average	0.89	0.80
LEAVES					
Plot 1	0.35	----	Plot 5	0.42	0.65
Plot 2	0.49	0.50	Plot 6	0.49	0.47
Plot 3	0.48	0.59	Plot 7	0.45	0.49
Plot 4	0.48	0.61	Plot 8	0.47	0.69
Average	0.45	0.57	Average	0.46	0.57

Table 61. Total nitrogen content for individual plots on north and south sites with burned and unburned treatments for roots, rhizomes and leaves. November 2, 1980 (correction factor = 0.66)

NORTH SITE			SOUTH SITE		
	BURNED	UNBURNED		BURNED	UNBURNED
<hr/>					
-----%					
ROOTS					
Plot 1	0.69	0.55	Plot 5	0.58	0.33
Plot 2	0.57	0.50	Plot 6	0.54	0.50
Plot 3	0.46	0.56	Plot 7	0.68	0.51
Plot 4	0.45	0.55	Plot 8	0.48	0.75
Average	0.53	0.54	Average	0.57	0.52
RHIZOMES					
Plot 1	1.07	1.11	Plot 5	0.89	0.66
Plot 2	0.94	1.18	Plot 6	0.77	0.74
Plot 3	0.71	0.85	Plot 7	0.84	0.73
Plot 4	0.70	0.77	Plot 8	0.57	0.83
Average	0.86	0.98	Average	0.77	0.74
LEAVES					
Plot 1	0.27	0.22	Plot 5	0.08	0.02
Plot 2	0.22	0.32	Plot 6	0.25	0.18
Plot 3	0.18	0.23	Plot 7	0.24	0.22
Plot 4	0.21	0.29	Plot 8	0.26	
Average	0.23	0.25	Average	0.22	0.17

Table 6m. Total nitrogen content for individual plots on the south site with burned and unburned treatments for roots, rhizomes and leaves. April 4, 1981 (correction factor = 0.76)

SOUTH SITE					
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.42	0.28	Plot 5	0.54	0.69
Plot 2	0.33	0.45	Plot 6	0.42	0.55
Plot 3	0.38	0.48	Plot 7	0.58	0.54
Plot 4	0.39	0.56	Plot 8	0.45	0.81
			Average	0.44	0.55
RHIZOMES					
Plot 1	0.45	0.26	Plot 5	0.59	0.81
Plot 2	0.41	0.44	Plot 6	0.52	0.83
Plot 3	0.43	0.59	Plot 7	0.71	0.72
Plot 4	0.55	0.70	Plot 8	0.54	0.86
			Average	0.53	0.65
LEAVES					
Plot 1	0.10	0.12	Plot 5	0.28	0.24
Plot 2	0.13	0.12	Plot 6	0.24	0.21
Plot 3	0.20	0.17	Plot 7	0.21	0.17
Plot 4	0.28	0.20	Plot 8	0.33	0.21
			Average	0.22	0.18

Table 6n. Total nitrogen content for individual plots on the south site with burned and unburned treatments for roots, rhizomes and leaves. April 26, 1981 (correction factor = 0.89)

SOUTH SITE					
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.41	0.79	Plot 5	0.32	0.43
Plot 2	0.40	0.50	Plot 6	0.44	0.47
Plot 3	0.54	0.40	Plot 7	0.56	0.45
Plot 4	0.58	0.54	Plot 8	0.46	0.87
			Average	0.46	0.56
RHIZOMES					
Plot 1	0.52	0.76	Plot 5	0.51	0.55
Plot 2	0.60	0.63	Plot 6	0.63	0.67
Plot 3	0.58	0.60	Plot 7	0.70	0.67
Plot 4	0.61	0.47	Plot 8	0.62	0.42
			Average	0.60	0.59
LEAVES					
Plot 1	1.73	2.37	Plot 5	1.63	1.31
Plot 2	1.65	1.51	Plot 6	1.53	1.92
Plot 3	1.70	----	Plot 7	1.74	1.75
Plot 4	1.59	2.06	Plot 8	2.07	2.12
			Average	1.71	1.63

Table 60. Total nitrogen content for individual plots on the south site with burned and unburned treatments for roots, rhizomes and leaves. May 3, 1981 (correction factor = 0.95)

SOUTH SITE					
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.35	0.56	Plot 5	0.58	0.55
Plot 2	0.43	0.48	Plot 6	0.57	0.48
Plot 3	0.42	0.56	Plot 7	0.69	0.47
Plot 4	0.66	0.57	Plot 8	0.35	0.66
			Average	0.51	0.54
RHIZOMES					
Plot 1	0.54	0.68	Plot 5	0.61	0.68
Plot 2	0.44	0.56	Plot 6	0.76	0.75
Plot 3	0.63	0.81	Plot 7	0.68	0.60
Plot 4	0.66	0.82	Plot 8	0.47	0.85
			Average	0.60	0.72
LEAVES					
Plot 1	1.52	1.65	Plot 5	1.36	2.19
Plot 2	1.60	1.79	Plot 6	1.74	2.06
Plot 3	1.75	1.83	Plot 7	1.87	1.93
Plot 4	1.55	2.01	Plot 8	1.75	2.09
			Average	1.64	1.94

Table 6p. Total nitrogen content for individual plots on the south site with burned and unburned treatments for roots, rhizomes and leaves. May 17, 1981 (correction factor = 0.89)

SOUTH SITE							
BURNED		UNBURNED		BURNED		UNBURNED	
-----%							
ROOTS							
Plot 1	0.43	0.76	Plot 5	0.38	0.60		
Plot 2	0.36	0.61	Plot 6	0.43	0.50		
Plot 3	0.50	0.62	Plot 7	0.52	0.58		
Plot 4	0.73	0.55	Plot 8	0.47	0.81		
			Average	0.48	0.63		
RHIZOMES							
Plot 1	0.47	0.84	Plot 5	0.67	0.74		
Plot 2	0.44	0.80	Plot 6	0.44	0.53		
Plot 3	0.58	0.69	Plot 7	0.67	0.62		
Plot 4	0.93	0.68	Plot 8	0.61	0.48		
			Average	0.60	0.67		
LEAVES							
Plot 1	1.68	1.72	Plot 5	1.95	2.13		
Plot 2	1.75	1.85	Plot 6	1.33	1.67		
Plot 3	1.81	1.82	Plot 7	1.57	1.96		
Plot 4	2.17	1.71	Plot 8	1.73	1.71		
			Average	1.75	1.82		

Table 6q. Total nitrogen content for individual plots on the south site with burned and unburned treatments for roots, rhizomes and leaves. June 3, 1981 (correction = 0.81)

SOUTH SITE					
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.63	0.69	Plot 5	0.40	0.53
Plot 2	0.47	0.64	Plot 6	0.33	0.46
Plot 3	0.47	0.48	Plot 7	0.34	0.60
Plot 4	0.32	0.67	Plot 8	0.28	0.56
			Average	0.41	0.58
RHIZOMES					
Plot 1	0.47	0.70	Plot 5	0.57	0.61
Plot 2	0.54	0.70	Plot 6	0.52	0.60
Plot 3	0.43	0.72	Plot 7	0.56	0.70
Plot 4	0.40	0.66	Plot 8	0.35	0.77
			Average	0.48	0.68
LEAVES					
Plot 1	1.49	1.51	Plot 5	1.51	1.47
Plot 2	1.42	1.54	Plot 6	1.35	1.30
Plot 3	1.65	1.33	Plot 7	1.36	1.24
Plot 4	1.15	1.58	Plot 8	1.20	1.41
			Average	1.39	1.42

Table 6r. Total nitrogen content for individual plots on the south site with burned and unburned treatments for roots, rhizomes and leaves. June 18, 1981 (correction factor = 1.00)

SOUTH SITE					
	BURNED	UNBURNED		BURNED	UNBURNED
-----%					
ROOTS					
Plot 1	0.19	0.28	Plot 5	0.23	0.36
Plot 2	0.47	0.20	Plot 6	0.31	0.38
Plot 3	0.27	0.33	Plot 7	0.25	0.35
Plot 4	0.19	0.28	Plot 8	0.21	0.35
			Average	0.27	0.32
RHIZOMES					
Plot 1	0.29	0.46	Plot 5	0.42	0.52
Plot 2	0.30	0.72	Plot 6	0.57	0.61
Plot 3	0.34	0.38	Plot 7	0.52	0.52
Plot 4	0.38	0.51	Plot 8	0.39	0.65
			Average	0.40	0.54
LEAVES					
Plot 1	0.84	0.94	Plot 5	0.86	0.88
Plot 2	0.89	1.26	Plot 6	1.19	1.05
Plot 3	0.87	0.98	Plot 7	0.96	1.26
Plot 4	0.99	0.83	Plot 8	1.01	0.95
			Average	0.95	1.02

Table 7a. Total amino acid concentration for individual plots on burned and unburned treatments for rhizomes and leaves.

RHIZOMES				LEAVES	
	BURNED	UNBURNED		BURNED	UNBURNED
-----ugN·g ⁻¹ -----					
May 19, 1980					
Plot 1	262	258	Plot 1	386	277
Plot 2	241	228	Plot 2	270	341
Plot 3	192	246	Plot 3	387	342
Plot 4	135	217	Plot 4	268	313
Average	207	237	Average	327	318
June 15, 1980					
Plot 1	224	232	Plot 1	181	201
Plot 2	190	304	Plot 2	250	213
Plot 3	157	307	Plot 3	226	220
Plot 4	208	309	Plot 4	247	269
Average	195	288	Average	226	226
July 13, 1980					
Plot 1	276	297	Plot 1	213	170
Plot 2	307	492	Plot 2	244	204
Plot 3	208	350	Plot 3	240	199
Plot 4	191	264	Plot 4	195	170
Average	245	351	Average	223	186

Table 7b. Total amino acid concentration for individual plots on burned and unburned treatments for rhizomes and leaves.

RHIZOMES			LEAVES		
	BURNED	UNBURNED		BURNED	UNBURNED
-----ugN.g ⁻¹ -----					
August 10, 1980					
Plot 1	319	342	Plot 1	157	205
Plot 2	224	563	Plot 2	154	175
Plot 3	296	457	Plot 3	177	155
Plot 4	295	260	Plot 4	180	168
Average	283	405	Average	167	176
September 27, 1980					
Plot 1	281	255	Plot 1	151	181
Plot 2	155	324	Plot 2	199	174
Plot 3	231	216	Plot 3	190	171
Plot 4	190	273	Plot 4	243	153
Average	239	267	Average	196	170
October 12, 1980					
Plot 1	343	300	Plot 1	145	269
Plot 2	193	334	Plot 2	266	140
Plot 3	389	324	Plot 3	167	130
Plot 4	328	251	Plot 4	161	123
Average	313	302	Average	185	165

Table 7c. Total amino acid concentration for individual plots on burned and unburned treatments for rhizomes and leaves.

RHIZOMES			LEAVES		
	BURNED	UNBURNED		BURNED	UNBURNED
-----ugN.g ⁻¹ -----					
April 4, 1981					
Plot 1	334	331	Plot 1	33	57
Plot 2	241	337	Plot 2	72	110
Plot 3	319	294	Plot 3	85	76
Plot 4	492	415	Plot 4	79	94
Average	346	344	Average	67	84
May 3, 1981					
Plot 1	477	450	Plot 1	587	566
Plot 2	409	592	Plot 2	555	1002
Plot 3	592	421	Plot 3	677	803
Plot 4	365	484	Plot 4	707	848
Average	461	487	Average	631	805
June 3, 1981					
Plot 1	352	472	Plot 1	323	287
Plot 2	320	513	Plot 2	224	283
Plot 3	317	287	Plot 3	294	520
Plot 4	252	291	Plot 4	226	250
Average	310	391	Average	267	335

SEASONAL NITROGEN TRANSLOCATION IN
BIG BLUESTEM, ANDROPOGON GERARDII VITMAN,
IN KANSAS DURING A DROUGHT YEAR

DEBORAH CHILDS HAYES
B.S., University of Montana, 1976

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements of the degree

MASTER OF SCIENCE

Division of Biology

KANSAS STATE UNIVERSITY

1982

ABSTRACT

Seasonal total nitrogen and amino-nitrogen translocations in big bluestem in the tallgrass prairie were studied on burned and unburned treatments within Konza Prairie Research Natural Area, Manhattan, Kansas. Total nitrogen concentrations in the leaves dropped from 1.46% and 1.83% on unburned and burned treatments, respectively, in May 1980 to 0.72% on both treatments in July. Levels further dropped to 0.21% and 0.23% total nitrogen in November 1980 for unburned and burned treatments, respectively. The May to July percentage decrease is believed due to a more rapid increase in plant biomass than in plant total nitrogen. The July to November decrease is assumed to be retranslocation of nitrogen into perennial belowground parts. During the same period rhizomes increased from 0.49% to 0.97% total nitrogen. Roots increased from 0.31% to 0.59% total nitrogen, indicating that roots are also used as storage organs. As 1980 was a dry year, comparisons with other studies indicate that drought stress may reduce the nitrogen content of big bluestem.

Although there was no significant difference in leaf amino acid concentration between treatments over the summer of 1980, the percent of total nitrogen as amino acids increased in the leaves during the summer of 1980, with a dramatic increase from mid-August to October. In April 1981, emerging leaves on the unburned plots were significantly higher in amino acid concentration than those on the burned plots (805 vs. 631 $\mu\text{gN}\cdot\text{g}^{-1}$). Rhizome amino acid concentration was significantly higher on the unburned plots, increasing from 207 $\mu\text{gN}\cdot\text{g}^{-1}$ in May 1980 to 283 $\mu\text{gN}\cdot\text{g}^{-1}$ and 405 $\mu\text{gN}\cdot\text{g}^{-1}$ in August 1980 for burned and unburned respectively. Levels dropped sharply in September and subsequently increased in October and over the winter of 1980. The unburned plots were higher in percent amino acids than burned plots throughout 1980, but the trend reversed in 1981. It is suggested that the high

percent of total nitrogen as amino acids in leaves and rhizomes in June and July 1980 is due to early senescence induced by drought stress. The increase in both leaf and rhizome amino acid concentration and percent of total nitrogen as amino acids in September 1980, is due to remobilization of proteins and retranslocation to the belowground parts as storage organs.