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Nitrate and protein concentration in orchardgrass (Dactylis glomerata L.) forage produced under several cutting management and nitrogen fertilization regimes

Charles Ramsey Lewis

To the Graduate Council:

I am submitting herewith a thesis written by Charles Ramsey Lewis entitled "Nitrate and protein concentration in orchardgrass (Dactylis glomerata L.) forage produced under several cutting management and nitrogen fertilization regimes." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

John H. Reynolds, Major Professor

We have read this thesis and recommend its acceptance:

Horace C. Smith, Laurence N. Skold

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

March 1, 1970

To the Graduate Council:

I am submitting herewith a thesis written by Charles Ramsey Lewis, Jr., entitled "Nitrate and Protein Concentration in Orchardgrass (Dactylis glomerata L.) Forage Produced Under Several Cutting Management and Nitrogen Fertilization Regimes." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

John H Reynolds
Major Professor

We have read this thesis and recommend its acceptance:

Horace C. Smith

Laurence N. Skold

Accepted for the Council:

Hilton A. Smith
Vice Chancellor for Graduate Studies and Research

NITRATE AND PROTEIN CONCENTRATION IN ORCHARDGRASS (DACTYLIS GLOMERATA L.) FORAGE PRODUCED UNDER SEVERAL CUTTING MANAGEMENT AND NITROGEN FERTILIZATION REGIMES

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Charles Ramsey Lewis, Jr.

March 1970

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ABSTRACT

The effect of high nitrogen fertilization and intensive management on the dry matter production, nitrate-nitrogen concentration and protein-nitrogen concentration of orchardgrass (Dactylis glomerata L.) was studied at Knoxville, Tennessee during 1969. Twelve combinations of three factors were incorporated in the experiment. The orchardgrass was harvested either four or eight times at stubble heights of 4 cm or 10 cm, and with nitrogen applications of 224, 448, or 672 kg/ha applied in two equal applications.

Dry matter yields of forage ranged from 3.82 to 8.46 metric tons per hectare. Nitrogen levels did not significantly affect yield, however management levels were highly significant. The highest yielding treatment was 448 kg/ha of nitrogen, 4-cutting frequency and 4-cm height. Lowest yields occurred at 448 kg/ha, 8-cutting frequency and 4-cm height. The difference in total yields indicates the detrimental effect of frequent harvests on stand persistence and the effect of periods of adverse environmental conditions during the months of May, June, and August.

Nitrate-nitrogen concentrations were found to be affected significantly, on harvest dates analyzed, by nitrogen application but usually not by cutting management. The highest concentration was accumulated at 672 kg/ha followed by 448 kg/ha and 224 kg/ha, respectively. Nitrate-nitrogen concentrations for the three nitrogen rates were high early in the season (April 29), .43, .41, and .13 percent respectively, reaching toxic levels at the 672 and 448 kg/ha rates.

Concentrations then declined until June 6 when values were .11, .05, and .01 percent. Following this date the second half of the nitrogen was applied and resulted in a slight increase in the nitrate-nitrogen concentration in the forage which remained below toxic levels. Concentrations of samples taken on July 22 were .24, .16, and .07 percent, respectively. By September 1, values had again declined with concentrations of .16, .06, and .00 percent.

Protein-nitrogen concentrations were affected by both nitrogen levels and management levels. Concentrations ranged from 2.55 to 5.33 percent during 1969. Concentrations were high, approximately 5 percent, for all treatments during the early part of April. Following this period, values dropped to approximately 3 percent and remained at that concentration for the remainder of the growing season. The highest concentration for the season occurred at the 672 kg/ha nitrogen level, 8-cutting frequency, and 4-cm stubble height. The lowest concentration occurred at the 224 kg/ha nitrogen level, 4-cutting frequency, and 10-cm stubble height. The highest protein-nitrogen concentrations at all nitrogen rates were found at the 8-cutting frequency.

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CHAPTER I

INTRODUCTION

The utilization of pure stands of perennial grasses for pasture and hay has become an increasingly important part of the Tennessee farming program in recent years. This has been the result of a variety of factors. Some of these are: limited persistence of grass-legume mixtures; added management practices required to maintain the legume in such mixtures; and the development of more suitable grass varieties.

However, one of the main factors is the increased availability and lower cost of nitrogen fertilizers which are required to provide the essential nutrient that was once supplied by the legumes in the mixtures through nitrogen fixation.

Some problems have occurred when attempts were made to use a pure stand of grass under intensive management. The major problem was failure to maintain both a persistent stand and high forage yields under intensive grazing. An additional problem has been the accumulation of nitrates in the forage which are toxic to livestock in excessive levels when high amounts of nitrogen fertilizers are applied.

Because of the importance of orchardgrass (Dactylis glomerata L.) in the forage program on Tennessee farms, a study of the effect of intensive management on this crop was considered to be valuable. The purpose of the investigation was to determine the effect of high rates

of nitrogen fertilization and several harvest management regimes on yield and on nitrate-nitrogen and protein-nitrogen concentrations in the orchardgrass forage.

CHAPTER II

LITERATURE REVIEW

Research has indicated that orchardgrass will respond more to higher rates of nitrogen than other cool-season grasses (13). However, because of the accumulation of excessive levels of nitrate under high nitrogen fertilization, plants fertilized heavily with nitrogen can cause serious physiological disturbances to grazing livestock. Corn silage high in nitrates caused deaths of cattle at near epidemic levels in central Missouri during 1954 (18). Oat hay and straw high in nitrate also resulted in livestock deaths in Wyoming (10) and oat pastures caused deaths in Florida (15) when livestock consumed the forage.

The causative agent of this toxic effect has been described by many investigators. When forages containing high levels of nitrate are ingested, the nitrate is converted to the nitrite form by micro-organisms in the rumen or intestine. This nitrite is then absorbed into the blood, which is then unable to absorb oxygen from the lungs. As a result, the animal suffers from lack of oxygen which can result in death, abortion, or production losses in the form of reduced weight gain or milk production. The degree of injury occurring is affected by the nitrate concentration of the forage, quantity consumed, and rate of intake (1, 6, 12, 30).

The concentration at which toxic conditions result has been determined by Wright and Davison (30). They found feeds containing

concentrations of from .34 to .45 percent nitrate-nitrogen to be toxic and advised mixing them with safer feeds prior to use.

The degree of accumulation of nitrate in the tissue of plants is dependent on a variety of factors. Among these are: species, stage of maturity, and part of plant; level of nitrogen fertilization; and degree of light intensity (3, 7, 15, 16, 30, 31). Factors found to have little effect on nitrate levels were variety within a species, source of nitrogen, placement of nitrogen, and lack of certain plant nutrients (7, 19). In addition, cutting management was not found to be significant in influencing the accumulation of nitrate in plant tissues (17, 24, 31).

It was observed by Hanway (12) that an increase in plant nitrate was usually accompanied by a decrease in water-soluble carbohydrates and an increase in potassium or sodium. The concentration of crude protein was also found to be increased by additional applications of nitrogen fertilizer (11, 21, 22).

Many investigators have provided information on the accumulation of nitrates in a number of plant species. Mayo in 1895 (10, 30) was the first to provide evidence that livestock injury was caused by high nitrate levels in corn roughage. Many reports have followed concerning the nitrate content of plants such as corn (4, 14, 18), small grain (3, 15), legumes (4, 20, 23), and several weedy species (25, 26). Relatively little research has been done on specific forage grass species. Some of the grasses that have been considered are intermediate wheatgrass (17), bromegrass (5), blue panicgrass (31), ryegrass (19), and orchardgrass (8, 11, 21, 22).

The investigations on orchardgrass have mainly related to the effect of increased nitrogen fertilization on the concentration of nitrogeneous compounds in the plant. Ferguson and Terry (8) reported nitrate-nitrogen concentrations,as percentages of total nitrogen, of 1.3, 1.7, 2.8, and 6.6 at 0, 250, 500, and 750 kg/ha of nitrogen when applied immediately after cutting. When nitrogen was applied 10 to 14 days prior to cutting, the concentrations were 1.7, 2.3, 5.8, and 8.9 percent.

Reid, Jung, and Kinsey (22) found that in May the percent nitrate in orchardgrass forage was 0.4, 0.3, 0.6, and 1.7 when nitrogen fertilizer had been applied at rates of 0, 56, 112, and 448 kg/ha, while in July the nitrate values were 0.3, 0.2, 0.3, 0.2, and 0.2 percent with 0, 56, 112, 224, and 448 kg/ha nitrogen. Crude protein was found to be 11.6, 12.8, 13.4, and 20.0 percent in May at the four rates of nitrogen, while in July the levels were 9.4, 10.7, 11.4, 11.4, and 13.0 percent at the five rates.

Gordon, Decker, and Wiseman (11) recorded similar results by applying nitrogen at 0, 672, and 672 kg/ha with shaded plants. Results during 1958, expressed as average percent nitrate on a dry weight basis, were 0.02, 0.85, and 1.35 at 0, 672, and 672 kg/ha plus shade respectively. Average values of crude protein were also observed to increase with increased nitrogen rates. Values were 13.6, 25.2, and 25.9 percent under the three treatments.

Poulton, Macdonald, and Vander Noot (21) found that percent crude protein in forage was 13.89, 17.52, and 18.02 percent with the addition of 112, 224, and 448 kg/ha of nitrogen respectively.

Few workers have incorporated both nitrogen levels and intensive management in their experiments. Stillings et al. (24) have incorporated management into their experiment, however, this was limited in that nitrate levels and protein-nitrogen were determined only for successively later cutting dates. Cutting dates occurred at three stages of maturity with eight to 10 days between stages. Nitrogen was applied as ammonium nitrate at rates of 56, 112, 224, 224-split, and 336 kg/ha. Results during 1959 showed that total nitrogen, expressed on a dry matter basis, ranged from 1.84 to 4.96 percent, while nitrate concentrations expressed as a percent of the total nitrogen were 0.0 to 11.5 percent. The trend during the experiment was for the total nitrogen and nitrate-nitrogen to increase with increasing applications of nitrogen, while successively later harvests resulted in decreasing concentrations of total and nitrate-nitrogen. Forage fertilized at 224 and 336 kg/ha of nitrogen was found to contain KNO_3 levels as high as 5.3 percent on a dry matter basis.

CHAPTER III

EXPERIMENTAL PROCEDURE

Boone orchardgrass was seeded with a cultipacker seeder at the Plant Science Farm, Knoxville, Tennessee on September 1, 1966. The soil at the site was a Sequoia silt loam with a pH of 6.2. The area was divided into plots of 1.8 x 7.3 meters. The forage from these plots was used to determine yields, percent nitrate-nitrogen, and percent protein-nitrogen in 1969.

The pH of the soil on October 22, 1968 was 5.8 to 6.5, the phosphorus soil test value 20 kg/ha (medium), and the potassium value 94 kg/ha (low). On November 5, 1968, 38 kg/ha phosphorus and 216 kg/ha potassium were added. The pH of the soil on September 30, 1969, 30 days after the last cut, was 5.4 to 6.7, the phosphorus value 16 kg/ha (low), and the potassium value 90 kg/ha (low).

A split-plot factorial experimental design was used with whole plots replicated three times. Whole plot treatments within each replication were three levels of nitrogen fertilization and the subplots were cutting management treatments. Within the whole plots, combinations of two cutting heights and two cutting frequencies were randomized as the four cutting management treatments.

The three nitrogen treatments were 224, 448, and 672 kg/ha of nitrogen, expressed hereafter as N_1, N_2, and N_3, respectively. The nitrogen was applied in the form of ammonium nitrate in two equal parts on March 17 and June 18, 1969.

The cutting frequencies were 3-week intervals (eight during the season) and 6-week intervals (four during the season) designated hereafter as C_8 and C_4. The cutting dates for C_8 were April 8, April 29, May 20, June 6, July 1, July 22, August 12, and September 1, and for C_4 were April 29, June 6, July 22, and September 1. The cutting heights used in combination with the frequencies were 4 cm and 10 cm, designated H_1 and H_2. Table 1 indicates the treatments employed and the terms used. The same 12 treatments listed in Table 1 had also been imposed during 1967 and yields obtained (16). During the 1968 season, in order to determine the carryover effect of the 1967 treatments, all plots were treated uniformly. Nitrogen was applied on all plots at the rate of 448 kg/ha in two equal parts on March 11 and June 20, 1968 and all plots were cut at a 7-cm height on April 23, May 21, June 18, July 15, and August 15, 1968.

In 1969 yields for each treatment were determined by cutting a 1 x 8 m strip from the center of each subplot. The forage was collected, dried at 70°C, and weighed to determine yield. Samples for nitrate-nitrogen and protein-nitrogen analysis were obtained by hand clipping randomly at the proper height 10 grams of orchardgrass from each plot. These samples were then dried at 70°C and ground in a Wiley mill. The invasion of weeds into each treatment was determined by estimating the amounts of weeds in each subplot before each cutting and recording it as the percent dry weight of the forage. Yields are reported as weed-free orchardgrass on a dry matter basis.

Nitrate concentrations for each treatment were determined by the naphthylamine procedure outlined by Woolley, Hicks, and

Table 1. Identification of treatments

Treatment codes	Nitrogen levels	Stubble heights	Number of cuts
	Kg/ha	Cm	
$N_1H_1C_8$	224	4	8
$N_1H_1C_4$	224	4	4
$N_1H_2C_8$	224	10	8
$N_1H_2C_4$	224	10	4
$N_2H_1C_8$	448	4	8
$N_2H_1C_4$	448	4	4
$N_2H_2C_8$	448	10	8
$N_2H_2C_4$	448	10	4
$N_3H_1C_8$	672	4	8
$N_3H_1C_4$	672	4	4
$N_3H_2C_8$	672	10	8
$N_3H_2C_4$	672	10	4

Hageman (29). This procedure involved placing a ground forage sample in 20 ml demineralized water and heating it in a boiling water bath. At the end of a 30 minute period a 1 ml aliquot was taken and added to an acetic acid solution to which a reagent powder consisting of barium sulfate, manganous sulfate, citric acid, sulfanilic acid, naphthylamine, and zinc powder was added. This mixture was then shaken and placed in a centrifuge. After centrifugation, the absorbance of the supernatant solution was determined in a Spectronic 20 spectrophotometer. From the absorbance value, the percent nitrate-nitrogen was calculated for each sample. Samples were analyzed in duplicate.

There is much confusion in the literature on the ways of reporting concentrations of nitrate. In this paper, percent nitrate-nitrogen (NO_3-N) is the basis for reporting nitrate concentrations. This way of reporting nitrate may be converted to other ways as follows. To convert from percent nitrate-nitrogen to percent nitrate, multiply by 4.43. To convert from percent nitrate-nitrogen to percent potassium nitrate, multiply by 7.22.

Percent protein-nitrogen of the samples was determined by placing a ground sample in concentrated sulfuric acid and allowing it to digest overnight. The mixture was then heated to over 200°C for 2.5 hours. At the end of this period, 15 ml of 35% hydrogen peroxide was added and the mixture reheated until clear and for 45 minutes after clearing. Following heating, the solution was placed in a 250 ml volumetric flask and made to volume with distilled water. From this 250 ml, an aliquot was placed in an Auto Analyzer (2, 9) and percent

transmission determined after the phenol-hypochlorite color reaction (28). From this transmission value the percent protein-nitrogen was calculated. Samples were analyzed in duplicate.

CHAPTER IV

RESULTS

I. WEATHER CONDITIONS

The temperature and precipitation data taken at the Plant Science Farm during the 1969 growing season (Table 2) indicate that weather conditions were not the most advantageous for growth. The period from March 1 to September 6 was characterized by periods of temperature and precipitation that were not considered normal for this period (27). Weekly precipitation was not evenly distributed during the growing season and there were three periods when precipitation was considered to be below favorable levels for growth. These were April 26 to May 30, June 7 to June 20, and August 23 to September 6. The first was five weeks in length which probably led to a soil moisture deficit. The second period was only two weeks in length, but followed the first by only one week and added to the soil moisture problem already existing. The third period occurred just prior to the final harvest date. Monthly precipitation totals were lower than normal for March, April, May, and July. The June precipitation level was slightly higher than normal but most of the precipitation occurred during a 1-week period following an extended dry period. During August, soil moisture conditions improved as a result of rainfall at twice the normal amount. However, this high amount of precipitation occurred during the first part of the month with moisture conditions again becoming inadequate during the latter part of the month.

Table 2. Average weekly minimum and maximum temperatures and weekly total precipitation for the growing season of March 1, 1969 to September 6, 1969*

Week of	Climatological week	Minimum temperature	Maximum temperature	Precipitation
		°C	°C	mm
Mar. 1	1	-3.9	7.8	17
Mar. 8	2	-6.1	6.7	18
Mar. 15	3	-0.6	16.1	24
Mar. 22	4	0.0	14.4	10
Mar. 29	5	1.7	18.9	22
Apr. 5	6	7.2	23.9	14
Apr. 12	7	10.0	23.9	17
Apr. 19	8	4.4	18.3	18
Apr. 26	9	5.6	23.3	9
May 3	10	10.6	28.3	4
May 10	11	5.6	23.3	9
May 17	12	13.3	27.2	6
May 24	13	13.3	28.9	6
May 31	14	11.7	28.9	48
Jun. 7	15	16.1	31.1	9
Jun. 14	16	16.1	29.4	8
Jun. 21	17	18.3	31.1	110
Jun. 28	18	19.4	33.9	0
Jul. 5	19	20.0	33.9	20
Jul. 12	20	19.4	33.3	9
Jul. 19	21	20.0	33.3	44
Jul. 26	22	17.8	31.1	2
Aug. 2	23	16.7	30.6	66
Aug. 9	24	17.2	30.6	0
Aug. 16	25	18.9	31.1	107
Aug. 23	26	14.4	30.0	4
Aug. 30	27	16.7	30.6	4
Sep. 6	28	13.3	27.8	32

*Data compiled by H. A. Fribourg, Agronomy Department, University of Tennessee, Knoxville, Tennessee.

The average weekly minimum temperatures were slightly below normal during the entire growing season except for two 1-week periods in July. The average weekly maximum temperatures were also below normal for the months of March and August. During April, May, June, and July the temperatures ranged slightly above normal.

II. FORAGE PRODUCTION

Forage production for 1969 is shown in Table 3 for each harvest throughout the season. Yields for each harvest date indicate that production was affected by the precipitation as well as management. During the latter part of the growing season yields increased slightly indicating that the high level of precipitation of July and August had some beneficial effects on growth. Yields in 1969 ranged from 3.82 to 8.46 metric tons/ha (Table 4).

The 224 kg/ha and 448 kg/ha nitrogen levels were represented in the highest yielding group of treatments in 1969. Of these two levels, 448 kg/ha was the higher yielding, however none of the nitrogen levels was found to be significantly different. All nitrogen treatments were found to be higher yielding in the 4-cutting frequency at both cutting heights while the lowest yielding treatments were at an 8-cutting frequency for both cutting heights (Table 5).

The effect of intensive management on the orchardgrass stand is evident from the degree of weed invasion at the end of the 1969 season (Table 6). At the short cutting height, H_1, and the frequent cutting period, C_8, the stand was almost completely destroyed. However, at the higher cutting height, H_2, and less frequent cutting period, C_4, the stand was invaded only slightly by weeds.

Table 3. Forage dry matter yields for individual harvests in 1969

Treat. codes	Harvest dates Apr. 8	Apr. 39	May 20	Jun. 6	Jul. 1	Jul. 22	Aug. 12	Sep. 1	Yearly totals
					Metric tons/ha				
$N_1H_1C_8$	1.20	2.09	0.52	0.25	0.19	0.08	0.03	0.00	4.35
$N_1H_1C_4$		4.21		1.13		1.04		0.89	7.27
$N_1H_2C_8$	0.75	2.04	0.33	0.27	0.44	0.64	0.47	0.87	5.82
$N_1H_2C_4$		2.98		0.84		1.24		2.07	7.13
$N_2H_1C_8$	1.03	1.86	0.54	0.20	0.13	0.03	0.03	0.00	3.82
$N_2H_1C_4$		4.13		1.52		0.92		1.89	8.46
$N_2H_2C_8$	0.46	2.28	0.36	0.36	0.37	0.38	0.44	1.09	5.74
$N_2H_2C_4$		2.93		1.08		1.20		2.39	7.60
$N_3H_1C_8$	1.14	1.88	0.55	0.24	0.17	0.03	0.04	0.00	4.05
$N_3H_1C_4$		3.61		1.31		0.69		0.96	6.57
$N_3H_2C_8$	0.44	2.42	0.33	0.34	0.36	0.34	0.35	1.11	5.68
$N_3H_2C_4$		2.50		1.09		1.07		2.24	6.91

Table 4. Total forage dry matter yields for 1969

Treatment codes	Total yields*
	Metric tons/ha
$N_2H_1C_4$	8.46[a]
$N_2H_2C_4$	7.60[ab]
$N_1H_1C_4$	7.27[abc]
$N_1H_2C_4$	7.13[abcd]
$N_3H_2C_4$	6.91 [bcd]
$N_3H_1C_4$	6.57 [bcd]
$N_1H_2C_8$	5.82 [cde]
$N_2H_2C_8$	5.74 [cde]
$N_3H_2C_8$	5.68 [de]
$N_1H_1C_8$	4.35 [ef]
$N_3H_1C_8$	4.05 [f]
$N_2H_1C_8$	3.82 [f]

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 5. Total forage dry matter yields for 1969 with management levels compared within nitrogen levels

Management levels	Nitrogen levels N_1	N_2	N_3	Average
	Metric tons/ha			
H_1C_8	4.35^{b*}	3.82^{c}	4.05^{b}	4.07
H_1C_4	7.27^{a}	8.46^{a}	6.57^{a}	7.43
H_2C_8	5.82^{ab}	5.74^{bc}	5.68^{ab}	5.75
H_2C_4	7.13^{a}	7.60^{ab}	6.91^{a}	7.21
Average	6.14	6.41	5.80	

*Values within each nitrogen level followed by the same letter are not significantly different at the .05 level of probability.

Table 6. Degree of weed invasion in each treatment at end of 1969 growing season

Treatment codes	Percent weeds
$N_2H_2C_4$	4
$N_1H_2C_4$	6
$N_3H_2C_4$	9
$N_2H_2C_8$	18
$N_3H_2C_8$	38
$N_1H_2C_8$	43
$N_2H_1C_4$	53
$N_1H_1C_4$	68
$N_3H_1C_4$	70
$N_2H_1C_8$	99
$N_1H_1C_8$	99
$N_3H_1C_8$	99

III. NITRATE-NITROGEN IN THE FORAGE

Nitrate-nitrogen concentrations for the harvest dates of April 8, April 29, May 20, June 6, July 1, July 22, August 12, and September 1, 1969 are given in Table 7. However, analyses of variance were calculated only on the April 29, June 6, July 22, and September 1 harvest dates because all management treatments were sampled on those dates. This same procedure was followed for the protein-nitrogen concentrations.

Significant effects were found on all cutting dates analyzed. Nitrogen fertilization was found to be significant for all cutting dates while management was only significant for the June 6 harvest date.

Table 8 gives the nitrate-nitrogen concentration of the forage harvested on April 29. Concentrations on this date ranged from a low of .07 percent to a high of .48. Comparison of nitrogen levels within management levels (Table 9) indicates that the nitrogen levels 672 kg/ha and 448 kg/ha produced higher nitrate-nitrogen concentrations than the 224 kg/ha level. Average values were .43, .41, and .13 percent. Management levels did not significantly affect the average nitrate-nitrogen concentrations.

On the June 6 harvest date nitrate-nitrogen concentrations ranged from .01 to .17 percent and were much lower than those of the April harvest date (Table 10). On this harvest date both management and nitrogen levels were found to be significant. The nitrogen level producing the greatest concentration was 672 kg/ha followed by 448 kg/ha and 224 kg/ha. Average concentrations at these levels were

Table 7. Nitrate-nitrogen concentrations in forage for individual harvests during 1969

Treat. codes	Harvest dates Apr. 8	Apr. 29	May 20	Jun. 6	Jul. 1	Jul. 22	Aug. 12	Sep. 1
	Percent nitrate-nitrogen							
$N_1H_1C_8$	.28	.09	.05	.01	.15	.04	.01	.00
$N_1H_1C_4$		.20		.02		.01		.00
$N_1H_2C_8$	.21	.07	.03	.01	.01	.06	.02	.00
$N_1H_2C_4$		.14		.01		.06		.00
$N_2H_1C_8$	.38	.45	.18	.04	.17	.18	.09	.00
$N_2H_1C_4$		.39		.08		.15		.03
$N_2H_2C_8$	.36	.45	.19	.05	.12	.14	.10	.09
$N_2H_2C_4$		.35		.04		.15		.10
$N_3H_1C_8$	.40	.42	.28	.08	.24	.24	.09	.15
$N_3H_1C_4$		.42		.17		.20		.14
$N_3H_2C_8$	.32	.48	.25	.06	.13	.22	.10	.19
$N_3H_2C_4$		.39		.13		.31		.16

Table 8. Nitrate-nitrogen concentrations in forage for the April 29, 1969 harvest

Treatment codes	Percent nitrate-nitrogen
$N_3H_2C_8$	.48[a*]
$N_2H_2C_8$	.45[a]
$N_2H_1C_8$	.45[a]
$N_3H_1C_4$	.42[a]
$N_3H_1C_8$	.42[a]
$N_2H_1C_4$	.39[a]
$N_3H_2C_4$	.39[a]
$N_2H_2C_4$	.35[ab]
$N_1H_1C_4$	.20[bc]
$N_1H_2C_4$	.14[c]
$N_1H_1C_8$	.09[c]
$N_1H_2C_8$	.07[c]

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 9. Nitrate-nitrogen concentrations in forage for April 29, 1969 with nitrogen levels compared within management levels

Nitrogen levels	Management levels H_1C_8	H_1C_4	H_2C_8	H_2C_4	Average
	Percent nitrate-nitrogen				
N_1	.09[b]*	.20[b]	.07[b]	.14[b]	.13
N_2	.45[a]	.39[a]	.45[a]	.35[a]	.41
N_3	.42[a]	.42[a]	.48[a]	.39[a]	.43
Average	.32	.34	.34	.30	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

Table 10. Nitrate-nitrogen concentrations in forage for the June 6, 1969 harvest

Treatment codes	Percent nitrate-nitrogen
$N_3H_1C_4$	.17[a*]
$N_3H_2C_4$	.13 [b]
$N_2H_1C_4$	.08 [c]
$N_3H_1C_8$	.08 [c]
$N_3H_2C_8$	.06 [cd]
$N_2H_2C_8$	.05 [d]
$N_2H_1C_8$	.04 [d]
$N_2H_2C_4$	.04 [de]
$N_1H_1C_4$	.02 [ef]
$N_1H_1C_8$	.01 [ef]
$N_1H_2C_4$	.01 [ef]
$N_1H_2C_8$	.01 [f]

*Values followed by the same letter are not significantly different at the .05 level of probability.

.11, .05, and .01 percent (Table 11). The management levels at which the highest accumulation of nitrate-nitrogen occurred were the 4-cutting frequency at both cutting heights, where concentrations were .09 and .06 percent, respectively (Tables 11 and 12).

The nitrate-nitrogen concentrations of the forage on July 22 are presented in Table 13. Concentrations on this date ranged from .04 to .31 percent, the increase in concentration over the June 6 date resulting from the application of the second half of the nitrogen. Nitrogen was the only significant treatment variable on this date with the highest concentration found at the 672 kg/ha level, followed by the 448 kg/ha and 224 kg/ha. The average concentrations for the three levels were .24, .16, and .07 percent (Table 14). Management levels did not significantly affect the nitrate-nitrogen concentrations. Values for all managements averaged .15 percent.

The final harvest date, September 1, is presented in Table 15. On this date nitrate-nitrogen levels ranged from .00 to .19 percent. The highest concentrations were found in the forage of the 672 kg/ha rate followed by 448 kg/ha and 224 kg/ha levels. Average concentrations were .16, .06, and .00 percent (Table 16). Nitrate-nitrogen concentrations were not significantly affected by management levels. Values for all managements averaged .07 percent.

Figure 1 represents the concentrations of nitrate-nitrogen on the cutting dates of April 8, April 29, May 20, June 6, July 1, July 22, August 12, and September 1 when all cutting managements were averaged within each nitrogen level. The general trend during the season at all nitrogen levels was for a high nitrate-nitrogen concentration

Table 11. Nitrate-nitrogen concentrations in forage for June 6, 1969 with nitrogen levels compared within management levels

Nitrogen levels	Management levels H_1C_8	H_1C_4	H_2C_8	H_2C_4	Average
	Percent nitrate-nitrogen				
N_1	.01[c]*	.02[c]	.01[b]	.01[c]	.01
N_2	.04[b]	.08[b]	.05[a]	.04[b]	.05
N_3	.08[a]	.17[a]	.06[a]	.13[a]	.11
Average	.04	.09	.04	.06	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

Table 12. Nitrate-nitrogen concentrations in forage for June 6, 1969 with management levels compared within nitrogen levels

Management levels	Nitrogen levels N_1	N_2	N_3	Average
	Percent nitrate-nitrogen			
H_1C_8	.01^{a*}	.04^{a}	.08^{bc}	.04
H_1C_4	.02^{a}	.08^{a}	.17^{a}	.09
H_2C_8	.01^{a}	.05^{a}	.06^{c}	.04
H_2C_4	.01^{a}	.04^{a}	.13^{ab}	.06
Average	.01	.05	.11	

*Values within each nitrogen level followed by the same letter are not significantly different at the .05 level of probability.

Table 14. Nitrate-nitrogen concentrations in forage for July 22, 1969 with nitrogen levels compared within management levels

Nitrogen levels	Management levels H_1C_8	H_1C_4	H_2C_8	H_2C_4	Average
	Percent nitrate-nitrogen				
N_1	.04[b*]	.10[b]	.06[b]	.06[b]	.07
N_2	.18[a]	.15[ab]	.14[ab]	.15[a]	.16
N_3	.24[a]	.24[a]	.22[a]	.31[a]	.24
Average	.15	.16	.14	.17	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

Table 15. Nitrate-nitrogen concentrations in forage for the September 1, 1969 harvest

Treatment codes	Percent nitrate-nitrogen
$N_3H_2C_8$	.19[a*]
$N_3H_2C_4$	.16[ab]
$N_3H_1C_8$	.15[ab]
$N_3H_1C_4$	.14[ab]
$N_2H_2C_4$	.10[bc]
$N_2H_2C_8$	.09[bcd]
$N_2H_1C_4$	.03[cd]
$N_2H_1C_8$	.00[d]
$N_1H_2C_8$	.00[d]
$N_1H_2C_4$	.00[d]
$N_1H_1C_4$	.00[d]
$N_1H_1C_8$	.00[d]

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 16. Nitrate-nitrogen concentrations in forage for September 1, 1969 with nitrogen levels compared within management levels

Nitrogen levels	Management levels H_1C_8	H_1C_4	H_2C_8	H_2C_4	Average
	Percent nitrate-nitrogen				
N_1	.00[b]*	.00[b]	.00[c]	.00[b]	.00
N_2	.00[b]	.03[b]	.09[b]	.10[a]	.06
N_3	.15[a]	.14[a]	.19[a]	.16[a]	.16
Average	.05	.06	.09	.09	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

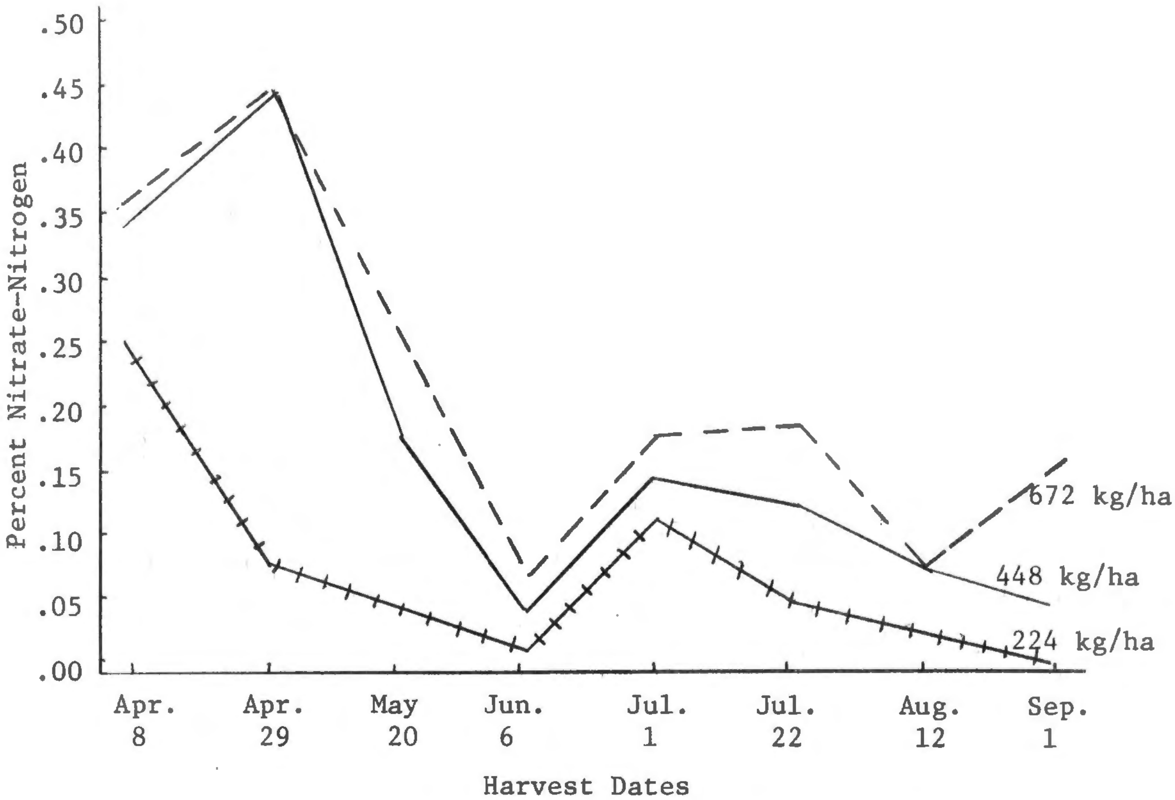

Figure 1. Percent nitrate-nitrogen for individual harvests during the 1969 growing season.

during April. Concentrations then decreased until June but increased slightly after the second application of nitrogen. Another decline in concentration followed the slight rise occurring after the nitrogen application. Concentrations at the 224 kg/ha level always remained below the concentration which is considered critical for livestock. However, the 672 kg/ha and 448 kg/ha treatments were above the values considered to be safe on the April 8 and April 29 harvest dates.

IV. PROTEIN-NITROGEN IN THE FORAGE

Protein-nitrogen concentrations for the harvest dates of April 8, April 29, May 20, June 6, July 1, July 22, August 12, and September 1 are presented in Table 17. Analyses of variance of the dates on which all management treatments were sampled (April 29, June 6, July 22, September 1) indicate that significant effects did not occur for all harvest dates. Nitrogen levels and management levels were found to be significant only for the April 29 and September 1 harvest dates.

Table 18 gives the protein-nitrogen concentration of the forage harvested on April 29. Concentrations ranged from 2.66 to 3.87 percent on this date. Comparison of nitrogen levels within management levels (Table 19) indicates that the nitrogen levels 672 kg/ha and 448 kg/ha produced higher protein-nitrogen concentrations than the 224 kg/ha level. Average values were 3.52, 3.40, and 2.86 percent. Table 20 compares management within nitrogen levels with the greatest

Table 17. Protein-nitrogen concentrations in forage for individual harvests during 1969

Treat. codes	Apr. 8	Apr. 29	May 20	Jun. 6	Jul. 1	Jul. 22	Aug. 12	Sep. 1
	Percent protein-nitrogen							
$N_1H_1C_8$	4.70	3.12	3.20	2.70	3.07	3.14	2.98	2.98
$N_1H_1C_4$		2.66		2.75		2.73		2.59
$N_1H_2C_8$	4.87	2.89	3.29	2.88	3.10	3.01	3.18	2.79
$N_1H_2C_4$		2.75		2.90		2.92		2.55
$N_2H_1C_8$	4.91	3.81	3.57	3.54	3.00	2.81	3.51	3.58
$N_2H_1C_4$		3.04		3.41		2.70		3.21
$N_2H_2C_8$	5.30	3.61	3.70	3.51	3.02	3.02	3.43	3.37
$N_2H_2C_4$		3.13		3.46		2.92		2.90
$N_3H_1C_8$	5.07	3.87	3.72	3.24	2.85	3.50	3.57	3.87
$N_3H_1C_4$		3.20		3.22		3.31		3.17
$N_3H_2C_8$	5.33	3.65	3.79	3.21	3.14	3.21	3.45	3.53
$N_3H_2C_4$		3.36		3.18		3.07		3.06

Table 18. Protein-nitrogen concentrations in forage for the April 29, 1969 harvest

Treatment codes	Percent protein-nitrogen
$N_3H_1C_8$	3.87[a*]
$N_2H_1C_8$	3.81[a]
$N_3H_2C_8$	3.65[ab]
$N_2H_2C_8$	3.61[ab]
$N_3H_2C_4$	3.36[bc]
$N_3H_1C_4$	3.20[cd]
$N_2H_2C_4$	3.13[cd]
$N_1H_1C_8$	3.12[cd]
$N_2H_1C_4$	3.04[cde]
$N_1H_2C_8$	2.89[def]
$N_1H_2C_4$	2.75[ef]
$N_1H_1C_4$	2.66[f]

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 19. Protein-nitrogen concentrations in forage for the April 29, 1969 harvest with nitrogen levels compared within management levels

Nitrogen levels	Management levels				Average
	H_1C_8	H_1C_4	H_2C_8	H_2C_4	
	Percent protein-nitrogen				
N_1	3.12[b*]	2.66[b]	2.89[b]	2.75[b]	2.86
N_2	3.81[a]	3.04[a]	3.61[a]	3.13[a]	3.40
N_3	3.87[a]	3.20[a]	3.65[a]	3.36[a]	3.52
Average	3.60	2.97	3.38	3.08	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

Table 20. Protein-nitrogen concentrations in forage for the April 29, 1969 harvest with management levels compared within nitrogen levels

Management levels	Nitrogen levels N_1	N_2	N_3	Average
	Percent protein-nitrogen			
H_1C_8	3.12^{a*}	3.81^{a}	3.87^{a}	3.60
H_1C_4	2.66^{b}	3.04^{b}	3.20^{c}	2.97
H_2C_8	2.89^{ab}	3.61^{a}	3.65^{ab}	3.38
H_2C_4	2.75^{b}	3.13^{b}	3.36^{bc}	3.08
Average	2.86	3.40	3.52	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

concentration within nitrogen levels occurring at the 8-cutting frequency for both stubble heights.

Protein-nitrogen concentrations are presented in Table 21 for the June 6 harvest date. There were no significant effects from either nitrogen or management for this harvest date as indicated by the values expressed in Table 21. The values ranged from 2.70 to 3.54 percent. These same non-significant effects were also observed on the July 22 harvest date (Table 22). Values for that date ranged from 2.70 to 3.50 percent.

The protein-nitrogen levels of the final harvest on September 1 are presented in Table 23. Nitrogen levels and management levels were both found to be significant. Concentrations on this date ranged from 2.55 to 3.87 percent. Table 24 compares nitrogen levels within management levels. Protein-nitrogen concentrations were greater at the 672 kg/ha level followed by the 448 kg/ha and 224 kg/ha. Average values were 3.41, 3.27, and 2.73 percent, respectively. Management levels within nitrogen levels are compared in Table 25. The management levels at which the highest concentration of protein-nitrogen occurred were the 8-cutting frequency at both stubble heights followed by the 4-cutting frequency at both stubble heights.

Figure 2 represents the concentrations of protein-nitrogen for the cutting dates of April 8, April 29, May 20, June 6, July 1, July 22, August 12, and September 1 when all cutting managements were averaged within each nitrogen rate. Values were approximately 5.0 percent at the first cutting date on April 8, decreasing to approximately

Table 21. Protein-nitrogen concentrations in forage for the June 6, 1969 harvest

Treatment codes	Percent protein-nitrogen
$N_2H_1C_8$	3.54[a*]
$N_2H_2C_8$	3.51[a]
$N_2H_2C_4$	3.46[a]
$N_2H_1C_4$	3.41[a]
$N_3H_1C_8$	3.24[a]
$N_3H_1C_4$	3.22[a]
$N_3H_2C_8$	3.21[a]
$N_3H_2C_4$	3.18[a]
$N_1H_2C_4$	2.90[a]
$N_1H_2C_8$	2.88[a]
$N_1H_1C_4$	2.75[a]
$N_1H_1C_8$	2.70[a]

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 22. Protein-nitrogen concentrations in forage for the July 22, 1969 harvest

Treatment codes	Percent protein-nitrogen
$N_3H_1C_8$	3.50[a*]
$N_3H_1C_4$	3.31[a]
$N_3H_2C_8$	3.21[a]
$N_1H_1C_8$	3.14[a]
$N_3H_2C_4$	3.07[a]
$N_2H_2C_8$	3.02[a]
$N_1H_2C_8$	2.92[a]
$H_1H_2C_4$	2.92[a]
$N_2H_2C_4$	2.92[a]
$N_2H_1C_8$	2.81[a]
$N_1H_1C_4$	2.73[a]
$N_2H_1C_4$	2.70[a]

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 23. Protein-nitrogen concentrations in forage for the September 1, 1969 harvest

Treatment codes	Percent protein-nitrogen
$N_3H_1C_8$	3.87 a*
$N_2H_1C_8$	3.58 b
$N_3H_2C_8$	3.53 b
$N_2H_2C_8$	3.37 bc
$N_2H_1C_4$	3.21 cd
$N_3H_1C_4$	3.17 cd
$N_3H_2C_4$	3.06 de
$N_1H_1C_8$	2.98 de
$N_2H_2C_4$	2.90 e
$N_1H_2C_8$	2.79 ef
$N_1H_1C_4$	2.59 f
$N_1H_2C_4$	2.55 f

*Values followed by the same letter are not significantly different at the .05 level of probability.

Table 24. Protein-nitrogen concentrations in forage for the September 1, 1969 harvest with nitrogen levels compared within management levels

Nitrogen levels	Management levels				Average
	H_1C_8	H_1C_4	H_2C_8	H_2C_4	
	Percent protein-nitrogen				
N_1	2.98^{c*}	2.59^{b}	2.79^{b}	2.55^{b}	2.73
N_2	3.58^{b}	3.21^{a}	3.37^{a}	2.90^{a}	3.27
N_3	3.87^{a}	3.17^{a}	3.53^{a}	3.06^{a}	3.41
Average	3.48	2.99	3.23	2.84	

*Values within each management level followed by the same letter are not significantly different at the .05 level of probability.

Table 25. Protein-nitrogen concentrations in forage for the September 1, 1969 harvest with management levels compared within nitrogen levels

Management levels	Nitrogen levels N_1	N_2	N_3	Average
	Percent protein-nitrogen			
H_1C_8	2.98^{a*}	3.58^{a}	3.87^{a}	3.48
H_1C_4	2.59^{a}	3.21^{ab}	3.17^{bc}	2.99
H_2C_8	2.79^{a}	3.37^{a}	3.53^{ab}	3.23
H_2C_4	2.55^{a}	2.90^{b}	3.06^{c}	2.84
Average	2.73	3.27	3.41	

*Values within each nitrogen level followed by the same letter are not significantly different at the .05 level of probability.

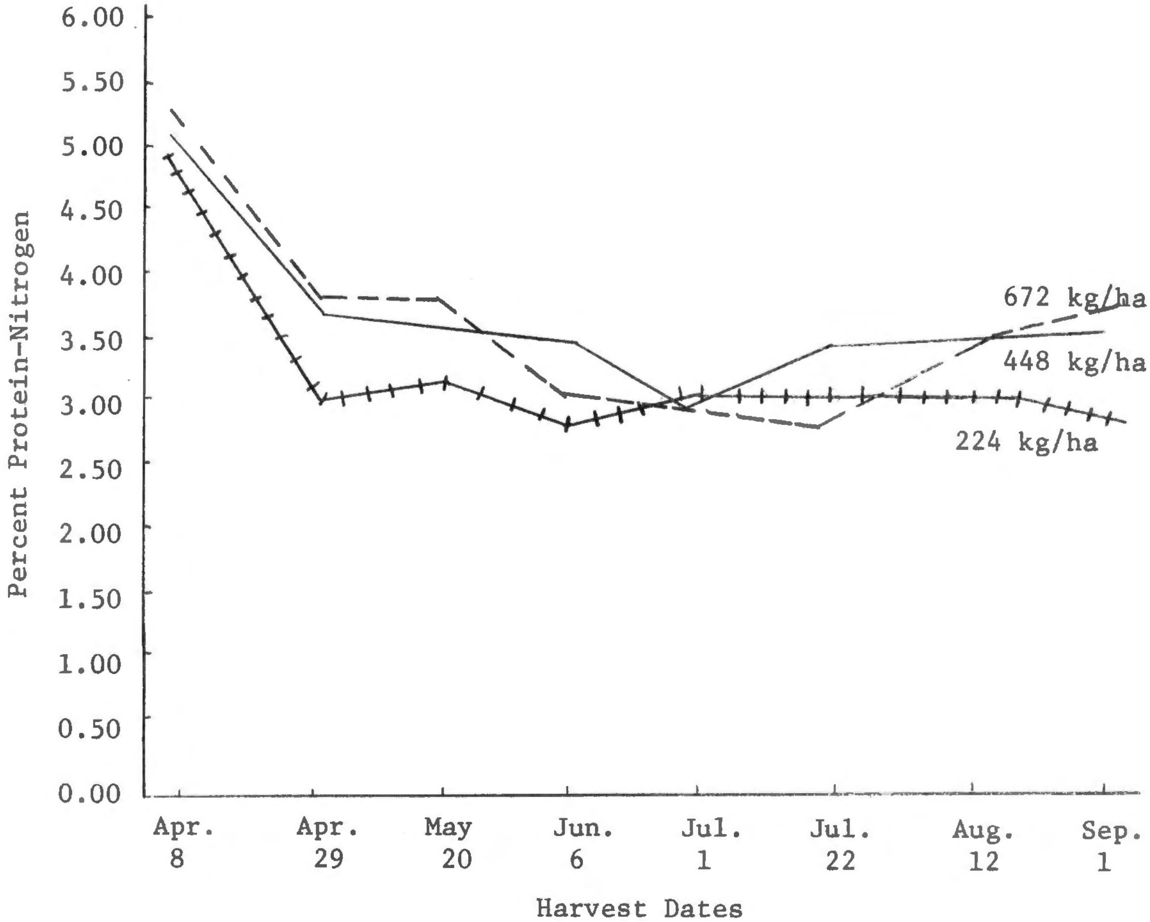

Figure 2. Percent protein-nitrogen for individual harvests during the 1969 growing season.

3.0 percent on July 1 and then increasing slightly during the latter part of the season.

Analyses of variance for 1969 forage yields, nitrate-nitrogen concentrations for 4 sampling dates, and protein-nitrogen concentrations for 4 sampling dates are shown in Table 26.

Table 26. Analyses of variance for 1969 forage yields, nitrate-nitrogen concentrations for 4 sampling dates, and protein-nitrogen concentrations for 4 sampling dates

Source of variation	Degrees of freedom	Mean squares	F-ratios
	1969 total forage yields		
Nitrogen	2	1.0959	.90 N.S.
Management	3	21.7204	41.09 **
N x M	6	.7501	1.42 N.S.
	Nitrate-nitrogen concentrations on April 29		
Nitrogen	2	.3539	252.79 **
Management	3	.0039	.36 N.S.
N x M	6	.0092	.85 N.S.
	Nitrate-nitrogen concentrations on June 6		
Nitrogen	2	.0288	41.14 **
Management	3	.0045	45.00 **
N x M	6	.0017	17.00 **
	Nitrate-nitrogen concentrations on July 22		
Nitrogen	2	.0942	13.85 *
Management	3	.0021	.84 N.S.
N x M	6	.0037	1.48 N.S.
	Nitrate-nitrogen concentrations on September 1		
Nitrogen	2	.0801	11.61 *
Management	3	.0042	2.80 N.S.
N x M	6	.0019	1.27 N.S.

Table 26 (continued)

Source of variation	Degrees of freedom	Mean squares	F-ratios
	Protein-nitrogen concentrations on April 29		
Nitrogen	2	1.5106	69.61 **
Management	3	.7516	24.97 **
N x M	6	.0268	.89 N.S.
	Protein-nitrogen concentrations on June 6		
Nitrogen	2	1.3776	5.15 N.S.
Management	3	.0094	.19 N.S.
N x M	6	.0153	.32 N.S.
	Protein-nitrogen concentrations on July 22		
Nitrogen	2	.5493	2.07 N.S.
Management	3	.1051	2.15 N.S.
N x M	6	.0704	1.44 N.S.
	Protein-nitrogen concentrations on September 1		
Nitrogen	2	1.5331	44.44 **
Management	3	.7038	36.28 **
N x M	6	.0321	1.65 N.S.

*Significant at .05 level of probability.

**Significant at .01 level of probability.

CHAPTER V

DISCUSSION

An increase in the rate of nitrogen fertilization from 224 to 448 or 672 kg/ha did not result in a significant increase in the yield of forage. Management levels were found to be significant during the 1969 growing season. The greatest yield occurred at the 4-cutting frequency for all nitrogen levels and cutting heights. Cutting heights at all nitrogen levels followed no set pattern in the 4-cutting frequency. However, at the 8-cutting frequency the 10-cm height produced more forage at all nitrogen levels than did the shorter 4-cm cutting height. These trends, in combination with the degree of weed invasion indicate that intensive management decreases the persistence of orchardgrass. The shorter cutting height and more frequent cutting frequency resulted in reduced yield and persistence.

As a result of the increase in precipitation during the second half of the growing season following the dry conditions during the first half, forage yields increased slightly later in the growing season at all management levels except in the 8-cutting frequency with short stubble. The lack of increase at that management level resulted from the loss of the stand after the May 20 harvest date early in the growing season due to dry conditions combined with intensive management.

Nitrate-nitrogen concentrations in the forage for the 1969 growing season ranged from .00 to .48 percent. Analyses of variance

indicate that nitrogen fertilization level was the most significant treatment variable influencing nitrate-nitrogen accumulation. Management levels were found to be significant only on June 6. This was the result of the dry conditions and high temperatures that preceded the June 6 harvest. The lack of soil moisture created conditions which resulted in cutting height and cutting frequency having critical effects on plant survival. Consequently, management became a significant factor in the nitrate-nitrogen concentration of the tissue. Nitrate-nitrogen concentration increased with increased levels of applied nitrogen from 224 to 672 kg/ha, with toxic concentrations (.34-.45 percent nitrate-nitrogen) being reached on April 8 and April 29 at the 448 and 672 kg/ha levels. Accumulations of high nitrate-nitrogen concentrations on April 8 and 29 were the result of cool temperatures during this period which favored accumulation, and the availability of nitrogen for uptake. Following these dates, levels dropped to concentrations considered to be safe (30).

On June 6 the management that produced the highest nitrate accumulations was the 4-cutting frequency at both stubble heights. This was probably related to the better condition of the grass following an extended dry period. The less frequent cutting resulted in more leaf and root growth enabling the plants to take up greater levels of nitrate during the dry periods.

Protein-nitrogen concentrations during 1969 ranged from 2.55 to 5.33 percent. Concentrations were affected both by nitrogen levels and by cutting management levels on the April 29 and September 1 harvest dates. The other two dates, June 6 and July 22, have values

that were not significantly different for either nitrogen levels or management levels. Management and nitrogen were significant on April 29 and September 1 as a result of the adequate soil moisture prior to harvest.

The availability of moisture increased nitrogen uptake and protein synthesis resulting in increased concentrations of protein-nitrogen in the tissue. On the other harvest dates, reduced moisture and high temperature created unfavorable growth conditions at all management and nitrogen levels resulting in non-significant effects. On the dates that significant differences were found, the highest protein-nitrogen concentrations occurred at the 672 kg/ha nitrogen level, cut at 4 cm, and at the 8-cutting frequency. The highest protein-nitrogen concentration, 5.33 percent, occurred on the April 8 harvest date when the plants were quite young and succulent. Later harvest dates had lower concentrations. However, protein-nitrogen concentrations on later harvest dates at the 8-cutting frequency were found to be slightly higher than those of the 4-cutting frequency as a result of the smaller, more tender regrowth produced under frequent cutting. This agrees with the reports that younger and more succulent tissue has the greatest amount of nitrogeneous compounds (13, 25).

Each of the three rates of nitrogen had a similar effect on the yields of the forage. However, the plants absorbed more nitrogen at the 448 and 672 kg/ha rates resulting in increased nitrate-nitrogen and protein-nitrogen concentrations. These nitrogeneous compounds were not only increased with increased nitrogen fertilization,

but these effects were observed for longer periods. Most of the nitrogen applied at the 224 kg/ha rate was utilized by the plant, however, at the 448 and 672 kg/ha rates little additional nitrogen accumulated in the grass tissue. Consequently, little benefit was derived from the higher rates of nitrogen application. The nitrogen that did accumulate in the tissue was largely protein-nitrogen. However, the percent utilized at 672 and 448 kg/ha was much less than that of the 224 kg/ha rate.

The application of the second half of the nitrogen on June 18 did not result in an increase in forage yield. However, the nitrogen did cause an increase in the nitrate-nitrogen concentration of the forage, though concentrations were not as high as those of early April.

Results of this investigation indicate that the application of nitrogen at rates of over 224 kg/ha on orchardgrass results in the accumulation of nitrates in the plant tissue at concentrations considered unsafe for livestock consumption. Cutting height and frequency were observed to have little effect on the nitrate-nitrogen concentration of the forage. Protein-nitrogen was found to be influenced by cutting frequency. The more frequent cutting resulted in higher concentrations of protein-nitrogen. However, cutting height had very little influence on protein-nitrogen concentration. In addition, the application of nitrogen at rates above 224 kg/ha does not result in increased forage yields.

CHAPTER VI

SUMMARY

The effect of high nitrogen fertilization and intensive management on the dry matter production, nitrate-nitrogen concentration and protein-nitrogen concentration of orchardgrass (Dactylis glomerata L.) was studied at Knoxville, Tennessee during 1969. Twelve combinations of three factors were incorporated in the experiment. The orchardgrass was harvested either four or eight times at stubble heights of 4 cm or 10 cm, and with nitrogen applications of 224, 448, or 672 kg/ha applied in two equal applications.

Dry matter yields of forage ranged from 3.82 to 8.46 metric tons per hectare. Nitrogen levels did not significantly affect yield, however management levels were highly significant. The highest yielding treatment was 448 kg/ha of nitrogen, 4-cutting frequency and 4-cm height. Lowest yields occurred at 448 kg/ha, 8-cutting frequency and 4-cm height. The difference in total yields indicates the detrimental effect of frequent harvests on stand persistence and the effect of periods of adverse environmental conditions during the months of May, June, and August. Yields were also adversely affected by the shorter cutting height during the latter part of the season.

Nitrate-nitrogen concentrations were found to be affected significantly, on harvest dates analyzed, by nitrogen application but usually not by cutting management. The highest concentration was accumulated at 672 kg/ha followed by 448 kg/ha and 224 kg/ha,

respectively. Nitrate-nitrogen concentrations for the three nitrogen rates were high early in the season (April 29), .43, .41 and .13 percent respectively, reaching toxic levels at the 448 and 672 kg/ha levels. Concentrations then declined until June 6 when values were .11, .05, and .01 percent. Following this date the second half of the nitrogen was applied and resulted in a slight increase in the nitrate-nitrogen concentration in the forage which remained below toxic levels of the forage. Concentrations of samples taken on July 22 were .24, .16, and .07 percent, respectively. By September 1, values had again declined with concentrations of .16, .06, and .00 percent.

Protein-nitrogen concentrations were affected by both nitrogen levels and management levels. Concentrations ranged from 2.55 to 5.33 percent during 1969. Concentrations were high, approximately 5 percent, for all treatments during the early part of April. Following this period, values dropped to approximately 3 percent and remained at that concentration for the remainder of the growing season. The highest concentration for the season occurred at the 672 kg/ha nitrogen level, 8-cutting frequency, and 4-cm stubble height. The lowest concentration occurred at the 224 kg/ha nitrogen level, 4-cutting frequency, and 10-cm stubble height. The highest protein-nitrogen concentrations at all nitrogen rates were found at the 8-cutting frequency.

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APPENDIX

Table 27. Average nitrate-nitrogen concentrations for harvest dates April 29, June 6, July 22, and September 1, 1969

Treatment codes	Harvest dates Apr. 29	Jun. 6	Jul. 22	Sep. 1
	Percent nitrate-nitrogen			
N_1	.13	.01	.07	.00
N_2	.41	.05	.16	.06
N_3	.43	.11	.24	.16
H_1C_8	.32	.04	.15	.05
N_1C_4	.34	.09	.16	.06
H_2C_8	.34	.04	.14	.09
H_2C_4	.30	.06	.17	.09

Table 28. Average protein-nitrogen concentrations for harvest dates April 29, June 6, July 22, and September 1, 1969

Treatment codes	Harvest dates Apr. 29	Jun. 6	Jul. 22	Sep. 1
	Percent protein-nitrogen			
N_1	2.86	2.81	2.93	2.73
N_2	3.40	3.48	2.86	3.27
N_3	3.52	3.21	3.27	3.41
H_1C_8	3.60	3.16	3.18	3.48
H_1C_4	2.97	3.13	2.91	2.99
H_2C_8	3.38	3.20	3.05	3.23
H_2C_4	3.08	3.18	2.97	2.84

Table 29. Nitrogen content of the forage tissue harvested during 1969

Treatment codes	Nitrate-nitrogen	Protein-nitrogen	Total nitrogen
		Metric tons/ha	
$N_1H_1C_8$	.006	.164	.170
$N_1H_1C_4$	.006	.193	.199
$N_1H_2C_8$	.004	.187	.191
$N_1H_2C_4$	.005	.194	.199
$N_2H_1C_8$	.014	.153	.167
$N_2H_1C_4$	.019	.263	.282
$N_2H_2C_8$	.015	.207	.222
$N_2H_2C_4$	.015	.226	.241
$N_3H_1C_8$	.015	.170	.185
$N_3H_1C_4$	.020	.211	.230
$N_3H_2C_8$	.018	.208	.226
$N_3H_2C_4$	.018	.220	.238

VITA

Charles Ramsey Lewis, Jr. was born in Silver Spring, Maryland on February 21, 1943. He attended elementary school and junior high school in that city. He moved to Alexandria, Virginia in 1956 and was graduated from Mount Vernon High School in 1961. The following September he joined the United States Marine Corps and in March 1964 was honorably discharged.

In September 1964 he entered Hiwassee College and in June 1966 received an Associate in Arts degree. He then entered the University of Tennessee and in June 1968 received a Bachelor of Science degree in Agriculture. In September 1968 he entered the Graduate School at the University of Tennessee and received the Master of Science degree in Agronomy in March 1970.

He is married to the former Rebecca Paulett Robertson of Narrows, Virginia.