To the Graduate Council:

I am submitting herewith a dissertation written by Kenneth Wayne Bell entitled "The Influence of Management on Yield and Composition of Tall Fescue (*Festuca arundinacea* Schreb.)." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Plant and Soil Science.

Henry A. Fribourg

H. A. Fribourg, Major Professor

We have read this dissertation and recommend its acceptance:

John H. Reynolds

Vernon H. Reich

J. B. McLaren

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

THE INFLUENCE OF MANAGEMENT ON YIELD AND COMPOSITION OF TALL FESCUE (FESTUCA ARUNDINACEA SCHREB.)

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Kenneth Wayne Bell

March 1981

ACKNOWLEDGMENTS

The author expresses his sincere appreciation to all who contributed assistance and encouragement in any way during this project. Special appreciation goes to:

The Plant and Soil Science Department (Dr. Lloyd F. Seatz, Head) and the Plant Science Farm personnel for the financial and physical support for this study;

Dr. Henry A. Fribourg for the knowledge and assistance received and for serving as Chairman of the Graduate Committee;

Dr. John H. Reynolds for his guidance, assistance and invaluable aid, and for serving on the Graduate Committee;

Dr. Vernon H. Reich for his advice, constructive criticism, and for serving on the Graduate Committee;

Dr. Joseph W. Holloway for the knowledge contributed and for serving on the Graduate Committee;

Dr. J. B. McLaren for his advice and concern, and for serving on the Graduate Committee;

Delaware State College (Mr. U. S. Washington, Jr., Chairman of Agriculture Department) for assistance; Mrs. Jean Nelson and Mrs. Mary Kelley for typing assistance;

My parents, Mr. Odell and Mrs. Mildred Bell, and my brother Dwight for their encouragement and support;

Mr. Rick Carlisle, Mr. Walter Schaeffer and Mr. Tim Bateman for their technical assistance in the field and laboratory;

My fellow graduate students for their fellowship throughout my graduate work.

ABSTRACT

Because of its extensive use in the southeastern U.S. and previous reports of varying quality during the year, the yield, mineral and chemical composition (acid detergent fiber and cell wall constituents) and *in vitro* dry matter digestibility (DMD) of Kentucky 31 tall fescue (Festuca arundinacea Schreb.) grown alone and with ladino clover (*Trifolium repens* L.) was determined over a two-year period involving various stockpiling management practices at Knoxville and Spring Hill, Tennessee, and at Dover, Delaware. All plots received 560 kg/ha of 0-20-20 on 1 June each year; the fescue growing alone received 56 kg N/ha from 6-12-12 on 1 March and an additional 56 kg N/ha as NH_4NO_3 at the beginning of each stockpiling period. Stockpiling periods began in July, August, September, November, or December and lasted from one to seven months. Frequently clipped plots were used to simulate continuous grazing.

Stockpiling treatments starting in July resulted in the highest yields, followed by those begun in August and September. Stockpiling treatments started after September yielded no appreciable growth during the stockpiling period, but did become green earlier and produced higher yields the following spring.

Nitrogen percentages were generally greater in regrowth than in stockpiled fescue. Varying levels of N, concentration, some of which were occasionally below the crude protein requirement for a dry pregnant

beef cow, indicated that animals grazing this forage may need protein supplement.

Peak levels of ADF occurred in January and February at Knoxville and Dover, but those at Dover were generally less than those at Knoxville. Cell wall constituents were greatest in the cooler months. Levels of *in vitro* DMD were higher in the fall (October) and lowest in the summer (August). Regrowth had a higher level of DMD than stockpiled material cut on the same date.

Mineral composition varied during the growing season and among locations. Fescue from similar treatments was generally lower in P, K, and Mg percentage at Dover than at Knoxville, but Ca levels were generally higher at Dover. Frequent clipping to simulate grazing did not affect mineral or chemical composition.

Stockpiling fescue tended to reduce quality, but stockpiled forage can be useful in a grazing system. Season of growth appeared to have a greater effect on composition than date of start of stockpiling or duration of stockpiling.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

CHAPTER I

INTRODUCTION

Tall fescue (<u>Festuca arundinacea</u> Schreb.) is a well-adapted, widely-used forage species in the midsoutheastern United States. Tall fescue has been faulted for low palatability and nutritional value. However, tall fescue has the ability to persist on droughty soils and soils of low fertility; it produces relatively high quality forage during late fall and when temperatures are warm enough during winter.

The ultimate value of a pasture is based on the feed produced and consumed. The nutritive value of a feed is a function of the amount consumed, its digestibility, and the efficiency of utilization of the products of digestion within the body of the animal. Successful systems of wintering animals on minimum amounts of barn-stored forages are important. Tall fescue can be a large component in these systems. In Tennessee beef cattle production is primarily dependent on tall fescue as the major species in permanent pastures.

There is a need for information on the effects of defoliation frequency and other management practices on quality components of tall fescue. Supply of pasture forage often does not coincide with domestic livestock needs. Forage production patterns may be a way to minimize the differences between animal feed requirements and forage supply.

Nutrition is fundamentally chemical in nature. A knowledge of chemical composition of feed consumed, and the reactions involved in digestion, should be sufficient to evaluate a forage through *in vitro* rumen fermentation and/or chemical analysis.

The purpose of this study was to determine the effects of simulated grazing management and stockpiling schemes on year-round quality, composition and productivity of tall fescue.

CHAPTER II

LITERATURE REVIEW

Evaluating forages requires the measurement of quantity and composition of forages produced per unit of land, labor, and capital. Nutritive value of the forage is characterized by its chemical composition, digestibility and nature of the digested products. Forage yield, botanical composition, nutritive value, digestibility, and consumption are methods of evaluation (26).

I. MANAGEMENT AND PRODUCTIVITY

Deferred grazing, or stockpiling, allows grass to accumulate in the fall and/or spring for grazing in winter and summer, respectively. Fall-saved forages can extend the grazing season in Virginia (8). A 15-day delay in cutting date caused a significant reduction in animal performance in Pennsylvania (37).

In order to realize the potential of tall fescue in a beef cattle forage system, high levels of management are required, and these include maximizing yields of quality forage without stand thinning, and utilizing fescue-clover mixtures (47). It has been reported that some managements improve digestibility in Missouri (18,46). Tall fescue maintained digestible dry matter (DDM) best during late fall and early winter when it could be used as fall-saved forage (22,48). McKee, Brown and Blaser (24) suggested that stand reduction by defoliation appears to be related to morphological stage of growth and season in

Virginia. Fall and winter harvesting of fescue caused little or no reduction of spring crop (40). Stockpiled forages are sufficient to satisfy the needs for dry pregnant beef cows (33,40), as recommended by the National Research Council (27).

Rayburn, Blaser and Wolf (31) found in stockpiled fescue canopies, harvested in December, that as time of deferral decreased from June to September the dry matter yields decreased from 3,920 to 840 kg/ha in Virginia. Tall fescue-legume mixtures with no added nitrogen (N) have been reported to yield dry matter approaching that of fescue alone with annual applications of 82 kg N/ha. Fescue-clover mixtures have not been considered as practical to stockpile because rank growth of fescue resulting from deferred grazing may eliminate most of the clover (47).

II. CHEMICAL COMPOSITION

All parts of the plant have high digestibility at early stages of vegetative growth. As maturity increases the digestibility of the stem decreases at a much faster rate than that of the leaf blade. Leaf sheath digestibility in grasses declines at a rate intermediate between that of leaf blade and of stem (3). The decline in digestibility is associated with a reduction in the content of water-soluble and protein constituents in the plant, and with a reduction in digestibility of the fiber (42).

Nonstructural carbohydrates (TNC) such as sugars and starches are readily available sources of energy to animals grazing forages. Jung et al. (17) found that seasonal fluctuation accounted for 75 percent of the variation in TNC in West Virginia. Temperatures low or high enough to cause physiological stress reduced TNC because they retarded carbohydrate accumulation. Average TNC values of cool season grasses were 55 percent higher in spring (May) and 64 percent higher in fall (October) than in summer.

Buckner et al. (12) also found that the grass increased in soluble and decreased in structural cell constituents during the fall season in Kentucky. Other investigators reported similar results (7,9,11,39,40).

Proximate analysis constituents, such as crude protein (CP), fiber, sugars, and moisture, have been associated with and found to be related to digestibility and palatability (12). Methods have been developed to analyze plant materials for chemical constituents (14,45) and minerals (38). Lane et al. (19) studied tall fescue genotypes varying widely in color. Leaf width and growth rate showed considerable variation, but color was found not to be an indicator of crude protein contained in the forage.

Successive cuttings of grasses throughout the growing season to simulate grazing resulted in fluctuations in composition. Protein content was uniform during spring and summer but increased in the fall, whereas lignin decreased in the fall (39).

Acid detergent fiber (ADF) content decreased with lower temperature and shorter day length. Acid detergent fiber, cell wall constituents (CWC) and yield were significantly correlated to in vitro dry matter digestibility (IVDMD) (9,11,36). Fiber, cellulose and ADF digestibility increased with age of plant (29). Allison (1) and Hannaway and Reynolds (16) suggested that neutral detergent fiber (NDF) peaked when stemmy material percentage was greatest. The levels of NDF were generally higher in the warmer months, the water soluble carbohydrates maxima occurred in the cooler months, and there was a high negative correlation between the two. Archer and Decker (2) found that reduced growth ratio and leaf senescence had a pronounced effect on quality of stockpiled forage in Maryland. Temperature did not greatly affect NDF, ADF or lignin. Fiber content increased with time during fall and early winter. Green leaves had lower levels of NDF, ADF and lignin than dead leaves.

Legume percentage in a fescue-legume pasture was found to increase as precipitation levels increased from May to August in Tennessee (6). Under those conditions, animal gains and forage quality were directly related to legume percentage, primarily because legumes contain more readily-digestible starches and sugars.

Crude protein (CP) content of tall fescue has been reported to be high enough throughout the winter to meet the requirements of nonlactating beef brood cows (40). Crude protein content decreased as length of stockpiling period increased (31). There was also a decrease in protein content as age of fescue increased throughout the fall and winter period (10,22,28,34).

Matches, Martz and Stone (23) reported a curvilinear decrease in percent CP from April (24 to 29) to mid July (8 to 10). Later in the season, CP levels ranged from 6 to 9 percent, averaging 7 percent from November to April. In fescue stockpiled from August to early winter, White (49) found a decrease in average CP content from 14 percent in October to 11.5 in January. Seasonal variations of CP have been related to growth activity, protein generally increasing with increases in temperature (7). However, some assert that crude protein cannot be relied upon for assessment of general forage quality (21).

III. MINERAL COMPOSITION

Mineral content in forages has been reported to be higher in the first cutting in spring than in each successive cutting (32). Loveland (20) found stockpiled forage to be lower in phosphorus (P) than continuous clipped fescue, but potassium (K), magnesium (Mg) and calcium (Ca) contents were variable.

Sabbe and Hileman (35) showed that concentration of P and Ca in fescue decreased with age of the forage. Magnesium concentration increased with age. Plant Mg was related to soil Mg only when the fescue was harvested at a young age. There appeared to be a decrease in plant Mg as K increased. Templeton et al. (41) reported a decrease in P and Mg and a tendency toward a decrease of Ca and K with age. Based on NRC requirements for high producing dairy cows, deficiencies of Ca, Mg, and P occurred in some forage but no deficiency of K was noted. In Missouri, Ocumpaugh and Matches (28) reported a linear reduction of about 0.1 percentage unit of K per week through most of the autumn-winter period. Pfander and Rubio (29) also in Missouri reported K content to be at a deficiency level for ewes (0.4%) in March. Hannaway (15) in Tennessee found the highest concentration of K in the cooler months, and also that Ca, Mg, and P concentrations were highest in the warmer months. Reynolds (33) found forage stockpiled from September to May useful for dry pregnant beef cows with Mg supplementation of the May forage. May and September forages were below the P requirements for lactating beef cows, and the May forage also needed Ca supplementation.

IV. DIGESTIBILITY OF TALL FESCUE

In vitro dry matter digestibility of tall fescue winter forage varies from year to year. Date of last summer or fall cutting, N fertilization, climatic conditions, and ratio of senesced to live tissue are factors found to influence IVDMD (4). An increase in dead leaf content decreased IVDMD. Ocumpaugh and Matches (28) found that the IVDMD of stockpiled fescue remained fairly constant (63 to 68 percent) from September to November. After growth was stopped in November by freezing, digestibility decreased. Fribourg and Loveland (13) in Tennessee reported IVDDM greater than 60 percent in fall-stockpiled fescue. Pritchard, Folkins and Pigden (30) found a 0.5 percent per day decrease from 65.3 one week before head emergence to 46.3 postflowering in Canada. They suggested that type of herbage and stage of development influenced the decrease in digestibility. The IVDMD of tall fescue in Canada had dropped to 50 percent by mid-June.

Marten and Hovin (21) reported decreased IVDDM with increased maturation. Bryan et al. (11) found the digestibility of tall fescue to be lowest in June and July, and highest in the fall. In Missouri, Matches et al. (22) reported a gradual decrease in digestibility from May to December. According to Ross and Reynolds (34) IVDMD declined after December or November, 1975 and 1976, respectively, in Tennessee. In contrast Brown et al. (10) in Virginia found that DMD did not decrease but increased with age.

Watson et al. (46) reported differences in digestibility between two locations in Oregon which probably explained the large amount of variation in the data reported.

V. SUMMARY

Tall fescue, when properly managed, can play a major role in a beef cattle forage system. Fescue-legume mixtures without N fertilization have been reported to produce yields comparable to fescue alone with N fertilization. The cool-season growth of tall fescue and its relatively high nutritive value during the fall and winter months is a positive factor for its utilization. Fall-saved fescue can extend pasture use, and has been ample for some classes of beef cattle. Harvesting the forage during fall or winter has resulted in little or no effect on the stand of the spring crop.

Stages of development and protein constituents are associated with the digestibility. As lignin content of stems increases with age, the digestibility of tall fescue decreases. The more soluble forms of carbohydrates are most useful to grazing animals. Physiological stress in the plant has been found to reduce the accumulation of these more available carbohydrates, thus digestibility and nutritive value of tall fescue have been influenced most by season of the year.

Mineral content of forages is higher in the first defoliation in the spring than with each successive defoliation. Phosphorus and Ca concentrations tend to vary inversely with age, while Mg varies directly with age. Calcium, P, and Mg have also been reported most abundant in warmer months, and K was most abundant in the cooler months.

Variations and conflicting results have been reported in digestibility and mineral content of tall fescue. Location and probably the associated (environmental) climatic conditions have been found to have a significant effect on digestibility and chemical composition.

CHAPTER III

MATERIALS AND METHODS

I. FIELD PROCEDURES

Several field experiments were carried out in East and Middle Tennessee, and in Delaware, in which tall fescue was subject to various management schemes.

Two sites were selected on an established stand of Kentucky 31 tall fescue at the Plant and Soil Science Field Research Laboratory, Knoxville, starting on 1 July 1978. The first used a stand of fescue (site 1) and the other a fescue-ladino clover mixture (site 2). The fescue alone had been established on an Etowah clay loam, and the fescue-clover mixture on an Etowah silt loam (fine-loamy, siliceous, thermic Typic Paleudults), 2 to 5 percent slopes.

The second experiment consisting of fescue alone, was established on Maury silt loam (fine, mixed, mesic Typic Paleudalf), 2 to 5 percent slopes, at the Middle Tennessee Experiment Station, Spring Hill. This experiment was initiated on 1 July 1979.

A third experiment was begun on 1 July 1979 on an existing stand of Kentucky 31 tall fescue at the Hickory Hill Agriculture Research Farm, Delaware State College, Dover, on a Sassafras sandy loam (fine loamy, siliceous, mesic Typic Hapludult), 1 to 2 percent slopes.

Experimental designs were, for the fescue growing alone, modified split-plot factorials, with month of initial stockpiling as main treatment and length of stockpiling before sampling as split-plot treatments. For the fescue-clover mixtures, fescue alone or fescue-clover were main treatments, months of initial stockpiling were split-plot treatments, and lengths of stockpiling before sampling were split-split plot treatments. The stockpiling treatments are described in Table 1.

The two sites at Knoxville and the Dover experiment were replicated 2 times, the one at Spring Hill had 3 replications. The smallest experimental unit measured 1.22 × 4.57 m. Data were collected in 1978, 1979 and 1980.

Fescue-only plots received 56 kg N/ha from 6-12-12 on or about 2 March each year, and stockpiled treatments received an additional 56 kg N/ha as NH_4NO_3 at the start of each stockpiling period. Fescue-only plots that were clipped frequently (Treatments 41, 51, 52 and 53) throughout the year received 56 kg N/ha as NH_4NO_3 at beginning of growth in spring. All plots, fescue alone and fescue-clover, received 560 kg/ha of 0-20-20 on or about 1 June each year.

Visual estimates of percentage clover and weeds were recorded for each plot prior to each harvest. An area 2.44 m^2 (0.53 × 4.57 m) was harvested from the center of each plot with a rotary mower at a 5-cm stubble, or at other heights where treatment dictated. Frequent clip consisted of harvesting on or about the first, tenth and twentieth day of each month throughout the year whenever growth exceeded 5 cm in height.

Dry weight of forage harvested from each plot was measured. Drying was done in a forced air oven at 65 C. The dry samples, or

TABLE 1. STOCKPILING SCHEMES GROUPED IN CATEGORIES ACCORDING TO TIME OF STOCKPILING START.

Treatment Number	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
11*	------->											
12	--------------->				--------------->							
13	----------------------->					----------------------->						
14	------------------------------->											
15	--------------------------------------->											
16	--->											
17	--->											
21		------->										
22		--------------->				------------------------------->						
23		----------------------->										
24		------------------------------->										
25		--------------------------------------->										
26		--->										
31			-------->									
32			---------------->				--------------->					
33			----------------------->									
34			------------------------------->									
35			--------------------------------------->									
36			--->									
41	Clipped to 5-cm stubble height 3 times each month throughout year, when growth permitted, starting 1 July.											
51	One-half of growth removed once each month starting 1 July.											
52	One-half of growth removed once each month starting 1 August.											
53	One-half of growth removed once each month starting 1 September.											

*Arrows denote stockpiling periods.

representative samples from the stockpiled materials, were ground in a Wiley Mill to pass a 2-mm screen. These ground samples were used for laboratory analyses.

Grab samples from a pasture with a history of inducing hypomagnesemia at The University of Tennessee Holston Farm, Knoxville, were randomly collected over the pasture at monthly intervals from August 1978 to February 1979. These samples were dried and ground as described above. Precipitation and temperature were recorded daily at the Knoxville Plant Science Field Research Laboratory Climatological Station.

II. LABORATORY PROCEDURES

The ground samples were analyzed for IVDMD, NDF, ADF, total N, Ca, Mg, P, and K. Due to the large number of samples, only selected samples were used for the digestibility, ADF, and NDF analyses.

Digestibility was determined using a revised version (25) of the two-stage Tilley and Terry (44) technique (Appendix Table 12). The design was a simple lattice with two replications over time. The laboratory replications coincided with field replications.

Neutral detergent fiber analyses were performed according to the method described by Van Soest (45) and Marcus and used to determine cell wall constituents (CWC). The Goering and Van Soest (14) technique was employed for determining ADF.

Crude protein was determined after forage samples were digested in concentrated H_2SO_4 and 35 percent H_2O_2. The analysis was done with the phenolhypochlorite reaction in a Technicon autoanalyzer. Potassium and

Ca concentrations were determined with a Technicon III dual flame photometer. Magnesium concentrations were determined colorimetrically by the ammonium vanadate reaction in the autoanalyzer. These autoanalyzer procedures have been described by Steckel and Flannery (38), and reported to yield results comparable to those from other known procedures (43). Concentrations for each element were reported on a percentage dry weight basis.

III. STATISTICAL ANALYSES

Data analyses were performed on the IBM 370-3031 at The University of Tennessee Computer Center. Procedures of the Statistical Analysis System (SAS) described by Barr et al. (5) were used.

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECT OF CLOVER

The mean percentages of legumes in each experiment, by harvest dates, are presented in Table 2. The lack of difference in clover content between the two sites may be attributed to the volunteer clover that grew in the plots that were supposed to have been fescue alone, thus lessening the potential effect of legumes at the fescue-clover site. The percentages are similar for the two sites. However, the overall mean percentages for sites 1 and 2 were 52 to 58 percent less the second year than the first. This reduction may have been a result of the treatments imposed. Due to lack of noticeable difference, the fescue and the fescue-clover sites at Knoxville will be pooled in summary tables across years.

II. YIELD

Dry matter yields of tall fescue at Knoxville are summarized in Table 3 and are presented for each year and location in Appendix Tables 13, 14, 15 and 16. In experiment 1, yields of fescue from stockpiling treatments which began in July 1978 ranged from 872 to 6,579 kg/ha; those where stockpiling began in August and September ranged from 1,971 to 3,256 and 454 to 1,043 kg/ha, respectively. Yields of treatments where stockpiling began in September were smaller than those of treatments

TABLE 2. LEGUME AND WEED CONTENT OF SITES AT KNOXVILLE.
(Mean of Two Replications)

Harvest Date	Site 1 Legume (%)	Site 1 Weed (%)	Site 2 Legume (%)	Site 2 Weed (%)
		1978—1979		
3 Jul 78	42	21	20	15
10 Jul 78	38	5	30	3
20 Jul 78	35	4	19	3
1 Aug 78	26	20	26	11
14 Aug 78	22	10	18	9
29 Aug 78	12	25	17	12
13 Sep 78	16	14	17	16
29 Sep 78	18	10	18	14
30 Oct 78	1	5	5	7
6 Dec 78	3	7	4	7
4 Jan 79	1	23	3	15
1 Feb 79	0	12	0	15
2 Mar 79	0	10	4	9
21 Mar 79	1	12	8	5
10 Apr 79	2	12	10	5
30 May 79	5	20	11	8
2 Jul 79	7	5	9	6
Mean	13.4		12.8	
		1979—1980		
23 Jul 79	10	16	16	9
31 Jul 79	8	7	9	9
8 Aug 79	3	5	5	10
20 Aug 79	6	11	5	9
29 Aug 79	7	11	7	10
10 Sep 79	6	14	7	10
1 Oct 79	11	12	6	10
9 Oct 79	4	8	5	9
31 Oct 79	4	4	5	8
3 Dec 79	4	6	4	10
3 Jan 80	4	10	3	11
25 Feb 80	3	12	5	14
10 Mar 80	4	6	3	9
Mean	5.6		6.1	

TABLE 3. MEAN DRY MATTER YIELDS OF TALL FESCUE SITES AT KNOXVILLE, JULY 1978-MARCH 1980.

Treatment	Stockpiling Started	Stockpiling Duration (Mos)	Jul Early	Jul Mid	Jul Late	Aug Early	Aug Mid	Aug Late	Sep Early	Sep Mid	Oct Early	Oct Mid	Early Nov	Early Dec	Early Jan	Early Feb	Mar Early	Mar Mid	Mar Late	Mid Apr	Early June
			kg/ha																		
11	Jul	1	136+			1024	369	154	106	331	322	75	51	28						239	207
12	Jul, Nov	2+2							2977	398	264	104	75	54						272	263
13	Jul, Dec	3+3									4733	172	148	118					210	354	315
14	Jul	4											4331	157						192	179
15	Jul	5												3984	118			67	114	160	118
16	Jul	6													3925			90	202	184	158
17	Jul	7														2721	3739++	97	193	205	171
21	Aug	1	169						1066	485	395	90	75	48						219	226
22	Aug, Dec	2+2.5								561	2843	151	99	37						327	257
23	Aug	3											3012	137					136	264	290
24	Aug	4												2796	106			73		163	132
25	Aug	5													2486			94	255	497	169
26	Aug	6														2353	1935++	102	222	226	167
31	Sep	1	159								1350	125	111	36						284	333
32	Sep	2											1406	129						359	433
33	Sep	3												1428	68				241	334	323
34	Sep	4													1142			104		348	324
35	Sep	5														1229		72	286	294	267
36	Sep	6															1580++	388	346	365	324
41	Frequently clipped Starting 1 Jul		148	78	332	420	351	119	133	405	320	84	56	34						256	188
51	Clipped 1/2 growth Starting 1 Jul		170		557	1043	676		422		1170		90	46					129	247	226
52	Clipped 1/2 growth Starting 1 Aug		158		780	306			1081		1206		149	73					110	221	203
53	Clipped 1/2 growth Starting 1 Sept		190						823		1203		148	40	57				130	226	252

+Mean of all years.

++Numbers are a result of delayed cutting of February harvest in 1980.

where stockpiling started in July or August. The August stockpiling treatments produced intermediate yields.

All stockpiling treatments showed a tendency toward a decline in yield by January or February. This may be explained by leaching of soluble materials from plants and senescence of plant parts.

Fescue in treatments where stockpiling was initiated in November or later did not grow appreciably during the stockpiling period; however, those treatments where stockpiling started in September or later became green earlier the following spring and produced slightly higher yields in April and May than other treatments. This was probably related to the N fertilizer application at the start of stockpiling as well as to the canopy cover and thermal protection provided by the stockpiled forage.

Date of start of clipping, or height of clipping, did not result in any noticeable effect on yield of plots that were frequently clipped. No frequently clipped treatment produced sufficient growth to harvest between December and March. This may be explained in part by reports that fescue will not grow when mean temperature is below 4 C. Even though no visual difference in growth vigor was apparent between the two sites in Knoxville, the forage yield of fescue grown alone in site 2 was less than that from corresponding treatments in site 1. The difference in yield was probably due to the thicker broadcast stand in site 1, compared to a drilled stand in site 2. In site 2, the yields from plots where stockpiling began in July ranged from 475 to 5,241 kg/ha. The smallest yield for this group of treatments was in March, compared to August for the corresponding group in site 1.

These differences were less during the period September to December, probably due to slower clover growth with cooler weather, and little associated rhizobia activity. The lesser yield was also due to the fact that no N fertilizer was applied at the start of stockpiling where clover had been established in the stand. Dry matter yield trends at Knoxville from July 1979 to March 1980 were similar to those noted in 1978-79. Site 2 produced slightly larger yields in 1979-80 than in 1978-79. Yields of site 1 in 1979-80 were slightly more than those from site 2 for the same year, but less than those of site 1 in 1978-79. Treatments where stockpiling began in September had the greatest increase in yield in both sites. Those yields ranged from 209 to 1,043 kg/ha in 1978-79 and 780 to 2,989 kg/ha in 1979-80. The yields of frequently clipped treatments were slightly more in 1979-80 than in 1978-79 but the yield patterns were similar.

Dry matter yields at Dover in 1979-80 were less than those recorded for corresponding treatments at Knoxville for the same year, with the exception of the first month of treatments when stockpiling began in July or August. This may be explained in part by the younger stand at Dover. The yields of stockpiling treatments started in July at Dover ranged from 2,806 to 2,909 kg/ha (Appendix Table 17). Treatments where stockpiling began in August and September ranged from 1,842 to 2,110 and 719 to 1,196 kg/ha, respectively. The frequently-clipped treatment in Dover showed a peak yield in mid-July and declined with each successive cut until late August. A second but smaller increase in yield was also noted in early September. Similar patterns were noted in Knoxville both years, however, in Knoxville the changes occurred approximately one week later in the season than in Dover, and the peak occurred in the fall in Knoxville and the late spring in Dover. This may be explained in part by the different temperature regimes at the two locations and the fact that fescue is a cool-season grass.

Yields at Spring Hill (Appendix Table 18) tended to be less than those of corresponding treatments at Knoxville during 1979-80. Yields at Spring Hill were more than the yield recorded for corresponding treatments at Dover with the exception of the first month of stockpiling treatments that began in July and August. This may be an indication of the need to begin stockpiling at an earlier date in Dover due to differences in climatic conditions. It may also have been influenced by the rapid leaching of nitrogen applied at the beginning of stockpiling on the sandy soil in Dover.

III. CHEMICAL COMPOSITION

Nitrogen

A summary of the N percent in tall fescue during the two-year period at Knoxville is presented in Table 4, and for each harvest in Appendix Tables 19, 20 and 21. Nitrogen levels at Knoxville ranged from 0.95 to 3.24 and from 1.32 to 3.32 percent in 1978-79 and 1979-80, respectively. During 1979-80 there was more variation in N percentage; the highest level recorded for the year (3.32) was in late July. The range of N levels was considerably less at Dover (.26 to 1.87) than at Knoxville. The low levels may have been influenced in part by the sandy soil. An increase in the length of stockpiling at Dover decreased N

TABLE 4. MEAN NITROGEN PERCENTAGE IN DRY MATTER OF TALL FESCUE AT KNOXVILLE, 1978-80.

Treatment	Stockpiling Started	Stockpiling Duration (Mos)	Jul Early	Jul Mid	Jul Late	Aug Early	Aug Mid	Aug Late	Sep Early	Sep Mid	Early Oct	Early Nov	Early Dec	Early Jan	Early Feb	Mar Early	Mar Late	Mid Apr	Late May
11	Jul	1				2.41	2.29		2.09	1.46	1.98	1.82	1.89	1.68				3.00	1.44
12	Jul, Nov	2+2							1.50	1.48	1.75	1.69	1.69					2.90	1.67
13	Jul, Dec	3+3									1.55	1.78		1.32			3.11	3.07	1.24
14	Jul	4											1.69					3.05	1.89
15	Jul	5											1.55				2.99	3.02	1.66
16	Jul	6												1.07			2.86	3.02	1.46
17	Jul	7													0.95		3.14	3.02	1.61
21	Aug	1							2.08	1.55	1.77	1.93	1.44	1.50				3.06	1.86
22	Aug, Dec	2+2.5									1.34	1.58	1.40					3.05	1.85
23	Aug	3										1.69	1.48	2.72			3.00	3.05	2.03
24	Aug	4											1.56	1.66				3.01	1.64
25	Aug	5												1.27			2.93	3.09	1.41
26	Aug	6													1.17			3.05	1.50
31	Sep	1									2.17	1.17	2.29					3.04	1.54
32	Sep, Jan	2+2											2.04					3.14	1.70
33	Sep	3											2.20				2.95	3.03	1.90
34	Sep	4												1.76				2.98	1.84
35	Sep	5													1.86	2.03		3.06	1.77
36	Sep	6																3.16	1.70
41	Frequently clipped		2.64	2.59	2.65	2.82	2.28		2.02	1.53	1.72		2.02					3.10	1.69
51	Clipped 1/2 growth each month, beginning beginning 1 Jul		2.64			2.80		2.41	2.24		1.68		2.08					3.12	1.87
52	Clipped 1/2 growth each month, beginning 1 Aug								2.17		1.68		1.84					3.12	1.59
53	Clipped 1/2 growth each month, beginning 1 Sep								1.93		1.64		2.10					3.14	1.62

content (Appendix Table 22). The highest percentages of N at Dover were recorded in September and October. There was no apparent explanation for the fluctuation in N percentage, but similar variability has also been reported by Sullivan et al. (39), who found that successive cuttings during the growing season caused fluctuations.

Percent N in tall fescue of frequently clipped plots appeared to be influenced more by season of the year than by time of starting the clipping. Nitrogen levels for continuously clipped treatments did not differ noticeably from those in stockpiling treatments. Animals grazing stockpiled forage may require a protein supplement in order to maintain an adequate protein level.

Acid Detergent Fiber and Cell Wall Constituents

Acid detergent fiber appeared to be lowest during the spring and summer both years at Knoxville (Table 5). The peak levels of ADF in 1978-79 at Knoxville occurred in January (Appendix Table 23). The ADF content in 1979-80 at Knoxville is presented in Appendix Table 24. Peak levels in 1979-80 were slightly more than in 1978-79. The ranges were 19.3 to 41.2 and 29.1 to 44.8 percent in 1978-79 and 1979-80, respectively.

Acid detergent fiber levels at Dover are presented in Appendix Table 25. Levels at Dover ranged from 25.8 to 38.4 percent. Peak levels of ADF in stockpiling treatments at Dover occurred in January and February and were considerably less than those at Knoxville.

Cell wall constituents at Knoxville ranged from 44.1 to 73.6 percent in 1978-79 and 56.5 to 74.6 percent in 1979-80. A summary of

TABLE 5. MEAN PERCENTAGE OF ACID DETERGENT FIBER AT KNOXVILLE, JULY 1978-MARCH 1980.

Treatment	Stockpiling Started	Stockpiling Duration (Mos)	Early Jul	Early Aug	Early Sep	Early Oct	Farly Nov	Early Dec	Early Jan	Early Feb	Early Mar	Mid Mar	Early Apr	Mid Apr	Early May
11	Jul	1		30.9											
12	Jul, Nov	2+2			32.1	36.2									
13	Jul, Dec	3+3				33.9	33.8		39.6						
14	Jul	4					35.4	28.9						21.3	
15	Jul	5						35.7	31.6						
16	Jul	6							40.5						
17	Jul	7			30.6					40.4	45.8				
21	Aug	1			30.2										
22	Aug, Dec	2+2.5				32.1									
23	Aug	3					33.0								
24	Aug	4						35.2							
25	Aug	5							38.0			42.1			
26	Aug	6								37.6	42.2				
31	Sep	1				33.2									
32	Sep, Jan	2+2					31.0								
33	Sep	3						29.1							
34	Sep	4							34.3						
35	Sep	5								35.6	41.9				
36	Sep	6											32.5	25.3	
41	Frequently clipped starting 1 Jul		27.6	34.1	29.8	33.4	34.7	36.0							26.9
51	Clipped 1/2 growth each month beginning 1 Jul			29.5		30.0	29.1								
52	Clipped 1/2 growth each month beginning 1 Aug				35.0	32.0	37.9								
53	Clipped 1/2 growth each month beginning 1 Sep														

the two years is presented in Table 6. The CWC levels were generally highest in January and February both years at Knoxville (Appendix Tables 26 and 27). These data are similar to those reported by Hannaway and Reynolds (16) in Tennessee, where NDF was higher in the warmer months, and by Archer and Decker (2) in Maryland, where green leaves had lower levels of NDF than dead ones. Percent CWC at Dover is presented in Appendix Table 28. The levels of CWC at Dover exhibited more variation throughout the growing season than at Knoxville. At Dover the levels ranged from 55.7 to 73.1 percent, the peak levels also occurring in January and February.

IV. IN VITRO DRY MATTER DIGESTIBILITY

Percent DMD was lowest in August (31 percent) during 1978-79 (Table 7). Increased length of stockpiling tended to increase digestibility. The results were similar to those reported by Brown et al. (10) in Virginia. This may partially be accounted for by the relatively mild temperatures during the fall of 1978 and the winter of 1979 (Appendix Table 48). Digestibility was significantly different among treatments in 1978-79. The coefficient of variation, coefficient of determination and mean DMD are presented in Appendix Table 29. The level of DMD ranged from as low as 38 percent in August to as high as 77 percent in October during 1979-80. Regrowth cut the same day as stockpiled material had a higher percentage DMD. The samples from the fescue-clover experiment did not have a greater percentage DMD than those from fescue-alone in either year.

TABLE 6. MEAN PERCENTAGE OF CELL WALL CONSTITUENT AT KNOXVILLE, JULY 1978-MARCH 1980.

Treatment	Stockpiling Started	Stockpiling Duration (Mos)	Early Jul	Early Aug	Early Sep	Early Oct	Early Nov	Early Dec	Early Jan	Early Feb	Early Mar	Early Apr	Mid Apr	Early May
11	Jul	1		65.7	61.9									
12	Jul, Nov	2+2			61.9	72.7								
13	Jul, Dec	3+3				71.0	57.0	60.3	63.0					
14	Jul	4					68.4	61.9					51.5	
15	Jul	5						70.3						
16	Jul	6							68.5					
17	Jul	7								73.5	68.2			
21	Aug	1			64.3									
22	Aug, Dec	2+2.5				64.8								
23	Aug	3					66.3							
24	Aug	4						66.3						
25	Aug	5							62.4					
26	Aug	6								71.2	68.8			
31	Sep	1				67.7								
32	Sep, Jan	2+2					63.1							
33	Sep	3						62.5						
34	Sep	4							65.5					
35	Sep	5								66.1	65.8			
36	Sep	6									65.2		52.9	
41	Frequently clipped starting 1 Jul		55.3	66.0	68.0		68.8	57.1						51.5
51	Clipped 1/2 growth each month beginning 1 Jul			66.2		63.9								
52	Clipped 1/2 growth each month beginning 1 Aug				62.3	62.9	67.5	58.3				46.7	51.4	
53	Clipped 1/2 growth each month beginning 1 Sep							55.8					55.5	51.5

TABLE 7. PERCENT DRY MATTER DIGESTIBILITY OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1978-80.

Treatment	1978-79											1979-80							
	3 Jul	20 Jul	1 Aug	29 Aug	13 Sep	29 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	30 Jul	29 Aug	1 Oct	31 Oct	3 Dec	3 Jan	4 Feb	10 Mar
(Fescue alone)																			
11			39	46		53	52	47				59	48	47	74				
12				45	58	72	46	44					62	50	70				
13						61	51										64		
14							51	53						48		58			
15								62								63	60		
16									66							57	66		
17									75	60								72	
21				37	54	58	50	59					45		76				
22						53	46	54							77				
23							42	57							55				
24																53	66		
25									66								56		
26									76	59								60	70
31						57	54	53					38	40					
32							45	49					43			40			
33													42	43	48	44			
34									52							57	56	47	
35									53	61								72	
36											53								65
41	45	47	37	45		69	46	37				48	49		75	56			
51	53		37	36		59	45	44				39	48		74				
52	48		31	38		56	43	57				39	47		71	51			
53				33		51	51	43					50						
(Fescue-clover)																			
11				37			48	52					60		52				
12				32			54	59					50		46				
13							59								43				
14							52	57								58			
15								58								62	66		
16									60							45	68		
17										60								70	
21						62	46								53				
22							47	63							51				
23							41	46							49				
24								55								65			
25									57								64		
26										59								74	
31						49	47	51							40	37			
32							57	52								35			
33								58								44	45		
34									49								65		
35									54	56								60	
36											55								59
41				33			36	40				49	48		55				
51	39		37	48			36	43				50			43	44			
52	45		60	48			55	48				47			48				
53															47				

There was a significant difference among runs, treatments and blocks in 1979-80, although the previous year, there was no significant difference between runs. Coefficient of determination (0.71 to 0.87) and mean digestibility increased in 1979-80 from the previous year, and coefficient of variation decreased (18.1 to 14.3).

V. MINERAL COMPOSITION

Phosphorus

Phosphorus content of tall fescue at Knoxville during 1978-79 varied but was generally higher in the spring (March, April and May) than at other times (Table 8). Sites 1 and 2 were similar in P content except during July and August when site 1 had a greater P content than site 2 (Appendix Tables 30 and 31). Table 7 shows that percent P at Knoxville in both years was generally higher in March to early July than during other periods in the growing season.

From September 1978 to March 1979, most treatments were below the minimum P requirement (0.18 percent) of a 450-kg beef cow at least once, whereas in the 1979-80 experimental period no treatment had a P level below the minimum requirement (Appendix Table 32). There is no apparent explanation for this difference. There was considerable difference in the ranges of P content in site 1 and site 2 during 1978-79. The ranges were 0.11 to 0.79 and less than 0.01 to 0.56 percent for sites 1 and 2, respectively. Phosphorus levels in tall fescue were less variable at Dover (Appendix Table 33). The range was 0.20 to 0.52 percent. Levels of P at Dover were not found to be below the requirement for a 450-kg dry pregnant beef cow at any harvest date during the experimental

TABLE 8. MEAN PERCENTAGE OF PHOSPHORUS IN DRY MATTER OF TALL FESCUE AT KNOXVILLE, 1978-80.

Treatment	Stockpiling		Jul			Aug		Sep		Early	Early	Early	Early	Early	Mar		Mid	Early
	Started	Duration (Mos)	Early	Mid	Late	Early	Mid	Early	Mid	Oct	Nov	Dec	Jan	Feb	Early	Late	Apr	June
11	Jul	1				0.38	0.74	0.48	0.43	0.35	0.14	0.22	0.35				0.47	0.37
12	Jul, Nov	2+2						0.34	0.34	0.35	0.14	0.18	0.26				0.47	0.36
13	Jul, Dec	3+3								0.31	0.26	0.36	0.34			0.53	0.48	0.37
14	Jul	4								0.39	0.13	0.17					0.45	0.35
15	Jul	5								0.36	0.38	0.12	0.33			0.37	0.48	0.37
16	Jul	6											0.13			0.36	0.47	0.36
17	Jul	7												0.10		0.42	0.48	0.37
21	Aug	1						0.37	0.39	0.23	0.15	0.24	0.30				0.46	0.34
22	Aug, Dec	2+2.5								0.22	0.11	0.23					0.48	0.35
23	Aug	3								0.34	0.15	0.20	0.50			0.39	0.47	0.34
24	Aug	4								0.35	0.38	0.19	0.40				0.48	0.35
25	Aug	5								0.34	0.39		0.14			0.40	0.48	0.35
26	Aug	6												0.13		0.44	0.47	0.34
31	Sep	1						0.37		0.21	0.04	0.27					0.46	0.37
32	Sep, Jan	2+2						0.38		0.50	0.09	0.24					0.50	0.39
33	Sep	3						0.40		0.48		0.25	0.36			0.49	0.50	0.38
34	Sep	4						0.40		0.48			0.21				0.49	0.39
35	Sep	5						0.38						0.17		0.42	0.49	0.40
36	Sep	6						0.38							0.22	0.43	0.49	0.39
41	Frequently clipped starting 1 Jul		0.46	0.34	0.28	0.35	0.35	0.42	0.43	0.31	0.07	0.28					0.47	0.34
51	Clipped 1/2 growth each month beginning 1 Jul		0.78	0.12		0.34		0.45		0.23	0.13	0.25				0.41	0.45	0.35
52	Clipped 1/2 growth each month beginning 1 Aug		0.77			0.35		0.40		0.23	0.08	0.23				0.41	0.46	0.32
53	Clipped 1/2 growth each month beginning 1 Sep		0.77					0.47		0.28	0.05	0.28	0.46			0.42	0.46	0.33

period. Increase in length of the stockpiling period tended to decrease P content at all locations. This may be accounted for in part by the lateness in the growing season as length of stockpiling increased.

Potassium

A summary of the percentage of K contained in tall fescue during a two-year period at Knoxville in presented in Table 9. Potassium content was lower during December to February than at any other time.

The K content for 1978-79 in sites 1 and 2 is presented in Appendix Tables 34 and 35. The stockpiled treatments generally had a lower K percentage than the frequently clipped fescue in site 1. The K content of tall fescue in site 2 was considerably higher than that of most corresponding treatments in site 1. Some treatments had fallen below the minimum requirement (0.8 percent) of a 450-kg dry pregnant beef cow by October in site 1 and by January in site 2. Potassium content of tall fescue at Knoxville during 1979-80 is presented in Appendix Table 36. Levels of K were generally lower during December and January than during any other time of the experimental period. Potassium levels never fell below the minimum requirement of a 450-kg dry pregnant beef cow in Knoxville during 1979-80.

The levels of K in Dover ranged from 0.62 to 3.04 percent (Appendix Table 37). The concentration of potassium decreased as the growing season progressed from July to March. The highest percentages of K were recorded in August. Deficient levels of K for a dry pregnant beef cow were first noted in February at Dover.

TABLE 9. MEAN PERCENTAGE OF POTASSIUM IN DRY MATTER OF TALL FESCUE AT KNOXVILLE, 1978-80.

Treatment	Stockpiling Started	Stockpiling Duration (Mos)	Jul Early	Jul Mid	Jul Late	Aug Early	Aug Mid	Aug Late	Sep Early	Sep Mid	Early Oct	Early Nov	Early Dec	Early Jan	Late Mar	Mid Apr	Late May
11	Jul	1				2.88	2.81		2.32	1.85	1.74	1.28	1.23	1.06		3.84	2.64
12	Jul, Nov	2+2							2.56	1.52	1.55	1.16	0.98			3.82	2.67
13	Jul, Dec	3+3								1.55	2.09	1.04	1.67	0.92	2.97	3.87	2.64
14	Jul	4									2.18	1.66	0.98			3.88	2.77
15	Jul	5									2.20	2.52	1.00	0.93	2.11	3.71	2.77
16	Jul	6												0.18	2.29	3.56	2.71
17	Jul	7													2.40	3.70	2.69
21	Aug	1							2.85	1.75	1.56	1.23	0.90	0.92	3.07	3.49	2.60
22	Aug, Dec	2+2.5									1.98	1.24	1.09		2.99	3.57	2.67
23	Aug	3									1.90	1.84	1.30	1.44	2.34	3.69	2.65
24	Aug	4									1.59	2.12	0.92	0.98		3.39	2.62
25	Aug	5									1.62	2.14		0.16	2.46	3.51	2.67
26	Aug	6													2.50	3.45	2.53
31	Sep	1							2.12		2.14	1.30	1.47			3.45	2.59
32	Sep, Jan	2+2							2.35		2.32	1.58	1.29			3.74	2.73
33	Sep	3							2.31		1.58		1.40	1.53	2.79	3.65	2.72
34	Sep	4							2.25		2.24			0.66		3.65	2.75
35	Sep	5							2.20						2.79	3.56	2.75
36	Sep	6							2.11		2.10				2.76	3.64	2.84
41	Frequently clipped beginning 1 Jul		2.59	2.37	3.19	3.92	3.32		2.54	2.10	1.82	1.06	1.26		3.07	3.55	2.59
51	Clipped 1/2 growth each month beginning 1 Jul		2.71			3.10	3.45		2.71		1.86	0.99	1:15		2.69	3.58	2.60
52	Clipped 1/2 growth each mongh beginning 1 Aug		2.59			2.99			2.94		1.84	0.77	1.07		2.70	3.71	2.63
53	Clipped 1/2 growth each month beginning 1 Sep		2.59						2.46		1.92	0.80	1.25	1.28	2.69	3.65	2.60

Magnesium

The Mg content of tall fescue varied (Table 10) at Knoxville and was generally lowest in early June. This trend was more obvious in site 2 (Appendix Table 39) than in site 1 (Appendix Table 38) during 1978-79. Magnesium content did not fall below the minimum requirement of a 450-kg dry pregnant beef cow (0.10 percent) at either Dover (Appendix Table 41) or Knoxville (Appendix Table 40) during 1979-80. Levels of Mg at Dover showed less variation than those at Knoxville, where the range was from 0.20 to 0.40 percent. In the experimental period July to March at Dover the peak levels of Mg were recorded in July and the lowest levels were in November.

Calcium

The mean percentage of Ca for the two-year period was generally lower during February and March than at any other period during the growing season (Table 11). Levels of Ca in tall fescue dry matter were generally greater in site 2 (Appendix Table 42) than in site 1 (Appendix Table 43). Calcium content in tall fescue at Dover (Appendix Table 45) was generally higher than that of corresponding treatments at Knoxville. Calcium levels at Knoxville were higher in 1979-80 (Appendix Table 44) than for corresponding treatments in 1978-79, with the exception of those plots cut in December when Ca levels were quite similar.

General Discussion

The relatively large yields of treatments where stockpiling started in July may mean that stockpiling of fescue starting in mid-June may be

TABLE 10. MEAN PERCENTAGE OF MAGNESIUM IN DRY MATTER OF TALL FESCUE AT KNOXVILLE, 1978-80.

Treatment	Stockpiling Starting	Stockpiling Duration (Mos)	Jul Early	Jul Mid	Jul Late	Aug Early	Aug Mid	Sep Early	Sep Mid	Early Oct	Early Nov	Early Dec	Early Jan	Early Feb	Mar Early	Mar Late	Mid Apr	Early Jun
11	Jul	1				0.32	0.44	0.30	0.34	0.27	0.37	0.45	0.26				0.39	0.21
12	Jul, Nov	2+2						0.30	0.23	0.35	0.32	0.30					0.48	0.17
13	Jul, Dec	3+3								0.41	0.36	0.39	0.24			0.43	0.42	0.15
14	Jul	4									0.45	0.24					0.43	0.08
15	Jul	5									0.40	0.33	0.33			0.45	0.39	0.17
16	Jul	6										0.67	0.27			0.49	0.39	0.25
17	Jul	7												0.30		0.50	0.42	0.26
21	Aug	1						0.38	0.23	0.28	0.36	0.46	0.34				0.39	0.22
22	Aug, Dec	2+2.5								0.33	0.40	0.48					0.41	0.16
23	Aug	3								0.26	0.44	0.36	0.20			0.44	0.43	0.25
24	Aug	4									0.48	0.48	0.28				0.35	0.24
25	Aug	5									0.40		0.28			0.38	0.33	0.26
26	Aug	6												0.39		0.39	0.38	0.25
31	Sep	1						0.34		0.24	0.34	0.36					0.37	0.20
32	Sep, Jan	2+2						0.38		0.46	0.38	0.44					0.34	0.23
33	Sep	3						0.36		0.52		0.43	0.37			0.41	0.43	0.21
34	Sep	4						0.34		0.40							0.42	0.27
35	Sep	5						0.33					0.23	0.32		0.42	0.37	0.30
36	Sep	6						0.34							0.16	0.44	0.38	0.26
41	Frequently clipped starting 1 Jul		0.46	0.30	0.34	0.47	0.48	0.46	0.27	0.32	0.43	0.44					0.38	0.23
51	Clipped 1/2 growth each month beginning 1 Jul		0.38			0.46		0.41		0.33	0.24	0.48				0.40	0.37	0.31
52	Clipped 1/2 growth each month beginning 1 Aug		0.39			0.51		0.41		0.32	0.37	0.42				0.46	0.42	0.26
53	Clipped 1/2 growth each month beginning 1 Sep					0.59		0.52		0.38	0.39	0.47	0.40			0.47	0.38	0.23

TABLE 11. MEAN PERCENTAGE OF CALCIUM IN DRY MATTER OF TALL FESCUE AT KNOXVILLE, 1978-80.

Treatment	Stockpiling Starting	Stockpiling Duration (Mos)	Jul Early	Jul Mid	Jul Late	Aug Early	Aug Mid	Sep Early	Sep Mid	Early Oct	Early Nov	Early Dec	Early Jan	Early Feb	Mar Early	Mar Late	Mid Apr	Early Jun
11	Jul	1				0.29	0.28	0.22	0.18	0.23	0.23	0.31	0.32				0.42	0.16
12	Jul, Nov	2+2						0.22	0.14	0.23	0.16	0.33					0.43	0.21
13	Jul, Dec	3+3								0.24	0.36	0.38	0.32			0.18	0.39	0.22
14	Jul	4								0.44	0.18	0.24					0.40	0.24
15	Jul	5									0.44	0.29	0.24			0.20	0.42	0.27
16	Jul	6											0.08			0.14	0.30	0.24
17	Jul	7												0.04		0.17	0.30	0.24
21	Aug	1						0.27	0.27	0.28	0.25	0.34	0.32				0.26	0.28
22	Aug, Dec	2+2.5								0.30	0.21	0.32					0.22	0.21
23	Aug	3								0.48	0.22	0.39	0.32			0.18	0.34	0.35
24	Aug	4								0.64	0.54	0.31	0.32			0.31	0.33	0.29
25	Aug	5								0.50	0.50		0.10			0.25	0.29	0.28
26	Aug	6												0.15		0.18	0.22	0.31
31	Sep	1						0.32		0.23	0.13	0.34					0.24	0.17
32	Sep	2						0.35		0.30	0.09	0.40					0.28	0.18
33	Sep	3						0.34		0.26		0.40	0.34			0.14	0.19	0.12
34	Sep	4						0.36		0.30			0.11				0.23	0.22
35	Sep	5						0.34						0.05		0.25	0.21	0.16
36	Sep	6						0.31							0.03	0.15	0.21	0.12
41	Frequently clipped beginning 1 Jul		0.35	0.27	0.24	0.28	0.30	0.26	0.17	0.26	0.08	0.55					0.30	0.16
51	Clipped 1/2 growth each month beginning 1 Jul		0.38			0.27		0.31		0.34	0.18	0.33				0.16	0.29	0.21
52	Clipped 1/2 growth each month beginning 1 Aug		0.36			0.25		0.27		0.28	0.18	0.30				0.16	0.27	0.23
53	Clipped 1/2 growth each month beginning 1 Sep							0.26		0.30	0.13	0.37	0.32			0.15	0.30	0.22

feasible. A delay in beginning stockpiling after July decreased dry matter yield of tall fescue. Other factors such as land availability and number of cattle on hand may be more important than yield in determining when to begin stockpiling in a beef-producing system.

The variability of quality components tended to indicate that quality responded more to season of the year than it did to stockpiling treatment. Differences in quality also occurred between Dover and Knoxville. These differences may have been influenced by soil differences, canopy composition or climatic conditions. The fescue at Dover generally contained less weeds and was a younger stand than the fescue at Knoxville. Climatic data were not available for Dover for 1979-80, so no comparisons could be made. Mineral percentage was generally lower in Dover than at Knoxville, with the exception of Ca. The percentage of Mg, K and N occasionally was below the requirements of a pregnant beef cow.

Dry matter digestibility showed a tendency to increase as length of stockpiling increased after December, possibly because of freezing and deterioration of the cell wall.

In future research better control of volunteer clover in plots seeded with fescue alone may provide a more conclusive evaluation of fescue-clover performance. There also exists a need for more research on ways to separate the treatment effects from seasonal effects in forage research.

CHAPTER V

SUMMARY AND CONCLUSIONS

The yield and quality of stockpiled and frequently clipped tall fescue grown alone and with ladino clover were determined during a two-year field study. Two sites were utilized at the Knoxville Plant Science Field Laboratory in 1978-79 and 1979-80, and in the second year, one at the Middle Tennessee Experiment Station, Spring Hill, and one at the Delaware State College Research Farm, Dover. Stockpiling periods began in July, August, September, November or December. Frequent clipping to simulate grazing began in July, August, or September. Nitrogen fertilizer was applied at the beginning of each stockpiling period at 56 kg N/ha.

Dry matter yields were higher for the stockpiling treatments which began in July than for those starting in August or September. Stockpiling treatments which began in September yielded considerably less than those begun in July or August at all locations, but resulted in higher yields the following spring. No appreciable growth occurred in plots where stockpiling began in November or December; however, it was noted that these plots became green earlier and resulted in greater yields the following spring, probably due to the late application of N fertilizer. Time of beginning frequent clipping to simulate grazing did not influence yields. Yields of stockpiled treatments at Dover were usually lower than corresponding treatments at other locations.

Nitrogen percentages at Dover were lower than those at Knoxville. Stockpiled forage may need to be supplemented in order to provide adequate levels of protein for grazing animals. Acid detergent fiber was lowest during the spring and summer in Knoxville, while peak levels of ADF occurred in January or February at Knoxville and Dover. Levels of CWC were greatest in January or February at both locations. Peak levels of CWC were lower and more variable at Dover than for corresponding treatments at Knoxville.

An increase in length of stockpiling after December exhibited a tendency toward an increase in digestibility of the stockpiled forage. Treatments varied significantly both years. Regrowth had greater digestibility than stockpiled fescue cut the same day.

Phosphorus content tended to decrease with an increase in length of stockpiling. Peak concentrations of P at Dover were lower and less variable than those at Knoxville. Phosphorus concentrations at Dover did not fall below the minimum requirement for a 450-kg dry pregnant beef cow, but most treatments at Knoxville did during the fall and winter of 1978-79.

Potassium concentrations were lowest from December to February during the two-year period at Knoxville. Levels of K at Knoxville did fall below the requirement for a dry pregnant beef cow during fall and winter 1978-79, whereas they did not during 1979-80. The highest levels of K at Dover were noted in August. The deficiency level of K at Dover was first recorded in February.

Magnesium percentages at Knoxville during the two-year period tended to be lowest in June. Levels of Mg at Dover did not fall below the minimum requirement of a dry pregnant beef cow and exhibited less variation than those at Knoxville. Levels of Mg at Dover tended to peak in July and were lowest in November. Levels of Mg in fescue collected from a pasture with a history of hypomagnesemia did not change from October to January and were greater than levels from the other locations.

Levels of Ca contained in the fescue at Knoxville during the two-year period were generally lowest during February and March. Fescue at Dover generally contained higher levels of Ca than fescue from corresponding treatments at Knoxville. Corresponding treatments cut in December of each year at Knoxville were quite similar in level of Ca, but on other harvest dates treatments were generally higher in Ca during 1979-80 than for the same treatments in 1978-79.

LITERATURE CITED

LITERATURE CITED

1. Allison, D. W. 1971. Influence of photoperiod and thermoperiod on the IVDMD and cell wall components of tall fescue. Crop Sci. 11:456-459.

2. Archer, K. A., and A. M. Decker. 1977. Autumn-accumulated tall fescue and orchard grass. 1. Growth and quality as influenced by nitrogen and temperature. Agron. J. 69:601-605.

3. Bailey, R. W. 1973. Structural Carbohydrates. pp. 157-211. In G. W. Butler and R. W. Bailey (eds.). Chemistry and biochemistry of herbage. Vol. 1. Academic Press, N. Y.

4. Balasko, J. A. 1977. Effects of NPK fertilization on yield and quality of tall fescue forage in winter. Agron. J. 69: 425-428.

5. Barr, A. J., J. H. Goodnight, J. P. Sall, W. H. Blair, and D. M. Chilko. 1979. SAS User's Guide. SAS Institute, Inc., Raleigh, N. C.

6. Barth, K. M., J. B. McLaren and C. D. Lane. 1972. Monthly changes in chemical composition and digestibility of orchardgrass-clover and fescue-lespedeza pasture. Tennessee Agric. Exp. Stn. Bull. 500.

7. Beuselinck, P. R., R. V. Frakes, D. O. Chilcote and L. D. Allison. 1979. The effect of season and maturity on perloline and digestibility in tall fescue. Amer. Soc. Agron. Abstr. p. 127.

8. Blaser, R. E., W. C. Stringer, E. B. Rayburn, J. P. Fontenot, R. C. Hammes, and H. T. Bryant. 1977. Increasing digestibility and intake through management of grazing systems. In Forage-Fed Beef: Production and marketing alternatives in the south. South. Coop. Ser. Bull. 220.

9. Bowman, D. E., and A. C. Law. 1964. Effects of temperature and day-length on the development of lignin, cellulose and protein, in Dactylis glomerata L. and Bromus inermis Leyss. Agron. J. 56:177-179.

10. Brown, R. H., R. E. Blaser, and J. P. Fontenot. 1963. Digestibility of fall-grown Kentucky 31 fescue. Agron. J. 55:321-324.

11. Bryan, W. B., W. F. Wedin, and R. L. Vetter. 1970. Evaluation of reed canary grass and tall fescue as spring, summer and fall-saved pasture. Agron. J. 62:75-80.

12. Buckner, R. C., J. R. Todd, P. B. Burrus II, and R. F. Barnes. 1967. Chemical composition, palatability, and digestibility of ryegrass-tall fescue hybrids, "Kenwell" and "Kentucky 31" tall fescue varieties. Agron. J. 59:345-349.

13. Fribourg, H. A., and R. W. Loveland. 1978. Production, digestibility, and perloline content of fescue stockpiled and harvested at different seasons. Agron. J. 70:745-747.

14. Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analysis. USDA handbook 379. U. S. Gov. Print. Off., Washington, D. C.

15. Hannaway, D. B. 1975. Chemical composition and yield of tall fescue (Festuca arundinacea Schreb.) as influenced by nitrogen and potassium fertilization. M. S. Thesis, The University of Tennessee, Knoxville.

16. Hannaway, D. B., and J. H. Reynolds. 1979. Seasonal changes in organic acids, water-soluble carbohydrates, and neutral detergent fiber in tall fescue forage as influenced by N and K fertilization. Agron. J. 71:493-496.

17. Jung, G. A., R. F. Kocher, C. F. Gross, C. C. Berg, and O. L. Bennett. 1974. Seasonal fluctuations of nonstructural carbohydrate concentrations in the forage of cool-season grasses. Int. Grassl. Congr. Proc. 12th (Moscow, U.S.S.R.) 3:215-224.

18. Kroth, E., R. Mahas, L. Meinke, and A. G. Matches. 1977. Maximizing production potential of tall fescue. Agron. J. 69:319-322.

19. Lane, C. D., K. M. Barth, J. B. McLaren, W. L. Sanders, and M. J. Constantin. 1975. Relationship of plant color to nutritive value and yield of tall fescue within season. Tennessee Farm Home Sci. Prog. Rep. 94:14-15.

20. Loveland, R. W. 1976. Digestibility, perloline content, and year-round production of tall fescue as influenced by soil fertility and stockpiling schemes. Ph.D. Dissertation, The University of Tennessee, Knoxville.

21. Marten, G. C., and A. W. Hovin. 1980. Harvest schedule, persistence, yield, and quality interactions among four perennial grasses. Agron. J. 72:378-387.

22. Matches, A. G., J. B. Tevis, and F. A. Martz. 1973. Yield and quality of tall fescue stockpiled for winter grazing. In Research in Agronomy. Univ. of Missouri, Dept. Agron., Columbia, Mo. Misc. Pub. 73-5.

23. ________, F. A. Martz, and P. C. Stone. 1966. Quality changes in accumulated growth of tall fescue. Amer. Soc. Agron. Abstr. p. 42.

24. McKee, W. H., R. H. Brown, and R. E. Blaser. 1967. Effect of clipping and nitrogen fertilization on yield and stand of tall fescue. Crop Sci. 7:567-570.

25. Moore, J. E., and D. G. Dunham. 1971. A revised procedure for the two-stage in vitro organic matter digestion of forages. Nutrition laboratory, Dept. Anim. Sci., Univ. of Florida, Gainesville, Florida. (Personal communication.)

26. Mott, G. O. 1973. Evaluating forage production. pp. 126-135. In Heath, M. E., D. S. Metcalfe and R. E. Barnes (ed.) Forages. Iowa State Univ. Press. Ames, Iowa. U.S.A.

27. National Research Council. 1970. Nutrient requirements of beef cattle (4th ed.) Nat. Acad. Sci., Washington, D. C.

28. Ocumpaugh, W. R., and A. G. Matches. 1977. Autumn-winter yield and fall grown fescue. Agron. J. 69:639-643.

29. Pfander, W. H., and E. Rubio. 1972. Composition and supplements for fall grown fescue. J. Anim. Sci. 35:233.

30. Pritchard, G. I., L. P. Folkins, and W. J. Pigden. 1963. The in vitro digestibility of whole grasses and their parts at progressive stages of maturity. Can. J. Plant Sci. 43:79-87.

31. Rayburn, E. B., R. E. Blaser, and D. D. Wolf. 1979. Winter tall fescue yield and quality with different accumulation periods and N rates. Agron. J. 71:959-963.

32. Reid, R. L., A. J. Post, and G. A. Jung. 1970. Mineral composition of forages. West Virginia Agric. Exp. Stn. Bull. 589T. 35 p.

33. Reynolds, J. H. 1975. Yield and composition of stockpiled tall fescue and orchardgrass forages. Tennessee Farm Home Sci. Prog. Rep. 94:27-29.

34. Ross, J. P., and J. H. Reynolds. 1979. Nutritive value of fall-stockpiled tall fescue. Tennessee Farm Home Sci. Prog. Rep. 112:44-48.

35. Sabbee, W. E., and L. H. Hileman. 1974. Nutrient composition of fescue and bermudagrass grown in Arkansas pastures. Arkansas Farm Res. XXIII (6):4.

36. Scales, G. H., C. L. Streeter, A. H. Denham, and G. M. Ward. 1974. A comparison of indirect methods of predicting in vivo digestibility of grazed forage. J. Anim. Sci. 38:192-199.

37. Spahr, S. L., E. M. Kesler, J. W. Bratzler, and J. B. Washko. 1961. Effect of stage of maturity at first cutting on quality of forages. J. Dairy Sci. 44:503-510.

38. Steckel, J. E., and R. L. Flannery. 1971. Simultaneous determinations of phosphorus, potassium, calcium, and magnesium in wet digestion solutions of plant tissue by auto analyzer. in L. N. Walsh, [Ed.] Instrumental methods for analysis of soils and plant tissue. Soil Sci. Soc. Amer., Madison, Wis., pp. 83-96.

39. Sullivan, J. T., T. G. Phillips, M. E. Loughlin, and V. G. Sprague. 1956. Chemical composition of some forage grasses. II. Successive cuttings during the growing season. Agron. J. 48:11-14.

40. Taylor, T. H., and W. C. Templeton, Jr. 1976. Stockpiling Kentucky bluegrass and tall fescue for winter pasturage. Agron. J. 68:235-239.

41. Templeton, W. C., Jr., P. L. Cornelius, T. H. Taylor, and J. A. Boling. 1979. Maturity and nitrogen fertilizer effects on mineral concentrations in Kentucky bluegrass and tall fescue herbages. Amer. Soc. Agron. Abstr. p. 133.

42. Terry, R. A., and J. M. A. Tilley. 1964. The digestibility of the leaves and stems of perennial ryegrass, cocksfoot, timothy, tall fescue, lucerne, and sainfoin, as measured by an in vitro procedure. J. Brit. Grassl. Soc. 19:363-372.

43. Thomas, R. L., R. W. Sheard and J. R. Moyer. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus and potassium analysis of plant material using a single digestion. Agron. J. 59:240-243.

44. Tilley, J. M. A., and R. A. Terry. 1963. A two-stage technique for the in vitro digestion of forage crops. J. Brit. Grassl. Soc. 18:104-111.

45. Van Soest, P. J. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Agric. Chem. 50:50-55.

46. Watson, C. E., Jr., R. V. Frakes, D. O. Chilcote, D. A. Sleper, and A. G. Matches. 1978. Genetic variation for perloline, N, and digestibility in tall fescue. Crop Sci. 18:458-460.

47. Watson, V. H., and C. E. Watson, Jr. 1978. Tall fescue in Mississippi. Mississippi Agric. Forestry Exp. Stn. Bull. 874:3-4.

48. Wedin, W. F., I. T. Carlson, and R. L. Vetter. 1967. Fall saved forages. Crops and Soils. 19(9):17-18.

49. White, H. E. 1975. Extension teamwork in stockpiled tall fescue test demonstrations. Agron. Abst., Amer. Soc. Agron. p. 18.

APPENDIX

TABLE 12. REVISED PROCEDURE FOR THE TWO-STAGE TILLEY-TERRY <u>IN VITRO</u> ORGANIC MATTER DIGESTION OF FORAGES.

I. Reagents:

1. McDougall's Artificial Saliva. (40 ml required per tube.) Since insoluble calcium phosphate will precipitate at the high pH of the buffer, the saliva must be prepared in two parts if it is to be stored.

   a. Buffer (quantities per liter, w/v)

      9.80 g Na HCO_2
      7.00 g Na_2HOP_4 • $7H_2O$ (3.71 gm anhydrous)
      0.57 g KCl
      0.47 g NaCl
      0.12 g $MgSO_4$ • $7H_2O$

   B. 4% (w/v) Calcium chloride solution

      4.0 g $CaCl_2$ per 100 ml (5.3 g $CaCl_2$ • $2H_2O$)

      Just before use, add 1 ml 4% $CaCl_2$ per liter of buffer to provide 0.04 g $CaCl_2$ per liter of artificial saliva.

2. 20% (v/v) HCl: Dilute 200 ml concentrated Hcl to one liter (6 ml required per tube).

3. 5% (w/v) Pepsin: Add 5 g of pepsin to 100 ml distilled water (2 ml required per tube).

II. Maintain fistulated steer on good quality alfalfa hay.

III. 1. Remove whole ingesta from top half of rumen contents and transfer to a 3-liter beaker lined with 2 layers of cheesecloth.

2. Squeeze contents, collecting fluid in the beaker.

3. Strain fluid through a layer of glass wool above 4 layers of cheesecloth; collect filtrate in an insulated jug which was warmed to 39 C in the incubator and flushed out with CO_2.

4. Carry fluid immediately to the laboratory, bubble CO_2 into the fluid, measure desired amount into warmed graduated cylinder (flushed with CO_2) and transfer to the bottle in the water bath which contains warmed (39 C), CO_2-saturated McDougall's saliva (see VI, 7, below).

IV. Procedure

A. Weigh Forage Samples:

1. For initial dry matter-organic matter determination: Place about 0.5 g sample in a dry, tared, numbered regular crucible and weight to nearest 0.0001 g. (Dry matter analysis is not essential, but this value can be used in connection with other analyses).

2. For in vitro digestion: place about 0.5 g sample, weighed to nearest 0.0001 g, in a numbered centrifuge tube. (Note: Weighings for dry matter-organic matter determinations and for in vitro digestion should be done at about the same time and prior to the day of inoculation. Weighing out samples and calculations of results are made easier if the samples in a given run are assigned a serial number (eg: 1-200) and if the crucibles and tubes are assigned the same numbers. For example, Sample No. 1 is placed in Crucible No. 1 and in Tube No. 1).

V. 1. Place regular crucibles containing samples in drying oven overnight at 105 C.

2. Cool in desiccator and weigh to nearest 0.0001 g.

VI. In Vitro Digestion:

1. Obtain four empty tubes for blanks (media only; no forage sample).

2. Turn on water bath and incubator (39 C).

3. Prepare appropriate quantity of buffer in 12 l bottle (40 ml per tube plus about 200 ml extra), add 1 ml 4% $CaCl_2$ per liter and place bottle in 39 C water bath. When large volumes (e.g.: 8 liters) are required, prepare saliva prior to the day of inoculation and allow it to warm up in water bath (39 C) overnight prior to inoculation.

4. Bubble CO_2 through the artificial saliva at a gentle rate. CO_2 may be started the day of inoculation.

5. Add 2 ml distilled water to all centrifuge tubes (including blanks) with automatic pipette, wet all forage particles by agitation using test tube mixer (do not do this until the day of inoculation).

TABLE 12 (Cont'd)

6. Check pH of artificial saliva; it should be approximately 6.9-7.0; the CO_2 bubbling through the solution lowers the pH; when solution is saturated with CO_2 and the bicarbonate buffer system is established, the pH will be 6.9-7.0.

7. Prepare inoculum as described in III above and add one (1) part rumen fluid to four (4) parts artificial saliva.

8. Allow the media (rumen fluid plus saliva) to mix for 10 minutes through the action of the bubbling CO_2.

9. Add 50 ml of media to each centrifuge tube, including blanks, using a dispensing burette (add media to the tubes at random and disperse the blanks randomly among the set of tubes).

10. Immediately after adding media, place tubes in waterbath, flush the remaining air out of the tubes by passing CO_2 into the tube for 15 seconds (do not bubble CO_2 into the media in the tubes); quickly stopper the tubes with the bunsen valve. (Note: addition of media is achieved most rapidly when two tubes are flushed simultaneously using the two 2-hole stoppers and when two persons work together, one adding media and the other flushing and stoppering tubes.

11. Transfer tubes to incubator at 39 C (including blanks).

12. After one hour incubation, swirl contents in tubes, by hand, with a gentle rotating motion, to insure that all forage particles are wet with media; repeat twice the first day and three times the second day.

13. After 48 hours incubation, remove the stoppers and wash any forage particles adhering to the stoppers into the tube with a minimum of distilled water; check pH of a few tubes at random, should be less than 7.

14. Add 1 ml 20% HCl, swirl tubes; add another 1 ml 20% HCl, swirl; and finally add 4 ml 20% HCl and swirl (total HCl = 6ml/tube); pH of media should be about 1-2 (to avoid excess foam, wait until each increment of acid is added to all tubes before swirling).

15. Add 2 ml 5% pepsin, swirl thoroughly, replace stoppers and return tubes to incubator at 39 C; repeat swirling twice the first day and three times the second.

TABLE 12 (Cont'd)

16. Prepare gooch crucibles by forming a glass wool mat from 3-4 pieces of glass wool (cut glass wool into squares, about 1/2", using paper cutter).

17. After 46 hours pepsin digestion, transfer the contents of the centrifuge tubes to the gooch crucibles using the crucible holder; use low vacuum, filtration should be rapid. Wash all residue from tube into crucible with hot distilled water. Wash residue in gooch crucible three times with hot distilled water.

18. Place gooch crucibles in drying oven at 105 C and dry to constant weight (overnight), cool in desiccator and weigh.

19. Place crucibles in muffle furnace at 500 C for 3 hours, cool in desiccator and weigh. (If digestible organic matter is desired).

TABLE 13. DRY MATTER YIELDS OF TALL FESCUE AT KNOXVILLE, 1978-79, SITE 1.
(MEAN OF TWO REPLICATIONS)

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
	kg/ha															
11				872	713	180	559	260	32	12					372	256
12						3358	479	231	65	38					452	467
13								6579	149					288	610	407
14									5250	129					215	307
15										4643				106	200	176
16											6274			127	254	221
17												2854		206	223	229
21						1971	586	329	51	22					309	270
22								4776	92	28					430	340
23									4106	92				125	319	329
24										3868					170	170
25											2995			237	323	219
26												3256		161	274	211
31								668	63	16					446	491
32									1043	127					411	565
33										903				252	422	325
34											633				407	325
35												454		368	381	329
36													481	393	454	370
41	221	88	188	397	709	200	770	311	45	16					346	256
51	182			831		985		1165	57	16				129	311	268
52	260			259		2133		1282	84	53				88	266	293
53	286					2078		1276	73	34				133	290	301

TABLE 14. DRY MATTER YIELDS OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1978-79, SITE 2.
(MEAN OF TWO REPLICATIONS)

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May	2 Jul
Fescue-alone																	
11				870	657	172	497	198	49	36					211	247	
12						2922	631	149	57	51					231	211	
13								5069	106					182	247	346	
14									5241	151					239	125	
15										4356				141	192	104	
16											3362			282	180	163	
17												3122		221	268	165	
21						2032	663	229	24	86					237	200	
22							561	3543	57	43					370	260	
23									3858	147				192	329	307	
24										3463					229	131	
25											3651			278	286	145	
26												1846		276	264	141	
31								1045	106	53					309	362	
32									1608	178					594	553	
33										895				311	420	434	
34											704				469	401	
35												627		346	383	354	
36													475	444	440	364	
41	135	57	155	432	631	241	680	245	20	40					307	202	
51	127		557		844	243		1233	14	36				110	196	161	
52	92		780			1698		1161	69	73				135	233	176	
53	206					213		1133	86	53				170	250	311	
Fescue-clover																	
11				799	317	122	506	215	32	36					135	118	
12						1356	571	243	28	61					133	110	
13								4127	98					159	206	192	
14									3786	133					122	104	
15										3325				96	88	75	
16											2825			196	118	90	
17												2186		151	125	118	
21						831	723	227	28	36					110	209	223
22								2997	77	40					182	172	
23									116	116				90	145	233	
24									2327	2327					90	96	
26											1991			250	883	145	
26												1956		229	141	149	
31								1079	98	38					98	145	168
32									1196	112					73	180	
33										590							
34											290						
35												399					
36													209	202	200	237	
41	109	90	65	90	305	133	516	211	24	45					116	106	147
51	135			437	508	190		1479	45	77				147	235	250	245
52	174			352		932		1481	49	49				108	163	141	161
53	178					178		1211	57	34				88	139	143	217

TABLE 15. DRY MATTER YIELDS OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1979-80, SITE 2.
(MEAN OF TWO REPLICATIONS)

Treatment	23 Jul	31 Jul	8 Aug	20 Aug	29 Aug	10 Sep	1 Oct	9 Oct	31 Oct	3 Dec	3 Jan	26 Feb	10 Mar
	kg/ha												
Fescue-alone								118	84				
11		1250	165	157	43	112	325	100	133				
12					3596	252	4010	165	264	118			
13									3872	196			
14										3534	110		65
15											3577		
16												3706	94
17								110	159				
21					426	297	268	172	125				
22							1612		2168	194			
23										2635			77
24											1944		
25												2102	114
26								188	163				
31							1217		780	106			
32										1979	73		
33											1399		106
34												1063	77
35													1750
36								118	84				
41	538	563	147	92	38	122	163		120				
51		1260			315		657		233				
52					409		883		204				
53							1153						
Fescue-clover								67	45				
11		780	200	104	53	180	479	127	84	65			
12					2831	200	327	172	102				
13							5045		3764	112			
14										4114	.69		
15													
16											3379	3557	
17													3557
21					379	245	463	98	67				
22							1682	180	69				
23									2272	94			
24										1493			
25											1362		
26												1235	
31							2043	92	57	36			
32									1561	77			
33										1608	45		
34											1014		
35												1311	
36													
41	272	372	125	90	53	190	506	75	57				
51		1090			358		1559		127	53			
52					397		1102		168				
53							989		147				

TABLE 16. DRY MATTER YIELDS OF TALL FESCUE AT KNOXVILLE, 1979-80, SITE 1.
(MEAN OF TWO REPLICATIONS)

Treatment	23 Jul	31 Jul	8 Aug	20 Aug	29 Aug	10 Sept	1 Oct	9 Oct	31 Oct	3 Dec	3 Jan	26 Feb	10 Mar
	kg/ha												
11		1571	163	202	63	133	456	39	65				
12					3797	256	389	86	84				
13							3567	178	170				
14									4071	221			
15										3932	174		69
16											4131		90
17												3954	100
21					758	397	852	61	122				
22							2450	102	176				
23									2559	178			
24										2989	106		69
25											2975		94
26												2469	90
31							2047	96	178				
32									2250	172			
33										2596	86		
34											2301		102
35												1313	67
41	772	668	188	174		153	483	59	108				
51		1596			438		924		174				
52					918		1327		290	118			
53							1454		319		57		
36													1411

TABLE 17. DRY MATTER YIELDS OF TALL FESCUE IN DOVER, 1979-80.
(MEAN OF TWO REPLICATIONS)

Treatment	3 Jul	12 Jul	23 Jul	3 Aug	13 Aug	23 Aug	5 Sep	21 Sept	2 Oct	12 Oct	22 Oct	1 Nov	3 Dec	3 Jan	4 Feb
	kg/ha														
11	320			2909	223	143				20	14				
12							2446	264	125	32	24				
13									2157	122	34				
14												2239			
15													2170		
16														2086	
17															2475
21							1196	327	133	30	24				
22									1764	129	51				
23												2103	102		
24													2110		
25														1842	
26															1867
31									719	120	34				
32												1196			
33													1055		
34														848	
35															979
									53	18	12				
41	293	520	436	452	237	59	172	118	280			110			
51				575			948		432			137			
52							1887		706			297			
53															

TABLE 18. DRY MATTER YIELDS OF TALL FESCUE AT SPRING HILL, 1979-80.
(MEAN OF 3 REPLICATIONS)

Treatment	2 Aug 79	1 Sep 79	2 Oct 79	2 Nov 79	13 Feb 80
	kg/ha				
11	1580	114	213		
12		1659	203		
13			2928		
14				2919	
21		953	176		
22			2345		
23				1964	
31			1388		
32				1267	
35					1495
41	1096	165	184		
51	885	513	648		
52		270	553		
53			318		

TABLE 19. PERCENT NITROGEN IN TALL FESCUE AND FESCUE-CLOVER DRY MATTER AT KNOXVILLE, 1978-79, SITE 2.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
Fescue alone																
11				2.25	2.36	1.09	1.17	1.40	1.50	1.32					3.10	1.18
12						1.41	1.38	1.51	1.74	2.04					3.00	1.06
13								1.81	1.80					3.23	3.18	1.64
14									1.85	1.59					3.07	1.10
15										1.08				3.22	3.15	1.54
16											0.95			3.20	3.16	1.04
17												0.99		3.19	3.20	1.29
21						1.64	1.03	1.78	1.87	1.55					3.19	1.59
22								1.01	1.53	1.84					3.16	1.85
23									1.27	1.48				3.11	3.13	1.46
24										1.65					3.18	2.09
25											1.16			3.16	3.15	0.82
26												1.07		3.08	3.11	0.90
31								2.19	2.53	2.35				3.11	3.13	1.01
32									1.64	1.98					3.18	1.14
33										1.81				3.22	3.10	1.84
34											2.01			3.21	3.17	1.64
35												1.79			3.20	1.44
36													2.08		3.17	0.79
41	2.79	2.59	2.48	2.69	2.26	1.52	1.58	1.56	1.74	2.02					3.13	1.07
51	2.59					2.07		1.01	1.69	1.59				3.22	3.04	1.68
52						1.93		1.16	1.74	1.62				3.15	3.15	1.38
53						1.18		1.16	1.59	1.64				3.21	3.12	1.49
Fescue-clover																
11				2.08	2.24	1.40	1.28	1.85	1.53	1.97					3.00	1.25
12						1.12	1.34	1.36	1.66	1.43					2.79	1.68
13								1.81	1.30					2.95	2.92	0.84
14									1.04	1.59					2.92	2.16
15										1.01				2.58	2.92	1.28
16											1.08			2.24	2.92	1.08
21						1.78	1.71	1.55	1.93	1.91				2.60	3.14	1.94
22								1.44	1.64	1.91					3.00	1.51
23									1.08	1.50				2.85	3.01	2.10
24										1.00					2.82	1.31
25											1.23			2.59	3.00	1.21
26												1.04		2.63	3.03	1.47
41		2.39	2.54	2.51	2.40	1.72	1.21	1.60	1.72	1.92					3.04	1.52
51				2.68		1.81		1.69	3.04	2.28				3.26	3.23	1.67
52				2.37		1.45		1.15	1.87	2.15				3.14	3.14	1.17
53						1.82		1.26	1.55	2.19				2.95	3.20	1.23
31								1.34	1.48	1.67					2.96	1.21
32									1.61	1.88					3.13	1.49
33										2.00				2.55	2.98	1.69
34											1.47				3.01	1.34
35												1.61			2.99	1.40
36													1.82	2.78	3.24	1.96
17												.95		3.06	2.98	1.28

TABLE 20. PERCENT NITROGEN IN DRY MATTER OF TALL FESCUE AT KNOXVILLE, 1978-79, SITE 1.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	32 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				2.41	2.28	2.21	1.95	1.66	1.84	2.40					2.91	1.90
12						1.505	1.72	1.63	1.13	1.91					2.90	2.28
13								1.04	1.39					3.15	3.11	1.25
14									1.01	1.47					3.15	2.37
15										1.72				3.17	3.00	2.17
16											1.06			3.16	2.97	2.25
17												0.95		3.17	2.88	2.25
21						1.87	1.91	1.54	1.59	2.31					2.85	2.05
22								1.07	1.00	1.86					2.99	2.19
23									1.76	1.48				3.04	3.01	2.12
24										1.27					3.03	1.53
25											1.31			3.05	3.12	2.19
26												1.40		3.16	3.02	2.12
31								2.11	1.65	2.85					3.02	2.39
32									1.43	2.28					3.12	2.47
33										1.98				3.09	3.02	2.16
34											2.03				2.77	2.54
35												2.18		3.21	2.99	2.47
36													2.16	3.10	3.06	2.34
41	2.50	2.80	2.94	2.53	2.31	1.97	1.81	1.63	1.75	2.14					3.12	2.47
51	2.69			2.60		2.15		1.47	1.46	2.38				2.93	3.09	2.26
52	2.56					1.92		1.61	1.42	2.04				3.13	3.08	2.23
53	2.74					2.13		1.52	1.37	2.49				2.91	3.11	2.13

TABLE 21. PERCENT NITROGEN IN DRY MATTER OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1979-80, SITE 2.

Treatment	23 Jul	31 Jul	8 Aug	20 Aug	29 Aug	10 Sep	01 Oct	09 Oct	31 Oct	03 Dec	03 Jan	26 Feb	10 Mar
Fescue alone													
11		2.90			3.32		2.37		2.41		1.68		
12					1.91		2.51		2.24				
13									2.64		1.32		
14										2.11			
15													
16											2.40		
17												2.31	
21					3.05		2.23		2.36		1.50		
22							1.84		2.18				
23									2.68		2.72		
24										2.32	1.66		
25											2.63		
26												2.30	
31					2.70								
32					2.40				3.22				
33										2.88	2.41		
34											2.76		
35												2.83	
36													3.02
41		3.32			2.72		2.10						
51		3.13			2.90		1.98						
52					3.16		2.06						
53					2.18		2.64				2.02		
Fescue-clover													
11		2.36			2.45								
12					1.60								
21					2.08								
31							2.29						
32									2.53				
33										2.36			
34											2.30		
35												2.38	
36					2.30						2.30		3.1
41		2.95			2.19								
51		3.26			2.44				2.28				
52		2.90			2.43				2.43				
53					2.34								

TABLE 22. PERCENT NITROGEN IN DRY MATTER OF TALL FESCUE AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb	10 Mar
11	0.51	0.95	1.41	1.66					
12			1.45	1.87					
13				0.66					
14					0.36				
15						0.34			
16							0.30		
17								0.27	
21			1.40	1.78					
22				0.94					
23					0.33	1.08			
24					0.40	0.72			
25							0.40		
26								0.32	
31				1.89					
32					0.85				
33						0.64			
34							0.49		
35								0.26	
36									0.34
41	0.41	1.11	0.88	1.67					
51	0.38	0.48	0.47	0.64	0.36				
52		0.34	0.80	1.83	1.15				
53				1.14	0.78				

TABLE 23. PERCENT ACID DETERGENT FIBER CONTENT IN TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, JULY 1978 TO APRIL 1979

Treatment	3 Jul	1 Aug	29 Aug	29 Sep	30 Oct	6 Dec	4 Jan	29 Jan	28 Mar	10 Apr	30 Apr
Fescue alone											
11		26.9									
12			33.1	36.2							
13				35.7	28.8						
14					35.8	29.8				21.3	
15						39.4					
16							41.1				
17								41.2			
21			33.6								
22			32.1								
23					32.7						
24						38.8					
25							39.4				
26								38.2			
31				33.7							
32					29.6						
33						31.0					
34							32.2				
35								32.7			
36									29.9		
41	27.6	31.1		33.4	33.8	28.0					29.3
51				31.2							
52					35.9	32.7			19.3	22.0	
53						23.8			19.7	25.3	
Fescue-clover											
11		26.4									
12			29.8								
13				32.2							
14					35.4						
15						39.6	31.6				
16							40.0				
17								40.4			
21			28.0								
22				32.2							
23					33.4						
24						36.3					
25							37.4				
26								37.1			
31				32.7							
32					32.5						
33						32.8					
34							37.7				
35								38.6			
36									35.1		
41				28.9	35.6						24.6
51				32.0							
52										26.0	
53									26.9		

TABLE 24. PERCENT ACID DETERGENT FIBER IN FESCUE AND FESCUE CLOVER AT KNOXVILLE, 1979-80.

Treatment	30 Jul	29 Aug	31 Oct	3 Dec	3 Jan	26 Feb	15 Mar
Fescue alone							
11	35.8	31.3					
12		32.0					
13			38.8		39.6		
14				28.0			
15				32.1			
16					42.4		
17							
21							
22							
23							
24				36.4			
25					38.9		42.1
26						42.1	
31							
32							
33							
34					32.6		
35						44.8	
41	37.2	31.6	36.1	38.3			
51	29.5		29.1				
52		37.2	37.8	29.3			
Fescue-clover							
11	34.6						
12		33.7					
15				38.3			
16					38.6		
17						45.8	
21		29.1					
24				31.6			
25					36.3		
26						42.3	
33				27.4			
34					34.9		
35						39.0	
41		28.8					
52		32.9					

TABLE 25. PERCENT ACID DETERGENT FIBER CONTENT IN TALL FESCUE AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb
11	35.3	33.2						
12			37.2					
13				37.3				
14					36.3			
15						33.8		
16							38.4	
17								38.1
21			32.3					
22				34.6				
23					32.1	32.8		
24						35.3		
25							35.9	
26								37.9
31				31.1				
32					26.2			
33						28.7		
34							32.4	
35								34.1
36								
41	37.2	32.5	35.1	31.5				
51	37.3		35.6		25.8			
52			31.2	35.2	26.0			
53					32.8	25.9		

TABLE 26. PERCENT CELL WALL CONSTITUENTS IN TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, JULY 1978 to APRIL 1979.

Treatment	3 Jul	1 Aug	29 Aug	29 Sep	30 Oct	6 Dec	4 Jan	29 Jan	2 Mar	28 Mar	10 Apr	30 Apr
Fescue alone												
11		63.2										
12			63.6	72.7								
13				75.0	53.8							
14					68.5	61.8					51.5	
15						71.2	67.0					
16							72.2					
17								73.4				
21			63.9									
22				66.0								
23					66.6							
24						71.2						
25												
26								70.3				
31				70.3								
32					61.4							
33						60.7						
34							60.8					
35								63.7				
36									64.6		56.9	
41	55.3					54.1						53.1
51				66.6								
52					65.0	60.1				45.1	49.0	
53						55.8				44.1	51.5	
Fescue-clover												
11		65.2										
12			59.5									
13				67.1								
14					67.3							
15						69.7						
16							71.1	73.6				
21			66.6									
22												
23												
24						67.9						
25							66.9					
26								72.1				
31				65.1								
32					64.8							
33						60.8						
34							67.8					
35								68.6				
36									65.9		49.3	
51				61.3								
52				62.9						48.3	53.9	
53										63.0		
41					67.8							51.5

TABLE 27. PERCENT CELL WALL CONSTITUENTS IN TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1979-80.

Treatment	3 Jul	29 Aug	31 Oct	3 Dec	3 Jan	26 Feb
Fescue alone						
11	68.7	66.8				
12					64.9	
13			70.3		63.0	
14			69.6	62.0		
15				63.6		
16					69.2	
17						67.5
21		60.5				
22						
23						
24				61.4		
25					64.0	
26						70.0
31						
32						
33						
34				59.9		
35					68.0	
36						71.8
41	66.0	72.2	73.0	60.1		
51			74.6			
52	64.9	62.3	69.9	56.5		
53		62.8				
Fescue-clover						
15				70.0		
17						69.0
21		66.0				
24				60.0		
25					70.1	
26						67.7
33				64.3		
34					61.7	
35						59.8
41		68.0				
51	66.2					
52	60.0					

TABLE 28. PERCENT CELL WALL CONSTITUENTS IN TALL FESCUE AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb
11	65.9	71.9						
12			68.7					
13				71.5				
14					71.3			
15						65.8		
16							73.1	
17								72.4
21			55.7					
22				68.4				
23					69.5	64.8		
24						70.0		
25							70.3	
26								72.2
31				63.9				
32					67.7			
33						66.7		
34							72.0	
35								67.5
41	65.3	62.9	65.3	71.9				
51	64.5		68.2		68.9			
52			65.3	69.3	68.6			
53					69.8	71.5		

TABLE 29. F-VALUES, COEFFICIENTS OF DETERMINATIONS (R^2) AND COEFFICIENTS OF VARIATION (C.V.) FOR DIGESTIBILITY OF TREATMENTS, RUNS AND BLOCKS WITHIN THE SIMPLE LATTICE, 1978-80.

Source	1978-79		1979-80	
	DF	F-Value	DF	F-Value
Run (Replicates)	1	2.36	1	296.39*
Treatments	168	1.62*	168	2.65*
Blocks (run)	24	3.88*	24	9.30*
R^2		0.71		0.87
C.V.		18.1		14.3
Mean Digestibility		49.5		51.3

*Significant at the .05 level of probability.

TABLE 30. PERCENT PHOSPHORUS IN TALL FESCUE DRY MATTER AT KNOXVILLE, 1978-79, SITE 1.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				0.64	0.74	0.79	0.72	0.60	0.11	0.15					0.51	0.40
12						0.60	0.61	0.64	0.13	0.18					0.50	0.35
13								0.60	0.16					0.49	0.49	0.36
14									0.10	0.15					0.45	0.33
15										0.11				0.34	0.46	0.36
16											0.11			0.33	0.46	0.31
17												0.12				
21						0.69	0.67	0.15	0.13	0.23					0.47	0.34
22								0.14	0.12	0.19					0.48	0.32
23									0.17	0.18				0.35	0.48	0.33
24										0.20						
25											0.12			0.36	0.47	0.34
26												0.17		0.39	0.46	0.30
31								0.18	0.17	0.26					0.46	0.35
32									0.14	0.23					0.48	0.38
33										0.18				0.49	0.49	0.36
34											0.17				0.46	0.38
35												0.22		0.44	0.47	0.41
36													0.21	0.43	0.47	0.39
41	0.75	0.70	0.67	0.67	0.75	0.70	0.72	0.36	0.13	0.29					0.49	0.33
51	0.78			0.68		0.75		0.13	0.13	0.22			0.39	0.39	0.46	0.37
52	0.77			0.63		0.71		0.18	0.11	0.21				0.41	0.47	0.30
53	0.77					0.75		0.15	0.08	0.28				0.41	0.46	0.30

TABLE 31. PERCENT PHOSPHORUS IN TALL FESCUE AND FESCUE-CLOVER DRY MATTER AT KNOXVILLE, 1978-79, SITE 2.

Treatment	3 Jul	10 Jul	30 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
Fescue alone																
11				0.23		0.39	0.30	0.23	**	0.22					0.48	0.33
12						0.29	0.16	0.18							0.48	0.36
13								0.13						0.44	0.48	0.36
14										0.14					0.49	0.37
15										0.09				0.45	0.49	0.37
16											0.13			0.42	0.51	0.36
17												0.10		0.46	0.52	0.36
21						0.25	0.21	0.21		0.22					0.48	0.32
22								0.18		0.25					0.49	0.35
23										0.15				0.44	0.49	0.33
24										0.18					0.51	0.33
25											0.15			0.44	0.50	0.35
26												0.13		0.45	0.48	0.35
31								0.17		0.26					0.50	0.37
32										0.22					0.56	0.39
33										0.31				0.53	0.55	0.38
34											0.23				0.52	0.38
35												0.16		0.43	0.52	0.39
36													0.24	0.47	0.55	0.41
41	0.16	0.19	0.09	*	0.16	0.27	0.26	0.25		0.26					0.46	0.32
51		0.15		*		0.31		0.19		0.19				0.44	0.44	0.32
52				0.11		0.20		0.22		0.20				0.43	0.48	0.31
53						0.37		0.26		0.25				0.44	0.46	0.33
Fescue-clover																
11				0.23		0.38	0.28	0.26		0.29					0.43	0.39
12						0.26	0.24	0.18		0.18					0.43	0.37
13								0.16						0.65	0.46	0.38
14										0.21					0.41	0.36
15										0.16				0.33	0.48	0.38
16											0.16			0.33	0.44	0.40
17												*		0.46	0.44	0.39
21						0.35	0.28	0.23		0.26					0.43	0.36
22								0.24		0.24					0.47	0.37
23										0.26				0.37	0.44	0.37
24										0.18					0.48	0.38
25											0.16			0.39	0.47	0.37
26												0.10		0.49	0.47	0.37
31								0.27		0.30					0.43	0.38
32										0.27					0.47	0.39
33										0.26				0.45	0.46	0.40
34											0.23				0.48	0.41
35												0.14		0.39	0.47	0.40
36													0.20	0.39	0.46	0.38
41		0.13	0.09	0.10	0.15	0.38	0.32	0.29		0.30					0.47	0.38
51		0.09		0.20		0.42		0.26		0.30				0.41	0.45	0.35
52				0.09		0.32		0.23		0.29				0.39	0.44	0.36

*Concentration was too low for detection.

**Data missing for 30 Oct 78.

TABLE 32. PERCENT PHOSPHORUS IN DRY MATTER OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1979-80.

Treatment	31 Jun	29 Aug	01 Oct	31 Oct	3 Dec	03 Jan
Fescue alone						
11		0.38	0.32	0.40		0.35
12		0.34	0.41	0.37		0.26
13			0.34	0.37	0.36	0.34
14			0.39	0.36		
15			0.36	0.38		0.33
16						
17						
21		0.36	0.33	0.38		0.30
22			0.32	0.37		
23			0.34	0.46		0.50
24			0.35	0.38		0.40
25			0.34	0.39		
31		0.49				
32		0.50	0.50			
33		0.52	0.48			0.36
34		0.54	0.48			
35		0.48				
36		0.48				
41	0.44	0.46	0.34			
51		0.42	0.34			
52	0.47	0.46	0.30			
53		0.46	0.44			0.46
Fescue-clover						
11	0.42					
12		0.21				
21		0.22				
31		0.25				
32		0.26				
33		0.28				
34		0.27				
35		0.27				
36		0.27				
41	0.49	0.28				
51	0.40	0.33				
52	0.43	0.32				
53		0.38				

TABLE 33. PERCENT PHOSPHORUS IN DRY MATTER OF TALL FESCUE AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb	10 Mar
11	0.20	0.24	0.49	0.52					
12		0.21		0.45					
13				0.23					
14					0.21				
15						0.21			
16							0.20		
17									
21			0.27	0.42					
22				0.24					
23					0.23	0.24			
24					0.22	0.21			
25							0.20		
26								0.20	
31									
32									
33									
34									
35									
36									
41	0.20	0.26	0.43	0.46					
51	0.20	0.22	0.30	0.45	0.40				
52		0.20	0.24	0.37	0.31				
53				0.38	0.32				

TABLE 34. PERCENT POTASSIUM IN TALL FESCUE DRY MATTER AT KNOXVILLE, 1978-79, SITE 1.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				2.72	2.67	2.70	1.91	1.34	0.93	1.05					4.06	2.66
12						2.69	1.28	1.28	0.32	0.38					4.14	2.73
13								2.18	0.80					3.18	3.92	2.53
14									1.24	0.55					4.36	2.90
15										0.36				2.09	3.78	2.81
16											*			1.92	3.79	2.77
17												*		1.99	4.00	2.63
21						3.03	1.75	1.22	0.72	0.92					3.34	2.39
22								2.09	0.45	0.73					3.44	2.48
23									1.42	0.73				2.30	4.06	2.56
24										0.46					3.24	2.58
25											*			2.21	3.57	2.71
26												*		2.40	3.47	2.33
31								1.90	1.02	1.09					3.31	2.46
32									1.36	1.22					3.55	2.62
33										1.19				2.84	3.51	2.62
34											0.56				3.52	2.56
36												0.29		2.74	3.42	2.69
36															3.32	2.42
41	2.55	2.26	2.73	2.90	2.91	2.90	1.99	1.45	1.01	1.62				2.49	3.35	2.64
51	2.60			2.98	3.13	2.75		1.78	0.93	1.44				2.54	3.30	2.46
52	2.59			2.83		3.14		1.50	0.58	0.80				2.64	3.36	2.37
53						2.69		1.51	.69	1.37						

*Concentration was too low for detection.

TABLE 35. PERCENT POTASSIUM IN TALL FESCUE AND FESCUE-CLOVER DRY MATTER AT KNOXVILLE, 1978-79, SITE 2.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				3.47	3.59	2.60	1.78	1.72	0.94	1.24					3.99	2.74
12						2.86	1.33	1.49	0.97	1.31					3.82	2.77
13								2.16	0.23					2.83	3.86	2.71
14									1.71	1.10					3.91	2.82
15										1.00					3.94	2.98
16											0.21			2.75	4.14	2.85
17												0.10		2.88	4.14	2.83
21						3.60	1.86	1.67	0.97	0.70				3.07	4.03	2.75
22								1.95	1.49	1.15				2.99	4.04	2.82
23									1.91	1.30					4.02	2.74
24										0.96					4.13	2.77
25											0.10			2.79	4.08	2.81
26												*		2.73	3.94	2.77
31								2.54	1.93	1.79					4.05	2.74
32									1.96	1.49					4.58	2.97
33										1.65				3.00	4.36	2.83
34											1.11				4.28	2.92
35										1.28					4.10	2.78
36										0.84				2.85	3.82	2.58
41	2.63	2.43	3.49	3.81	3.70	2.73	2.40	1.94	1.21	0.74				2.77	3.96	2.76
51	2.82			3.57	3.76	2.96		1.67	0.80	0.97				2.73	3.88	2.84
52				3.51		3.46		1.74	0.83							
53						2.59		1.98	0.92	1.21					3.48	2.53
Fescue-clover										0.65					3.51	2.51
11				2.63	2.17	2.60		1.78	0.99	1.09				2.89	3.84	2.68
12						2.48	1.96	1.20	0.92	0.92					3.36	2.59
13							1.55	1.64	0.86					2.13	3.41	2.52
14									1.49		0.14			2.19	2.74	2.52
15												*		2.34	2.96	2.62
16										1.09					3.11	2.66
17																
21						2.73	1.65	1.44	1.14							
22								1.89	1.02	1.02					3.24	2.70
23									1.61	1.17				2.37	2.98	2.64
24										0.87					2.81	2.51
25											0.21			2.39	2.88	2.48
26												*		2.36	2.94	2.50
31								1.97	0.94	1.15					2.98	2.58
32									1.41	1.08					3.09	2.64
33										1.15				2.53	3.14	2.70
34											0.32				3.11	2.78
35												0.10		2.66	3.02	2.70
36													0.56	2.66	3.23	2.86
41			3.36	3.17	3.35	2.55	1.91	1.87	0.95	1.23				3.07	3.56	2.57
51				3.04		2.73		2.01	1.24	1.45				2.72	3.87	2.57
52				3.12		2.52		1.73	0.89	1.39				2.79	3.70	2.66

*Concentration was too low for detection.

TABLE 36. PERCENT POTASSIUM IN DRY MATTER OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1979-80.

Treatment	31 Jul	29 Aug	1 Oct	31 Oct	3 Dec	3 Jan
11	2.99	1.60	2.10	2.25		1.06
12		2.44	2.22	2.42		
13			2.36	2.28	2.24	0.92
14			2.18	2.21	0.92	
15			2.20	2.52		0.93
21		2.62	1.91	2.08		0.92
22			1.99	1.98		
23			1.90	2.40	1.44	1.44
24			1.59	2.12		0.98
25			1.62	2.14		
31		1.91				
32		2.20	2.32			
33		2.14	1.58			1.53
34		2.12	2.24			
35		2.07				
36		1.72	2.10			
41	3.11	2.32	2.00			
51		2.61	1.96			
52	2.64	3.05	2.38			
53		2.18	2.26		1.28	
Fescue-clover						
11	2.61	2.09				
12		2.31				
21		2.28				
31		2.33				
32		2.50				
33		2.48				
34		2.37				
35		2.33				
36		2.49				
41	2.97	2.18				
51	2.82	2.51				
52	2.85	2.52				
53		2.37				
						1.28

TABLE 37. PERCENT POTASSIUM IN DRY MATTER OF TALL FESCUE AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb	10 Mar
11	2.03	3.04	2.60	2.45					
12			1.83	2.39					
13				1.83					
14					1.46				
15						1.18			
16							0.86		
17								0.72	
21			2.88	2.60					
22				2.86					
23				2.77	2.10	1.57			
24					1.98	1.61			
25							1.00		
26								0.62	
31									
32					2.59				
33						1.97			
34							1.29		
35								0.89	
36									0.68
41	1.90	3.29	2.47	2.44					
51	1.91	3.02	2.45	2.62	2.10				
52		3.32	2.79	2.76	2.12				
53				2.72	2.64				

TABLE 38. PERCENT MAGNESIUM IN TALL FESCUE DRY MATTER AT KNOXVILLE, 1978-79, SITE 1.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				0.55	0.55	0.52	0.42	0.34	0.31	0.44					0.44	0.26
12						0.48	0.44	0.46	0.29	0.37					0.42	0.19
13								0.48	0.25	0.40				0.60	0.36	0.18
14									0.52						0.36	0.02
15										0.35				0.67	0.37	0.21
16											0.29			0.54	0.37	0.38
17												0.08		0.62	0.37	0.36
21						0.59	0.54	0.20	0.25	0.35					0.40	0.25
22								0.40	0.25	0.33					0.34	0.26
23									0.37	0.26				0.63	0.52	0.22
24										0.34					0.31	0.25
25											0.15			0.51	0.25	0.26
26												0.47		0.55	0.36	0.36
31								0.22	0.22	0.28					0.36	0.35
32									0.33	0.41					0.33	0.31
33										0.29				0.58	0.46	0.40
34											0.24				0.41	0.41
35												0.16		0.51	0.40	0.47
36													0.12	0.62	0.36	0.43
41	0.56	0.42	0.56	0.43	0.59	0.67	0.51	0.46	0.25	0.22					0.36	0.34
51	0.39			0.56		0.70		0.33	0.24	0.33				0.47	0.32	0.41
52				0.46		0.69		0.40	0.42	0.34				0.56	0.38	0.36
53						0.71		0.39	0.40	0.33				0.59	0.25	0.23

TABLE 39. PERCENT MAGNESIUM IN TALL FESCUE AND FESCUE-CLOVER DRY MATTER AT KNOXVILLE, 1978-79, SITE 2.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	30 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				0.35	0.37	*	0.26	*	0.34	0.26					0.27	0.21
12						*	0.21	0.17	0.30	0.23					0.38	0.15
13								0.35	0.31					0.46	0.38	0.14
14									0.33	0.24					0.38	0.14
15										0.21				0.43	0.32	0.29
16											0.27			0.47	0.39	0.12
17												0.42		0.50	0.40	0.27
21						0.27	0.11	0.39	0.43	0.48					0.39	0.14
22								0.29	0.61	0.53					0.40	0.10
23									0.48	0.26				0.42	0.29	0.22
24										0.50					0.29	0.06
25											0.31			0.41	0.28	0.04
26												0.35		0.42	0.31	0.27
31								0.43	0.34	0.16					0.41	0.18
32									0.36	0.35					0.41	0.14
33										0.39				0.44	0.48	0.13
34											0.23				0.34	0.12
35												0.40		0.44	0.40	0.23
36													0.18	0.45	0.39	0.26
41	0.35	0.30	0.20	0.29	0.45	0.42	*	0.11	0.55	0.56					0.37	0.14
51	0.31			0.25		0.47		0.19	0.22	0.60				0.40	0.41	0.14
52				0.37		0.42		0.23	0.33	0.46				0.45	0.39	0.12
53						*		0.24	0.34	0.50				0.47	0.49	*
Fescue-clover																
11				0.29	0.41	*	*	0.40	0.37	0.65					0.45	0.16
12						*	*	0.19	0.24						0.65	*
13								0.39	0.40	0.53				0.23	0.53	0.13
14									0.47						0.56	*
15										0.44				0.26	0.48	*
16										0.67	0.26			0.47	0.42	0.24
17												0.40		0.37	0.48	0.16
21						0.27	*	0.17	0.32	0.54					0.37	0.27
22								0.31	0.39	0.58					0.50	0.13
23								0.06	0.42	0.55				0.27	0.48	0.32
24										0.59					0.45	0.40
25											0.39			0.23	0.47	0.49
26														0.21	0.47	0.13
31								*	0.45	0.64					0.33	*
32									0.45	0.55					0.29	0.25
33										0.60				0.21	0.35	*
34											0.19				0.50	0.28
35												0.40		0.32	0.30	0.20
36													0.18	0.25	0.40	*
41		0.17	0.26	0.29	0.40	*	0.22	0.34	0.49	0.54					0.42	0.21
51				0.32		0.09		0.39	0.25	0.51				0.33	0.39	0.37
52				0.24		0.03		0.27	0.37	0.46				0.38	0.49	0.31

*Concentration was too low for detection.

TABLE 40. PERCENT MAGNESIUM IN TALL FESCUE AND FESCUE-CLOVER DRY MATTER AT KNOXVILLE, 1979-80.

Treatment	31 Jul	29 Aug	1 Oct	31 Oct	3 Dec	3 Jan
11	0.82	0.32	0.30	0.45		0.26
12		0.37	0.59	0.46		
13				0.46	0.24	0.24
14				0.47		
15				0.40		0.33
21		0.44	0.34	0.37		0.34
22			0.33	0.36		
23				0.48		0.20
24				0.48		0.28
25				0.40		
31		0.39				
32		0.48	0.46			
33		0.48	0.52			0.37
34		0.40	0.40			
35		0.35				
36		0.40				
41	0.84	0.39	0.38			
51		0.44	0.42			
52	0.76	0.51	0.36			
53	0.59	0.48	0.52			0.40
Fescue-clover						
11	0.58	0.31				
12		0.29				
21		0.33				
31		0.28				
32		0.27				
33		0.25				
34		0.27				
35		0.31				
36		0.27				
41	0.50	0.36				
51	0.70	0.37				
52	0.72	0.38				
53		0.35				

TABLE 41. PERCENT MAGNESIUM IN TALL FESCUE DRY MATTER AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb	10 Mar
11	0.30	0.26	0.24	0.22					
12			0.22	0.26					
13				0.26					
14					0.30				
15						0.25			
16							0.24		
17								0.24	
21			0.35	0.22					
22				0.24					
23					0.22	0.30			
24					0.24	0.25			
25							0.29		
26									
31				0.24				0.36	
32					0.21				
33						0.24			
34							0.25		
35								0.27	
36									0.24
41	0.36	0.26	0.24	0.30					
51	0.40	0.24	0.24	0.24					
52		0.25	0.28	0.22	0.22				
53				0.24	0.20				

TABLE 42. PERCENT CALCIUM IN TALL FESCUE AND FESCUE-CLOVFR DRY MATTER AT KNOXVILLE, 1978-79, SITF 2.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
Fescue alone																
11				0.20	0.27	0.21	0.16	0.17	*	0.32					0.37	0.18
12						0.21	0.21	0.17	0.03	0.28					0.37	0.24
13								0.18	*					0.13	0.37	0.24
14									0.07	0.16					0.37	0.24
15										0.25				0.15	0.33	0.27
16											0.03			*	0.35	0.22
17												0.04		0.13	0.35	0.22
21						0.29	0.40	0.21	0.03	0.33					0.30	0.19
22								0.21	*	0.34					0.33	0.22
23									0.07	0.42				0.15	0.33	0.22
24										0.24					0.63	0.17
25											0.05			0.42	0.58	0.22
26												0.14		0.13	0.33	0.27
31								0.21	0.07	0.33					0.37	0.17
32									0.03	0.49					0.37	0.14
33										0.57				0.11	0.37	0.17
34											0.08				0.35	0.14
35												*		0.35	0.35	0.24
36													*	0.11	0.37	0.17
41	0.35	0.22	0.22	0.20	0.38	0.26	0.23	0.16	0.03	0.43					0.35	0.17
51	0.37			0.20		0.26		0.21	*	0.44				0.09	0.35	0.36
52				0.16		0.32		0.14	*	0.26				0.09	0.30	0.24
53						0.20		0.21	*	0.24				0.11	0.35	0.34
Fescue-clover																
11				0.42	0.40	0.24	0.23	0.21	*	0.48					0.44	0.19
12						0.24	0.26	0.23	*	0.52					0.49	0.24
13								0.21	*					0.24	0.40	0.27
14									0.03	0.46					0.47	0.29
15										0.55				0.24	0.44	0.39
16											*			0.25	0.21	0.27
17												*		0.25	0.21	0.42
21						0.27	0.32	0.23	0.30	0.54					0.36	0.52
22								0.25	*	0.47					0.19	0.29
23									*	0.49					0.36	0.62
24										0.60				0.31	0.24	0.57
25											0.14			0.24	0.21	0.49
26												*		0.20	0.24	0.52
31								0.19	0.11	0.60					0.19	0.32
32									*	0.55					0.31	0.37
33										0.57				0.20	0.12	0.17
34											0.08				0.29	0.49
35												*		0.28	0.19	0.20
36													*	0.22	0.19	0.15
41		0.31	0.29	0.35	0.38	0.26	0.23	0.23	*	0.81					0.44	0.29
51				0.36		0.32		0.25	0.19	0.44				0.29	0.42	0.24

*Concentration was too low for detection.

TABLE 43. PERCENT CALCIUM IN TALL FESCUE DRY MATTER AT KNOXVILLE, 1978-79, SITE 1.

Treatment	3 Jul	10 Jul	20 Jul	1 Aug	14 Aug	29 Aug	13 Sep	31 Sep	30 Oct	6 Dec	4 Jan	1 Feb	2 Mar	21 Mar	10 Apr	30 May
11				0.24	0.18	0.17	0.14	0.20	0.20	0.14					0.45	0.12
12						*	0.14	0.22	0.12	0.20					0.43	0.14
13								*	0.19					0.16	0.40	0.14
14									0.14	*					0.35	0.18
15										*				0.20	0.50	0.14
16											0.12			*	0.33	0.12
17												*		0.14	0.35	*
21						*	*	0.27	0.18	0.16					0.13	0.14
22								0.35	0.18	0.15					0.13	0.12
23									0.28	0.25				0.21	0.34	0.22
24										*					0.13	0.14
25											0.10			0.10	0.08	0.14
26												0.16		0.14	0.08	0.14
31								0.29	0.20	*					0.15	*
32									0.17	0.15					0.15	*
33										*				0.10	*	*
34											0.16				*	*
35												*		0.17	0.10*	*
36													*	0.12	*	*
41	0.36	0.27	0.22	0.15	0.13	0.16	*	0.18	0.18	*					0.10	*
51	0.39			0.15		0.11		0.37	0.18	0.11				0.10	0.11	*
52	0.36			0.10		*		0.31	0.17	0.15				0.18	0.11	0.14
53						0.11		0.33	0.23	0.25				0.12	0.15	0.12

*Concentration was too low for detection.

TABLE 44. PERCENT CALCIUM IN DRY MATTER OF TALL FESCUE AND FESCUE-CLOVER AT KNOXVILLE, 1979-80.

Treatment	31 Jul	29 Aug	1 Oct	31 Oct	3 Dec	3 Jan
Fescue alone						
11	0.30	0.24	0.35	0.47		0.32
12		0.25	0.35	0.43		
13			0.49	0.52	0.38	0.32
14			0.44	0.47		
15				0.44	0.39	0.24
21		0.33	0.42	0.48		0.32
22			0.41	0.42		
23			0.48	0.46		0.32
24			0.64	0.54	0.45	0.32
25			0.50	0.50		
31		0.28				
32		0.30	0.30			
33		0.30	0.26		0.40	0.34
34		0.36	0.30			
35		0.31				
36		0.31				
36		0.28				
41	0.30	0.26	0.46			
51		0.45	0.51			
52	0.35	0.33	0.46			
53		0.36	0.44			0.32
Fescue-clover						
11	0.31					
12		0.35				
21		0.36				
31		0.35				
32		0.40				
33		0.39				
34		0.36				
35		0.36				
36		0.34				
41	0.38	0.35				
51	0.38	0.39				
52		0.40				
53		0.38				

TABLE 45. PERCENT CALCIUM IN DRY MATTER OF TALL FESCUE AT DOVER, 1979-80.

Treatment	3 Jul	3 Aug	5 Sep	2 Oct	1 Nov	3 Dec	3 Jan	4 Feb	10 Mar
11	0.49	0.27	0.26	0.19					
12			0.30	0.21					
13				0.15					
14					0.15				
15						0.24			
16							0.19		
17									
21			0.38	0.18				0.32	
22				0.34					
23					0.21	0.17			
24					0.24	0.25			
25							0.15		
26								0.12	
31				0.35					
32					0.28				
33						0.20			
34							0.26		
35								0.20	
36									0.25
41	0.68	0.31	0.33	0.21					
51	0.74	0.33	0.37	0.27	0.26				
52		0.35	0.40	0.22	0.31				
53				0.29	0.32				

TABLE 46. PERCENT NITROGEN, PHOSPHORUS, POTASSIUM, MAGNESIUM AND CALCIUM IN TALL FESCUE DRY MATTER AT HOLSTON FARM, 1978-79.

Treatment	30 Oct	5 Dec	4 Jan
N	2.41	2.29	1.98
P	0.17	0.18	0.16
Mg	0.70	0.72	0.73
K	3.52	2.95	1.66
Ca	0.66	*	*

*Concentration was too low for detection.

TABLE 47. TOTAL PRECIPITATION (mm) FROM ONE HARVEST DATE TO THE NEXT HARVEST DATE AT KNOXVILLE.

1978-79		1979-80	
Starting Period	Total Precip.	Starting Period	Total Precip.
3 Jul 78	17	3 Jul 79	216
10 Jul 78	51	23 Jul 79	42
20 Jul 78	37	31 Jul 79	01.
1 Aug 78	132	1 Aug 79	47.
14 Aug 78	23	20 Aug 79	35.
29 Aug 78	18	29 Aug 79	57.
13 Sep 78	07	10 Sep 79	80.
30 Sep 78	25	1 Oct 79	09.
20 Oct 78	151	9 Oct 79	52.
6 Dec 78	188	31 Oct 79	165.
4 Jan 79	144	3 Dec 79	65.
1 Feb 79	113	3 Jan 80	215.
28 Feb 79	00	26 Feb 80	00.
1 Mar 79	-	29 Feb 80	00
2 Mar 79	-		
21 Mar 79	-		
10 Apr 79	243		
30 May 79	171		

TABLE 48. MEAN DAILY MAXIMUM AND MINIMUM TEMPERATURES WITHIN PERIODS BETWEEN HARVEST DATES AT KNOXVILLE.

1978-79				1979-80			
Period Starting	Max	Min	Mean	Period Starting	Max	Min	Mean
3 Jul 78	26.4	24.3	25.0	3 Jul 79	25.2	19.	22.7
10 Jul 78	26.1	20.5	23.4	23 Jul 79	26.3	18.3	24.5
20 Jul 78	27.8	23.0	25.8	31 Jul 79	26.6	23.6	25.2
1 Aug 78	26.7	20.8	24.3	8 Aug 79	27.2	17.7	22.6
14 Aug 78	27.2	23.6	25.4	20 Aug 79	26.1	23.6	24.8
29 Aug 78	26.1	22.2	24.4	29 Aug 79	25.5	19.7	23.7
13 Sep 78	26.1	19.4	23.1	10 Sep 79	23.8	16.9	19.5
30 Sep 78	20.3	09.4	14.3	1 Oct 79	20.5	10.0	14.8
30 Oct 78	16.1	04.4	11.1	9 Oct 79	20.5	6.1	13.0
5 Dec 78	14.2	-03.3	05.4	31 Oct 79	19.7	-4.1	8.5
4 Jan 79	05.2	-07.2	-01.0	3 Dec 79	12.5	-4.1	3.8
1 Feb 79	13.6	-07.2	02.1	3 Jan 80	14.4	-0.4	2.0
2 Mar 79	-	-	-	26 Feb 80	9.4	-2.2	4.2
21 Mar 79	-	-	-	29 Feb 80	2.5	2.5	2.5
				31 Mar 80	13.2	0.0	6.6

VITA

Kenneth Wayne Bell was born February 18, 1947, in Huntingdon, Tennessee. He is the son of Mr. Odell and Mrs. Mildred Bell. He graduated from Webb High School in McKenzie, Tennessee, in May 1964. He received the Bachelor of Science degree in agronomy in June 1968 and the Master of Science degree in plant science in 1969 from Tennessee State University. While enrolled as a student he was employed as Laboratory Assistant from September 1964 to June 1968 and as Graduate Research Assistant from June 1968 to August 1969 in the Department of Plant and Soil Science. During the summer of 1967, he was employed by the United States Department of Agriculture Soil Conservation Service as a student trainee.

In September 1969 he joined the Department of Agriculture and Natural Resources at Delaware State College as an instructor. While on leave from Delaware State College, he worked as a Graduate Research Assistant in the Plant and Soil Science Department of The University of Tennessee, Knoxville, from August 1977 to August 1979 and during the summer of 1980. He received the Doctor of Philosophy degree with a major in Plant and Soil Science from The University of Tennessee, Knoxville, in March 1981.

He is a member of the American Society of Agronomy, Crop Science Society of America, Delaware Veterinary Medical Institute, Alpha Phi Alpha Fraternity and Phi Delta Kappa Honor Fraternity.