I. Effects of Dormant Season Herbage Removal on Flint Hills Rangeland

II. Near-Infrared Reflectance Spectroscopy Analysis of Total Nonstructural Carbohydrates in Big Bluestem Rhizomes

by

LISA MARIE AUEN

B.S., Kansas State University, 1983

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1987

Approved by:

Clenton E. Owensby
Major Professor

TABLE OF CONTENTS

Acknowledgements

I am grateful for the opportunity to conduct my research on the Konza Prairie Natural Resource Area and wish to thank the late Dr. Lloyd Hulbert, past Director of the Konza Prairie for allowing me to do so.

I am indebted to my major professor, Dr. Clenton E. Owensby, for his unique "whatever you think" attitude which forced me to search for answers and for routinely helping me get the trucks out of the mud.

I thank Dr. Patrick Coyne and Dr. James Guikema for their advice and willingness to serve on my graduate committee. I also wish to thank Dr. Phil Simms and Khaja Khaleeluddin for their analytical laboratory assistance and Dr. David Wetzel for his NIRS expertise and allowing me to use his research NIRS instrument.

A very special thank you to my parents, Mr. and Mrs. Luke Auen, who assisted tremendously in field data collection and provided vast amounts of support and encouragement towards the completion of this research project.

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX TABLES

I. Effects of Dormant Season Herbage Removal on Flint Hills Rangeland

Introduction

Kansas Flint Hills range is converted to saleable red meat more efficiently by intensive-early (IES) stocking than by season-long stocking. IES results in higher animal gains per hectare without sacrificing individual animal performance. Thus, producers realize more profit compared to season-long systems. In addition, IES cattle are sold in July when traditionally fewer cattle are sold and prices are higher.

IES consists of stocking at double the season-long rates during the first half of the growing season followed by removing the animals and allowing the forage to regrow the remainder of the season in order to replenish carbohydrate reserves (Launchbaugh and Owensby, 1978). Regrowth on IES pastures was responsible for higher herbage yields at the end of the growing season compared to season-long stocked pastures (Smith and Owensby, 1978). Winter grazing of regrowth on IES pastures would be an alternative to feeding hay and provide producers greater flexibility in purchasing cattle.

The objective of this study was to determine the feasibility of grazing IES pastures during winter months. Ungrazed plots were mowed on the first of October, November, January, March, April, or May to determine the effects on subsequent herbage production and total nonstructural carbohydrate reserves in big bluestem (*Andropogon gerardii* Vitman) rhizomes.

Materials and Methods

Location. The study area was on the Konza Prairie Research Natural Area near Manhattan, Kansas (Hulbert, 1985). The plots were located on a loamy upland range site with a Benfield-Florence complex soil (Benfield series: fine, mixed, mesic, udic argiustolls; Florence series: clayey-skeletal, montmorillonitic, mesic, udic argiustolls). The site was burned by a wildfire in early spring of 1982.

Vegetation. The vegetation within the plots was typical of the Flint Hills range ecosystem. The dominant grasses were big bluestem (*Andropogon gerardii* Vitman), indiangrass (*Sorghastrum nutans* (L.) Nash), and little bluestem (*Andropogon scoparius* Michx.).

Treatments. Treatments were mowing and removing herbage, or mowing and leaving herbage on different plots on the first of each month from October 1983 to April 1984 and October 1984 to April 1985. Snow cover eliminated December and February treatments. The comparison standard plots were removal of herbage on 1 May by burning in 1984 and by mowing and raking in 1985.

The 3x3 m plots were mowed to a 5-cm stubble height with a sicklebar mower and the cut herbage was either raked off or returned evenly over the plots.

Experimental design and analysis. The study was conducted using a randomized complete block design with three blocks. A varying 2-3% slope was the blocking factor. Data were statistically analyzed using SAS PROC GLM (SAS, 1982) for unbalanced data and least squares means separation ($P<0.10$). All data were pooled to determine if overall treatment differences existed after adjusting for missing data. Mean separation by

sampling date proved impractical on the overall means because of missing data. Therefore, the data were separated by dates into 3 subclasses, 1 January - 1 March, 15 March - 1 July, and 1 August - 15 December to pinpoint when differences occurred.

Herbage production. Herbage production for all treatments was determined by hand clipping a 1 m sq area to 5 cm on 15 May, 1 June, 15 June, 1 July, and 15 July, 1984 and 1985. All herbage samples were dried for 72 hr at 55 C and weighed to estimate dry-matter production.

Total Nonstructural Carbohydrates (TNC). Rhizomes from six big bluestem plants were collected from each plot every two weeks from 1 October, 1983 to 1 May, 1984 and 1 October, 1984 to 1 May, 1985 and monthly from 1 June to 1 September of both years. The rhizomes were placed in paper bags, dried for 72 hr at 55 C, and stored in plastic trash cans. After completion of the study, all rhizomes were cleaned with coldwater washing, redried for 48 hr, roots were removed, ground with a Udy Cyclone Mill (1 mm mesh), and stored in a dark plastic vial. The rhizomes were analyzed for TNC (mg g^{-1}) using a Technicon InfraAlyzer 400 (I/A 400) near-infrared reflectance spectrophotometer. The wavelengths 1680, 1778, 1818, 1940, and 2348 nm gave the best multiple regression equation with a 0.9871 multiple correlation coefficient.

The I/A 400 was calibrated using 40 rhizome samples from the 1 May treatment selected across all sampling dates. The TNC content of these 40 samples were predetermined using a dual-enzyme method (Khaleeluddin and Bradford, 1986). TNC concentrations have been shown to be highly correlated with pool sizes in another group of warm-season, tallgrass

species, the Old world bluestems (*Bothriochloa sp.*) (Coyne and Bradford, in press).

Soil moisture. Soil moisture was determined gravimetrically on 1 May, 1 June, 15 July, 1984 and 1 May, 15 May, 15 June, 15 July, 1985. Two soil samples were taken from the 0-15 cm layer of each plot. The mean of those two samples was used in analysis.

Results and Discussion

Herbage production. None of the winter mowing treatments reduced herbage yields the following season (P=0.13). Higher herbage yields occurred in 1984 than 1985 (P=0.0001), with the average herbage yield on 15 July, 1984 being 3145 kg/ha compared to 2386 kg/ha on 15 July, 1985. Precipitation during May and June was higher in 1984 than 1985 (Figure 1). It is likely that the greater available soil water during the growing season of 1984 produced the higher herbage yields in 1984 versus 1985.

Total Nonstructural Carbohydrates (TNC). Winter mowing only lowered TNC in big bluestem rhizomes in the October-raked, April-raked, and April-nonraked treatments during the 15 March to 1 July period of both years (P=0.02) (Table 1). Figures 2-4 show TNC for these treatments are lower than the May treatment primarily during April, but converged towards similar low points in May and June. Considering there were no reductions in herbage yields in these treatments compared to the May treatments and that TNC did not differ during any other sampling period. The lower TNC did not affect growth potential nor later TNC levels.

TNC in big bluestem rhizomes was lower in 1984 than 1985 (P=0.03). Precipitation during July and August of 1983 and 1984 was lower than in July and August of 1985 (Figure 1). Knapp (1985) reported drought-stress occurred in big bluestem from July to mid-August of 1983, during which net photosynthesis of big bluestem declined to near zero. Following precipitation in September, photosynthetic rates in big bluestem returned to about half the season maximum (Knapp, 1985). Lack of precipitation in July and August of 1984 could also have caused some drought-stress in big bluestem. Lower photosynthetic rates caused by the mid-season droughts likely produced less carbohydrates resulting in less carbohydrates being translocated to rhizomes. The combination of possible lower carbohydrate storage in 1983 and the mid-season drought in 1984 probably caused the lower TNC in 1984 compared to 1985.

Soil moisture. Plots on which herbage was returned to the soil surface following winter mowing had more total soil moisture than plots on which herbage was removed (P=0.04). There were no differences among mowing treatments in total soil moisture in the 0-15 cm layer (P=0.16).

Conclusions

Winter herbage removal in central Kansas decreased herbage production in subsequent seasons by as much as 50% (Launchbaugh, 1972). However, shortgrasses dominate in central Kansas compared to the tallgrass dominance in the Flint Hills. Morphologic differences in the reserve carbohydrate storage locations between short and tall grasses were likely responsible for our results being contradictary to Launchbaugh's results. In dominant Flint Hills tallgrasses, rhizomes are

the primary storage organs, whereas shortgrasses utilize the crown-area as the primary area of reserve storage. Winter herbage removal exposed the crown areas to temperature fluctuations which might have caused some reduction in food reserves of the shortgrasses to compensate for the alternating cold and warm temperatures. In addition, all reserve carbohydrates may not have been translocated below cutting height for the shortgrasses which would directly remove reserve carbohydrates and make them unavailable for growth the following season.

Winter mowing in the Flint Hills did not reduce herbage yields the following season and the reduction of TNC in big bluestem rhizomes observed in some treatments had no effect on herbage yields. Furthermore, removing all herbage by mowing above 5 cm on a given date during the winter would be more detrimental to subsequent herbage yields than selective herbage removal through the winter by grazing.

Owensby *et al.* (1977) showed that TNC in big bluestem rhizomes was lower during the growing season under IES compared to season-long stocking, but the removal of cattle on 15 July from the IES pastures gave adequate time for the big bluestem to regrow and translocate similar amounts of carbohydrates to the rhizomes as were translocated under season-long stocking at the onset of dormancy. They showed that under IES, the translocation of carbohydrates occurred primarily during September, with little movement thereafter throughout the winter season. Therefore, the time at which cattle are returned to the IES pastures for winter grazing would be crucial. Stocking before 1 October would result in lower carbohydrate storage and lower herbage production the following season.

This study indicates that cattle producers may use IES pastures during the winter after sufficient regrowth has occurred. Assuming other dominant warm-season grasses respond similarly, to winter forage removal as does big bluestem.

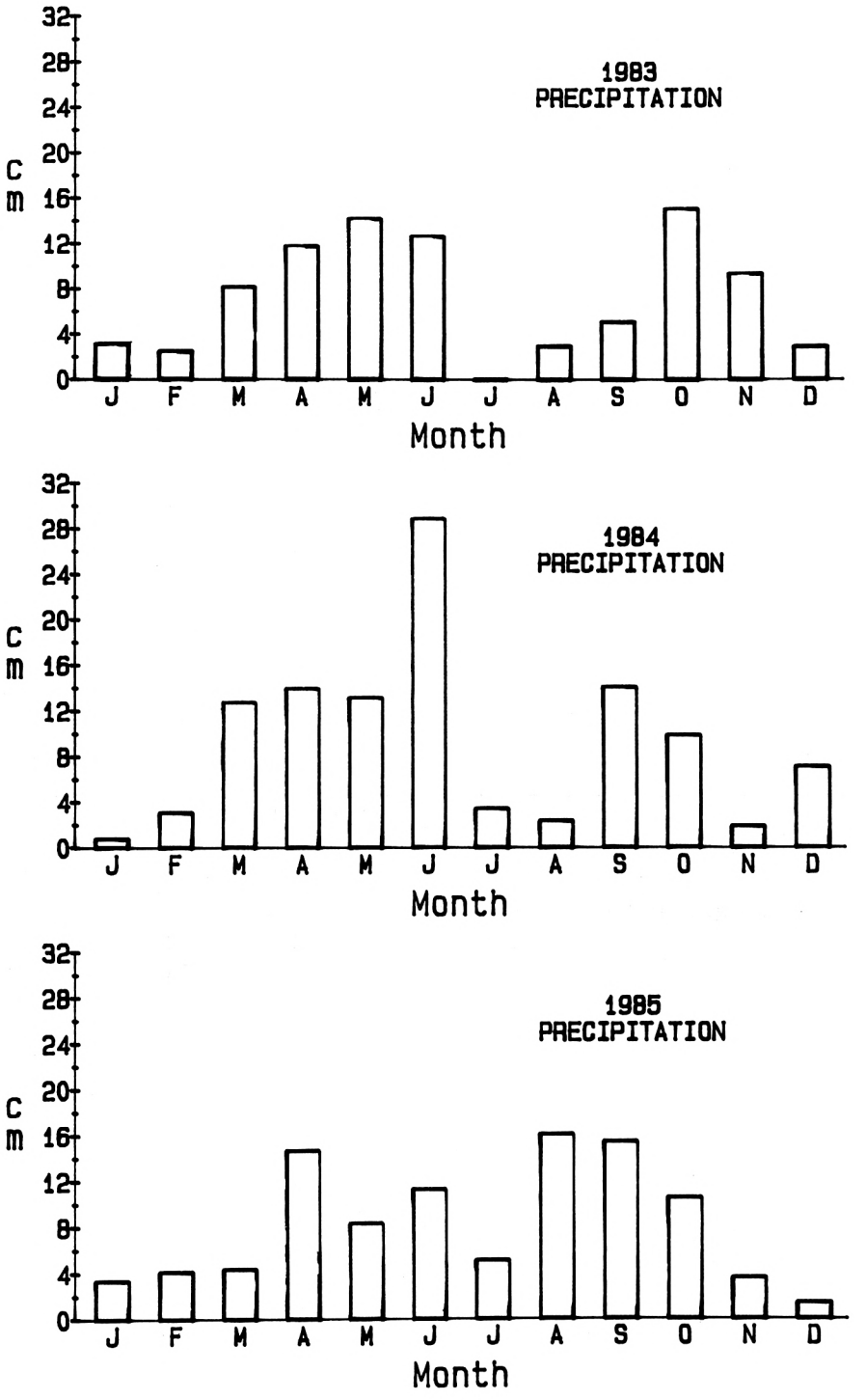

Figure 1. Total monthly precipitation at Manhattan, Kansas for 1983, 1984, and 1985.

Table 1. Means[1] of total nonstructural carbohydrates (mg g^{-1}) in big bluestem rhizomes following winter mowing[2] treatments, on Flint Hills bluestem rangeland from October 1983 to September 1985. Treatments were mowing and removing herbage, mowing and leaving herbage, or not winter mowing on different plots on the first of each month from October 1983 to May 1984[3] and October 1984 to May 1985. Statistical differences from the May treatment only existed during 15 March - 1 July (P=0.02).

Date Mowed	Herbage Removed	Total Nonstructural Carbohydrates (mg g^{-1}) Jan 1 - Mar 1	Mar 15 - Jul 1	Aug 1 - Dec 15
October 1	Yes	7.63	4.13 **	8.37
	No	8.75	5.19	9.25
November 1	Yes	9.25	5.23	9.57
	No	9.53	5.83	10.42
January 1	Yes	8.87	5.69	9.23
	No	8.36	5.36	9.16
March 1	Yes	9.40	5.46	8.53
	No	7.56	5.82 **	9.31
April 1	Yes	8.20	4.63 **	8.09
	No	9.05	4.39 **	8.08
May 1	Yes	8.72	5.49	9.39

1. Means are from 3 replications.
2. 3x3 m plots were mowed to a 5-cm stubble height with a sicklebar mower.
3. The 1 May mowing treatment was not a winter mowing date, it was the comparison standard.
4. Means for 1985 only.

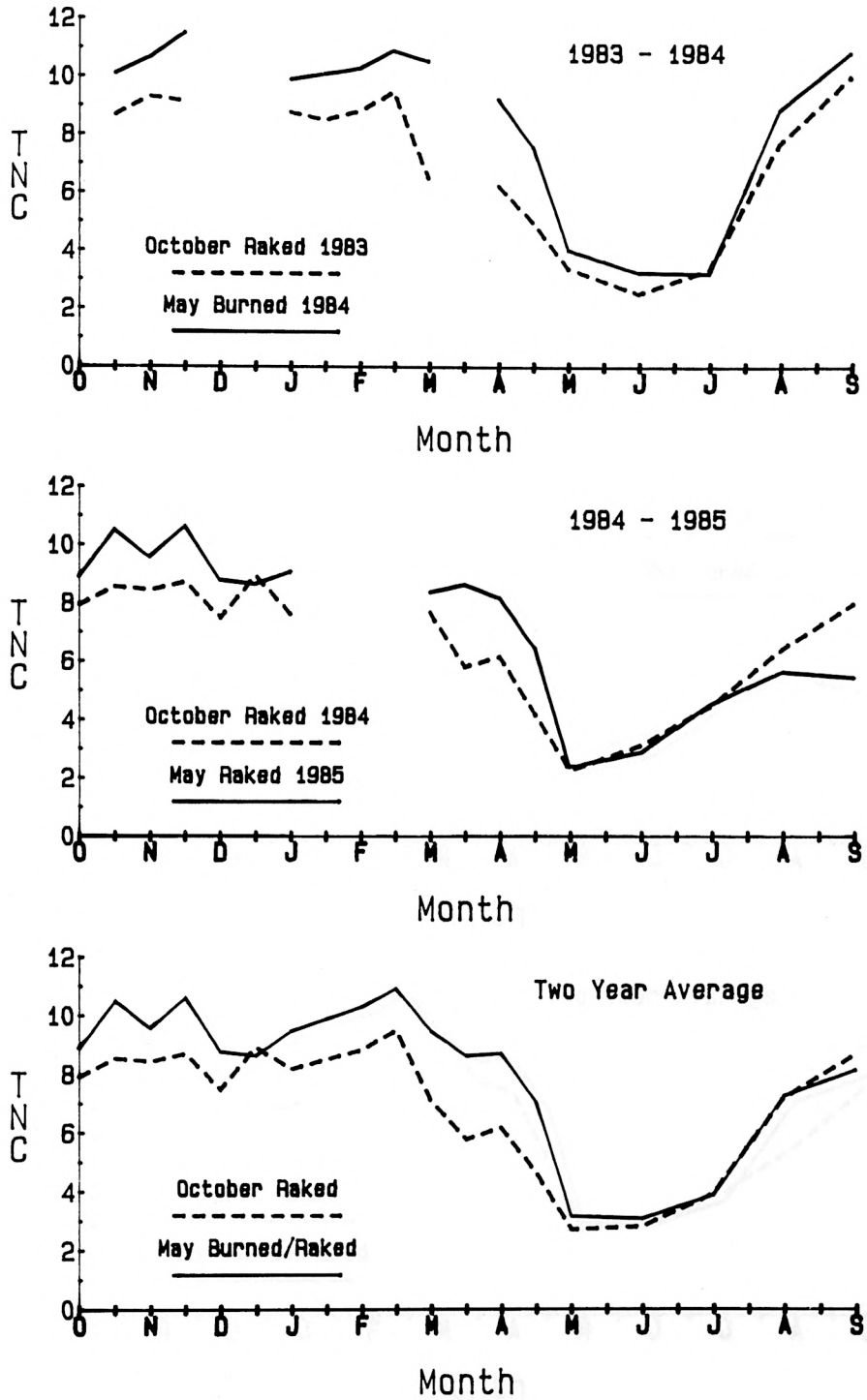

Figure 2. Means of total nonstructural carbohydrates (mg g^{-1}) in big bluestem rhizomes for October 1983 through September 1985 following 1 October mowing and removing herbage and 1 May burned or mowed and raked treatments. Means from 3 replications.

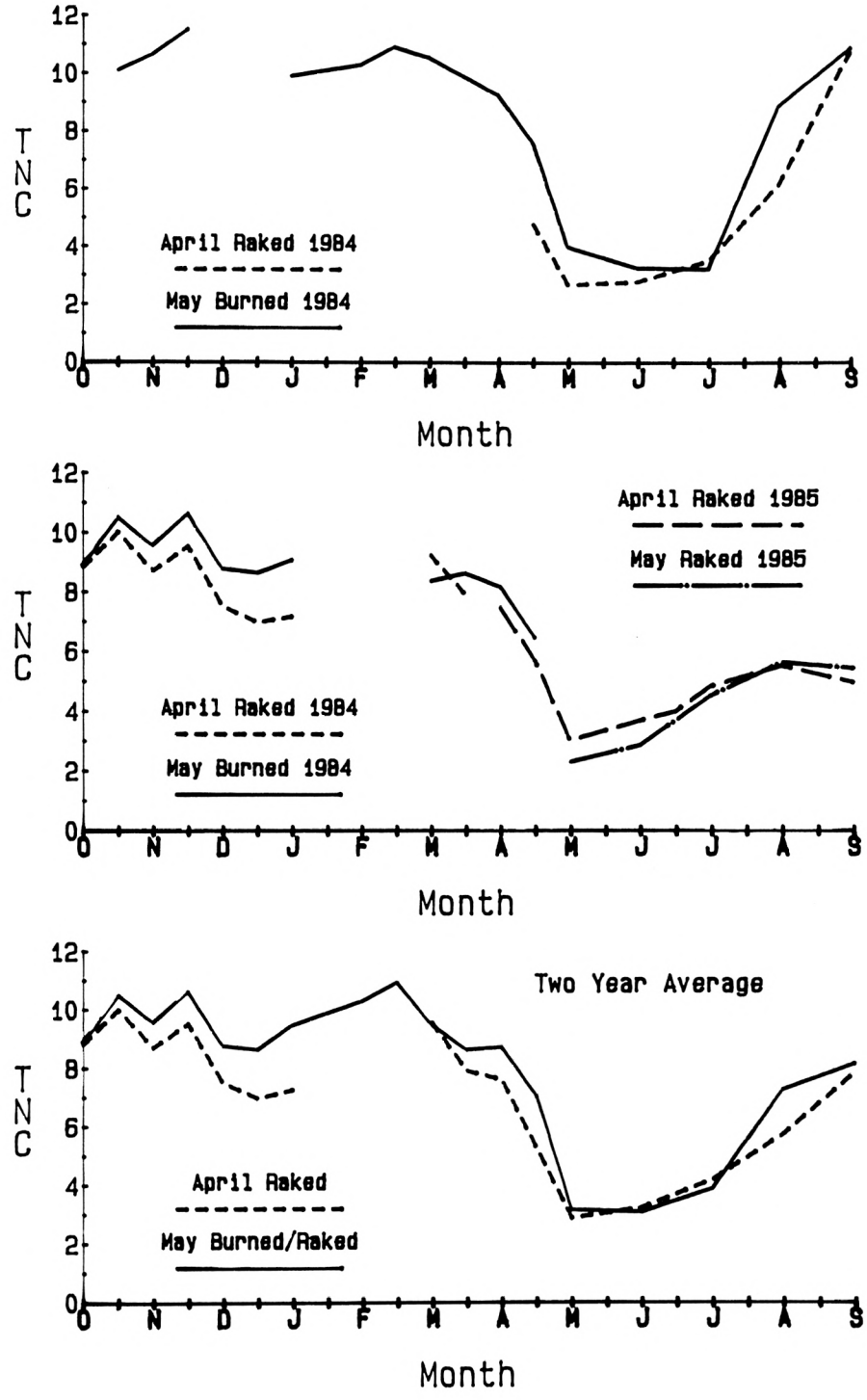

Figure 3. Means of total nonstructural carbohydrates (mg g^{-1}) in big bluestem rhizomes for October 1983 through September 1985 following 1 April mowing and removing herbage and 1 May burned or mowed and raked treatments. Means from 3 replications.

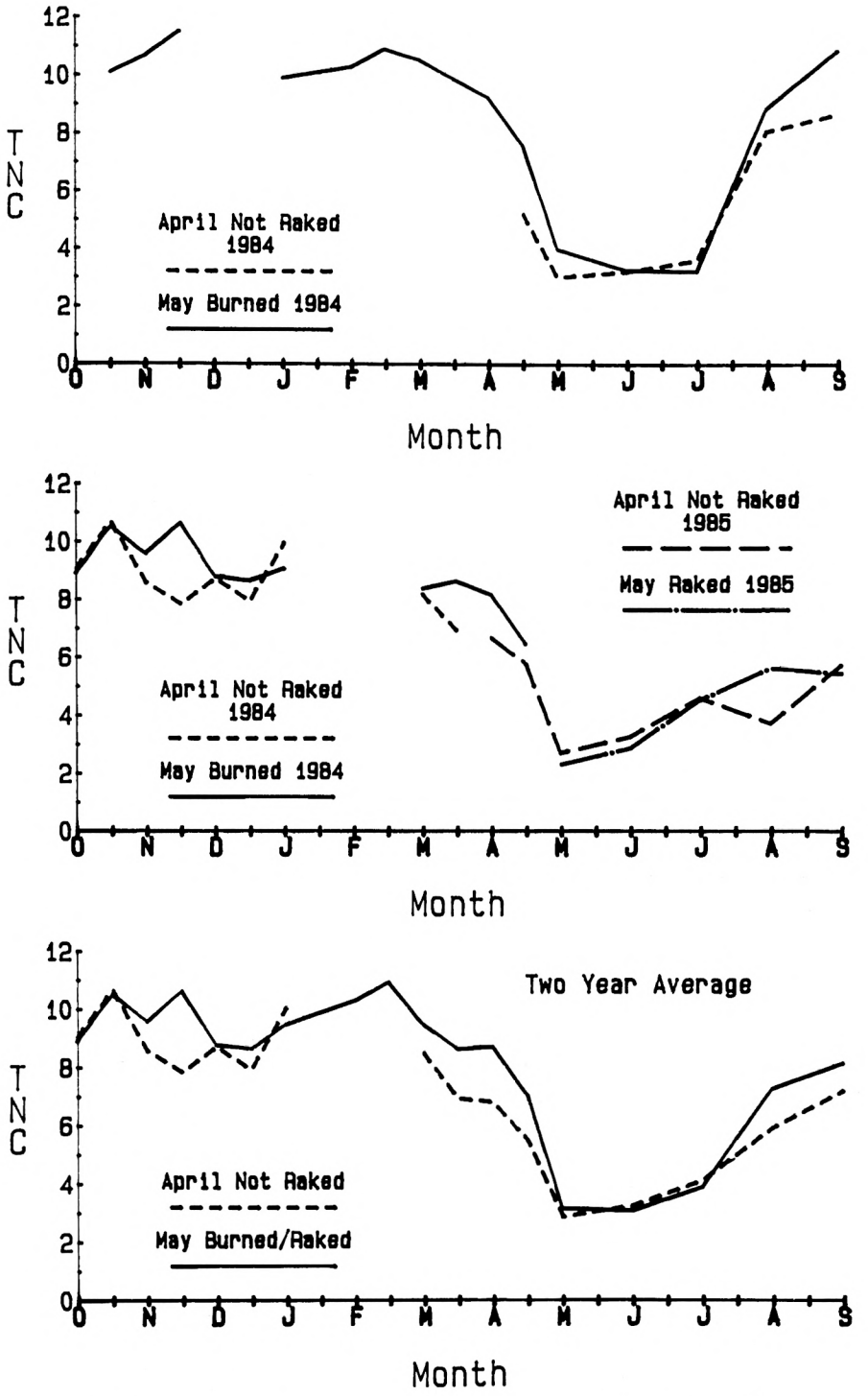

Figure 4. Means of total nonstructural carbohydrates (mg g^{-1}) in big bluestem rhizomes for October 1983 through September 1985 following 1 April mowing and leaving herbage and 1 May burned or mowed and raked treatments. Means from 3 replications.

Literature Cited

Coyne, P. I. and J. A. Bradford. 1987. Nitrogen and carbohydrate partitioning in Caucasian and WW-Spar Old World Bluestems. J. Range Manage. (in press).

Hulbert, Lloyd C.. 1985. History and use of Konza Prairie Research Natural Area. The Prairie Scout 5:63-93.

Khaleeluddin, Khaja and Linda Bradford. 1986. Dual enzyme method for determination of total nonstructural carbohydrates. J. Assoc. Off. Anal. Chem. 69:162-166.

Knapp, Alan K.. 1985. Effect of fire and drought on the ecophysiology of *Andropogon gerardii* and *Panicum virgatum* in a tallgrass prairie. Ecology 66:1309-1320.

Launchbaugh, John L.. 1972. Effects of fire on shortgrass and mixed prairie species. Proc. Tall Timbers Fire Ecology Conf. 12:129-151.

Launchbaugh, J. L. and C. E. Owensby. 1978. Kansas Rangelands: their management based on a half century of research. Kansas Agr. Expt. Sta. Bul. 622. 56p.

Owensby, Clenton E., Ed F. Smith, and Jerry R. Rains. 1977. Carbohydrate and nitrogen reserve cycles for continuous, season-long and intensive-early stocked Flint Hills bluestem range. J. Range Manage. 30:258-260.

SAS Institute Inc.. SAS User's Guide: Basics, 1982 Edition. Cary, NC: SAS Institute Inc., 1982. 923p.

Smith, Ed F. and Clenton E. Owensby. 1978. Intensive-early stocking and season-long stocking of Kansas Flint Hills range. J. Range Manage. 31:14-17.

II. Near-Infrared Reflectance Spectroscopy Analysis of Total Nonstructural Carbohydrates in Big Bluestem Rhizomes

Introduction

Near-infrared reflectance spectroscopy (NIRS) has been used in the grain milling industry for quality analyses of wheat products and by-products for several years. More recently, forage quality analyses using NIRS have been developed (Marten *et al.*, 1983).

NIRS has great potential for non-destructive analysis for a variety of compounds. Analyses for organic constituents which involve substantial wet chemistry with limited throughput lend themselves to NIRS, a more rapid, efficient system. Among routine research analyses in the range plant physiology area, determination of total nonstructural carbohydrates (TNC) requires substantial time and equipment. The standard assay was developed by Smith (1969) and involves enzyme digestion and titration. Initial work by Brink and Marten (1986) indicated that NIRS could be used to determine TNC concentrations in alfalfa (*Medicago sativa*).

Our objective in this study was to determine if NIRS technology could be extended to the measurement of TNC in big bluestem (*Andropogon gerardii*) rhizomes.

Materials and Methods

Sample collection. The sample collection area was located on the Konza Prairie Research Natural Area near Manhattan, Kansas (Hulbert, 1985) with typical tallgrass vegetation. The plots were located on a loamy upland range site with a Benfield-Florence complex soil (Benfield series: fine, mixed, mesic, udic argiustolls; Florence series: clayey-skeletal, montmorillonitic, mesic, udic argiustolls). The plots were not grazed, but

were burned on 1 May, 1984 and mowed to a 5-cm stubble height and raked on 1 May, 1985.

Rhizomes from six big bluestem plants were collected from 12, 3x3 m plots, every two weeks from 1 October, 1983 to 30 April, 1984 and 1 October, 1984 to 30 April, 1985 and monthly from 1 May to 1 September of both years. The rhizomes were placed in paper bags, dried for 72 hr at 55 C, and stored in plastic trash cans. After completion of the study, all rhizomes were cleaned with coldwater washing, redried for 48 hr, roots removed, ground with a Udy Cyclone Mill (1 mm mesh), and stored in dark plastic vials.

Chemical analysis. Forty rhizome samples covering the range of available TNC (mg g^{-1}) in rhizomes of big bluestem were analyzed for TNC using the dual-enzyme extraction and copper-iodometric titration method (Khaleeluddin and Bradford, 1986). These data were used as the standard for calibrating the NIRS method.

Near-Infrared Reflectance Spectroscopy (NIRS). Each of the 40 samples were analyzed by a scanning Technicon InfraAnlyzer 500 (I/A 500) near-infrared reflectance monochromator at 2 nm increments from 1100 to 2498 nm for a total of 700 absorbance readings/sample (hereafter, raw absorbance data). Output from the I/A 500 was digitized and stored using a Hewlett-Packard HP-1000 minicomputer. After the absorbances for all 40 samples were stored, a step-wise multiple regression using the values obtained by chemical analysis as the independent variable was used to select wavelength combinations.

Wavelength selection using raw absorbance data. Three and 4 wavelength combinations were selected from all possible wavelength combinations by step-wise regression. Excessively long processing time limited the number of wavelengths that could be added to the regression equation. Therefore, a 5-wavelength combination was selected by forcing the 4 wavelengths previously selected into the equation and then adding the fifth by step-wise regression (Table 2).

Wavelength selection for fixed-filter systems. Routine analytical work is usually done using a less-expensive, fixed-filter instrument, *i. e.* the Technicon InfraAnlyzer 400 (I/A 400). Presently, there are 28 wavelength filters commercially available in sets of 19 for the I/A 400.

A filter-transform program was used to adjust the raw absorbance data taken from the I/A 500 to appear as if they were collected from a I/A 400 equipped with the 28 wavelengths. This program facilitates transferring calibrations from the I/A 500 to the I/A 400.

Wavelength combinations were selected using the same step-wise regression program on the adjusted data as used on the raw absorbance data (Table 3). Fewer absorbance values per sample allowed for more wavlengths to be added to the regression equation. However, the I/A 400 is limited to 19 wavelength filters during analysis. Therefore, the standard research filter set, Filter 1, was used to select wavelength combinations for the I/A 400 (Table 4). The same filter-transform program was used to adjust the raw absorbance data to represent absorbances from the I/A 400 with the Filter 1 set. Again, fewer absorbances allowed for more wavelengths to be used in the regression equations.

The differences between 6 and 7 wavelength combinations from the Filter 1 set were minimal, indicating these combinations could be correlated too highly to the 40 samples and not be robust enough to predict unknowns. Therefore, the 5 wavelength combination was used to calibrate the I/A 400. **Calibration of the I/A 400.** Only slight correlation differences occurred between the wavelength combinations chosen from the 28 possible wavelengths and the Filter 1 set. Therefore, the I/A 400 was calibrated with the wavelengths chosen from the Filter 1 set. Wavelengths 1680, 1778, 1818, 1940, and 2348 were used to calibrate the I/A 400 to the 40 rhizome samples. The 40 samples were analyzed again by the I/A 400. Digitized absorbances from the I/A 400 were transferred and stored on tape by a HP-9815 calculator. A multiple regression program on the HP-9815 calculated coefficients for the regression equations.

Results and Discussion

TNC determined by NIRS was highly correlated with lab TNC determined by wet chemistry (Figure 5). The regression equation was

$$\hat{Y} = 16.989 - 170.488a - 4952.493b + 7556.115c - 135.890d - 2304.622e$$

where, respectively, a,b,c,d, and e were the absorbance values at wavelengths 1680, 1778, 1818, 1940, and 2348. The regression equation produced a 0.987 multiple correlation coefficient with a standard error of prediction of 0.473. Granted, the standard error of prediction cannot be better than that expected for the wet chemistry method (Khaleeluddin and Bradford, 1986), but the increased efficiency in time required for analysis by NIRS was an order of magnitude greater than wet chemistry analysis. For example, there were no chemicals to mix, no glassware to wash, no

sample weighing *etc.*. NIRS enabled analysis of 200 or more samples/day versus 20 samples/day by wet chemistry in our laboratory.

The yearly fluctuations of TNC in big bluestem rhizomes analyzed by NIRS were representative of big bluestem rhizomes (Owensby *et al.*, 1977).

Conclusion

Our study showed it was possible to analyze for TNC concentrations in big bluestem rhizomes using the NIRS system with precision equal to that of wet chemistry. The ease and speed of analyzing large numbers of samples by NIRS plus the non-destructive analysis makes it a viable alternative to wet chemistry.

Table 2. Wavelength combinations selected by a step-wise regression for the best possible correlation between actual[1] and predicted total nonstructural carbohydrate (mg g^{-1}) in big bluestem rhizomes using the absorbance data collected from a Technicon InfraAnlyzer 500 near-infrared scanning monochromator.

	Wavelength Combinations (nm)		
	2318	1720	1720
	2374	1770	1770
	2444	1840	1840
		1920	1920
			1950
Multiple Correlation Coefficient (MCC)	0.9703	0.9819	0.9840
Standard Error of Estimate (SEE)[2]	0.7469	0.5910	0.5618
Estimated Prediction Error (EPE)[3]	0.7568	0.6246	0.5910
Estimated Precision (EP)[4]	0.2193	0.2921	0.2627

1. Actual total nonstructural carbohydrates (mg g^{-1}) were determined by the dual-enzyme method developed by Khaleeluddin and Bradford (1986).

2. SEE = Error based on difference between NIRS estimate and wet chemistry estimate of known TNC samples.

3. EPE = Error based on NIRS estimate of unknown TNC samples.

4. EP = Estimated precision between NIRS estimate and actual TNC content.

Table 3. Wavelength combinations selected by a step-wise regression for the best possible correlation between actual[1] and predicted total nonstructural carbohydrate (mg g^{-1}) in big bluestem rhizomes using the adjusted raw absorbance data for the 28 wavelengths available for the Technicon InfraAnlyzer 400 near-infrared fixed-filter spectrophotometer.

	Wavelength Combinations (nm)		
	1650	1680	1734
	1778	1778	1778
	1840	1840	1818
	2348	1905	2100
		2348	2310
			2348
MCC	0.9759	0.9843	0.9868
SEE	0.6845	0.5571	0.5176
EPE	0.7529	0.5985	0.5463
EP	0.2750	0.2157	0.2208

1. Actual total nonstructural carbohydrates (mg g^{-1}) were determined by the dual-enzyme method developed by Khaleeluddin and Bradford (1986).

Table 4. Wavelength combinations selected by a step-wise regression for the best possible correlation between actual[1] and predicted total nonstructural carbohydrate (mg g^{-1}) in big bluestem rhizomes using the adjusted raw absorbance data for the 19 wavelength, Filter 1, set available for the Technicon InfraAnlyzer 400 near-infrared fixed-filter spectrophotometer.

	Wavelength Combinations (nm)			
	1722	1680	1734	1722
	1778	1778	1778	1778
	1818	1818	1818	1818
	1940	1940	2100	1982
		2348	2310	2100
			2348	2310
				2348
MCC	0.9718	0.9835	0.9868	0.9874
SEE	0.7462	0.5554	0.5176	0.5123
EPE	0.7733	0.5792	0.5463	0.5466
EP	0.3879	0.2935	0.2208	0.2282

1. Actual total nonstructural carbohydrates (mg g^{-1}) were determined by the dual-enzyme method developed by Khaleeluddin and Bradford (1986).

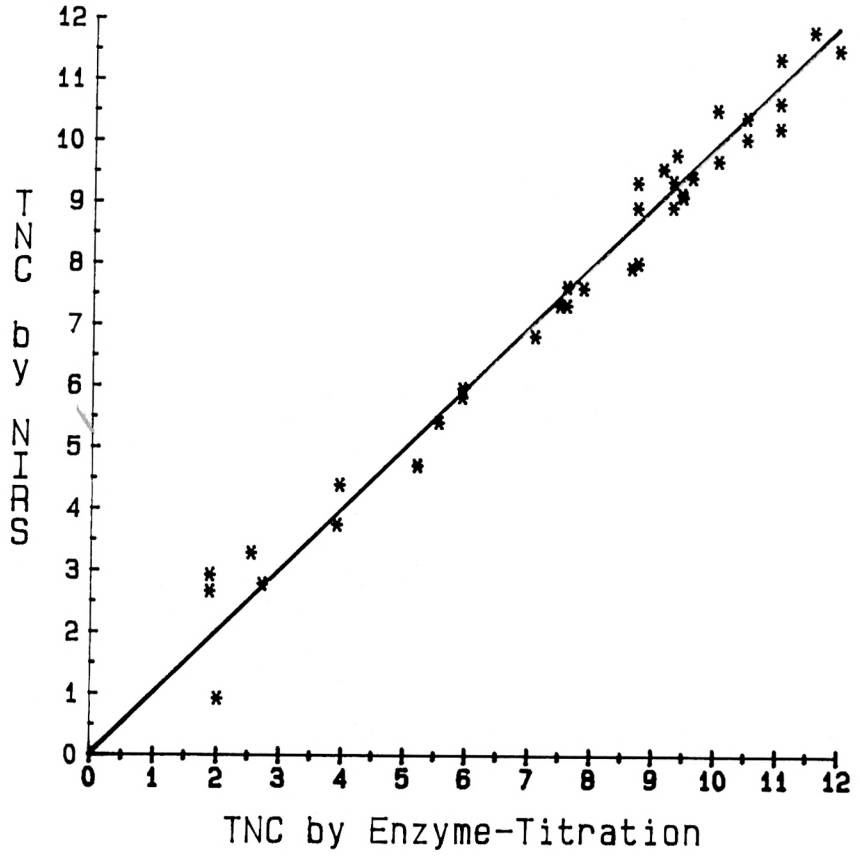

Figure 5. Big bluestem rhizome total nonstructural carbohydrates (mg g^{-1}) as analyzed by NIRS and the enzyme-titration method. Forty samples were used to generate the regression equation $\hat{Y}$ = 16.989 - 170.488a - 4952.497b + 7556.121c - 135.890d - 2304.624e where, respectively, a, b, c, d, and e were the absorbance values of the sample at wavelengths 1680, 1778, 1818, 1940, and 2348. The multiple correlation coefficient was 0.987 with a standard error of prediction of 0.473.

Literature Cited

Brink, G. E. and G. C. Marten. 1986. Analysis of alfalfa root carbohydrate concentration by near infrared reflectance spectroscopy. Crop Sci. 26:159-161.

Hulbert, Lloyd C.. 1985. History and use of Konza Prairie Research Natural Area. The Prairie Scout 5:63-93.

Khaleeluddin, Khaja and Linda Bradford. 1986. Dual enzyme method for determination of total nonstructural carbohydrates. J. Assoc. Off. Anal. Chem. 69:162-166.

Marten, G. C., J. L. Halgerson, and J. H. Cherney. 1983. Quality prediction of small grain forages by near infrared reflectance spectroscopy. Crop Sci. 23:94-96.

Owensby, Clenton E., Ed F. Smith, and Jerry R. Rains. 1977. Carbohydrate and nitrogen reserve cycles for continuous, season-long and intensive-early stocked flint hills bluestem range. J. Range Manage. 30:258-260.

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

APPENDIX

Literature Review

The nutritional value of native bluestem rangeland is of the highest quality during the early-growing season, then steadily declines through the remainder of the season (McIlvain, 1955; Owensby and Anderson, 1969). Woolfolk *et al.* (1975) showed decreasing crude protein, neutral detergent solubles, and cellulose contents along with increasing fiber and lignin contents from June to October in the diets of steers grazing Tallgrass Prairie. Lower steer gains coincide with the reduction in forage quality (Anderson *et al.*, 1970). The average daily gain for steers grazing rangeland near Scotts Bluff, Nebraska from May to October gradually decreased from 1.04 kg/hd/day early in the season to 0.15 kg/hd/day by the end of the season (Anon., 1975). Launchbaugh (1957) showed the average rate of gain on steers grazing shortgrasses near Hays, Kansas from May to October began to decrease in mid-July and continued to decrease through the remainder of the season. Intensively grazing rangeland when forage quality is high would provide greater conversion efficiency of grass to red meat than traditional season-long stocking.

Intensive-early stocking

Smith and Owensby (1978) developed an intensive-early stocking grazing system to maximize the use of native Flint Hills rangeland when the forage quality is high without degrading the plant community or animal performance.

Intensive-early stocking is stocking at twice the normal season-long rate during the first-half of the growing season (1 May - 15 July), then removing the cattle on 15 July to allow the forage to regrow before frost (Smith and Owensby, 1978). They showed that gain per acre and the daily

individual steer gains were higher under intensive-early stocking versus season-long stocking (1 May - 1 October). Intensive-early stocked pastures were more evenly grazed than the season-long stocked pastures and percentages of warm-season tallgrasses increased in the intensive-early stocked pastures as compared to the season-long stocked pastures. In addition, by the end of the growing season the plant regrowth on the intensive-early stocked pastures was substantial enough to equal the production on the season-long stocked pastures.

Plant regrowth on intensive-early stocked pastures after 15 July is crucial to maintaining plant vigor. During this time the defoliated plants regrow and replenish carbohydrate reserves in the rhizomes. Cook (1966) stated that any intensively-used plants should have a rest period to allow time for them to restore their carbohydrate reserve levels. He stated that carbohydrate reserves were responsible for initiating new growth in the spring and that herbage production was inversely related to the amount of stored carbohydrates.

Total Nonstructural Carbohydrates

Smith (1969) developed a method for extracting and determining the total nonstructural carbohydrates in plant tissue. Using this method, McKendrick *et al.* (1975) was able to determine the carbohydrate cycle in big bluestem (*Andropogon gerardii* Vitman) rhizomes.

Big bluestem rhizome carbohydrate reserve cycle involves the gradual depletion of the reserves early in the growing season to a low-point in June, during that period the rhizome buds are swelling and elongating

into emerging leaves (McKendrick *et al.*, 1975; Rains *et al.*, 1975). Then, in June, after the plants have sufficient photosynthetic material to produce the carbohydrates required for maintaining growth, they translocate reserve carbohydrates back to the rhizomes (McKendrick *et al.*, 1975). In August, carbohydrate reserves are used to produce new root growth on the rhizomes. Carbohydrate reserves are replenished again in September at the onset of dormancy when big bluestem begins translocating carbohydrates from the above-ground foliage to the rhizomes (McKendrick *et al.*, 1975; Rains *et al.*, 1975). The maximum amount of carbohydrate reserves in the big bluestem rhizomes is reached in December and remains relatively stable throughout the dormant period (McKendrick *et al.*, 1975; Owensby *et al.*, 1977).

Any defoliation during the growing season of a plant will reduce the normal reserve carbohydrate storage level and subsequently reduce plant growth (Cook, 1966). One year of intensive defoliation of big bluestem throughout the entire growing season drastically reduced the total nonstructural carbohydrate content in the rhizomes and reduced herbage production the following year (Owensby *et al.*, 1974)

Time of herbage removal also affects amount of reserve carbohydrates. Clipping near the end of the growing season reduces carbohydrate reserves more than clipping in the early growing season (Cook, 1966). One year of clipping big bluestem to a 5-cm stubble on 1 September lowered total nonstructural carbohydrates in the rhizomes and stem bases on 1 October than clipping on either 1 June, 1 July, or 1 August (Owensby *et al.*, 1970).

Intensive-early stocking lowered the total nonstructural carbohydrates in big bluestem rhizomes during the growing season more than season-long stocking, but the removal of cattle on 15 July from the intensive-early stocked pastures gave adequate time for big bluestem to store similar amounts of carbohydrates in rhizomes as were stored under season-long stocking (Owensby *et al.*, 1977).

Since the majority of the total nonstructural carbohydrates are translocated to big bluestem rhizomes before 1 October, winter grazing intensive-early stocked pastures after 1 October should not significantly reduce the amount of total nonstructural carbohydrates stored in the rhizomes of big bluestem.

Herbage production following fall or winter herbage removal

Owensby and Anderson (1969) clipped separate plots of native Flint Hills rangeland on the first of each month from 1 June through 1 November for 6 years. They showed that clipping on 1 September, 1 October, or 1 November did not reduce herbage yields the following season.

In central Kansas, removing old growth by mowing and raking on 1 November, 1 January, 1 March, 1 April, or 1 May for 3 years reduced herbage yields of buffalograss, blue grama, and western wheatgrass by as much as 50% when compared to not mowing (Launchbaugh, 1972). In addition, mowing and raking or burning Mixed and Shortgrass Prairie for 2 years on 1 October reduced herbage yields by 40% of that of the unmowed, with burning being reduced more than the mowed and raked (Launchbaugh, 1972).

Fall burning is more detrimental to subsequent herbage yields than fall mowing and raking. Launchbaugh (1972) reported that mowing and

raking, and mowing and not raking on 1 November for 8 years did not reduce herbage yields as much as fall mowing and burning the mowed herbage on 1 November or 1 April. The complete removal of surface mulch by burning causes destruction of the surface soil aggregate size by raindrop impact. Raindrop impact increases the microporosity of the surface soil which decreases infiltration rates and ultimately reduces soil moisture available for herbage growth. Mowing and raking still leaves enough surface litter to protect the soil surface from raindrop impact.

Launchbaugh (1972) showed that fall-mowed plots with the mowed material left had the greatest amount of soil moisture penetration 24 hr after 8.9 cm of precipitation as compared to fall mowing and raking, or fall mowing and burning the mowed herbage in the fall or spring. He also reported that the available soil moisture was lower in the burned plots than the raked plots. Hopkins (1954) stated that mulched versus unmulched plots had higher available soil moisture from lower amounts of evaporation and higher infiltration rates.

Higher levels of available moisture soil moisture in mulched areas does not always produce higher herbage production. Herbage yields maybe higher in unmulched areas versus mulched areas. Hulbert (1969) showed that herbage yields on native-ungrazed Flint Hills prairie with the mulch removed by burning or by mowing on 9 April out produced those areas with mulch. He concluded that the soil moisture was higher in the mulched areas because of less evaporation from the soil surface and less transpiration due to lower herbage production.

Although, Launchbaugh's studies showed lower herbage yields from winter forage removal on Mixed and Shortgrass prairie, no detrimental effects occurred from fall herbage removal in the tallgrass region.

Literature Cited

Anderson, K. L., C. E. Owensby, and E. F. Smith. 1970. Burning bluestem range. J. Range Manage. 23:81-92.

Anon. 1965. Management of yearling steers on summer pasture. Nebraska Section, Amer. Society of Range Management Newsletter 13:3-5.

Cook, C. Wayne. 1966. Carbohydrate reserves in plants. Utah Agr. Expt. Sta. Resources Series #31. 47p.

Hopkins, H. Harold. 1954. Effects of mulch upon certain factors of the grassland environment. J. Range Manage. 7:255-258.

Hulbert, Lloyd C.. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. Ecology 50:874-877.

Launchbaugh, John L.. 1957. The effect of stocking rate on cattle gains and on native shortgrasses vegetation in west-central Kansas. Ft. Hays Branch, Kansas Agr. Expt. Sta. Bul. 394. 29p..

Launchbaugh, John L.. 1972. Effects of fire on shortgrass and mixed prairie species. Proc. Tall Timbers Fire Ecology Conf. 12:129-151.

McKendrick, Jay D., Clenton E. Owensby, and Robert M. Hyde. 1975. Big bluestem and indiangrass vegetative reproduction and annual reserve carbohydrate and nitrogen cycles. Agro-Ecosystems 2:75-93.

McIlvain, E. H.. 1955. Range improvement studies at the U.S. Southern Great Plains Field Station. Progress Rep. 5506. 37p..

Owensby, C. E. and Kling L. Anderson. 1969. Effect of clipping date on loamy upland bluestem range. J. Range Manage. 22:351-354.

Owensby, Clenton E., Gary M. Paulsen, and J. D. MeKendrick. 1970. Effect of burning and clipping on big bluestem reserve carbohydrates. J. Range Manage. 23:358-362.

Owensby, Clenton E., Jerry R. Rains, and Jay D. McKendrick. 1974. Effects of one year of intensive clipping on big bluestem. J. Range Manage. 27:341-343.

Owensby, Clenton E., Ed F. Smith, and Jerry R. Rains. 1977. Carbohydrate and nitrogen reserve cycles for continuous, season-long and intensive-early stocked Flint Hills bluestem range. J. Range Manage. 30:258-260.

Rains, Jerry R., Clenton E. Owensby, and Kenneth E. Kemp. 1975. Effects of nitrogen fertilization, burning, and grazing on reserve constituents of big bluestem. J. Range Manage. 28:358-362.

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

Smith, Ed F. and Clenton E. Owensby. 1978. Intensive-early stocking and season-long stocking of Kansas Flint Hills range. J. Range Manage. 31:14-17.

Woolfolk, John S., Ed F. Smith, Robert Schalles, Benny E. Brent, Leniel Harbers, and Clenton E. Owensby. 1975. Effects of nitrogen fertilization and late-spring burning of bluestem range on diet performance of steers. J. Range Manage. 28:190-193.

RELATED TABLES

Table 5. Mean[1] herbage production (kg/ha) following winter mowing[2] treatments, on Flint Hills bluestem rangeland for the 1984 and 1985 growing seasons. Treatments were mowing and removing herbage, mowing and leaving herbage, or not winter mowing on different plots on the first of each month from Octcober 1983 to May 1984[3] and October 1984 to May 1985. No statistical differences were shown among mowing treatments (P=0.13).

Date Mowed	Herbage Removed	1984 Herbage Production (kg/ha)				
		May 15	June 1	June 15	July 1	July 15
October 1	Yes	144	1319	1355	2440	2530
	No	143	780	1728	3008	3018
November 1	Yes	214	991	2031	2746	3204
	No	153	949	2111	3145	2756
January 1	Yes	312	1653	1937	2376	3192
	No	184	914	1673	2936	3119
March 1	Yes	238	1026	1887	2812	3308
	No	202	916	2087	2947	3197
April 1	Yes	222	899	1834	3192	3408
	No	172	1178	1806	3300	3596
May 1	Yes	55	638	1539	2511	3270

Date Mowed	Herbage Removed	1985 Herbage Production (kg/ha)				
		May 15	June 1	June 15	July 1	July 15
October 1	Yes	787	727	1466	1735	2228
	No	685	1443	1684	1751	2664
November 1	Yes	840	1273	1740	1586	2665
	No	553	901	1669	1649	2492
January 1	Yes	1050	1495	1981	1760	2268
	No	693	1084	1539	1679	2471
March 1	Yes	747	1551	1920	2084	2345
	No	573	981	1337	1882	2118
April 1	Yes	617	1120	1532	1732	2552
	No	576	1083	1608	1843	2232
May 1	Yes	246	791	1316	1641	2206

1. Means are from 3 replications.
2. 3x3 m plots were mowed to a 5-cm stubble height with a sicklebar mower.
3. The 1 May mowing treatment was not a winter mowing date, it was the comparison standard.

Table 6. Total soil moisture (%) means[1], following winter mowing[2] treatments, on Flint Hills bluestem rangeland for the 1984 and 1985 growing seasons. Treatments were mowing and removing herbage, mowing and leaving herbage, or not winter mowing on different plots from October 1983 to May 1984[3] and October 1984 to May 1985. No statistical differences were shown among mowing treatments (P=0.16).

Date Mowed	Herbage Removed	1984 Total Soil Moisture (%) May 1	June 1	July 1
October 1	Yes	33.7	17.1	24.0
	No	33.3	20.9	22.7
November 1	Yes	29.8	16.6	22.5
	No	35.3	19.7	23.4
January 1	Yes	35.3	17.4	24.7
	No	33.4	19.4	23.5
March 1	Yes	33.9	17.8	24.0
	No	35.7	19.2	24.6
April 1	Yes	31.8	16.5	22.6
	No	30.6	19.4	22.7
May 1	Yes	33.0	19.2	23.4

Date Mowed	Herbage Removed	1985 Total Soil Moisture (%) May 1	May 15	June 15	July 15
October 1	Yes	34.3	29.2	35.6	10.4
	No	36.1	30.2	34.2	11.1
November 1	Yes	32.0	27.1	33.2	10.2
	No	40.5	30.4	35.5	11.7
January 1	Yes	36.8	29.0	41.3	10.3
	No	36.7	30.0	37.2	9.6
March 1	Yes	35.1	28.9	34.4	10.8
	No	37.2	30.3	38.9	11.1
April 1	Yes	32.6	26.9	32.3	9.3
	No	36.9	28.4	33.5	10.7
May 1	Yes	36.8	28.5	35.2	10.5

1. Means are from 3 replications.
2. 3x3 m plots were mowed to a 5-cm stubble height with a sicklebar mower.
3. The 1 May mowing treatment was not a winter mowing date, it was the comparison standard.

I. Effects of Dormant Season Herbage Removal on Flint Hills Rangeland

II. Near-Infrared Reflectance Spectroscopy Analysis of Total Nonstructural Carbohydrates in Big Bluestem Rhizomes

by

LISA MARIE AUEN

B.S., Kansas State University, 1983

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1987

Effects of Dormant Season Herbage Removal on

Flint Hills Rangeland

Abstract

The potential for grazing regrowth on intensive-early stocked Flint Hills pastures was studied. Treatments, in a randomized complete block design, were mowing and removing herbage, mowing and leaving herbage, applied at the beginning of each month from October 1983 to April 1984 and October 1984 to April 1985 and 1 May burning/mowing comparison standard. Big bluestem (*Andropogon gerardii* Vitman) rhizomes were collected from the plots at biweekly intervals from October through April and monthly thereafter for total nonstructural carbohydrate (TNC) (mg g^{-1}) analysis using near-infrared reflectance spectroscopy. The plots were clipped for herbage production biweekly from 1 May to 15 July, 1984 and 1985. Soil samples were taken from 0-15 cm in each plot on 1 May, 1 June, 1 July, 1984 and 1 May, 15 May, 15 June, 15 July, 1985 to gravimetrically determine total soil moisture.

Winter mowing dates had no effect on herbage yields the following season. Herbage yields were higher and TNC was lower in 1984 than 1985. Greater precipitation during May and June of 1984 compared to 1985 was likely responsible for the higher yields in 1984. Conversely, less precipitation in July, August, and September of 1983 than normal probably resulted in lower carbohydrate storage at the end of the growing season which carried over through the 1984 growing season.

TNC was lower in the October-raked, April-raked, and April-nonraked, treatments compared to the May-raked treatment only between 15 March and 1 July of both years. Lower TNC did not result in lower herbage production.

Winter mowing dates had no effect on total soil moisture. Total soil moisture was higher in plots with the mowed herbage returned than in plots with herbage removed.

Cattle producers can apparently restock intensive-early stocked pastures after 1 October. The availability of intensive-early stocked pastures as a winter forage provides more marketing flexibility for cattle producers.

Near-Infrared Reflectance Spectroscopy Analysis of Total Nonstructural Carbohydrates in Big Bluestem Rhizomes

Abstract

Near-infrared reflectance spectroscopy (NIRS) was used to determine the total nonstructural carbohydrate (TNC) (mg g^{-1}) content of big bluestem (*Andropogon gerardii*) rhizomes.

Forty rhizome samples covering the range of available TNC in rhizomes of big bluestem were analyzed for TNC content using the Khaleeluddin-Bradford dual-enzyme extraction method followed by the Shaffer-Somogyi copper-iodometric titration method. These 40 samples were again analyzed by a Technicon InfraAnlyzer 500 (I/A 500) NIRS

scanning monochromator. A step-wise multiple regression program identified wavelength combinations which produced the highest correlation between enzyme extraction-titration analysis and NIRS wavelength-absorbance analysis. The best wavelength combination chosen from the I/A 500 absorbance data was used to calibrate a Technicon InfraAnlyzer 400 (I/A 400), a fixed-filter, 19-wavelength instrument.

A multiple regression program calculated the regression coefficients from the absorbance values collected from the same 40 samples on the I/A 400 at wavelengths of 1680, 1778, 1818, 1940, and 2348. The final regression equation produced a multiple correlation coefficient of 0.987 with a standard error of prediction of 0.473.

NIRS analysis of TNC in big bluestem rhizomes produced yearly fluctuations representative of big bluestem rhizomes.

This study showed that NIRS is a rapid, efficient alternative to the enzyme extraction-titration method when large numbers of samples are to be analyzed.