EFFICIENCY OF APPLIED NITROGEN RECOVERY BY MIDLAND BERMUDAGRASS UNDER HIGH FERTILITY AND IRRIGATION

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BY MIDLAND BERMUDAGRASS UNDER HIGH

FERTILITY AND IRRIGATION

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CHAPTER I

INTRODUCTION

Successful dairying and livestock production depend upon high quality pastures. Pasture yields and forage quality are entirely dependent upon the supply of available nutrients in the soil, especially nitrogen. If adequate amounts of these nutrients are not furnished, forage yield and plant stands will deteriorate.

Bermudagrass is of major importance for livestock enterprises in the Southern United States. It was recognized as an outstanding pasture grass early in Oklahoma agriculture. The excellent response of Bermudagrass to nitrogen fertilization has been well established in Oklahoma as well as other areas in the Southern states. The need for nitrogen fertilizer on improved pastures is increasing due to the nutrient requirements for higher yields and lower fertility levels of soils. The feeding value of Bermudagrass is also increased by nitrogen application because of increased protein content (36). Oklahoma soils, in general are deficient in organic matter and the problem of soil nitrogen is directly related to the status of soil organic matter (1). However, there is comparatively little information available on the recovery of applied nitrogen to Bermudagrass on Oklahoma soils.

The purpose of this study is to report the results of an experiment designed to determine the recovery of different rates of applied nitrogen on Midland Bermudagrass grown on Port silt loam and the fate of fertilizer nitrogen.

CHAPTER II

LITERATURE REVIEW

1. Effect of Rates and Carriers of Nitrogen on Bermudagrass

Green plants can utilize four kinds of compounds as sources of nitrogen: ammonium salts, nitrates and organic nitrogen compounds (32).[1] However, most plants absorb nitrogen in the form of nitrates.

Several investigators have investigated different aspects of nitrogen fertilization of Bermudagrass. Dotzenko (16) evaluated six species of grasses for forage yield, total nitrogen content and the percent recovery with five levels of nitrogen fertilization. He observed a highly significant increase in forage yield and nitrogen content where nitrogen was applied. He also noted that the high rates of nitrogen fertilizer application resulted in loss of stand as well as reduced percentage of nitrogen recovery in the forage.

Grable and Johnson (23) studied the efficiency of recovery of applied nitrates by perennial ryegrass from different soils. They found that fertilizers were generally more efficient at high rates of application and that efficiency decreased with increasing rates on some soils and was constant on others. The regression analysis indicated that efficiency was not related to ability of the unfertilized soils to furnish nitrogen to the plant and that increases in nitrogen uptake due to nitrogen application controlled efficiency rather than the absolute yield of nitrogen. Because the efficiency was lower on fine-textured soils, they

[1] Figures in parenthesis refer to literature cited.

proposed that the lower efficiency may have been caused by denitrification losses which were a result of a slow oxygen diffusion.

It was also reported by Miller, et al. (34) that increasing nitrogen fertilization increased nitrogen percentage of each of the forages and resulted in a slightly lower percentage of crude fiber in the common Bermudagrass.

Holt, et al. (26) found that nitrogen deficiency is often the first limiting factor for Bermudagrass growth and showed that common Bermuda and Coastal Bermuda yields were more than doubled by application of 80 pounds nitrogen per acre.

Gausman and Crowley (19) stated that nitrogen was the only fertilizer which significantly increased the yeild of Bermudagrass. This increase was roughly doubled for plots which received 160 pounds of nitrogen per acre as compared to plots which received no nitrogen. They also found that the yield of plots which received 160 pounds of nitrogen per acre was approximately 2 tons of air-dried forage per acre greater than those which received 80 pounds nitrogen.

Burton and DeVane (8) reported that splitting the application of nitrate of soda and nitrate of ammonia in wet seasons increased Bermudagrass yield significantly. It was found in the same study that the recovery of nitrate of soda nitrogen applied in four split applications was 42.3, 60.2, 65.7 and 64.4% of rates of 50, 100, 200 and 400 pounds of nitrogen respectively. They also obtained a relative yield of 100, 102, 86, and 77 from applying sodium nitrate, ammonium nitrate, cyanamide and uramon on Bermudagrass. Nitrate of soda and nitrate of ammonia are equally effective pound for pound of nitrogen and more effective than uramon and cyanamide when applied as top dressing material on Bermudagrass (6).

Time and frequency of clipping is a very important factor in determining the quality of hay. The average protein content of coastal Bermuda hay fertilized with 300 pounds of nitrogen per acre and cut at a frequency of 2, 3, 4, 6, and 8 weeks was 17.4, 16.6, 15.2, 11.3, and 10.3 percent respectively (7).

Investigations by Prine and Burton (38) showed that increases in nitrogen rates applied on Bermudagrass increased the hay yield, protein percentage, and nitrate content of the soil. The increase in nitrogen application resulted in increases in stem length, plant height, and length of the longest leaf blade per stem. Burton, Jackson and Knox (10) reported that forage yields decrease as the shade or light-reduction increases and the rate of decrease is much faster at the high nitrogen levels.

Six nitrogen sources were tested by Burton and Jackson (9) on Bermudagrass. Ammonium nitrate was found to be the best source when applied at rates of 100, 200, and 400 pounds per acre, and gave an average hay (at 16% moisture) yield of 5.35, 7.49, and 10.17 tons per acre.

In a recent work by Jackson and Burton (27) it was shown that the urea form of nitrogen when applied to the surface of a coastal Bermudagrass sod is consistently inferior to ammonium nitrate. The inferiority of urea as compared to ammonium nitrate was due to gaseous losses of appreciable quantities of the applied nitrogen caused by enzymatic action of urease usually associated with organic matter. Organic matter permits the transformation of urea into ammonium carbonate which is an unstable compound. Due to lack of intimate contact with the soil exchange complex, the ammonia released probably escaped into the atmosphere.

Alexander (1) in greenhouse and field studies on Bermudagrass observed that increasing rates of nitrogen fertilizers increased percentage of nitrogen in the forage of all Bermuda strains grown in Oklahoma and that the Midland strain had the highest percentage of nitrogen utilization.

Elder and Murphy (17), working with irrigated Bermudagrass in Oklahoma, reported that Bermudagrass irrigated and treated with 200 to 400 pounds of nitrogen per acre produced 7,000 to 8,000 pounds of dry matter in 120 days. Their investigations about grazing characteristics of Bermuda showed that one pound of applied nitrogen on common Bermuda grown on a good soil produced 1.5 pound of beef over a non-nitrogen treated pasture.

2. Soil Nitrogen, its Gains and Losses

Nitrogen is the major limiting soil fertility factor for Bermudagrass production on many soils. In trials to obtain more information about soil nitrogen losses and gains under various systems of soil management a number of experimentations were performed by various investigators in different areas.

Chapman, Liebig and Rayner (12) reported on data obtained from a lysimeter study and concluded that greater losses of nitrogen occur in sandy or porous easily drained souls, than from heavier soils in which the ease and movement of water are less. They also found that nitrates are the predominant form of nitrogen in most soil leachates and nitrogen losses through leaching of soils treated with nitrate fertilizers are greater than from ammonium or organic fertilizers. According to this study it was also found that nitrogen leaching losses were greater where the level of nitrogen fertilization was high. Collison and Walker (14) emphasized three factors influencing nitrogen losses by leaching from fertilizers. These factors are: distribution of rainfall, growth made by plants and the source of nitrogen used. Russell (39) noted that the chief constituents of drainage water are the easily removed anions such as nitrates, sulfates, chlorides and bicarbonates together with cations sodium and calcium.

Collison and Mensching (13) found that more than 99% of the nitrogen in the leachates from lysimeters in New York was present as nitrates and less than 1% was present as ammonium and only a trace was present as nitrites. Reason for the relatively low loss of ammonia and nitrite was based on the low initial concentration of these compounds and the retention of ammonia by the soil.

Another lysimeter study made by Lyon, Bizzell, Wilson and Leland (30) showed that loss of nitrates increases with nitrate concentration and loss of water. Their explanation, for the nitrates greater loss from a fallow soil than from a cropped soil, was because of the absence of crops to absorb the nitrates. Morgan and Street (35) reported that nitrates are lost through leaching more rapidly from a coarse than from a fine textured soil because of the water greater losses.

Erosion causes serious losses of nitrogen also. Massey and Jackson (31) determined the percent nitrogen in eroded soil and found that the original soil was 2.7 times higher in nitrogen than the eroded soil.

Daniel and Langham (15) studied the total nitrogen and organic matter content in cropped, virgin and drifted soils of the Southern High Plains. The results indicated that the drift soil material had an average of 24.5% less organic matter and 28% less nitrogen content than the virgin soil.

Rainfall may increase the nitrogen content of the soil (33). Lightning unites nitrogen and oxygen to form nitrogen oxides. The latter may decompose or unite with water in the atmosphere and reach the soil in the rain or snow. In addition small amounts of nitrogen are added in ammonical or organic forms present in the atmosphere, in dust, or in gaseous contaminations. But the amount brought down varies with seasonal conditions and proximity to factories and cities. The total quantity of nitrogen brought down to the earth in precipitation varies from 2 to 20 pounds per acre per year (33). Nitrogen fixation may also occur by the photochemical reactions at the surface of the soil (2). Nitrogen fixation could be a non-symbiotic association (2), by which certain free living organisms change elemental nitrogen into organic combinations. These organisms could be plants as Nostoc calothrix (blue green algae) or bacteria either aerobic as azotobacter or anaerobic as the non-photosynthetic clostridium (heterotrophic) or desulfovibrio (autotrophic). The amount of nitrogen changed into gaseous forms and lost was expressed mathematically by Allison (3) by accounting for all known soil nitrogen gains and losses as follows: (Y) represented the amount of nitrogen changed into gases and lost.

Then:

Y = [initial N in the soil] + [added N] - [N removed by crops] - [N leached] - [N eroded]- [residual N].

There are three different mechanisms for this kind of nitrogen loss according to Alloson (3): -

1. Denitrification: as N_2, N_2O or NO
2. Interaction of nitrous acid and amines or ammonium according to the Van-Slyke reaction. This reaction likewise yields elemental nitrogen and one-half comes from each source: -

$$R - NH_2 + HNO_2 = R - OH + H_2O + N_2 \uparrow$$

Van Slyke Reaction

$$\text{or} \quad NH_3 + HNO_2 \rightarrow N_2 \uparrow + 2H_2O$$

3. Volatilization of ammonia.

Earlier work by Allison et al. (5) led him to believe that it was highly improbable that molecular nitrogen could be formed by any Van-Slyke reaction in arable soils. However, data obtained by Francis, Beard and Smith (18) supports the hypothesis that the instability or reactivity of nitrous acid in the soil is at times responsible for large losses of gaseous nitrogen from fully aerobic soils. Loewenstein, Englebert, Attoe, and Allen (29) agreed that denitrification and nitrate reduction processes are largely responsible for much of the nitrogen evolution from soils of the humid regions, but complete anaerobiosis is usually deemed essential for the process to assume significant proportions and announced that some <u>pseudomonas</u> <u>spp</u>. denitrify under aerobic conditions even when well supplied with oxygen.

In a recent work by Allison, Carter and Sterling (4) it was made clear that although appreciable denitrification did not occur until oxygen partial pressure was much reduced, it can be pointed out that under field conditions denitrification would be expected, at times even in open well drained soils. In another experiment, Allison and Carter showed that denitrification is of minor importance in soils that are kept strictly aerobic. Under field conditions this ideal condition may not exist at all times, even in open porous soils. Gaseous losses of nitrogen that do occur under well aerated soil conditions may be attributed chiefly or wholly to processes other than denitrification.

3. <u>Ammonium Nitrate Behaviour in Soils</u>

Ammonium nitrate is a very soluble salt. Soluble salt fertilizers when applied to soils are dissolved in the soil solution, surrounding the zone of fertilizer application. Thus the fertilizer solution becomes quite concentrated and the rate and distance of movement of the salt from the point of application depends upon the nature of the salt, the characteristics of the soil and the climatic conditions (40).

Like other salts, ammonium nitrate is an ionizable compound. Its ions are (NH_4^+) and(NO_3^-). The ammonium ion will react either with soil carbonic acid forming ammonium carbonate ionizing into (NH_4^+) and (HCO_3^-) or by direct attachment to the negatively charged soil colloids (20): -

$$NH_4\ NO_3 \rightleftharpoons (NH_4^+) + (NO_3^-)$$

$$2NH_3 + H_2CO_3 \longrightarrow (NH_4)_2\ CO_3$$

$$(NH_4)_2\ CO_3 \rightleftharpoons (2\ NH_4^+) + (CO_3^+)$$

$$NH_3 + H_n \text{——Colloid} \longrightarrow H_{n-1} \text{——} NH_4 \text{ - Colloid}$$

Ammonium ions are relatively immobile in soils. Percolating water moves little of this form of nitrogen below the application zone. Soils with low cation exchange capacity permit appreciable movement of ammonium nitrogen into the subsoil and once ammonia is nitrified then it will be subject to leaching (6). Nitrate ions are negatively charged and do not react with soil colloids or enter directly into formation of insoluble organic compounds in the soil. Extraction of soil with water readily removes the nitrates from the soil unless it is absorbed by plants or microorganisms. Nitrate nitrogen is readily leached especially in sandy soils. Moreover nitrate ions during prolonged dry periods, may accumulate in the top few inches of the surface soil by the upward movement of the capillary stream and becomes unavailable to plants (40). The ready mobility of nitrate nitrogen accounts for the high recovery of 60% or more of the applied nitrogen by plants (6).

Kresege and Satchell (28) found that there was no ammonia volatilized from ammonium nitrate and ammonium sulfate fertilizers as long as the soil pH did not rise above neutral. Wagner and Smith (41) supported the opinion that nitrogen fertilizers may undergo losses by volatilization and measured losses ranged up to 85% of the treatment. They reported that nitrogen volatilization losses may be elemental, ammonia, nitric oxide, or nitrogen dioxide forms.

Weir (42) explained the effect of ammonium ions on soil properties. Ammonium ions from ammonium sulfate displace calcium ions from the base exchange complex and calcium ions combine with the sulfate ions forming calcium sulfate which becomes subject to leaching. Nitrification of ammonium ions results in the formation of nitric acid. The nitric acid may react with exchangeable calcium or magnesium ions and bring about further increase of hydrogen in the soil base exchange complex. This is why ammonium nitrate leaves an acid residue in the soil. However, the ammonium ion may displace potassium, thereby making soil potassium more available (42).

Millar (33) explained the phenomenon of nitrogen accumulation in soils from fertilizers and considered that the application of nitrogen fertilizers does not contribute directly to a permanent increase in the soil nitrogen content because available forms of nitrogen leach out unless used by soil organisms or plants and the organic materials are converted into available forms rapidly if they are of value as fertilizers. Then by increasing root growth, nitrogen fertilizers may cause a small increase in organic matter, and an increase in crop yield opens the way for a greater addition of nitrogen in the form of residues and manure. Stimulation of activity of microorganisms may lead to a larger microbial cell accumulation.

CHAPTER III

EXPERIMENTAL PROCEDURES

The experiment was conducted on an irrigated alluvial soil on the Agronomy Research Farm, Stillwater, Oklahoma. The test area was established to Midland Bermudagrass in 1959. Midland Bermudagrass, like Coastal, was developed in Georgia (24). It is a hybrid between Coastal and a hardy variety from Indiana. Previous to the establishment of the experiment the site had been used for alfalfa experimentation. Data included in this thesis are materials obtained from a field study for the years 1960 and 1961. Objectives of this study were to determine the fate of nitrogen applied on Midland Bermudagrass as indicated by plant and soil nitrogen content determinations.

Soil Used in the Experiment:

The experiment was located on a Port silt loam soil. The surface soil is noncalcareous but the subsoil is alkaline to calcareous. Parent material of the Port series is a reddish calcareous silty alluvium from subhumid plains underlain in part by Red Beds. Soil on the experimental site was slightly acid in reaction, level (0 to 1 percent slope) and water uptake is slow at the surface and internal transmission is moderate. Profile description of the Port series is given in the appendix.

Field Experimental Procedure:

In March 1960 and 1961 four hundred pounds of 0-20-0 and a hundred pounds of 0-0-60 per acre were broadcasted uniformly on the plots. Nitrogen carrier used as an applied nitrogen source in the experiment was ammonium nitrate (33-0-0).

The design used in the experiment was a randomised block of four replicates, with eight treatments in each replicate. The treatments were: check, 200, 400, 600, 800, 1000, 1200, and 1400 pounds nitrogen per acre. In broadcasting the ammonium nitrate a split application method was used. It was applied to the plots at four different times during the season. Each one-fourth of the amount of nitrogen added in every treatment was broadcasted at forty day intervals. To simulate the grazing conditions as nearly as possible the grass was clipped every 20-24 days.

During the growing season a sprinkler irrigation system was used to maintain a high soil moisture condition.

Soil samples with depths to 66" were obtained from each plot prior to and after each application, both seasons, while forage samples were collected from plots at each clipping date.

Laboratory Chemical Analysis

To achieve the objectives of the experiment the following determinations were made:

1. determination of total nitrogen content, by depth for soils of all plots prior to and after each season;
2. determination of the nitrogen content of the forage material of all the plots at each clipping date;
3. determination of the depth of any nitrogen accumulation within the soil profiles of each plot.

Soil samples obtained from the field were air dried and processed for analysis by crushing the aggregates with a metal roller and sieving through a 20 mesh screen. Total nitrogen content for these samples was determined by the Gunning Kjeldahl Method (25).

Forage material was sterilized, oven dried and ground to pass through 20 mesh screen. Total nitrogen content in the forage material was also determined by the Kjeldahl Method (25).

CHAPTER IV

RESULTS AND DISCUSSION

The results reported in this study were primarily concerned with the forage yields, nitrogen accumulation within soil profiles and soil nitrogen balances as influenced by plant growth and application of different nitrogen rates.

Forage Yields

Forage nitrogen content data are reported in Table II. There was a marked increase in the nitrogen content due to the application of the first two nitrogen rates (200 and 400 pounds per acre). Forage nitrogen content was increased by the lower rates and then remained almost constant at the higher nitrogen rates. There is a similarity in the changes taking place in the forage nitrogen content for the years 1960 and 1961 that makes the curves for the two years almost parallel especially at the lower nitrogen rates (Figure 1). However, Midland Bermudagrass exhibited higher nitrogen content in 1960 than in 1961 probably due to consumption of the soil nitrogen reserves and seasonal favorableness.

Comparing the forage nitrogen of the clipping starting dates for both 1960 and 1961 reveals that 5/20/1960 values are higher than 5/25/1961. This difference was probably due to the previous growth of alfalfa on the site. The 5/25/1960 harvest indicates that plant growth on the check plots was too slow for adequate sampling. Differences observed

TABLE I

PERCENT AVERAGE NITROGEN CONTENT OF MIDLAND BERMUDAGRASS AS INFLUENCED BY RATE OF NITROGEN FERTILIZATION

Nitrogen rates lbs/acre	Percent Total Nitrogen by Dates*													
	1960							1961						
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	5/25	6/9	6/30	7/20	8/10	8/31	9/27
0	2.53	2.45	1.71	1.74	1.80	1.58	1.93		1.42	1.83	1.62	1.62	1.82	1.66
200	2.97	2.48	2.38	1.90	2.49	1.90	3.38	2.73	1.95	2.54	1.45	2.33	1.98	2.49
400	4.43	2.10	3.17	2.28	3.14	2.49	3.60	3.26	2.44	3.01	1.82	2.56	2.37	3.02
600	3.78	2.49	3.19	2.72	3.39	2.90	3.75	3.79	3.17	3.31	2.48	2.98	2.62	3.00
800	3.92	2.75	3.48	2.88	3.38	2.79	3.56	3.79	3.37	3.52	2.72	3.16	3.03	2.91
1000	4.05	2.53	3.56	3.30	3.58	2.72	3.73	4.14	3.42	3.22	2.97	3.16	3.01	3.12
1200	3.97	2.80	3.23	2.94	3.60	2.71	3.76	4.16	3.36	3.53	2.75	3.17	3.13	3.08
1400	4.22	2.98	3.42	3.27	3.52	2.98	3.67	4.39	3.57	3.54	2.95	3.13	3.28	3.20

*Average of 4 replications.

TABLE II

AVERAGE FORAGE NITROGEN IN POUNDS PER ACRE AS INFLUENCED BY THE NITROGEN RATES

Nitrogen rates lbs/acre	Pounds of Forage Nitrogen Per Acre*															
	1960								1961							
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	Total	5/25	6/9	6/30	7/20	8/10	8/31	9/27	Total
0	30.15	35.35	10.36	8.61	7.04	5.74	3.07	100.33		2.63	3.50	6.21	4.55	3.11	10.43	30.43
200	60.17	47.99	50.93	16.00	59.01	13.79	36.64	284.53	22.93	12.03	37.44	15.14	55.29	7.94	62.82	213.59
400	104.46	68.65	76.52	27.16	64.68	46.81	29.45	417.73	54.38	25.82	71.31	19.82	70.02	14.98	87.70	344.03
600	99.19	86.60	77.52	41.32	61.83	67.74	21.53	455.73	58.40	56.84	67.06	55.73	61.51	25.39	70.80	395.73
800	104.59	109.92	73.01	60.37	42.52	64.25	16.48	471.14	54.96	61.91	63.40	67.65	57.20	33.54	66.55	405.21
1000	109.03	105.07	71.09	66.96	36.59	60.87	18.05	467.66	53.20	66.04	52.97	72.23	49.39	36.39	66.24	396.46
1200	105.48	125.97	61.72	60.42	40.07	58.29	14.97	466.92	45.30	63.07	59.90	69.08	55.29	40.50	69.33	399.14
1400	118.12	131.33	60.53	73.67	27.53	63.30	14.97	489.45	42.98	74.33	58.72	74.90	45.51	42.80	74.91	387.18

*Average of 4 replications.

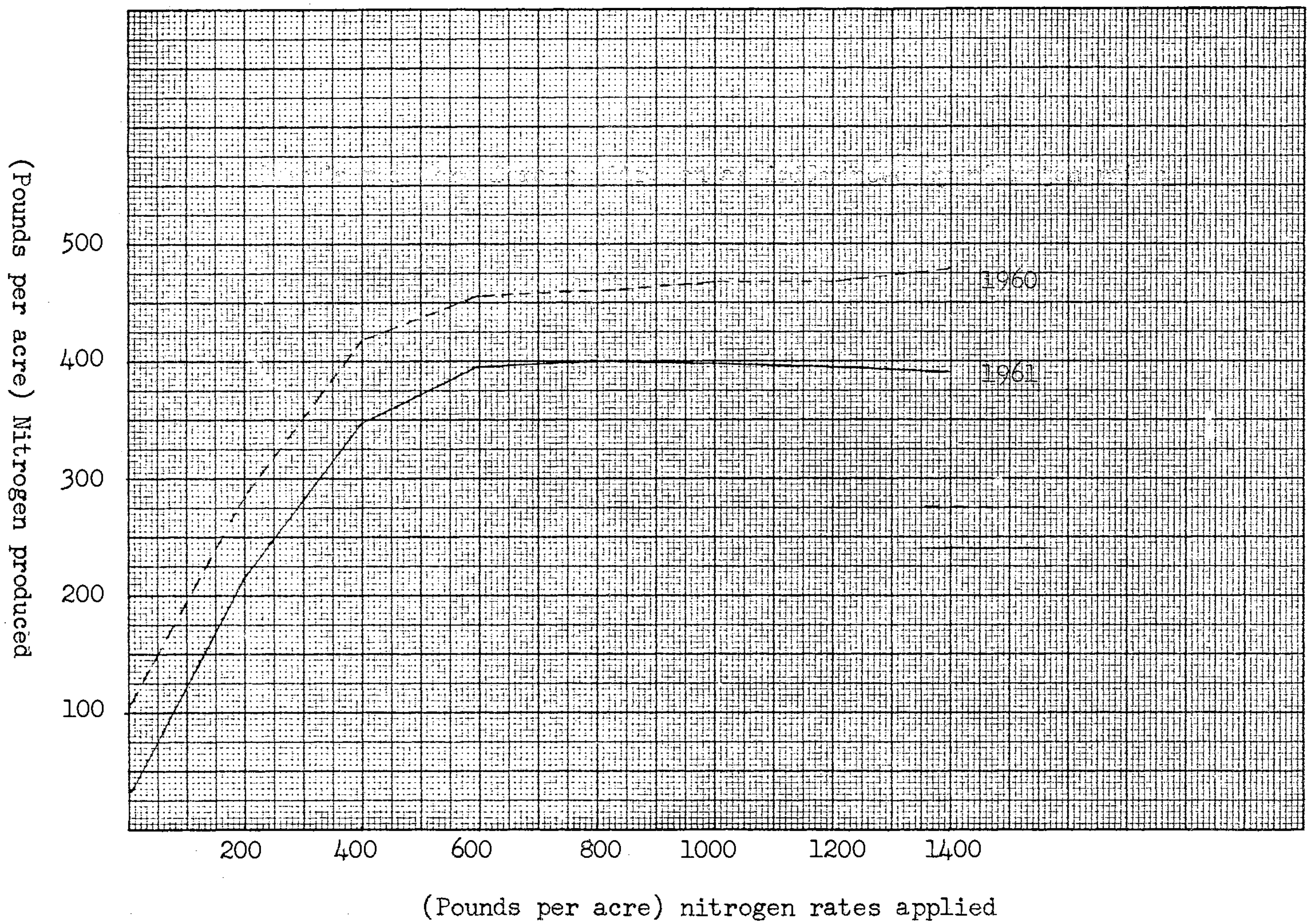


Figure 1. Pounds per acre forage nitrogen as influenced by nitrogen rates.

among the forage nitrogen at different dates of clipping was caused mainly by the split application of the nitrogen rates and the Midland Bermudagrass physiological condition.

Dry matter data obtained (Table III) shows the same differences between the years 1960 and 1961 as influenced by the application of nitrogen. A high response expressed as pounds per acre was obtained from applying 200 and 400 pounds per acre of nitrogen, while higher rates of nitrogen seemed to cause no further increase in nitrogen uptake (Figure 2). Curves representing changes in dry matter content with nitrogen rates for the years 1960 and 1961 are almost parallel especially at the lower rates of nitrogen (Figure 2).

Dry matter content of the clippings decreased with increasing nitrogen in 1960 and increased in 1961. The most probable reason for this is that soil nitrogen reserve from the previous crop was gradually consumed, while 1961 increase was caused by the slow, slight increase of nitrogen caused by the nitrogen fertilizer applications. Differences noticed among the dry matter content of the clippings was primarily caused by the split application of the nitrogen rates and the plant physiological condition.

There is not much difference in the annual nitrogen recovery by Midland Bermudagrass for the years 1960 and 1961 grown on Port silt loam treated with various nitrogen rates (Table IV). Nitrogen recovery values decreased in the same direction with the increase in nitrogen rates (Figure 3), and annual nitrogen recovery ranged from 92.10% to 27.41%. The highest recovery was obtained from the lowest nitrogen rate treatment and the lowest recovery was obtained from the highest nitrogen rate. Midland Bermudagrass nitrogen recovery values per clipping fluctuated

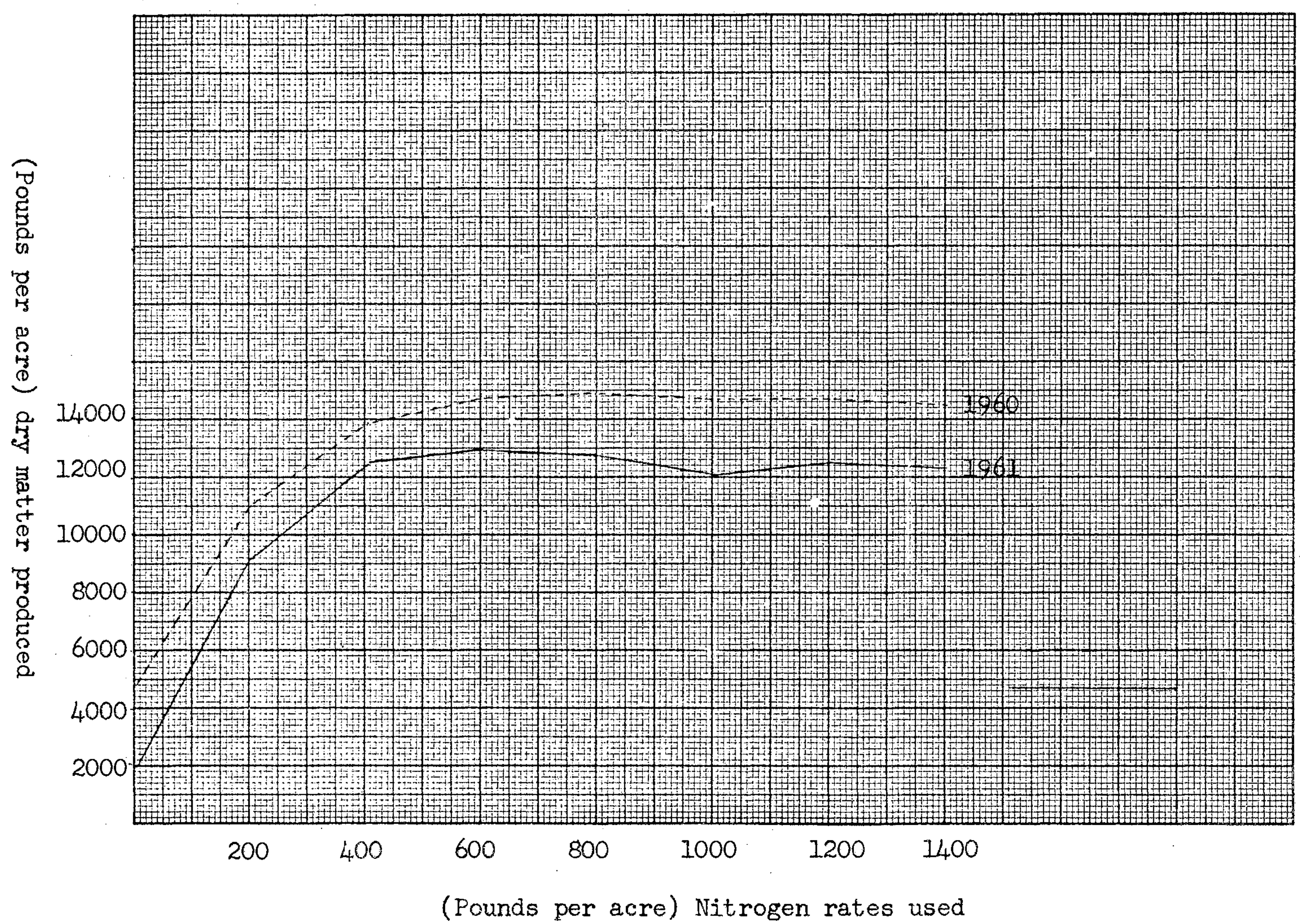


Figure 2. Pounds per acre dry matter produced as influenced by nitrogen rates applied.

TABLE III

AVERAGE OF DRY MATTER IN MIDLAND BERMUDAGRASS PER CLIPPING EXPRESSED AS POUNDS PER ACRE FOR THE YEARS 1960 AND 1961 AS INFLUENCED BY THE NITROGEN RATES APPLIED

Nitrogen rates lbs/acre	Pounds of Dry Matter Per Acre by Date															
	1960								1961							
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	Total	5/25	6/9	6/30	7/20	8/10	8/31	9/27	Total
0	1192	1443	606	495	391	363	159	4,649		185	191	383	281	171	628	1,839
200	2026	1935	2140	842	2370	726	1084	11,123	840	617	1474	1044	2373	401	2523	9,272
400	2358	3269	2414	1191	2060	1880	818	13,990	1668	1058	2369	1089	2735	632	2904	12,455
600	2624	3478	2430	1519	1824	2336	574	14,785	1541	1793	2026	2247	2064	969	2360	13,000
800	2668	3997	2098	2096	1258	2303	463	14,883	1450	1837	1801	2487	1810	1107	2287	12,779
1000	2692	4153	1997	2029	1022	2238	484	14,615	1285	1931	1645	2432	1563	1209	2123	12,188
1200	2657	4499	1911	2055	1113	2151	398	14,784	1089	1877	1697	2512	1744	1294	2251	12,464
1400	2799	4407	1770	2253	782	2124	408	14,543	979	2082	1659	2539	1454	1305	2341	12,359

TABLE IV

PERCENT NITROGEN RECOVERY BY MIDLAND BERMUDAGRASS
FOR ALL PLOTS BY DATE

Nitrogen rates lbs/acre	Percent Nitrogen Recovery 1960								1961							
	5/20	6/13	7/5	7.26	8/16	9/6	9/26	Annual Recovery	5/25	6/9	6/30	7/20	8/10	8/31	9/27	Annual Recovery
200	15.01	6.32	20.29	3.70	25.99	4.03	1.68	92.10	11.47	4.70	16.97	4.47	25.37	2.02	2.62	91.58
400	18.58	8.33	16.54	4.63	14.41	1.03	6.60	77.85	13.60	5.80	16.95	3.29	16.37	2.97	19.32	78.40
600	11.51	8.54	11.19	5.45	9.13	1.03	3.08	59.22	9.73	9.04	10.59	8.25	9.49	3.71	10.06	60.88
800	9.30	7.54	7.83	6.53	4.44	7.31	2.12	45.01	6.87	7.41	7.49	7.68	6.58	3.80	7.02	46.85
1000	7.89	6.97	6.07	5.88	2.96	5.51	1.50	36.70	4.32	6.34	4.95	6.60	4.48	3.33	5.58	35.60
1200	6.28	7.55	2.34	4.36	2.75	4.38	0.99	28.65	3.50	5.04	4.70	5.24	4.23	3.12	4.91	30.73
1400	6.28	6.86	3.58	4.68	1.46	4.80	0.85	27.79	3.07	5.12	3.95	4.91	2.93	2.84	4.61	27.41

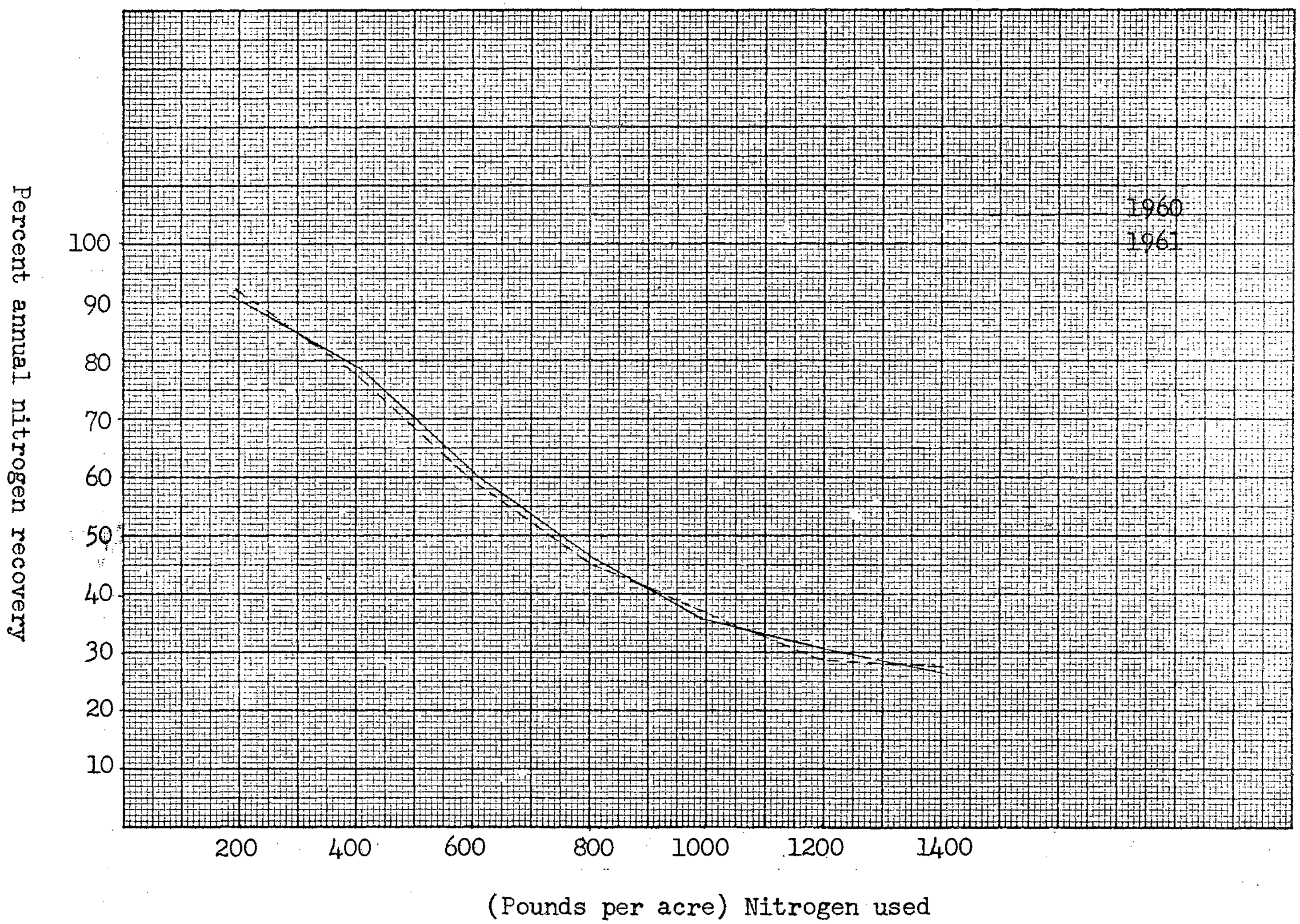


Figure 3. Annual nitrogen recovery by Midland Bermudagrass for 1960 and 1961 as influenced by the nitrogen rates applied.

between 0.99% to 25.99% and there was no consistent uniform change in the percent recovery from one clipping to the next within any of the treatments.

Soil Nitrogen

Examining the average total soil nitrogen data reported in Table V indicates that nitrogen content was always high at the surface throughout the experimentation period and it decreased with an increase in soil depth. This decrease in the soil nitrogen content continued only to certain depths -- which differ from one plot to another. At those depths soil nitrogen content started to increase again. In one of the profiles the nitrogen content found at depth of 60 - 72" was as high as the nitrogen content at the surface of the same profile.

It appears that some of the nitrogen applied at the surface gradually moved down into the profile and accumulated. The translocation of the nitrogen was by the irrigation water percolating through the medium textured alluvial soil, leaching most of the nitrogen which was not absorbed by the plant roots or by the soil microorganisms to lower depths.

All the soil profiles from each plot show some degree of nitrogen accumulation specially at 60 - 72", 48 - 60", 54 - 66" and 42 - 54" depths. Abundant, sprinkler irrigation water was applied with the high rates of applied nitrogen on this medium textured soil. This system will probably always lead to leaching of the nitrates unless it is converted into ammonia and organic nitrogen by the soil microorganisms.

In a trial to make a soil nitrogen balance sheet for the year 1960, nitrogen losses were generally found to be increasing with the increase

TABLE V

AVERAGE CONTENT OF THE SOIL NITROGEN AS INFLUENCED BY NITROGEN APPLICATION

Nitrogen rates lbs/acre	Percent Soil Total Nitrogen by Depth 1960							1961						
	0-6"	6-12"	12-24"	24-36"	36-48"	48-60"	60-72"	0-6"	6-18"	18-30"	30-42"	42-54"	54-66"
0	0.056	0.042	0.018	0.019	0.018	0.018	0.021	0.055	0.033	0.019	0.017	0.018	0.026
200	0.048	0.041	0.027	0.033	0.013	0.024	0.019	0.044	0.016	0.018	0.017	0.020	0.026
400	0.053	0.048	0.022	0.015	0.015	0.032	0.060	0.053	0.037	0.021	0.014	0.023	0.042
600	0.064	0.039	0.022	0.017	0.017	0.021	0.036	0.041	0.038	0.014	0.020	0.023	0.017
800	0.052	0.039	0.022	0.015	0.016	0.017	0.026	0.063	0.035	0.016	0.017	0.015	0.033
1000	0.054	0.044	0.021	0.017	0.018	0.019	0.021	0.068	0.046	0.020	0.018	0.019	0.026
1200	0.061	0.056	0.018	0.013	0.017	0.027	0.040	0.068	0.034	0.027	0.020	0.018	0.031
1400	0.059	0.045	0.016	0.015	0.014	0.026	0.033	0.062	0.038	0.023	0.022	0.020	0.033

in rates of nitrogen applied. But, the nitrogen from the 800, 1200 and 1400 pounds per acre, treatments were found to be smaller than expected (Table VI).

Losses were due mainly to leaching and volatilization since factors leading to leaching and volatilization were present and mentioned in other parts of this study.

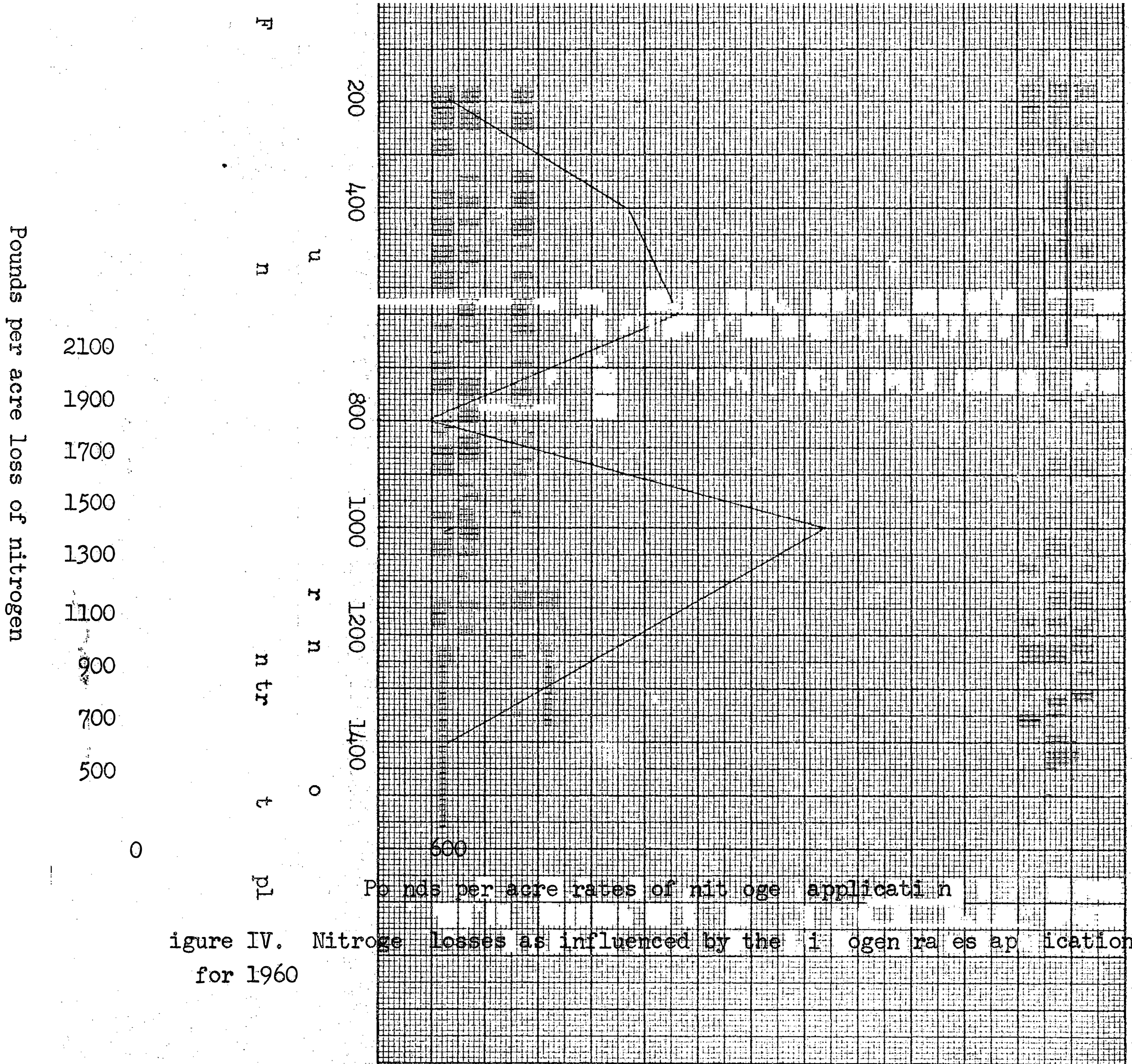
Nitrogen losses caused by erosion were insignificant since the experimental site is a level bottom land soil and the soil was covered by the plants throughout the experimentation period.

Smaller calculated nitrogen losses from the 800, 1200 and 1400 pounds per acre treatments were probably caused chiefly by experimental errors or leaching below the area of sampling.

TABLE VI

SOIL NITROGEN BALANCE SHEET TABLE FOR 1960

Pounds Nitrogen Rates B	Pounds Original Soil Nitrogen A	A + B	Pounds Nitrogen Removed by Plants C	Pounds Calculated Nitrogen Remained in the Soil $(A+B)-C = D_1$	Pounds Nitrogen Remained in the Soil Found by Analysis D_2	Loss $D_1 - D_2$
0	5720	5720	100.33	5619.67	5620	
200	6420	6620	284.530	6335.47	5760	575.47
400	7780	8180	417.73	7762.27	6540	1222.27
600	6580	7180	455.70	6724.30	5300	1424.3
800	6060	6860	460.43	6399.57	5900	499.57
1000	7960	8960	443.67	8516.33	5620	1996.33
1200	6940	8140	467.66	7672.34	6560	1212.34
1400	6240	7640	389.45	7250.55	6680	570.55



igure IV. Nitroge losses as influenced by the i ogen ra es ap ication
for 1960

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this experiment were to determine the effect of different nitrogen rates on Midland Bermudagrass yields and the fate of the applied nitrogen in the Port silt loam soil.

A randomised block design of four replicates with eight treatments was used. Uniform application of adequate phosphorus and potash was applied to plots prior to nitrogen application. Nitrogen was applied as ammonium nitrates at 0, 200, 400, 600, 800, 1000, 1200, and 1400 pounds of nitrogen per acre. All nitrogen rates were applied according to the split application method.

Grazing conditions were simulated by clipping the grass every 20-24 days and the high soil moisture conditions were maintained by the use of a sprinkler irrigation system.

From the data included in this report, the following conclusions can be made:

1. Lower nitrogen rates (200 and 400 pounds per acre) markedly increased the Midland Bermudagrass forage nitrogen content while higher nitrogen rates did not induce marked further increase.
2. 1960 and 1961 forage nitrogen content curves exhibited the same general characteristics. They were almost parallel, however, 1960 nitrogen content was higher than 1961.
3. Split application of the applied nitrogen caused differences among

the forage nitrogen content of the clippings.

4. Changes in dry matter content of Midland Bermudagrass as influenced by nitrogen rates was almost the same compared to changes which took place in the forage nitrogen content for both 1960 and 1961.
5. There was not much difference in the annual nitrogen recovery by Midland Bermudagrass for the years 1960 and 1961.
6. Nitrogen recovery values decreased as applied nitrogen rates increased.
7. All soil profiles from each plot showed a high nitrogen content at the surface and some degree of nitrogen accumulation at deeper depths especially at the depths of 60-72, 48-60, 54-66, 42-54 inches.
8. Nitrogen losses were generally found to be increasing with the increase in rates of applied nitrogen.

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A P P E N D I X   A

PORT SILT LOAM

APPENDIX A

PORT SILT LOAM

Port silt loam is an alluvial soil occurring on an irrigated soil on the Oklahoma State University Agronomy farm. Surfaces are smooth, varying from weakly concave to convex with gradients of about 1 percent. Surface textures vary from very fine sandy loam to silt loam and colors range from dark-brown to reddish-brown. Although considerable variation is expected in this unit a typical profile would include 8 to 12 inches of brown or reddish-brown silt loam over reddish brown clay loam stratified with fine sandy loam between 18 and 30 inches. The above would grade to clay loams banded with silt loams and possibly thin layers of silty clays. The soil is about neutral in reaction throughout. Buried soil profiles are occasionally found at 36 to 48 inches.

The surface structure of this soil is not well aggregated but apparently there is no tendency toward massive clodiness or surface cracking.

The profile described below was taken from an area, 250 feet east and 30 feet north of the southwest corner of the experimental area.

Profile

A_{1_p}	0-8"	Reddish-brown (5 Yr 4/4; 3/4 when moist). Coarse silt loam with considerable very fine sand; weak medium granular, friable; pH 7.0; grades sharply to layer below.
A_1	8-16"	Reddish-brown (2.5 Yr 5/4; 4/4 when moist). Light clay loam, slightly streaked with brown (7.5 Yr 5/2, 4/2 when moist). Weak medium granular; friable; permeable; pH 7.0; Occasional fine black concretions; grades to the layer below.
C	16-50"	Stratified yellowish-red (5 Yr 5/5; 4/5 when moist). Very fine sandy loam and reddish-brown (5 Yr 5/4; 4/4 when moist). Silt loam and light clay loam; the very fine sandy loam is structureless; the silt loam and clay loam are weak medium granular and porous; the layer is permeable and the reaction is pH 6.5.

Soil Survey Staff, Agronomy Department, Oklahoma State University. Detailed soil survey of the agronomy farm, Stillwater, Oklahoma. Processed Series P-315 Feb. 1959.

CHEMICAL CHARACTERISTICS OF PORT SILT LOAM AS DETERMINED BY LABORATORY ANALYSIS

Soil depth in inches	pH 1:2	pH Soil Paste	Available P Acetic Acid p.p.m.	Total P p.p.m.	% O.M.	CEC m.e./100 gm. Soil	Exchange-able Ca m.e./100 gm. Soil	Exchange-able Mg m.e./100 gm. Soil	Exchange-able K m.e./100 gm. Soil	Exchange-able Na m.e./100 gm. Soil
0-8"	6.9	6.7	18.8	213	1.07	8.74	4.60	3.17	0.15	0.04
8-16"	6.6	6.5	2.8	190	0.54	9.58	5.10	3.58	0.10	0.04
16-50"	6.6	6.5	2.2	12	0.34	9.09	5.40	3.00	0.08	0.09

A P P E N D I X B

SOIL NITROGEN CONTENT

PERCENT NITROGEN CONTENT OF THE SOIL AS INFLUENCED BY
NITROGEN APPLICATION REP. I

Nitrogen Rates lb/acre	% Soil Total Nitrogen by Depth												
	1960							1961					
	0-6"	6-12"	12-24"	24-36"	36-48"	48-60"	60-72"	0-6"	6-18"	18-30"	30-42"	42-54"	54-66"
0	0.051	0.037	0.024	0.024	0.016	0.010	0.009	0.050	0.039	0.013	0.021	0.015	0.051
200	0.038	0.047	0.014	0.014	0.010	0.037	0.011	0.057	0.032	0.017	0.020	0.014	0.013
400	0.059	0.052	0.025	0.019	0.008	0.029	0.053	0.065	0.047	0.026	0.004	0.023	0.045
600	0.064	0.004	0.023	0.017	0.011	0.021	0.040	0.067	0.049	0.017	0.025	0.021	0.040
800	0.054	0.033	0.020	0.018	0.023	0.005	0.013	0.057	0.026	0.016	0.015	0.021	0.010
1000	0.009	0.034	0.017	0.017	0.004	0.000	0.001	0.066	0.034	0.019	0.010	0.011	0.016
1200	0.059	0.075	0.020	0.011	0.021	0.013	0.048	0.065	0.038	0.022	0.021	0.020	0.044
1400	0.063	0.050	0.014	0.021	0.019	0.026	0.040	0.070	0.044	0.020	0.023	0.022	0.049

PERCENT NITROGEN CONTENT OF THE SOIL AS INFLUENCED BY NITROGEN APPLICATION REP. II

Nitrogen Rates lb/acre	% Soil Total Nitrogen by Depth												
	1960							1961					
	0-6"	6-12"	12-24"	24-36"	36-48"	48-60"	60-72"	0-6"	6-18"	18-30"	30-42"	42-54"	54-66"
0	0.059	0.046	0.019	0.012	0.017	0.020	0.012	0.059	0.038	0.018	0.018	0.012	0.010
200	0.042	0.041	0.053	0.078	0.010	0.016	0.011	0.063	0.033	0.016	0.014	0.019	0.006
400	0.052	0.039	0.018	0.011	0.016	0.046	0.045	0.029	0.038	0.017	0.016	0.022	0.054
600	0.065	0.057	0.023	0.012	0.019	0.007	0.010	0.048	0.041	0.006	0.028	0.032	0.016
800	0.047	0.036	0.019	0.010	0.010	0.013	0.019	0.060	0.049	0.013	0.008	0.017	0.011
1000	0.063	0.053	0.018	0.016	0.017	0.010	0.008	0.072	0.043	0.023	0.019	0.022	0.011
1200	0.063	0.058	0.020	0.018	0.016	0.030	0.041	0.072	0.018	0.041	0.017	0.019	0.007
1400	0.057	0.065	0.022	0.012	0.018	0.017	0.014	0.066	0.050	0.026	0.021	0.016	0.011

PERCENT NITROGEN CONTENT OF THE SOIL AS INFLUENCED BY NITROGEN APPLICATION REP. III

Nitrogen Rates lb/acre	% Soil Total Nitrogen by Depth												
	1960							1961					
	0-6"	6-12"	12-24"	24-36"	36-48	48-60"	60-72"	0-6"	6-18"	18-30"	30-42"	42-54"	54-66"
0	0.053	0.033	0.019	0.027	0.023	0.002	0.019	0.051	0.028	0.015	0.016	0.008	0.021
200	0.050	0.002	0.023	0.021	0.012	0.010	0.011	0.057	0.019	0.015	0.014	0.017	0.057
400	0.036	0.048	0.024	0.014	0.015	0.022	0.052	0.054	0.029	0.023	0.016	0.021	0.015
600	0.047	0.043	0.024	0.015	0.015	0.028	0.049	0.053	0.026	0.016	0.015	0.020	0.046
800	0.049	0.049	0.025	0.011	0.013	0.003	0.014	0.062	0.016	0.023	0.023	0.014	0.044
1000	0.055	0.045	0.026	0.015	0.019	0.036	0.019	0.060	0.026	0.018	0.019	0.012	0.032
1200	0.054	0.048	0.016	0.008	0.012	0.005	0.010	0.055	0.036	0.025	0.020	0.002	0.004
1400	0.056	0.035	0.018	0.010	0.005	0.016	0.024	0.040	0.032	0.018	0.020	0.016	0.010

PERCENT NITROGEN CONTENT OF THE SOIL AS INFLUENCED BY NITROGEN APPLICATION REP. IV

Nitrogen Rates lb/acres	% Soil Total Nitrogen by Depth												
	1960							1961					
	0-6"	6-12"	12-24"	24-36"	36-48"	48-60"	60-72"	0-6"	6-18"	18-30"	30-42"	42-54"	54-66"
0	0.061	0.053	0.011	0.013	0.017	0.040	0.043	0.060	0.025	0.028	0.013	0.038	0.023
200	0.062	0.075	0.017	0.019	0.018	0.032	0.042		0.053	0.024	0.018	0.029	0.026
400	0.066	0.053	0.022	0.017	0.022	0.030	0.090	0.062	0.035	0.018	0.018	0.025	0.052
600	0.080	0.050	0.018	0.024	0.022	0.026	0.045	0.087	0.035	0.016	0.012	0.017	0.030
800	0.059	0.036	0.025	0.020	0.017	0.046	0.059	0.074	0.047	0.010	0.030	0.017	0.068
1000	0.090	0.044	0.024	0.020	0.032	0.029	0.054	0.078	0.045	0.020	0.023	0.029	0.043
1200	0.066	0.042	0.016	0.014	0.020	0.060	0.062	0.073	0.043	0.020	0.020	0.031	0.067
1400	0.059	0.031	0.011	0.017	0.014	0.044	0.052	0.072	0.025	0.029	0.023	0.027	0.055

A P P E N D I X C

FORAGE NITROGEN CONTENT

PERCENT NITROGEN CONTENT OF BERMUDAGRASS AS INFLUENCED BY
RATE OF NITROGEN FERTILIZATION REP. I

Nitrogen Rates lb/acre	% Plant Total Nitrogen by Date													
	1960							1961						
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	5/25	6/9	6/30	7/20	8/10	8/31	9/27
0	2.34	1.54	1.73	1.68	1.93	1.35	1.70		1.17	1.99	1.43	1.91	2.06	2.49
200	2.41	1.74	2.21	1.68	2.51	1.86	3.10	2.49	3.24	2.12	1.35	2.29	1.68	2.39
400	2.99	1.90	2.88	1.95	3.12	2.08	4.15	3.02	2.58	3.21	1.89	2.57	2.22	2.78
600	3.73	2.34	3.05	3.01	3.26	3.02	4.02	3.65	3.03	3.34	2.95	3.19	2.73	3.01
800	3.94	2.64	3.30	2.84	3.48	2.77	3.52	3.79	3.47	3.56	2.62	3.22	2.84	3.01
1000	3.73	2.38	3.50	3.16	3.81	2.56	3.76	3.88	3.29	3.50	3.05	3.23	3.02	3.18
1200	4.16	2.95	3.44	3.29	3.83	2.85	3.95	4.28	3.45	3.51	2.56	3.11	3.26	2.84
1400	4.05	3.03	2.98	3.07	3.53	2.77	4.00	4.46	3.71	3.56	2.96	3.19	3.23	3.18

PERCENT NITROGEN CONTENT OF BERMUDAGRASS AS INFLUENCED BY RATE OF NITROGEN FERTILIZATION REP. II

Nitrogen Rates lb./acre	% Plant Total Nitrogen by Date													
	1960							1961						
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	5/25	6/9	6/30	7/20	8/10	8/31	9/27
0	2.60	4.30	1.83	1.92	1.74	1.85	1.95		1.49	1.49	1.46	1.53	1.78	1.29
200	3.27	1.94	2.43	1.98	2.72	1.86	3.26	3.32	1.34	2.98	1.46	2.36	2.00	2.64
400	3.45	2.23	3.01	2.53	2.95	2.76	3.92	3.58	2.58	2.88	1.81	2.54	2.56	2.99
600	3.73	2.59	3.22	2.59	3.62	2.84	3.72	3.58	3.17	3.11	2.60	3.24	2.69	2.86
800	3.91	2.61	3.56	2.55	3.20	2.82	3.56	4.09	3.25	3.59	2.83	3.10	3.03	2.90
1000	4.03	2.32	3.55	3.26	3.42	2.72	3.83	4.34	3.42	3.37	3.01	3.14	2.98	2.97
1200	3.85	2.87	3.12	3.32	3.47	2.71	3.81	4.10	3.36	3.49	2.95	3.13	2.95	3.63
1400	4.09	3.09	3.31	3.08	3.32	2.93	3.70	4.09	3.29	3.39	2.84	3.07	3.39	2.99

PERCENT NITROGEN CONTENT OF BERMUDAGRASS AS INFLUENCED BY
RATE OF NITROGEN FERTILIZATION REP. III

Nitrogen Rates lb /acre	% Plant Total Nitrogen Content by Date													
	1960							1961						
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	5/25	6/9	6/30	7/20	8/10	8/31	9.27
0	2.60	2.35	1.57	2.10	1.62	1.42	1.89		1.45	1.75	1.83	1.69	1.67	1.40
200	3.28	2.41	2.56	2.20	2.45	1.78	3.52	2.54	1.76	2.17	1.33	2.27	1.70	2.20
400	3.64	2.08	3.65	2.22	3.27	2.59	2.93	3.26	2.11	3.02	1.76	2.91	2.37	3.02
600	4.05	2.63	3.54	3.15	3.42	2.94	4.15	4.00	3.53	3.56	2.77	3.00	2.84	3.03
800	3.88	2.92	3.57	3.08	3.65	2.95	4.08	4.15	3.43	3.46	2.93	3.18	3.15	2.91
1000	4.41	2.50	3.49	3.26	3.49	2.67	3.76	4.24	3.49	3.52	2.99	3.30	3.24	3.24
1200	3.77	2.75	3.04	3.45	3.49	2.75	3.67	4.14	3.31	3.74	2.89	3.31	3.06	2.76
1400	4.41	2.72	3.75	3.72	3.57	3.04	3.49	4.58	3.70	3.64	2.97	3.05	3.19	3.54

PERCENT NITROGEN CONTENT OF BERMUDAGRASS AS INFLUENCED BY RATE OF NITROGEN FERTILIZATION REP. IV

Nitrogen Rate lb/acre	% Plant Total Nitrogen by Date													
	1960							1961						
	5/20	6/13	7/5	7/26	8/16	9/6	9/26	5.25	6/9	6/30	7/20	8/10	8/31	9/27
0	2.57	1.62	1.69	1.29	1.91	1.70	2.17		1.56	2.10	1.74	1.36	1.76	1.47
200	2.91	3.84	2.32	1.75	2.28	2.21	3.63	2.55	1.45	2.90	1.66	2.40	2.52	2.72
400	3.63	2.19	3.12	2.42	3.20	2.51	3.41	3.18	2.48	2.94	1.81	2.21	2.31	3.29
600	3.61	2.39	2.93	2.14	3.27	2.79	3.11	3.93	2.95	3.23	1.58	2.48	2.21	3.09
800	3.96	2.84	3.50	3.04	3.19	2.60	3.06	3.86	3.31	3.48	2.49	3.15	3.10	2.82
1000	4.02	2.93	3.72	3.50	3.60	2.92	3.56	4.09	3.48	3.50	2.83	2.97	2.81	3.07
1200	4.08	2.63	3.30	2.69	3.59	2.51	3.60	4.10	3.32	3.36	2.58	3.12	3.24	3.10
1400	4.33	3.10	3.63	3.21	3.64	3.17	3.47	4.43	3.56	3.58	3.01	3.20	3.26	3.60

VITA

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