FORAGE SAMPLING TECHNIQUES AND EVALUATION OF FACTORS AFFECTING STEER GAINS ON MIDLAND BERMUDAGRASS

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PREFACE

It is hoped that the following pages, dealing with forage sampling techniques and forage quality determinations, will benefit future forage quality work by providing a more detailed explanation of collection of forage samples via the esophageal fistula and determination of forage intake by use of chromic oxide as an external indicator. Also, it is hoped that this thesis will help forage researchers to select techniques that will best serve their purpose in continuing efforts to define "forage quality". Nevertheless, the great challenges that face the agronomists, biochemists, and animal scientists, in future efforts to produce more animal product per unit area in an evermore demanding world are vividly brought into focus.

This study was encouraged and supervised by my major professor, Dr. Lavoy I. Croy. I wish to extend my sincere thanks to Dr. Croy for his valuable advice and assistance in laboratory procedures and in preparation of this thesis. Grateful appreciation is also extended to Dr. Wilfred E. McMurphy for his advice and assistance in collection of samples. The knowledge and leadership Dr. McMurphy and Dr. Croy have shared with me during this research project have been an inspiration both academically and personally. Special appreciation is extended to the other members of my advisory committee, Dr. Robert M. Reed, Department of Agronomy, Dr. Jack E. McCroskey, Department of Animal Science and Dr. Robert D. Morrison, Department of Mathematics and Statistics for their assistance in interpretation of statistical data

and offering constructive suggestions in preparation of this thesis.

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Special thanks are expressed to my parents, Elmer and Minnie Smith for their encouragement throughout my college training.

Finally, but most appropriately, deep gratitude is expressed to my wife, Sue, for typing the manuscript and for her understanding, encouragement, and sacrifices during this study.

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CHAPTER I

INTRODUCTION

The research reported in this dissertation is divided into three chapters, each a manuscript prepared for publication in The Agronomy Journal. Except for minor modifications, the manuscripts appear just as they will be submitted for publication.

Literature on forage quality contains many conflicting results, which may have resulted from inadequate sampling techniques. The use of the esophageal fistula for collection of samples representative of an animal's diet has received much attention in recent forage research. External indicators have also received much attention in attempts to estimate daily intake by animals. Techniques and procedures involved in sample collection for nutritive value and quantity of voluntary intake determinations of steers grazing Midland bermudagrass are presented in Chapter II.

There has been controversy over the need for esophageal fistulated animals to make sample collections in monoculture pastures. Chapter III presents a comparison of the chemical constituents and *in vitro* digestibility of esophageal fistula and hand-clipped samples from the same pastures.

Numerous attempts have been made to define properties of forage that can be measured and used to predict animal performance. Various chemical constituents of the forage, i.e., nitrogen, cell wall

constituents, neutral detergent fiber, acid detergent fiber, lignin, and cellulose as well as digestibility and intake of forage have been related to animal gains. A discussion of the validity of these factors in predicting animal gains on Midland bermudagrass (Cynodon dactylon (L.) Pers.) pastures with varying fertility levels is presented in Chapter IV.

CHAPTER II

SAMPLE COLLECTION TECHNIQUES FOR DETERMINATION OF NUTRITIVE VALUE AND VOLUNTARY INTAKE OF MIDLAND BERMUDAGRASS (CYNODON DACTYLON (L.) PERS.)[1/]

Abstract

Bermudagrass (Cynodon Dactylon (L.) Pers.) is increasing in popularity as a high yielding forage for grazing animals. Many conflicting results are found in the literature pertaining to forage quality which may have resulted from different procedures of sampling forage. Techniques have been described for collection of samples for determination of the nutritive value and quantity of voluntary intake of steers grazing Midland bermudagrass.

Additional Key Words for Indexing: esophageal fistula, chromic oxide.

Introduction and Literature Review

Bermudagrass is increasing in popularity as a high yielding forage for grazing animals and producers are vitally interested in management practices which improve its forage quality (Hawkins and

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[1/] Article co-authored with Lavoy I. Croy and Wilfred E. McMurphy to be submitted for publication in Agronomy Journal.

Rollins, 1960; Suman et al., 1962; Spooner and Ray, 1970). Forage quality is difficult to define, but the best measure of quality is probably animal performance, average daily steer gains or total production. An increase in forage quality will be reflected in better animal performance. Forage chemical constituents that have been correlated with animal performance are nitrogen content, carbohydrates, lignin, cellulose, and silica as well as other factors such as palatability, digestibility, water content, and total forage available (Sheehan, 1969; Gangstad, 1964, McIlvaine and Shoop, 1966; Allinson and Osbourn, 1970).

Sullivan (1969) pointed out that much of the literature on forage quality contains conflicting results, which may have resulted from the use of different preocedures in both the field and the laboratory. Our knowledge of the chemical composition of plants has been limited and confused by inadequate methods of analysis. Proper sampling and treatment of the sample before the analysis and extrapolation of data after the analysis is of great consequence and a standard procedure should be adopted. Collection of a sample that will exactly duplicate forage selected by grazing animals is not possible nor is it possible to determine the exact quantity of forage consumed by grazing animals. Although, there are techniques that may be employed which provide superior estimates of quality and quantity of forage consumed, there is still much room for improvement in the precision and reduction of labor in some steps. The purpose of this treatise is to present techniques and procedures involved in the collection of samples for determination of the nutritive value and quantity of voluntary intake of steers grazing Midland bermudagrass.

Sampling for the determination of nutritive value of forage intake by animals was hampered greatly by selective grazing (Lesperance, Bohman and Marble, 1960). When animals were allowed to graze heterogenous species populations, this problem was greatly magnified (Hardison et al., 1954), but even when grazing a monoculture pasture, consideration must be given to selective grazing of plant parts. Steers equipped with esophageal fistula have been used to collect samples representative of what other animals in the pasture are selecting. Guthrie, Rollins, and Hawkins (1968), with Coastal bermudagrass and Campbell (1964), using Midland bermudagrass found that samples collected via esophageal fistula were significantly higher in protein and ash and lower in acid detergent fiber and lignin than hand-clipped samples from the same pastures.

A good estimate of the quantity of forage consumed would help explain animal performance in relation to laboratory quality determinations. Unfortunately, conventional methods of placing animals in digestion stalls for measuring intake of harvested forages are not applicable to pasture conditions. Various methods have been used to estimate the quantity of intake of grazing animals but most all methods work on the principle of estimation of fecal output and division by estimation of indigestibility of the forage. Fecal output has been estimated by total collection, and by the use of external indicators. Digestibility of intake has been estimated by in vivo nylon bag technique (Van Keuren and Heinemann, 1962), in vitro digestion technique (Tilley and Terry, 1963) and with internal indicators (Kuhlman, 1963). The use of indicators has been of great value in the determination of fecal output. Indicators eliminate the

need for total collection of fecal material and allow animals to graze under more natural conditions at lowered expense and labor. An external indicator must be an inert material which is not destroyed nor absorbed from the digestive tract of the animal, has no undesirable physiological effect on the digestive tract, passes through the digestive system at a uniform rate, and can be determined in feed or fecal samples (Sandiford, 1968). Two of the most commonly used indicators of fecal output are polyethylene glycol (PEG) and chromic oxide (Cr_2O_3). Sandiford (1968) compared chromic oxide and PEG in digestion stalls using steers fed Midland bermudagrass hay and found chromic oxide to be superior to PEG as an estimate of fecal output. In a survey of laboratories in the U.S. and Canada, Putnam (1962) found that chromic oxide was a satisfactory technique in most of the laboratories but researchers had reservations concerning a disadvantage of chromic oxide, i.e., the diurnal variation of the concentration of chromium in the feces over a twenty-four hour period and the shift in the diurnal variation pattern from one grazing trial to another. A diurnal variation pattern must be established for each grazing trial and "grab" samples should be taken at the same time each day in order to allow making needed corrections for diurnal variation.

Materials and Methods

Steers were halter broken prior to surgery to facilitate handling and reduce stress on the animals during collection period. Fistulation of the animals must be accomplished at least six weeks prior to the sampling period. This allows time for sufficient healing to avoid tearing and bleeding of the wound when the closure

device is removed or replaced. The poor success with previous esophageal fistula animals (Van Dyne and Torell, 1964) could be the result of many factors; however, most of the failures were due to poor surgical techniques and/or improper care after surgery (Thedford, 1971). Surgical techniques which improve the chances of obtaining good fistulas are 1) removal of animals from feed for twenty-four hours prior to surgery, 2) tranquilization, 3) clipping of hair around the area to be opened, 4) disinfecting, 5) use of a local anesthetic, 6) admission of a rubber tube into esophagus to facilitate locating the esophagus, 7) incision of skin approximately three inches long, 8) removal of no skin, 9) blunt separation of sterno caphalius and sterno hyoideus, 10) longitudinal incision in the esophagus approximately three inches in length, and 11) suturing the edges of the esophagus to the underside of the skin. Suturing in this manner forms an opening that resembles a natural opening of the body from the esophagus to the outside of the neck. This procedure places the fistula more to the side of the esophagus and less beneath the neck than previous surgery techniques (Figure 2.1) (Cook et al., 1958). This location of the fistula minimizes the amount of tissue to be separated and moves the incision farther from the jugular vein and vagosympathetic nerve trunk. A healing powder was used and the fistula plugged with an appropriate closure device. An insectide should be used even in winter to prevent maggots and antibiotics should be administered for four days succeeding surgery. Animals should be turned on green pasture or fed fine textured hay. Rabbit pellets or concentrates were less desirable than the fine textured hay since more clogging occurred under the cannula plate. A tilting surgery

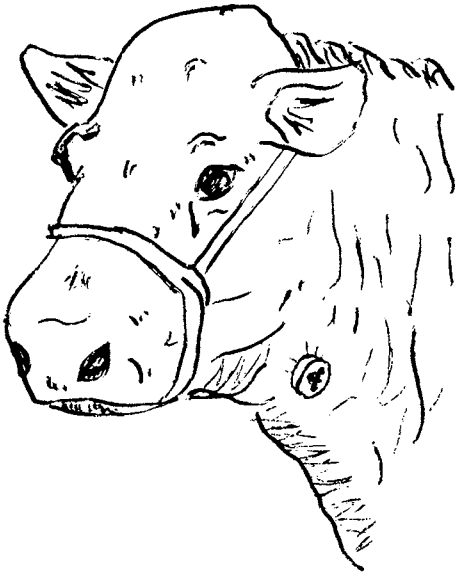

Figure 2.1. Location of cannula in relation to animal's neck

table to secure animals during surgery, worked well to minimize labor and improve safety for the animal.

Careful observation of animals was required to keep the fistulas operative. Animals should be checked twice daily during the first few weeks following surgery to guard against loss of the closure device. Loss of the closure device for long periods of time (8 to 10 hrs) causes contraction of fistula to the extent that it may no longer be operative and can cause great losses of rumen microflora through regurgitation which is harmful to the animal.

Different types of cannulas and plugs have been tried with varying degrees of success. Some of these are discussed in a review by Van Dyne and Torell (1964). Many previous cannulas tend to form a pouch or pocket in the esophagus causing difficulty in sampling and frequent losses of the cannula. This problem is essentially eliminated by using an off-centered plate and turning it every seven to ten days. This requires extra labor but lengthens the usable life of the animal.

The closure device that best served out purpose (Figure 2.2) was a modification of "3C" described by Van Dyne and Torell (1964). This cannula plate was made from a piece of polyvinyl chloride plastic material constructed by 1) longitudinally splitting a section of one and one-quarter inch diameter water pipe approximately four and one-half inches in length, 2) punching a square hole off center in the bottom of the cannula plate to hold the shoulders of the carriage bolt, 3) sanding the rough or sharp edges smooth. Ordinary laboratory stoppers of the appropriate size to fit the cannula were used to plug the fistula with the first stopper shaped with a knife to fit around the

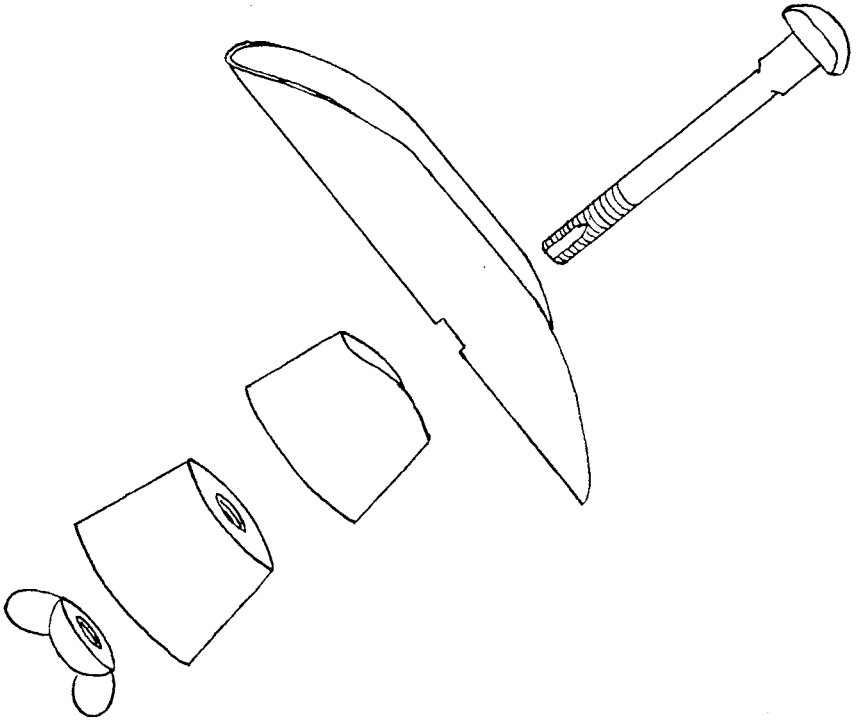

Figure 2.2. Cannula disassembled showing the various parts

cannula plate, thus giving a tighter fit and less leakage. Two or three stoppers were used depending on the depth of the esophagus. A wing nut held the stoppers in the fistula and could be quickly removed or replaced. The head of the carriage bolt was ground on two sides in order to fit snugly longitudinally in the cannula plate to avoid catching forage and becoming clogged. The thread end of the bolt was filed flat on two sides to facilitate holding with pliers, without damaging threads. Occasionally, the saliva may leak into the threads and cause difficulty in removing the wing nut.

The collection bags were constructed by a local automobile-upholstry shop from a water-proof canvas with grommets in the bottom to allow saliva drainage. The bag was secured around the animal's neck with three straps that were buckled on top with an adjustable buckle. Small adjustable straps connected to the bag with D rings were either snapped or buckled to small D rings in the surcingle on each side of the animal's body (Figure 2.3).

Steers were penned the previous evening between 9 p.m. and 11 p.m. to insure grazing the following morning. The late grazing was permitted to avoid excessive hunger which might reduce selectivity. However, Hodgson (1969) reported no changes in nitrogen content nor the organic matter digestibility or samples collected via esophageal fistulated sheep after overnight fasting.

Mean values from four fistulated steers were used in interpreting data to remove animal variation. Steers were fitted with collection apparatus at approximately 7 a.m. and allowed to graze for approximately one to one and one-half hours. Samples collected via the esophageal fistula were transferred from the collection bags to properly labelled

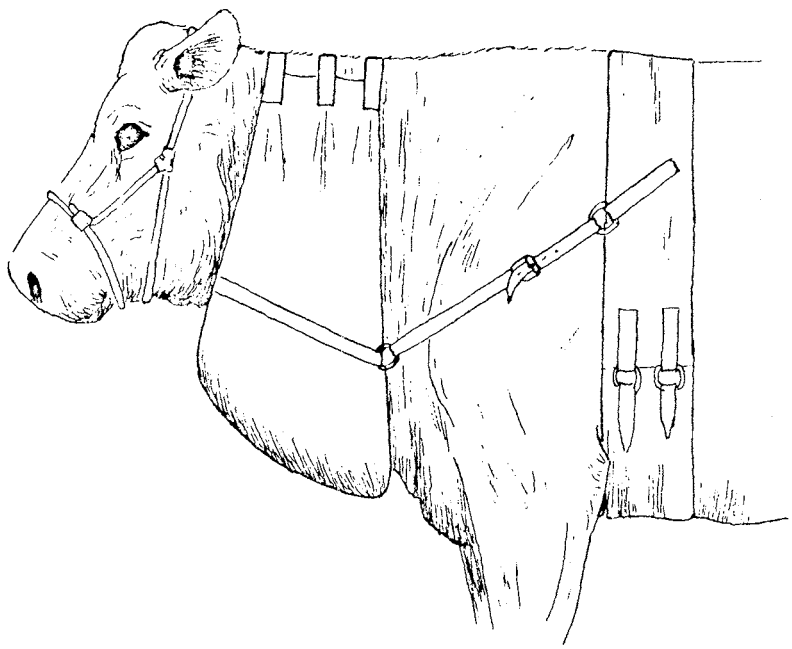

Figure 2.3. Steer equipped with harness ready for collection

plastic bags, frozen immediately, and kept frozen until laboratory analyses were begun. Samples were ground through a 1 mm mesh screen in a Wiley Mill by first freezing the mill by passing dry ice through it. If the mill was kept frozen, it was easily cleaned between samples with a stiff brush.

Chromic oxide (15.00 gms) was administered daily at 8 a.m. in ordinary 45 cc veterinarian supply gelatin capsules. Capsules were given for five days prior to beginning collection of fecal samples to allow equilibration of chromic oxide throughout the digestive system and uniform excretion levels over twenty-four hour periods. On the sixth through the tenth days, a rectal "grab" sample of feces was collected from each steer at the time the capsule was administered. A palpating glove was used for sampling and was changed or rinsed with water after each sample was collected. Samples were placed in plastic bags and frozen for storage and later dried in a forced draft oven. Samples were composited across steers within trials on an equal dry volume basis to remove any day to day variation in excretions. The diurnal variation curve was established from samples collected from four steers at four-hour intervals during the last twenty-four hours of the grazing trial. Chromium concentration was converted to unadjusted fecal output by the following formula:

$$\text{Unadjusted fecal output (gm DM/day)} = \frac{Cr_2O_3 \text{ consumed (gm/day)}}{Cr_2O_3 \text{ in feces (gm/gm DM)}}$$

A diurnal variation curve was drawn and a mean plotted (Figures 2.4-2.7). The deviation from the mean in percentage of unadjusted fecal output at the time the sample was collected was used as a correction factor to derive the adjusted or true fecal output. This allows only

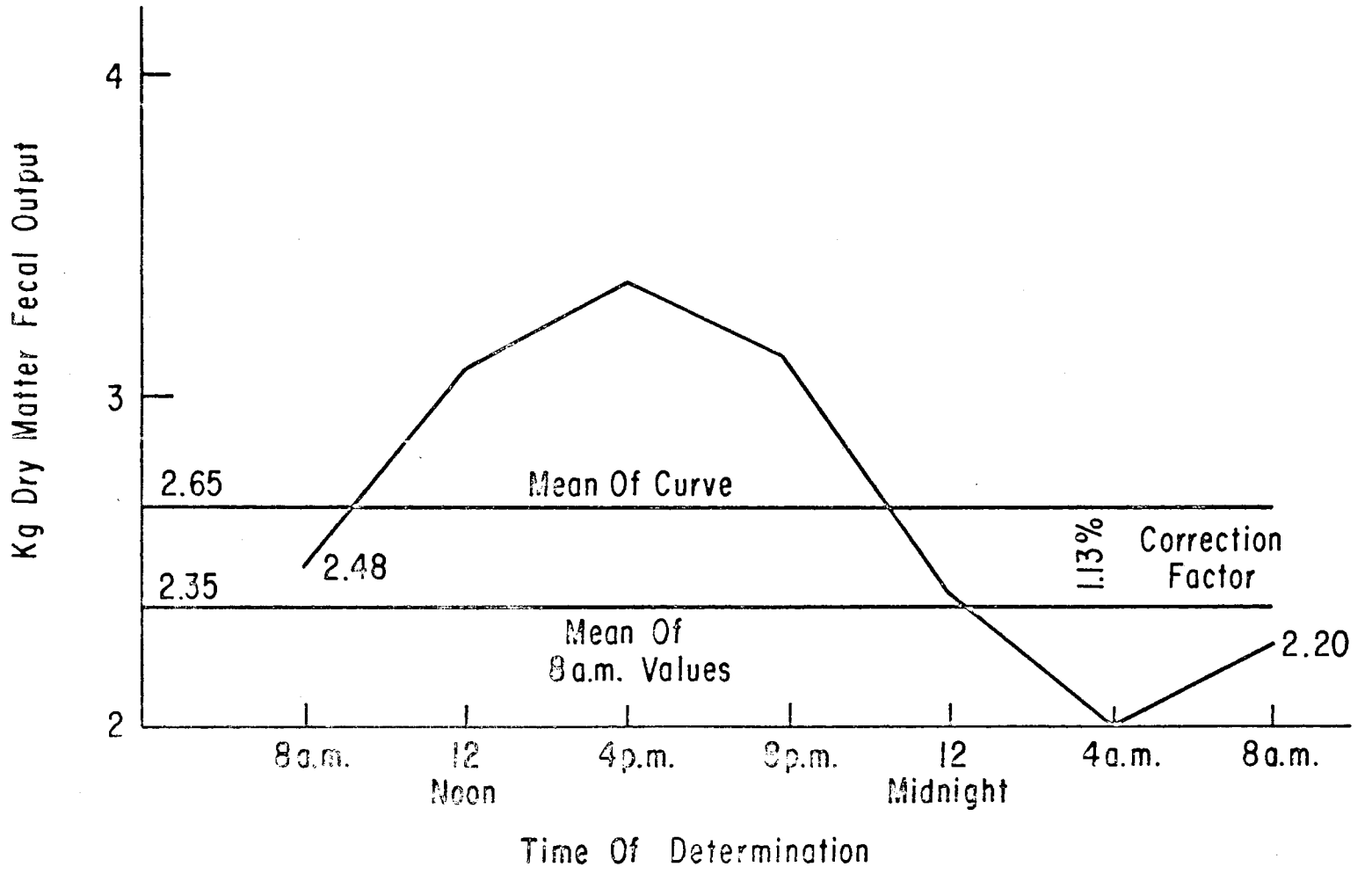

Figure 2.4. Diurnal variation excretion curve determined by chromic oxide indicator for May

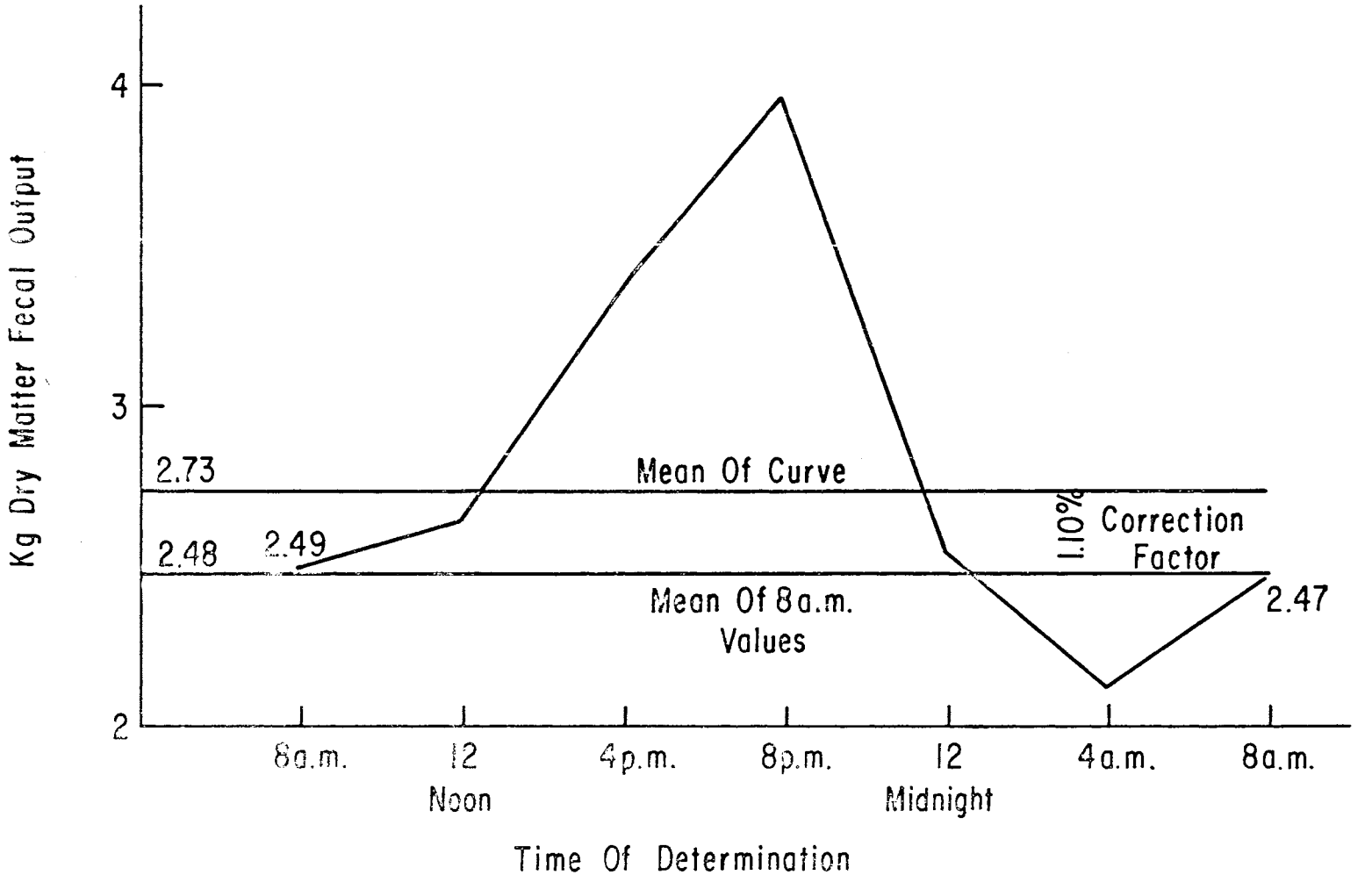

Figure 2.5. Diurnal variation excretion curve determined by chromic oxide indicator for June

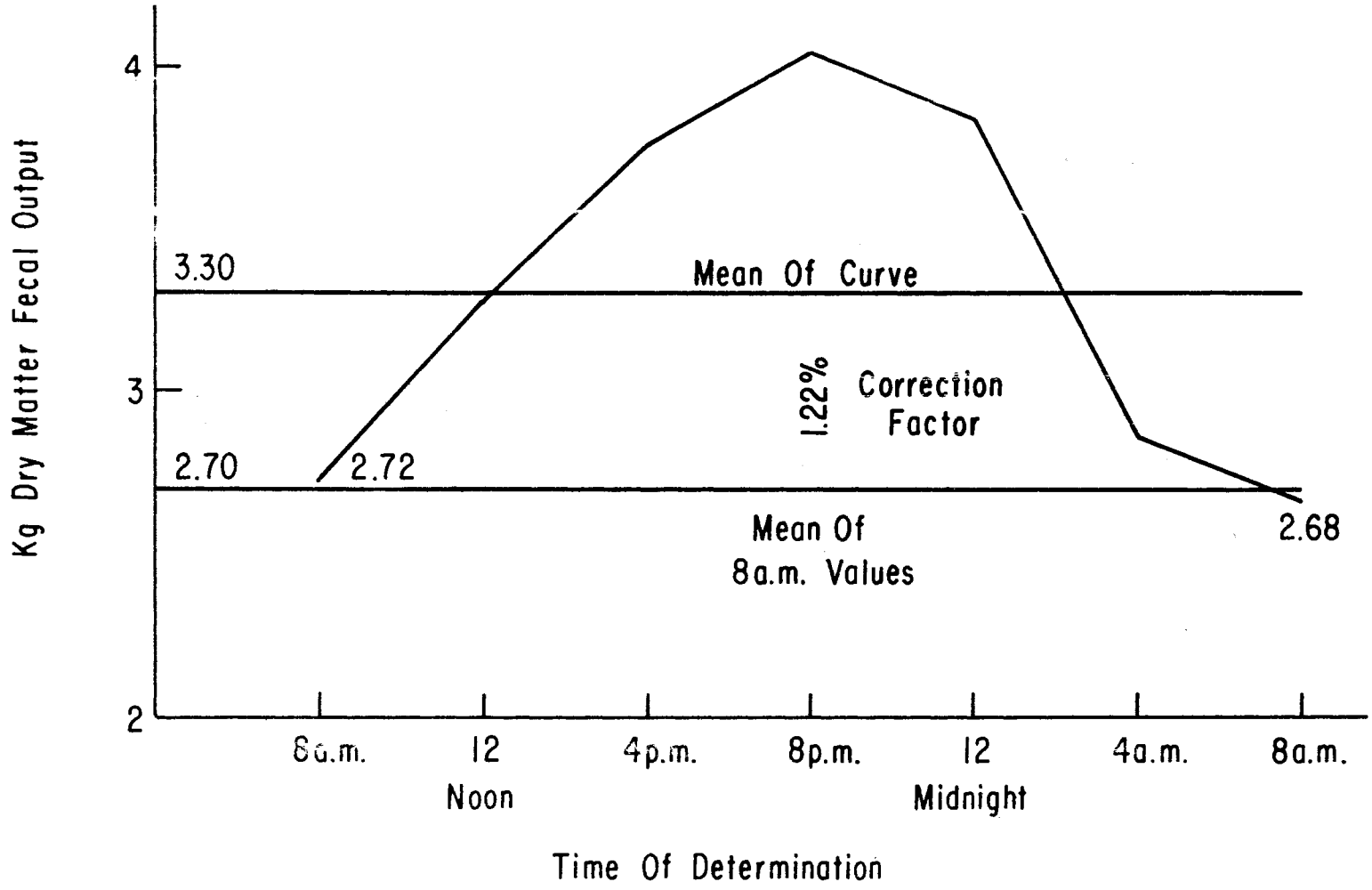

Figure 2.6. Diurnal variation excretion curve determined by chromic oxide indicator for July

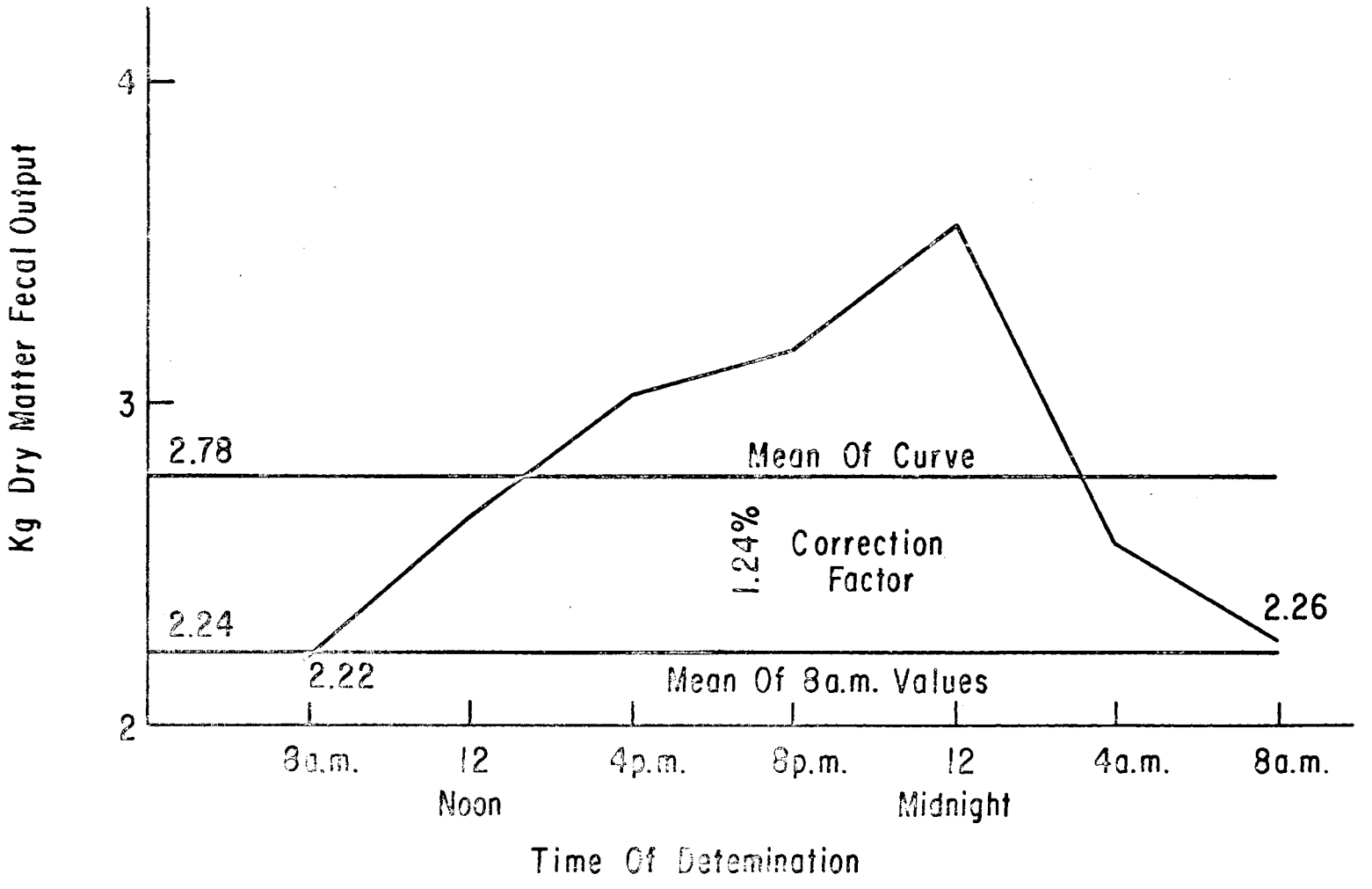

Figure 2.7. Diurnal variation excretion curve determined by chromic oxide indicator for August

one diurnal variation curve to be established when testing different treatments where fecal output is likely to differ among treatments. The curve was established from samples collected at four-hour intervals beginning at 8 a.m. over a twenty-four hour period. The curve mean was divided by the mean of the two 8 a.m. values to establish a correction factor.

$$\text{Correction factor} = \frac{\text{Mean output value of 24 hr. curve}}{\text{Mean of two 8 a.m. output values of curve}}$$

The correction factor was used to adjust all 8 a.m. values to estimated true fecal output. Fecal output was converted to intake by division using percent indigestibility estimated by *in vitro* dry matter disappearance

$$\text{Intake (gm/day)} = \frac{\text{Adjusted fecal output (gm DM/day)}}{100 - \%\text{ in vitro digestibility}} \times 100$$

Discussion

Techniques have been described for collection of samples for the nutritive value and quantity of voluntary intake of steers grazing Midland bermudagrass. This was a laborious task and called for close observation of fistulated animals even in periods when samples were not being collected. Some fistulated steers became thin due to normal stress placed on animals equipped with esophageal fistula and some losses of cannula plug for several hours. This weight loss might have been avoided if steers had been supplemented with grain during the periods when no samples were being collected. Steers were separated each morning and each was placed in a different pasture. There was some tendency for fistulated steers to graze closer to the adjoining pasture containing another fistulated steer instead of grazing with the

herd in the particular pasture being sampled. This might have been eliminated if the experiment had been designed to allow fistulated steers to remain together while collecting samples.

The greatest disadvantage in fecal output determination with the use of chromic oxide was the diurnal variation in chromium excretion.

CHAPTER III

CHEMICAL CONSTITUENTS AND *IN VITRO* DIGESTIBILITY OF MIDLAND BERMUDAGRASS SAMPLED COLLECTED VIA ESOPHAGEAL FISTULATED STEERS AND HAND CLIPPINGS[1/]

Abstract

Comparisons were made throughout the warm growing season between hand-clipped samples and samples collected via esophageal fistulated steers grazing Midland bermudagrass overseeded with small grains. Samples collected via esophageal fistula were found to be higher in IVDMD and Kjeldahl N but lower in cellulose. Non-significant ($P < .05$) trends were noted for esophageal steers to select forage lower in ADF and lignin. Hand-clipping of samples was inadequate for exact duplication of the grazing animal's diet.

Additional Key Words for Indexing: acid detergent fiber, lignin, cellulose, neutral detergent fiber.

Introduction and Literature Review

Selectivity by grazing animals in their choice of diets has long

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[1/] Article co-authored with Lavoy I. Croy and Wilfred E. McMurphy to be submitted for publication in Agronomy Journal.

bewildered researchers in attempts to duplicate these diets for further study. In 1749, Hesselgren (1749) noted different degrees of discrimination between sheep, goats, cattle, horses and pigs when offered hundreds of plant species, both singly and in mixtures. Since then much effort has been devoted toward defining the forage characteristic(s) that were responsible for selective grazing. A number of factors appear to be associated with the forage and the animal that influence selectivity. Many of the earlier workers /Davies (1925), Jones (1933), and Stapledon (1934)/ suggested that the degree of selectivity was determined by the amount of palatable forage available. Tiemann and Muller (1949) found no appreciable correlation between palatability and nutritive value of forage in several classes of livestock, but found that harshness and hairiness reduced acceptability. Hardison, et al. (1954) found that degree of selectiveness was greatest when an abundance of varied herbage existed and decreased as the supply declined. Stapledon (1934) suggested that such factors as the botanical composition of the sward, fertility of the soil, the quantity of manure, and burned or dried forage may affect selectivity by the animal.

In many of the earlier grazing studies, endeavors to duplicate the diet were made by close observation of the grazing animal and hand-plucking a sample thought to be similar. Cook, Harris, and Stoddart (1951) suggested that hand-plucking plant material comparable to the forage eaten was satisfactory on stands of pure species, but totally inadequate on complex mixtures. The search for better sampling techniques has contributed to the increased use of the esophageal fistula. Lesperance, Bohman, and Marble (1960) compared feeds of known

value to samples collected from these same feeds via the esophageal fistula and concluded that the fistula sample represented the best estimate of the foraging animal's diet. The esophageal fistula has been used extensively in rangeland research and data have proved this to be a valuable tool to researchers when sampling a mixture of forages. Hoehne, Clanton, and Streeter (1968) in a study of the *in vitro* digestibility of forbs consumed by cattle found that fourteen percent of the esophageal sample consisted of forbs selected from a sward consisting of only 4.8 percent forbs. Forbs were higher in Ca, P, crude protein, total sugars and had higher dry matter digestion coefficients, but less dry matter than did the grasses. Obioha, *et al.* (1970) Campbell, Eng, and Pope (1968) and Weir and Torrell (1959) found that protein and ash contents were higher in the esophageal sample, but lignin and crude fiber were higher in the hand-clipped sample.

The greatest variabilities have been found when a wide variety of forages were available for grazing. However, when hand-clipped samples were compared to esophageal fistula collected samples in Coastal bermudagrass pastures, Guthrie, Rollins, and Hawkins (1968) found the esophageal fistula collected samples was higher in protein and ash, but lower in acid detergent fiber and lignin than the hand-clipped samples. These results were consistent with the work of Campbell (1964) with Midland bermudagrass. The purpose of the present study was to further evaluate the use of the esophageal fistula as a means of collecting samples from Midland bermudagrass pastures overseeded with small grains under varying nitrogen fertility levels during the months of May, June, July, and August.

Materials and Methods

This study was conducted on a Taloka silt loam soil on the Eastern Pasture Research Station near Muskogee, Oklahoma. The pasture experimental design was a randomized block with four nitrogen treatments in two replications. Each pasture was approximately three acres in size and consisted of pure stands of Midland bermudagrass which had been overseeded with a mixture of Elbon Rye (Secale cereale L.) and Agent Wheat (Triticum aestivum L.) and supplied with P and K in accordance with soil test results. The four nitrogen treatments were 134, 169, 403, and 538 kg/ha (120, 240, 360, 480 lbs./A.) applied in split applications using urea (Table 3.1).

The collection study design was two replications of a four by four Latin square.

Tests were conducted May 24-June 2, June 21-June 30, July 20-July 29, and August 23-September 1. Four Hereford steers equipped with esophageal fistulas, as described in Chapter II, were each allowed to graze one pasture in the square on each of four consecutive days and then moved to the second square for the next four days. Close observation of the grazing animals was made and hand-clipped samples were collected selectively throughout the pasture in an effort to duplicate as closely as possible the diet of the grazing steers. Samples were placed in plastic bags and frozen for storage.

Samples were ground through a 1 mm screen in a Wiley Mill, as described in Chapter II, and comparisons were made of Kjeldahl N in accordance with the Official Methods of Analysis (1960), cell wall constituents (NDF), acid detergent fiber (ADF), permanganate lignin,

TABLE 3.1

NITROGEN FERTILIZER APPLICATION DATES AND RATES

(KILOGRAMS/HECTARE)

Date	134 N	269 N	403 N	538 N
Oct 15	22	22	22	22
Feb 1	44	67	89	112
May 15		45	73	101
June 1	34			
June 15		45	73	101
June 15	34	45	73	101
Aug 15		45	73	101

TABLE 3.2

Chemical constituents of esophageal and hand-clipped samples

Constituent	Sample Method	Month				N in Kg/Ha			
		May	June	July	August	134	269	403	538
% IVDMD	Esop	51.04*	47.56	44.78*	46.83*	46.91*	49.45*	46.05	47.81
	Hand	44.30	46.06	36.90	41.09	40.19	42.70	41.64	43.82
% Nitrogen	Esop	2.48	2.48*	1.88	2.37*	2.04	2.36	2.34	2.49
	Hand	2.75	2.07	1.86	1.97	1.81	2.31	2.17	2.35
% NDF	Esop	59.81	82.30	78.93	61.22	65.86	74.94	69.77	71.69
	Hand	75.41	68.50	69.96	72.78	72.71	68.61	75.53	68.81
% ADF	Esop	28.52	31.92	34.25	32.68	29.94	32.67	31.16	32.60
	Hand	34.44	34.77	34.25	31.11	35.09	32.82	35.81	30.84
% Lignin	Esop	4.44	3.88	4.64	3.92	4.28	3.98	4.32	4.32
	Hand	5.04	4.55	4.72	3.91	4.78	4.51	4.48	4.43
% Cellulose	Esop	24.03*	24.23*	27.60	26.13	23.68	26.63	26.24	25.45
	Hand	27.82	27.94	27.17	24.75	25.58	26.15	28.80	25.15

* Significant at $P < .05$ level between esophageal and hand-clipped samples.

and cellulose according to Goering and Van Soest (1970). Comparisons were also made of the in vitro digestibility, determined by a modification of the Tilley and Terry procedure (1963). Approximately 1 gm oven dry forage samples were placed in 50 ml centrifuge tubes with 25 ml of buffer solution (McDougall's sheep saliva) and 10 ml of strained rumen liquor. After a forty-eight hour incubation period, bacterial activity was stopped by overnight refrigeration and pepsin digestion followed.

Results and Discussion

The esophageal samples were higher in dry matter digestibility and kjeldahl N but lower in ADF, lignin, and cellulose than the hand-clipped samples (Table 3.2). NDF values did not follow any detectable pattern. There was a good relationship between the esophageal hand-clipped samples for IVDMD and Kjeldahl N for the respective fertility levels within dates; however, the relationship across dates was not close since the animals selected samples which were quite similar for IVDMD and Kjeldahl N (Table 3.3). In contrast, the hand-clipped samples improved in IVDMD and Kjeldahl N in response to added fertility across dates. No explanation is apparent for the high hand-clipped IVDMD value in June. The higher hand-clipped Kjeldahl N value in May is probably more representative of the bermudagrass forage available, but at this time the small grains were headed and were offering dry matter as opposed to the lush early growth of the bermudagrass. Observation of the grazing animals confirmed that steers were consuming appreciable quantities of the mature grain. However, an underestimate of this quantity in selecting hand-clipped

TABLE 3.3

CORRELATIONS OF ESOPHAGEAL AND HAND-CLIPPED SAMPLES

Constituent	Fertility levels across dates	Dates across fertility levels
% IVDMD	.52	.73*
% Nitrogen	.59	.98**
% NDF	-.66	-.94**
% ADF	-.80*	-.27
% Lignin	.05	.68
% Cellulose	-.09	-.46

* Significant at $P < .05$ level.

** Significant at $P < .01$ level.

samples is possible. The apparent randominess of the NDF values for the esophageal samples suggest that NDF is not a criterion for selective grazing by steers and the high negative correlation between hand-clipped and esophageal collected NDF is probably an artifact. The consistently lower values for ADF and lignin in esophageal samples agree with expected trends but to a lesser magnitude than reported by Guthrie, Rollins and Hawkins (1968) and Campbell (1964). Steers selected forage lower in cellulose in May and June but failed to do so in July and August. This may be a result of a higher stocking rate imposed in an attempt to utilize the forage available. More trampling and excreta imposed by the higher stocking rate possibly influenced selectivity more than cellulose.

Conclusions

The data reported indicate that steers are selective grazers even in monocultures and that hand-clipping samples to duplicate the diet of the grazing animal may be misleading especially when efforts are being made to exactly duplicate IVDMD, Kjeldahl N, and cellulose contents of the diet.

When high stocking rates were imposed in order to utilize the forage available, factors other than chemical constituents of the forage may have affected the selectivity of the steers and thus made duplication by hand-sampling more difficult.

CHAPTER IV

TECHNIQUES USED TO EVALUATE MIDLAND BERMUDAGRASS QUALITY IN RELATION TO ANIMAL GAINS[1/]

Abstract

Tests were conducted on Midland bermudagrass throughout the growing season under varying nitrogen treatments to determine the validity of chemical constituents, forage intake, available forage, and digestible dry matter as criterion for predicting animal gains. Forage intake was the major factor influencing animal gains in a given month but could not be used across months as an explanation for animal gains. Intake values were increased by an increase in *in vitro* digestibility of forage, but the increases were not of predictable magnitude. High lignin values were associated with low intake values in July and August but failed to show significant correlations in May and June. Gain per hectare and average daily gains were influenced more by steer days per hectare and total forage available than by chemical constituents and digestibility.

Additional Key Words for Indexing: steer days, Midland bermudagrass, nitrogen fertility.

[1/] Article co-authored with Lavoy I. Croy and Wilfred E. McMurphy to be submitted for publication in Agronomy Journal.

Introduction and Literature Review

Bermudagrass was one of the earliest grasses introduced into Oklahoma agriculture. This species was first established from seed on the Oklahoma Agriculture Experiment Station at Stillwater in the spring of 1892 (Neal, 1893). Few Oklahoma farmers at this time recognized the merits of bermudagrass, instead it developed into one of the worst weeds known to the row crop farmer and much more effort was spent trying to eradicate the species than trying to improve it. Bermudagrass began to gain popularity in Oklahoma in the 1930's and 1940's as a soil binding crop during the dust bowl era and soon began to be recognized as a potential high producing pasture crop (Denman, Huffine, and Arnold, 1971). Midland bermudagrass was released jointly by the Oklahoma Agricultural Experiment Station, the Georgia Agricultural Experiment Station and Crops Research Division, Agricultural Research Service, United States Department of Agriculture in 1953 (Harlan, Burton, and Elder, 1954). Since its release, it has become Oklahoma's leading warm season pasture variety and continues to gain popularity each year.

The grasslander's common measuring unit of pasture or other forage production is green or dry weight yield per acre and forage quality is often thought of as being synonymous with protein content of the forage (Sell et al., 1959). Although this may be satisfactory for some, the ultimate use of forage is for animal production and the most reliable measure of forage quality is animal response to the forage consumed. This is often influenced by factors other than total yield and protein content. Numerous attempts have been made to

estimate over-all forage quality or certain chemical components of quality including chemical composition, *in vitro* digestibility, rate of intake, and digestibility determined by indicator methods as well as by the conventional digestion trial (Mott, 1959).

Troelsen and Beacom (1970) evaluated hays and silages from grasses, legumes, and cereals and observed that *in vitro* organic matter digestibility of the herbage was highly correlated with liveweight gains and with dry matter intake, dry matter digestibility and digestible energy. Fuller (1964) found less winter weight loss in lactating cows when a Midland bermudagrass hay ration was supplemented with protein than with milo (*Sorghum vulgare Pers.*), suggesting that Midland hay more nearly met energy requirements of cows than protein requirement and that an increase in protein content of this hay would have increased quality. In studies of the seasonal variation of Midland bermudagrass, McCroskey, Brackett and Renbarger (1968) found that crude protein and cell contents values were positively related to dry matter digestibility. Dry matter digestion was negatively correlated with acid-detergent fiber and lignin contents. Sheehan (1969) showed that with progressive stages of maturity there was a decrease in leaf percent, nitrogen content of forage, *in vitro* digestibility and voluntary intake, but a crude fiber increase in perennial ryegrass (*Lolium perenne L.*) and cocksfoot (*Dactylis glomerata L.*). Voluntary intake was positively correlated with *in vitro* digestibility and negatively correlated with crude fiber content. Colburn and Evans (1967) found that cellulose, lignin, crude protein and ash accounted for ninety-five percent of the total acid detergent fiber of grasses and concluded that cell wall constituents, particularly

the acid detergent fiber fraction, represented a more complete forage entity than crude fiber. A correlation coefficient of +0.99 was found between relative rate of disappearance of digestible cellulose *in vitro* and intake of digestible dry matter by cows consuming high dry matter lucerne (*Medicago sativa* L.)-timothy (*Phleum pratense* L.)-bromegrass (*Bromus inermis* L.) silage (Gill, Conrad, Hibbs, 1969). The relationship between the cellulose-lignin complex, voluntary food consumption by sheep, and dry matter digestibility was studied by Allinson and Osbourn (1970) using Italian ryegrass (*Lolium multiflorum* Lam.), lucerne and sainfoin (*Onobrychis viciaefolia* Scop.). Changes in maturity of a forage during a single growth phase produced changes in dry matter digestibility that were closely associated with changes in cellulose digestibility and inversely related to lignin content. Differences in voluntary food consumption resulting from changes in degree of maturity of a single forage variety in one growth phase were also closely correlated with both dry matter and cellulose digestibility and inversely with lignin content. Differences were related more closely to percent of total digesta derived from cellulose than that derived from the lignin-cellulose complex.

Crampton (1957) suggested a relationship between cellulose digestion and voluntary intake by the animal in which the rate of digestion is inhibited by anything that represses microflora activity. If cellulose digestion is retarded, the material remains in the rumen longer, but the sooner the ingesta moves out of the rumen the sooner hunger recurs and more food is eaten. However, Hungate (1966) reported that the most complete digestion of forages would be obtained with the longest retention time in the rumen, suggesting a negative relation

between total digestion and intake. Thus it may be inferred that there was a relationship between fermentation time and intake, but not total digestion and intake. Van Soest (1965) has shown that the lignin was not as highly correlated with intake as it was with digestibility.

Due to the many discrepancies in laboratory analyses and animal performance, many researchers have turned to management practices as a method of predicting animal performance. In studies of herbage intake by grazing sheep, Allden and Whittaker (1970) found that the rate of intake was closely associated with plant height, but when herbage accessibility imposed limitations on feeding rates, sheep only partly compensated for the reduced forage availability with an increase in grazing time. This is in general agreement with conclusions by Bryant et al. (1970) that the quality of herbage ingested decreased if the grazing pressure reduced availability of herbage and the animal's opportunity for selective grazing. The animal therefore ingested a larger portion of the whole plant and more of the mature herbage if there was an insufficient opportunity for selective grazing; whereas, a grazing pressure that provided an opportunity for selective grazing usually gave greater output per animal. In studies of the chemical composition and in vitro digestibility of vertical layers of Coastal bermudagrass, Wilkson, Adams, and Jackson (1970), found that although "quality" as indicated by chemical composition and in vitro digestibility was greater in the upper layers, more total nutrients were present in the basal layers of the sward as a result of a greater dry matter yield.

Varied fertility rates and grazing patterns have received much attention in efforts to study factors involved in maximum animal output

per unit area. Working with Coastal bermudagrass, Pensacola bahiagrass (Paspalum notatum Flugge) and common bermudagrass with 121, 242, and 484 Kg N/ha, Suman et al. (1962) found maximum beef gain/hectare were obtained from Coastal bermudagrass fertilized with 484 kilograms nitrogen per hectare and that rotational grazing of Coastal increased beef gains very little. Protein content of the grasses varied according to season and fertility rate, but was not the factor limiting production. Spooner and Ray (1969), compared four fertility treatments a) 67:67:67 b) nine (metric) tons chicken manure c) 242:147:103, which was equivalent to the nine (metric) tons chicken manure in nitrogen, P_2O_5 and K_2O and d) 672:336:336 kilograms per hectare on bermudagrass pastures in Southwest Arkansas. Average daily gain was lower in "d" and highest in "b". Steer days per hectare and total gain per hectare were increased by the application of fertilizer. This agrees with results by Alder et al. (1968) obtained from perennial ryegrass-white clover (Trifolium repens L.) pastures. Hawkins and Rollins (1960) report higher intake values with rotational grazing of Coastal bermudagrass and continuous grazing of bahiagrass in a study to compare rotational and continuous grazing management.

In other studies of fertility effects, Reid and Jung (1965) noted palatability differences with sheep in tall fescue (Festuca arundinacea Schreb.) grown under different fertility treatments. Primary selection was for fescue treated with phosphorus fertilizer, and the second selection was for fescue fertilized at a low level of nitrogen. These results were also obtained by Reid, Jung and Murray (1966) with orchardgrass with both sheep and rabbits; however, in neither study was there a consistent relationship between palatability

and intake as determined in the conventional system. In further studies with orchardgrass, Reid, Jung, and Kinsey (1967) found that as the fertility level was raised from zero to 504 Kg N/ha, there was a significant increase in intake. Burton, Southwell, and Johnson (1956) showed palatability of Coastal bermudagrass was improved substantially by nitrogen fertilization. There was no evidence to indicate that annual rates up to 1680 kilograms per hectare decreased palatability.

Attempts have been made to find correlations between management and chemical constituents of a forage. When Coastal bermudagrass was clipped at two-week intervals, increasing rates of nitrogen decreased the lignin content of the forage, but at six and eight-week intervals, lignin tended to increase with increasing increments of nitrogen. When fertilized with 121 kilograms or less of nitrogen per hectare, eight week old grass contained no more lignin than two and three week old grass. When fertilized at heavier rates, the lignin content increased with age of grass (Knox, Burton, and Baird, 1958). Partial explanation of these results is offered as increased leafiness of the forage harvested, but leafiness may not decrease lignin content in all cases. Neatherly (1972) reported higher lignin content in leaves of Midland bermudagrass than in stems.

It would appear from previous literature that no one criterion can adequately denote forage quality for all forages in varying stages of growth under different fertility treatments for separate classes of livestock. One or a limited number of factors can perhaps be used safely in evaluating a forage under limited conditions for a specific purpose and with a particular class of livestock. It was the purpose

of this research to determine if chemical constituents, intake or digestible dry matter of Midland bermudagrass can be competently used to predict gains of steers grazing Midland bermudagrass with varying fertility levels.

Materials and Methods

This study was conducted at the Eastern Pasture Research Station, Muskogee County, Oklahoma. The soil type was Taloka silt loam 0-3% slope. In the fall of '70, a mixture of Agent wheat and Elbon rye was overseeded on eight three-acre pastures of essentially pure stands of Midland bermudagrass arranged two replications of four nitrogen fertility treatments in a randomized block design. The treatments were 134, 269, 408, and 538 kg N/hectare (120, 240, 360, and 480 lbs N/acre) applied in split applications as shown in Table 3.1. Phosphorus and potassium was applied in accordance with soil test results. Good to choice pure bred Hereford and Angus steer calves, weighing 200 to 230 kg were purchased in February and stocking rate on the pastures was adjusted by the put-and-take method to remove forage as it grew in attempts to determine seasonal productivity of pastures. Shade, water and mineral mix were provided in each pasture. Four steers in each pasture were designated as "tester" steers with put-and-take steers added as needed to obtain uniform forage utilization. Steer days per hectare and total gain/hectare were determined by using both groups of steers, but intake values and average daily gain were obtained only from "tester" steers.

Esophageal fistulated steers were used to collect forage samples

for laboratory analyses by methods described in Chapter III.

The following data were collected for each month on each treatment 1) average daily gain 2) total gain/hectare 3) steer days per hectare 4) average dry matter intake 5) dry matter digestibility 6) nitrogen content of forage 7) acid detergent fiber content of forage 8) lignin content of forage 9) cellulose content of forage 10) cell wall constituents of forage and 11) total forage available.

Collection trials were conducted May 24-June 2, June 21-June 30, July 20-July 29, and August 23-September 1. Average daily gain and total gain were determined for the twenty days prior to collection trial in order to remove the decrease in gains incurred by handling steers daily. Steer days per hectare were determined for the entire month and all other values are representative of the forage during the ten day collection trials. Forage samples were collected via esophageal fistula as described in Chapters II and III and intake and fecal analysis were determined from fecal samples collected as described in Chapter II. Laboratory analyses were the same as those outlined in Chapters II and III. Forage available was estimated from two 0.9 m x 7.6 m clippings from each pasture.

Results and Discussion

May

Average daily gain and total gain per hectare in the 134 N treatment were lower than the three higher nitrogen fertilizer treatments (Table 4.1). Total gain per hectare tended to increase linearly through the higher fertility treatment, but average daily

TABLE 4.1

Forage entities, animal performance, and forage intake during May

	kg/ha			
	134 N	269 N	403 N	538 N
Av. Daily Gain, kg	0.77	1.18	1.17	1.12
% Esop. N	2.29	2.27	2.35	3.03
% Esop. NDF	59.81	58.86	62.50	58.09
% Esop. IVDMD	50.87	50.87	46.89	55.55
% Esop. ADF	24.20	30.01	27.23	28.64
% Esop. Lignin	5.01	4.07	4.92	3.77
% Esop. Cellulose	22.71	24.72	27.22	21.48
Avail. forage Kg/ha	1409	4240	2288	1193
Gain/ha, kg	67.82	113.22	117.71	128.92
Steer days/ha	88.92	85.22	86.45	104.98
Intake, kg/day[1]	5.05	5.84	5.09	6.46

[1] Estimated using Cr_2O_3

gain showed a slight trend downward in response to 403 N and 538 N treatments. Steer days per hectare were greater in the 538 N treatment with no differences in the other three treatments. Daily intake of steers was higher in the 269 N and 538 N treatment than in the 134 N and 538 N treatments. Cellulose content in the 403 N treatment was largest with the 269 N treatment having a higher content than the 538 N treatment. No significant differences were found between treatments in nitrogen, cell wall constituents, *in vitro* digestibility, acid detergent fiber or lignin content.

Low average daily gains in the low nitrogen treatment may have been the result of lower daily intakes by steers caused by reduced total forage; however, daily intake values were also low in the treatment receiving 403 kg N with no suppression of average daily gains. The low intake values and high cellulose content in the 403 N treatment with apparently no depression of average daily gain may be an artifact produced by grazing of small grains which were producing seed. The lack of suppression of average daily gains by cellulose in the early part of the growing season may be attributed to the high digestibility of cellulose in young plants (Kamstra, Moxon, and Bentley, 1958). Higher average daily gain and intake values in the 269 N treatment may suggest that an opportunity for selection of more palatable forage results in higher animal performance. Fontenot and Blaser (1965) have also reported dry matter intake to be related to the amount of selective grazing by sheep under range conditions. Thus, under a system of grazing which allows maximum selection, one expects to obtain a high rate of

performance per animal unit, since the animal has large amounts of highly nutritious feed available to consume. However, in this study differences in nutritional value of forage consumed were not found in May. The higher intake values and lower total forage available in the 538 N treatment suggests that palatability of Midland bermudagrass was increased by nitrogen fertilizer which agrees with the report of Burton, Southwell, and Johnson (1956) on palatability of Coastal bermudagrass.

June

Average daily gains were highest in the 269 N treatment with no differences in the other three treatments (Table 4.2). With the increase in steer days per hectare, in spite of lower average daily gains, the treatment receiving 403 kg N produced as much total gain per hectare as the treatment receiving 269 kg N. The 403 N treatment also showed an increase over the 134 N treatment in in vitro digestibility. Average daily gain values obtained from the eight "tester" steers (two replications) were not representative of the gains made by 'put and take' steers in the same pastures. This is pointed out by the over estimation of average daily gain in some treatments and underestimation in others. There was more total forage available in the 538 N treatment without an accompanying increase in average daily gains or in vitro digestibility, suggesting under utilization of the forage in spite of a large increase in steer days per hectare. The average daily gain in June seems to be a result of low intake values. Although no significant differences were found in intake values, small decreases in average daily intake

TABLE 4.2

Forage entities, animal performance and forage intake during June

	134 N	269 N	403 N	538 N
Av. Daily Gain, kg	0.72	0.98	0.69	0.69
% Esop. N	2.18	2.70	2.55	2.49
% Esop. NDF	57.81	86.74	69.13	85.51
% Esop. IVDMD	43.56	48.66	50.81	47.22
% Esop. ADF	31.47	32.93	31.90	31.22
% Esop. Lignin	4.23	3.84	3.39	4.06
% Esop. Cellulose	23.17	25.12	25.31	23.34
Avail. forage Kg/ha	1713	2407	2364	4468
Gain/ha, kg	49.32	83.51	95.85	67.43
Steer days/ha	74.10	90.16	119.80	160.55
Intake, kg/ha[1]	5.00	5.61	5.29	4.84

[1] Estimated using Cr_2O_3

can reduce gains drastically. This suggests that a Type II statistical error may have been committed. It seems likely that as steer days per hectare increased, more forage was messed, therefore, becoming less palatable resulting in steers grazing smaller quantities. This selective grazing resulted in more available forage and finally considerable, but more mature forage of low quality.

July

Although there are no differences in average daily gains between treatments the trend is still for higher average daily gains and intake values in the 269 N treatment; however, there is little correlation between intake and average daily gains in the 403 N and 538 N (Table 4.3). Treatment 134 N has a higher intake value than treatments 403 N and 538 N but average daily gains failed to respond to the higher intake values. The higher cell wall constituents in treatment 403 N cannot be shown to have an adverse effect on average daily gain nor intake. Intake values decreased as steer days per hectare and total forage available increased. These results are reversed from those obtained in May, and infer under utilization of forage in which the forage was more mature and of poorer quality. Again, we were unable to show the particular aspect of quality responsible for the lower intake; however, intake values did follow trends in <u>in vitro</u> digestibility and were reversed to the trend in lignin content. The lower intake may possibly be accredited to longer retention time of the forage in the rumen but more likely to palatability differences incurred with the higher concentration of animals.

TABLE 4.3

Forage entities, animal performance, and forage intake during July

	134 N	269 N	403 N	538 N
Av. Daily Gain, kg	0.63	0.97	0.78	0.72
% Esop. N	1.77	1.90	1.81	2.07
% Esop. NDF	77.84	73.02	90.73	74.12
% Esop. IVDMD	45.44	47.63	44.21	41.86
% Esop. ADF	29.58	35.06	35.49	36.86
% Esop. Lignin	3.94	4.43	4.64	5.55
% Esop. Cellulose	23.10	29.39	28.51	29.38
Avail. forage Kg/ha	2960	4056	6073	5986
Gain/ha, kg	52.13	90.24	84.64	113.78
Steer days/ha	79.04	95.10	135.85	181.55
Intake, kg/ha[1]	6.56	7.01	6.02	5.18

[1] Estimated using Cr_2O_3

August

Intake values in August seemed to be affected by the same factors in July. Lignin and steer days per hectare appeared to hamper intake in August whereas *in vitro* digestibility seemed to stimulate intake. Average daily gains were of such low values in the 538 N treatment, that steer days per hectare failed to bring the total gain per hectare above the lower fertility treatments (Table 4.4).

Conclusions

Certainly forage intake and the digestibility of the forage are major factors influencing animal gains and intake is positively correlated to *in vitro* digestibility and in more mature forages negatively correlated to lignin content of the forage. This may be a result of lignin lowering the percent digestion simply by its own indigestibility or by forming complexes with cellulose thus reducing the digestibility of cellulose. Stocking rates are interrelated to gain per animal and gain per hectare. Individual animal gains may be sacrificed in order to reach a peak production per hectare. Stocking rates on highly fertilized Midland bermudagrass may reach the point that intake values are hampered although sufficient amounts of forage are available. This introduces abnormal animal variability in selection for forage that is not fouled with feces and urine instead of for the chemical constituents normally thought to be associated with selective grazing and animal gains.

Attempts to correlate a single variable with animal response has limited success since there is an interaction of variables. When the

TABLE 4.4

Forage entities, animal performance, and forage intake during August

	134 N	269 N	403 N	538 N
Av. Daily Gain, kg	0.09	0.15	0.12	0.01
% Esop. N	1.91	2.59	2.65	2.36
% Esop. NDF	67.97	51.13	56.71	69.05
% Esop. IVDMD	47.77	50.64	42.31	46.62
% Esop. ADF	34.34	32.69	30.03	33.69
% Esop. Lignin	3.93	3.56	4.31	3.90
% Esop. Cellulose	25.75	27.30	23.91	27.58
Avail. forage Kg/ha	5130	5466	5531	5704
Gain/ha, kg	19.62	21.30	9.53	-41.48
Steer days/ha	98.80	121.03	172.90	229.71
Intake, Kg/ha[1]	5.79	6.49	5.14	5.24

[1] Estimated using Cr_2O_3

effect of modifying variables becomes great then it is difficult to delineate exactly what is the influencing factor. Grazing pressure may force the animals to choose forage which they would not take if they had wider choices. Unknown animal and/or plant variability continues to plague the forage researcher.

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APPENDIX

TABLE I

Chemical constituents of feces and hand clipped samples

May

	134 N	269 N	403 N	538 N
% Fecal N	1.57	1.92	1.90	2.08
% Fecal NDF	63.58	57.73	53.94	55.14
% Fecal ADF	43.04	38.77	40.48	39.30
% Fecal Lignin	10.34	10.42	10.82	10.07
% Fecal Cellulose	22.62	20.37	19.84	20.09
% Hand-clipped ADF	40.69	35.06	39.05	22.07
% Hand-clipped Lignin	5.90	5.59	4.58	4.10
% Hand-clipped cellulose	31.04	28.14	31.89	20.21
% Hand-clipped N	2.12	2.79	2.88	3.21
% Hand-clipped NDF	77.29	73.12	86.15	65.10
% Hand-clipped IVDMD	47.95	39.40	42.35	47.50

TABLE II

Chemical constituents of feces and hand clipped samples

June

	134 N	269 N	403 N	538 N
% Fecal N	1.48	1.99	1.72	1.83
% Fecal NDF	66.07	58.31	61.35	61.75
% Fecal ADF	35.60	34.92	33.95	35.31
% Fecal Lignin	7.58	7.71	7.08	7.59
% Fecal Cellulose	20.78	19.68	19.85	18.88
% Hand-clipped ADF	32.07	35.59	32.98	38.45
% Hand-clipped Lignin	4.50	4.42	3.74	5.56
% Hand-clipped Cellulose	25.44	28.81	27.19	30.34
% Hand-clipped N	1.52	2.28	2.49	1.99
% Hand-clipped NDF	69.98	66.85	63.49	73.70
% Hand-clipped IVDMD	41.25	54.50	45.20	43.30

TABLE III

Chemical constituents of feces and hand clipped samples

July

	134 N	269 N	403 N	538 N
% Fecal N	1.34	1.34	1.37	1.62
% Fecal NDF	68.03	67.09	66.99	65.26
% Fecal ADF	37.99	38.68	38.09	37.67
% Fecal Lignin	8.43	9.76	8.90	8.68
% Fecal Cellulose	23.19	22.39	22.68	22.13
% Hand-clipped ADF	34.72	31.23	37.93	33.11
% Hand-clipped Lignin	4.61	4.55	5.32	4.40
% Hand-clipped Cellulose	27.62	24.80	30.02	26.25
% Hand-clipped N	1.76	2.06	1.61	2.02
% Hand-clipped NDF	68.52	67.34	74.74	69.23
% Hand-clipped IVDMD	34.40	33.50	40.10	39.60

TABLE IV

Chemical constituents of feces and hand clipped samples

August

	134 N	269 N	403 N	538 N
% Fecal N	1.51	1.68	1.54	1.79
% Fecal NDF	64.43	63.96	64.61	62.07
% Fecal ADF	39.97	38.76	39.38	37.67
% Fecal Lignin	8.87	8.17	8.48	8.12
% Fecal Cellulose	21.42	21.49	21.35	20.28
% Hand-clipped ADF	32.87	28.49	33.32	29.75
% Hand-clipped Lignin	4.14	3.50	4.31	3.67
% Hand-clipped Cellulose	26.22	22.85	26.11	23.80
% Hand-clipped N	1.86	2.13	1.72	2.19
% Hand-clipped NDF	75.04	67.13	77.75	71.23
% Hand-clipped IVDMD	37.15	43.40	38.90	44.90

TABLE V

Average daily gains with selected fecal and esophageal entities

	May	June	July	August
Av. Daily Gain x % Fecal N	.87	.67	-.28	-.54
% Fecal NDF	-.90	-.69	-.07	.82
% Fecal ADF	-.92	.04	.83	.55
% Fecal Lignin	.25	.55	.99	.79
% Fecal Cell.	-.97	-.04	-.51	.93
% Esop. N	.23	.62	.16	.34
% Esop. NDF	.06	.86	-.20	-.86
% Esop. IVDMD	-.07	.17	.60	.21
% Esop. ADF	.89	.92	.50	-.43
% Esop. Lignin	-.55	-.02	.03	-.18
% Esop. Cell.	.44	.48	.69	-.34

TABLE VI

Average daily gains with hand-clipped and steer performance entities

		May	June	July	August
Av. Daily Gain x	% Hand-clipped ADF	-.38	.14	-.47	.03
	% Hand-clipped Lignin	-.59	-.13	.01	.07
	% Hand-clipped N	.86	.26	.47	-.38
	Avail. forage Kg/ha	.52	-.24	.09	-.42
	% Hand-clipped Cell.	-.29	.22	-.49	-.00
	% Hand-clipped NDF	-.06	-.24	-.17	-.10
	% Hand-clipped IVDMD	-.69	.94	-.30	-.35
	Gain/ha	.93	.25	.38	.92
	Steer days/ha	.05	-.43	-.11	-.73
	Intake	.47	.82	.48	.63

TABLE VII

Correlations of forage intake with selected factors

	May	June	July	August
Intake x % Fecal N	.80	.55	-.91	.02
% Fecal NDF	-.40	-.71	.81	.23
% Fecal ADF	-.74	-.49	.88	.16
% Fecal Lignin	-.73	-.01	.55	-.58
% Fecal Cell.	-.48	.11	.47	.54
% Esop. N	.81	.69	-.64	-.03
% Esop. NDF	.79	.64	-.12	-.52
% Esop. IVDMD	.84	.54	.99	.89
% Esop. ADF	.70	.97	-.51	.34
% Esop. Lignin	-.98	-.52	-.85	-.86
% Esop. Cell.	-.58	.86	-.30	.47
Avail. forage Kg/ha	.00	-.48	-.75	-.39
Steer days/ha	.76	-.47	-.93	-.70

TABLE VIII

Animal gain with selected fecal and esophageal entities

	May	June	July	August
Gain/ha x % Fecal N	.98	.59	.76	-.77
% Fecal NDF	-.94	-.77	-.95	.92
% Fecal ADF	-.89	-.91	-.19	.84
% Fecal Lignin	-.01	-.58	.31	-.48
% Fecal Cell.	-.97	-.38	-.98	.99
% Esop. N	.57	.82	.90	-.04
% Esop. NDF	-.09	.40	-.22	-.58
% Esop. IVDMD	.20	.99	-.49	.21
% Esop. ADF	.83	.47	.95	-.20
% Esop. Lignin	-.68	-.95	.94	-.10
% Esop. Cell.	.17	.93	.90	-.43

TABLE IX

Animal gains with hand-clipped steer performance entities

	May	June	July	August
Gain/ha x % Hand-clipped ADF	-.67	.06	-.30	.27
% Hand-clipped Lignin	-.82	-.53	-.22	.28
% Hand-clipped Cell.	-.58	.30	-.32	.27
% Hand-clipped N	.99	.99	.55	-.52
Avail. forage Kg/ha	.20	.04	.78	-.74
% Hand-clipped NDF	-.28	-.74	.04	.09
% Hand-clipped IVDMD	-.37	.56	.54	-.64
Steer days/ha	.41	.25	.85	-.92
Intake	.67	.64	-.61	.59

TABLE X

Correlations of esophageal sample dry matter digestion with selected factors

		May	June	July	August
% Esop. IVDMD x	% Esop. N	.80	.83	-.54	-.25
	% Esop. NDF	-.92	.39	-.17	-.15
	% Esop. ADF	.24	.36	-.39	.68
	% Esop. Lignin	-.77	-.93	-.76	-.98
	% Esop. Cell.	-.92	-.87	-.16	.79
	% Hand-clipped IVDMD	.52	.50	-.85	.37

TABLE XI

Correlations of available forage with selected factors

		May	June	July	August
Avail. forage Kg/ha x	% Esop. N	-.56	.29	.52	.70
	% Esop. NDF	.00	.26	.42	-.11
	% Esop. IVDMD	-.35	.18	-.68	-.26
	% Esop. ADF	.63	-.48	.86	-.36
	% Esop. Lignin	-.19	.11	.82	.07
	% Esop. Cell.	.51	-.28	.74	.27

TABLE XII

Correlations of esophageal entities with various factors

	May	June	July	August
% Esop. N x % Hand-clipped N	.70	.86	.74	.06
% Esop. NDF x % Hand-clipped NDF	.96	-.03	.96	.31
% Esop. ADF x % Hand-clipped ADF	-.51	-.16	-.11	-.32
% Esop. Lignin x % Hand-clipped Lignin	.44	.69	-.22	.88
% Esop. Cell. x % Hand-clipped Cell.	.71	.07	-.26	-.84

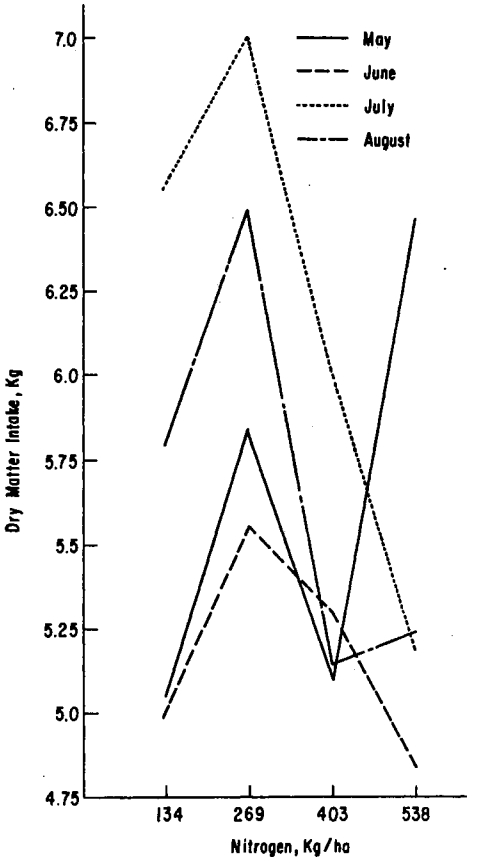

Figure A1. Average Daily Intake

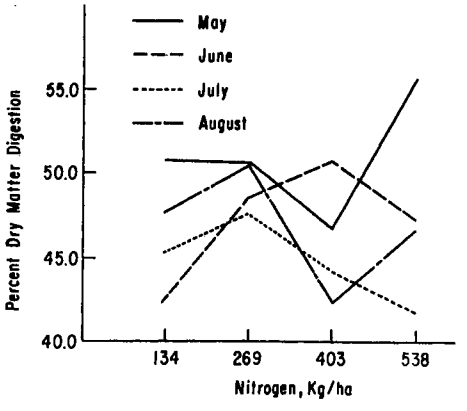

Figure A2. % Esophageal IVDMD

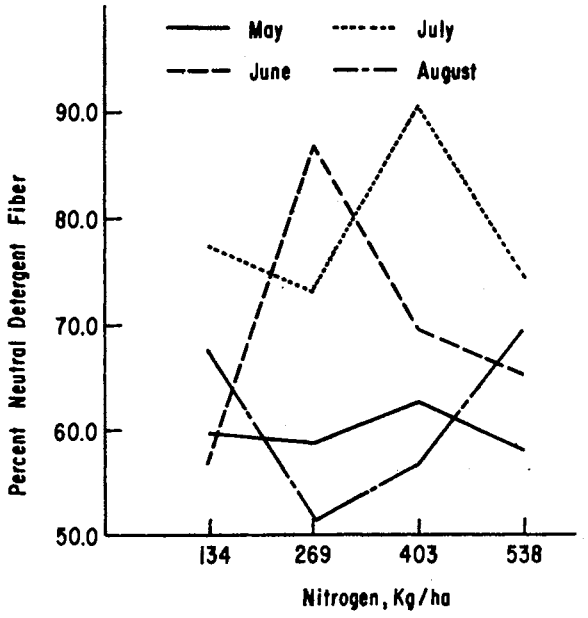

Figure A3. % Esophageal NDF

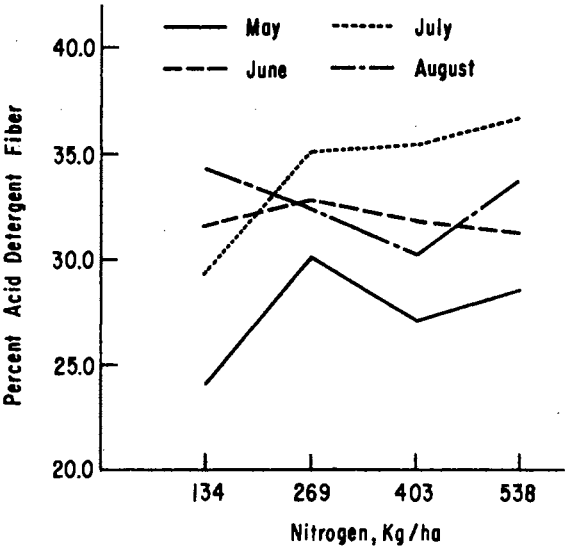

Figure A4. % Esophageal ADF

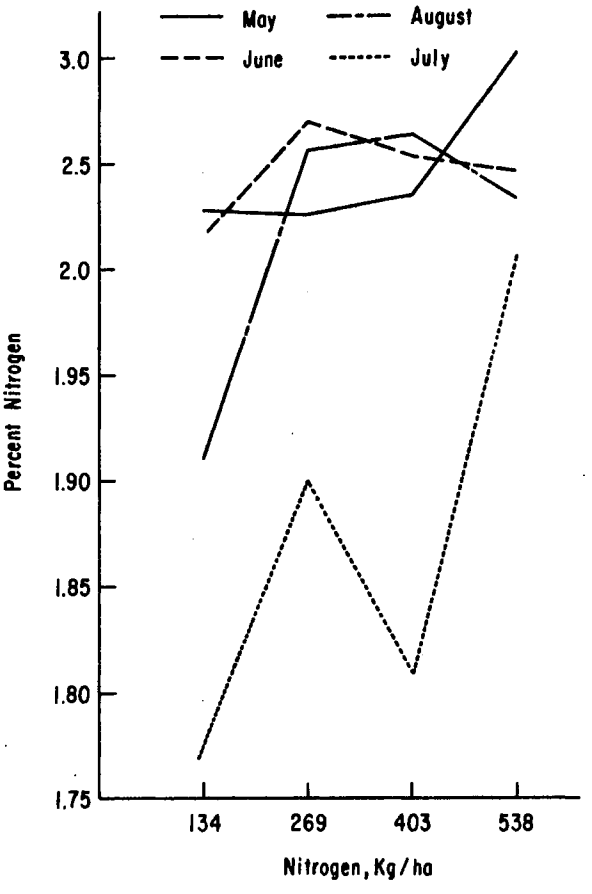

Figure A5. % Nitrogen in the esophageal forage sample

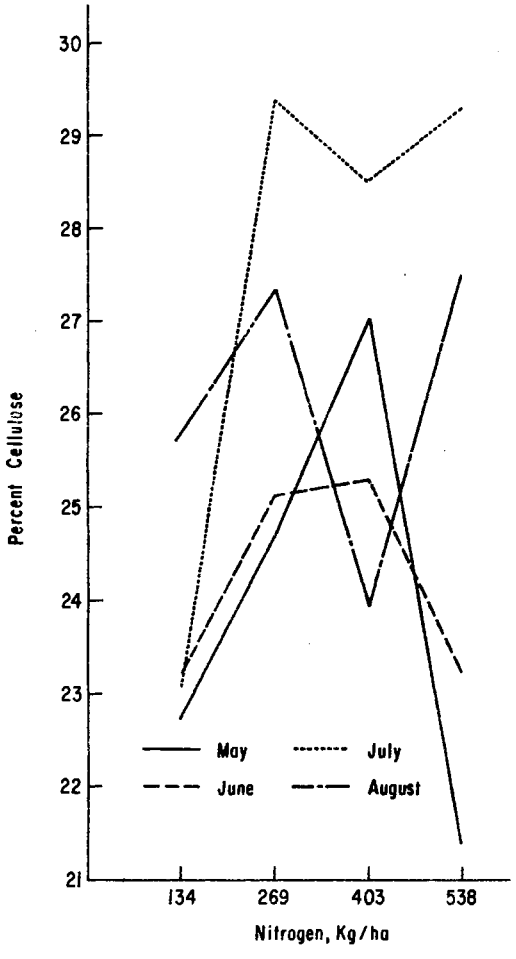

Figure A6. % Cellulose in esophageal samples

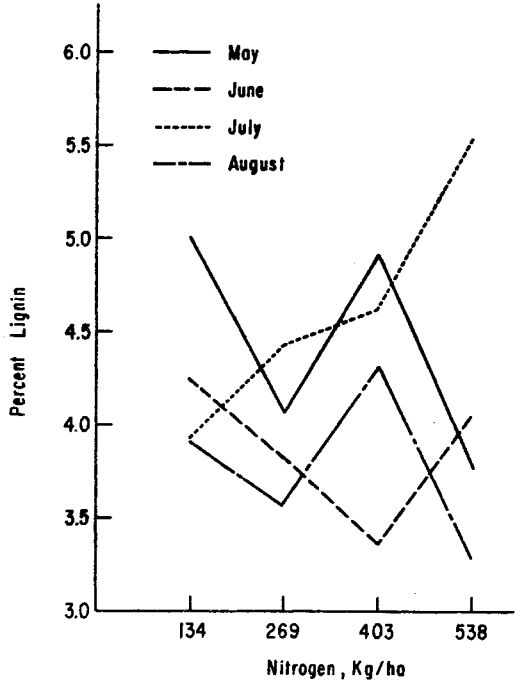

Figure A7. % Lignin in esophageal samples

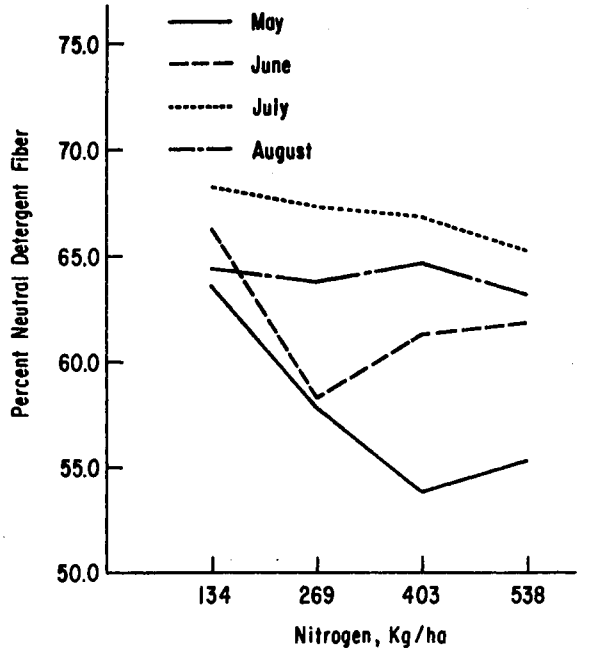

Figure A8. % Fecal NDF

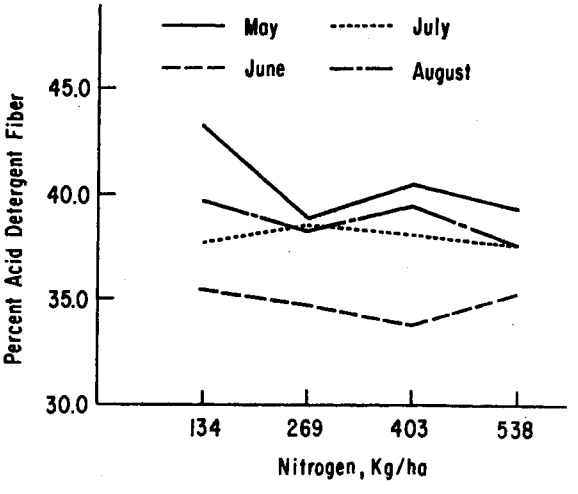

Figure A9. % Fecal ADF

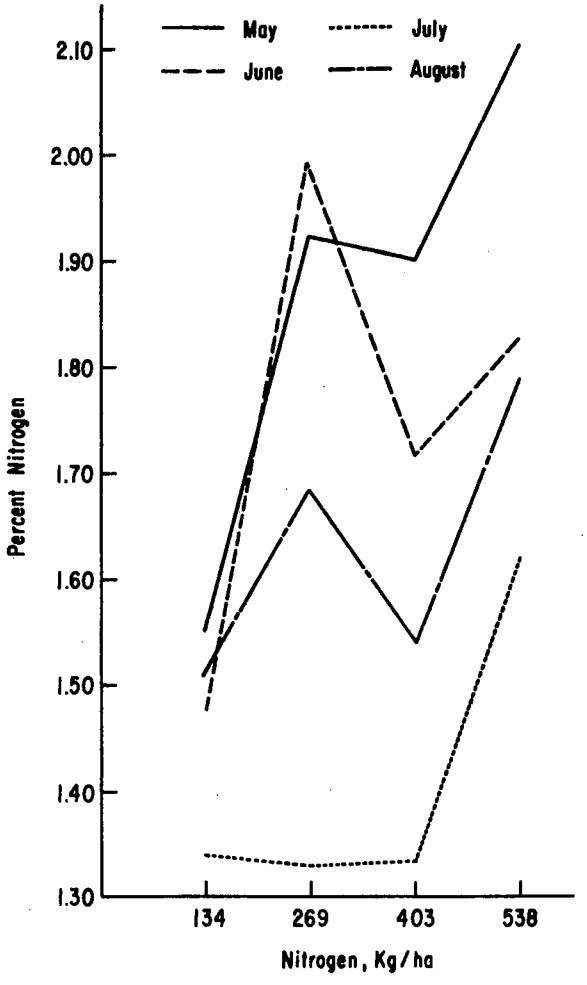

Figure A10. % Nitrogen in fecal samples

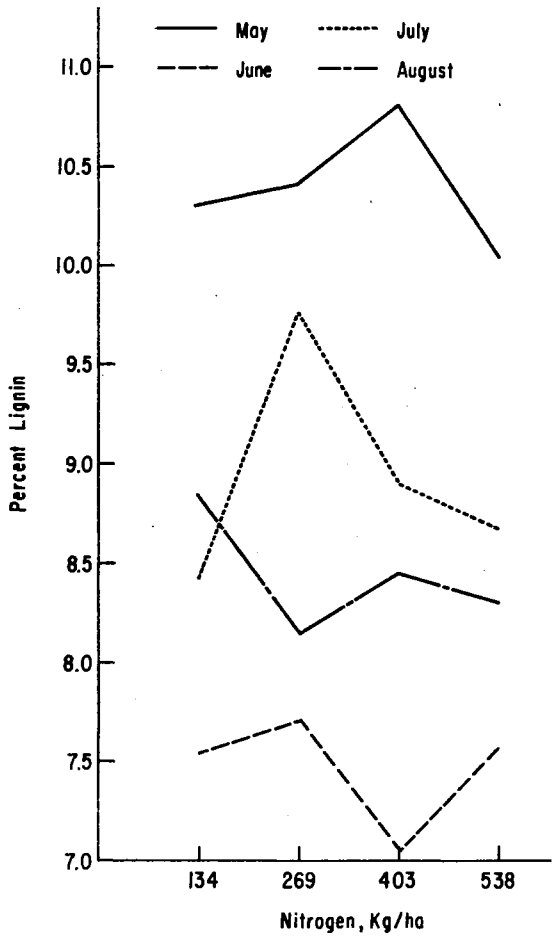

Figure A11. % Lignin in fecal samples

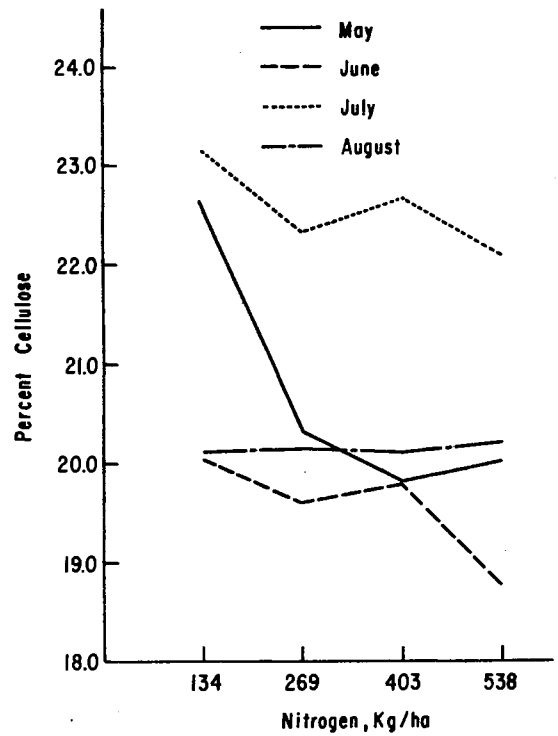

Figure A12. % Cellulose in fecal samples

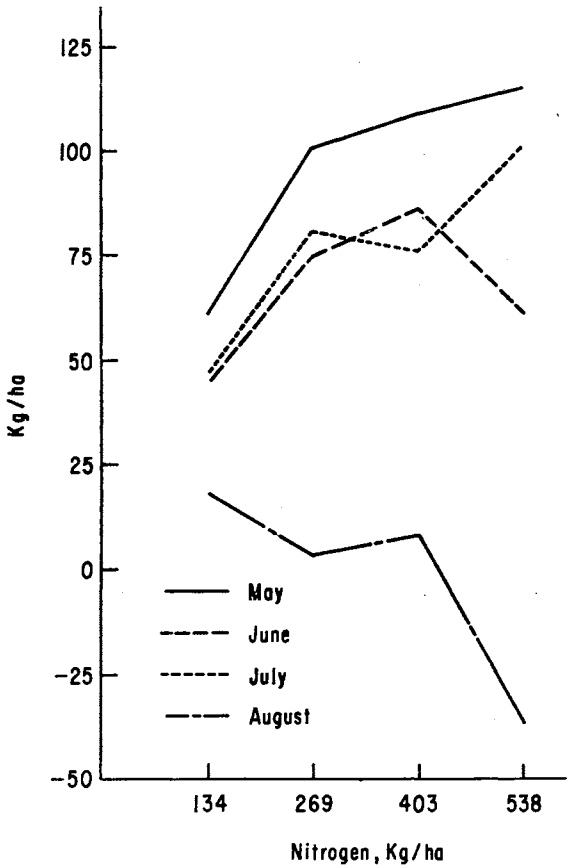

Figure A13. Animal gains per hectare

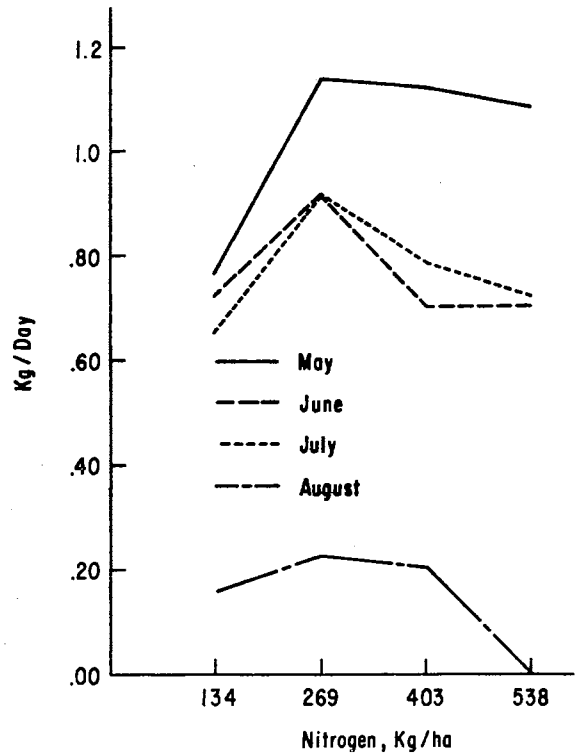

Figure A14. Average daily steer gains

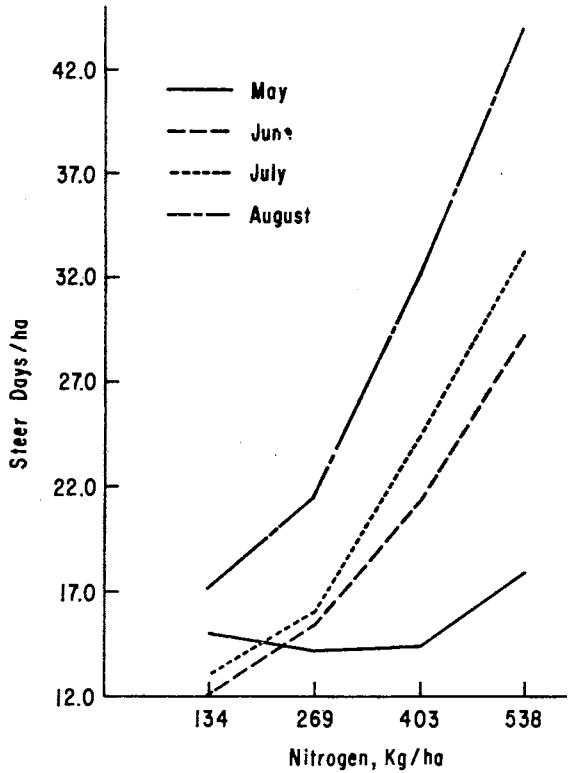

Figure A15. Stocking rate (steer days per hectare)

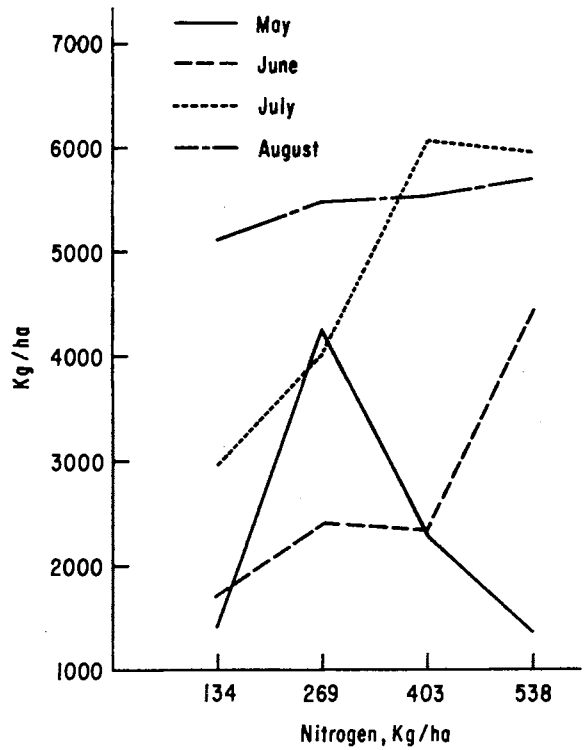

Figure A16. Available forage (kg/hectare)

VITA

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