THE EFFECTS OF TOPDRESSING ANHYDROUS AMMONIA ON WINTER WHEAT AND BERMUDA GRASS SOD

By

Walter E. Hill

Bachelor of Science

Panhandle A & M College

Goodwell, Oklahoma

1964

Submitted to the faculty of the Graduate
College of the
Oklahoma State University
in partial fulfillment of the
requirements for the degree of
MASTER OF SCIENCE
May, 1966

THE EFFECTS OF TOPDRESSING ANHYDROUS AMMONIA ON WINTER WHEAT AND BERMUDA GRASS SOD

Thesis Approved:

Billy B. Tucker
Thesis Adviser

W. C. Elder

Lester W. Reed

J. H. Boggs
Dean of the Graduate College

ACKNOWLEDGEMENTS

The author is grateful to the Agronomy Department of Oklahoma State University for providing the facilities for this thesis study. Acknowledgement is also given to Phillips Petroleum Company of Bartlesville, Oklahoma for providing special equipment and fund support of this study.

Special appreciation is extended to Dr. Billy B. Tucker, chairman of my graduate committee, and to Dr. Lester W. Reed and Professor Clifford W. Elder for their help and guidance during my graduate study.

I wish to express appreciation to my parents, Mr. and Mrs. Robert R. Hill, for their encouragement during the course of my undergraduate and graduate study.

I also wish to give special recognition to my wife, Rita, not only for the typing of this manuscript, but also for her patience and encouragement which contributed much to this study.

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Anhydrous NH_3 has been widely used as an agricultural source of nitrogen since the early 1940's. Many experiments have been conducted concerning the response of agricultural crops to anhydrous NH_3. Generally speaking responses from anhydrous NH_3 have compared favorably with responses from other sources, but because of the method of application anhydrous NH_3 has not been a consistent and efficient source of nitrogen for topdressing small grains or bermuda grass sod.

The wide chisel-type applicator knife, as has been used, required large amounts of power for use in sod, and resealing of the subsequent furrow has been a problem. Physical damage to sod and small grain plants and drying of the surface soil caused by cultivation has resulted in farmers being reluctant to use anhydrous NH_3 as a topdressing for these crops.

Recently, a new design of ammonia applicator has been developed. This applicator employs a rolling coulter to open a narrow silt into which the NH_3 is injected, thereby reducing the power requirement. It was hoped that the coulter applicator would reduce significantly the damage incurred when topdressing winter wheat.

Experiments involving the use of anhydrous NH_3 as a topdressing to winter wheat and bermuda grass sod were established at several key locations. Rates of anhydrous NH_3 were compared to equivalent rates of $(NH_2)_2CO$ and NH_4NO_3.

These experiments were designed to yield information concerning the response of winter wheat and bermuda grass to anhydrous NH_3 topdressed with the rolling coulter type applicator.

CHAPTER II

LITERATURE REVIEW

The extent to which applied anhydrous NH_3 is desorbed from soils is of great importance. The desorption or volatilization of anhydrous NH_3 is affected by many soil and environmental factors. Among these are soil pH, soil texture, soil moisture, soil structure, and the depth of application (1, 2, 3, 40).

Baker *et al*. (3) measured NH_3 losses from soil by trapping the escaped NH_3 in an acid absorption tower. They found that losses of NH_3 were small when practical rates were applied under optimum moisture conditions and at a depth of at least 4 inches. At Michigan, Hansen *et al*. (22) measured NH_3 losses from surface and from 2-inch depths of application. The loss-rate curve for the surface application was almost logarithmetic in nature. Losses were still observed after six hours. Loss from the surface soil amounted to about 27 per cent of the NH_3 applied. Losses at the 2-inch application depth represented 4 per cent of the total applied.

Other studies (35) report NH_3 losses ranging from 63 to 100 per cent when low pressure solutions were sprayed on the soil surface. Soil texture or soil moisture did not influence the rate of loss and volatilization was small when the liquids were injected at a 2-inch depth. Cummings _et al._ (15) also found that when nitrogen solutions containing NH_4 were mixed with the upper 2½ inches of air-dry soil no volatilization occurred. Soil reaction did not effect the sorption of NH_4-N by soils of various textures.

Jackson and Chang (24) and Baker (2) observed maximum NH_3 retention at the 4-inch depth of application. Stanley and Smith (38) measured the loss of NH_3 from a Putnam silt loam treated with NH_3 at depths of 3, 6, and 9 inches and at varying moisture percentages. Their results show that at the 6-inch application depth losses were below 5 per cent and losses at the 9-inch application depth were almost nil. However, losses at the 3-inch application depth ranged from 14 per cent to almost zero depending on the soil moisture content. Desorption decreased from 12 per cent to almost zero as the moisture content increased from 2 per cent (air dry) to 15-18 per cent (saturation). As soil moisture content was increased to 23 per cent the desorption of NH_3 increased to 14 per cent.

There has not been an optimum moisture condition for maximum NH_3 retention reported in the literature. Apparently NH_3 desorption is prevalent under both wet and dry conditions. Stanley and Smith (38) report that the rate of loss from the dry soil was rapid, whereas the loss from the wet soil was steady and increased with time. This indicates that the NH_3 was being lost by diffusion through the wet soil as opposed to the knife openings.

Innes (23) observed small losses of NH_3 when aqua NH_3 was applied to dry soils, whereas moist soils suffered heavy losses which paralled their water losses.

Brown and Bartholomew (11) found an interaction between NH_3 sorption and moisture content of clays. Dry bentonite was a more efficient NH_3 sorber than moist bentonite at NH_3 pressures below 60-100 mm of mercury. At high moisture tension and low NH_3 pressures, moist bentonite proved to be the most efficient sorber. Competition between aqueous vapor and NH_3 for sorption sites was offered as a possible explanation.

Fine textured soils retain higher percentages of NH_3. McDowell and Smith (31) studied the retention of 100 pound per acre rates of NH_3 applied to soils of different textures ranging from a Dexter fine sandy loam to a Houston clay. The Houston clay was 44 times more efficient than the Dexter fine sandy loam. Other workers (3, 5, and 24) found that at low rates of NH_3 application soil texture did not limit NH_3 retention. Jackson and Chang (24) found that moist beach sand retained approximately 80 per cent of the applied NH_3.

The maximum movement of anhydrous NH_3 occurs with coarse textured soils. McDowell and Smith (31) found that the major portion of the applied anhydrous NH_3 remained in the 0-1 inch retention zone of a Houston black clay. Maximum NH_3 movement of 3 inches was obtained with a Dexter fine sandy loam.

McIntosh and Frederick (32) report an NH_3 concentration at the point of injection of about 2,000 ppm of NH_3. This concentration decreased to about 200 ppm NH_3 in the area 1½ inches away from the injection zone. After two weeks the area 2½ inches away from the point of injection contained about 100 ppm NH_3.

Smirnov and Fedicheva (36) found that very little of the NH_3 of aqueous NH_3 moved away from the point of application. Aqueous NH_3 was rapidly nitrified and the NO_3 formed moved away laterally and downwards. Tyler *et al.* (40) also found that the downward movement of NH_3 was slight, except in coarse textured soils where it moved greater than 2 inches; whereas, upward movement occurred in all soils studied.

The effect of soil reaction has also been studied. Jackson and Chang (24) found that when adequate application depth was maintained increases in pH did not prevent NH_3 retention. Brown and Bartholomew (10) found no difference in NH_3 retention of Ca-bentonite adjusted to pH's of 8, 9, or 10.

Soil structure also exerts an influence on retention of anhydrous NH_3. Stanley and Smith (38) found that aggregates larger than ¼ inch but less than 1 inch retained NH_3 more efficiently than aggregates smaller than ¼ inch.

The nitrification of applied anhydrous NH_3 proceeds more rapidly on the outer edges of the retention zone where the NH_3 concentration is less than 400 ppm. As NH_3 concentration decreases, nitrification proceeds toward the center of the zone. Nitrification in the center of the retention zone can be limited by low pH and by nitrate accumulation (32).

Anhydrous NH_3 stimulates the nitrification process more than equivalent amounts of $(NH_4)_2SO_4$. Anhydrous NH_3 applied to soil raises the pH into a more nearly optimum range for nitrification and initially provides a base for the neutralization of the nitric acid produced (7).

Anderson (1) found that one-half of 800 ppm NH_4-N had been nitrified after three weeks incubation at 37° F. Extensive NH_4-N movement took place during the first three weeks; lateral and upward movement being more pronounced than downward movement. Nitrification was more pronounced at 42° F and 52° F.

Birecka _et_ _al_. (4) found that NH_3 did not affect bacteria but decreased the number of fungi around the zones of injection. Blue and Eno (6, 8) also found that high concentrations of NH_4 nitrogen reduced the fungi and nematode populations. The bacteria and actinomycetes populations were increased, except for a period not longer than three days after application on a neutral soil.

Many comparisons have been made of crop response to the various forms of nitrogen fertilizers. Early work by Hammons (21) in Mississippi established the fact that anhydrous NH_3 was equal to NH_4NO_3 for production of oat forage and grain when the fertilizers were applied in the fall, but NH_4NO_3 was more effective for spring applications.

Eck et al. (17) in Oklahoma and Peterson (34) in Indiana conducted experiments comparing anhydrous NH_3 and NH_4NO_3 applied in the fall and spring for wheat yields. In most cases the fall application of the two materials produced similar yields. However, spring applications of anhydrous NH_3 sometimes produced lower yields than NH_4NO_3. Eck et al. (17) proposed that in dry years mechanical damage to the wheat stand by the applicator reduced yields. Peterson (34) and Jameson (26) also attributed reduction in yield to mechanical damage to wheat plants by the applicator knives.

Experiments by Jackson et al. (25) on wheat in Eastern Washington show that $(NH_4)_2SO_4$, NH_4NO_3, anhydrous NH_3, $(NH_2)_2CO$, and $Ca(NO_3)_2$ are all equally effective in increasing yields of wheat. Experiments in Nebraska by Lowry et al. (29) found similar results with $(NH_2)_2CO$, anhydrous NH_3, and NH_4NO_3.

Some fertilizer salts have reduced germination of some crops. Cummins and Parks (16) found that anhydrous NH_3 and $(NH_2)_2CO$ were injurious at low concentrations. These injurious effects were attributed to the high concentrations of NH_4 ions in the vicinity of the seed. Okuda and Takahashi (33) report the inhibition of germination by a solution containing 0.012 per cent free NH_3.

Anhydrous NH_3 has been reported to be a good source of nitrogen for other small grain crops. Anhydrous NH_3 has been shown to be an efficient source of nitrogen for rice. Anhydrous NH_3 placed 6 inches deep in the soil gave higher rice yields than NH_4NO_3 or cyanamid (42).

In other studies (9, 14, 18, and 41) anhydrous NH_3 and $(NH_4)_2SO_4$ produced equal yields of rice when they were applied just before planting. $(NH_4)_2SO_4$ was more efficient than anhydrous NH_3 on flooded land (41). Govinda and Venkata (19) found that rice and sugar cane responded to ammonia liquor and $(NH_4)_2SO_4$ in a similar manner.

NH_4 sources when used as a late emergency application reduced the quality of other sugar crops such as sugar beets (28). This is because of slow nitrification which results in a high soil NO_3 accumulation late in the growing season.

Corn (20, 37) and sorghums (30) have responsed similarly to NH_4 and NO_3 sources of nitrogen. Smith (37) found no statistical differences in the response of corn to anhydrous NH_3 or NH_4NO_3 in nine fertility trials. Grissom (20) reports little difference in response of corn to fall or spring application of various nitrogen sources.

Work with forage crops has not been as encouraging as with the cultivated crops. Damage to the sod by applicators have reduced yields (12, 27). In experiments on bermuda grass, Burton and Jackson (12) found that anhydrous NH_3 consistently gave the lowest yield the first harvest, and the highest yield the second and third harvest, and a total yield below the top source. Anhydrous NH_3 applied in March as a single application gave yields equal to the best source, but when the applications were split, yields were low because of poor distribution of the applied nitrogen.

Laughlin (27) found that applicator knives have significantly reduced yields of bromegrass the first harvest following treatment.

Anhydrous NH_3 has been effective with some horticultural crops. Campbell (13) compared NH_4NO_3, Na_2NO_3, and anhydrous NH_3 on cabbage, tomatoes, and beans. The anhydrous NH_3 was as effective as the other two sources.

Tiedjens and Robbins (39) grew tomatoes, soybeans, peach, apple, and rose seedlings in various solutions containing NH_4-N and NO_3-N at various pH levels. Tomatoes and soybeans grew luxuriantly in all the NH_4OH cultures, and soybeans grew more rapidly in each pH level than any of the plants supplied with NO_3-N. Rose, peach, and apple seedlings absorbed and assimilated NH_3 much better from an alkaline than from an acid cultural medium.

CHAPTER III

BERMUDA GRASS FERTILITY

Methods and Materials

Experiments I, II

Field experiments on well-established bermuda grass sod were initiated in the summer of 1964. The location, soil type, and soil chemical data for each experimental site are presented in Table I of the Appendix. Four replications of the following fourteen treatments were established in a randomized complete block design at the Muskogee and Stillwater Research Stations. The fourteen treatments were comprised of rates of 50, 100, 200, and 400 pounds of nitrogen per acre as NH_4NO_3, $(NH_2)_2CO$, and anhydrous NH_3. Two control treatments were used. The first consisted of no treatment and the second was cultivation of the sod with the applicator knives. The 400 pound rates of nitrogen were applied as split applications of 200 pounds each.

Experiment III

The third bermuda grass fertility experiment was established at the Stillwater Research Farm in 1965. This experiment was concerned with the effects anhydrous NH_3 applicator knife spacings have on the response of bermuda grass to anhydrous NH_3. Factorial treatment combinations of four rates of nitrogen (50, 100, 150, and 200 pounds) per acre and three applicator knife spacings (8, 12, and 16 inches) were organized into a randomized complete block with four replications.

All rates of anhydrous NH_3 were applied utilizing the new rolling coulter type applicator. A six-foot experimental applicator furnished by the Phillips Petroleum Company of Bartlesville, Oklahoma was used in all experiments. A John Blue model A-3700 Mark "100" nitrolator was used to regulate the flow of NH_3. The nitrolator was calibrated by measuring the quantity of NH_3 released during a given period of time for the various settings on the nitrolator scale.

Rates of $(NH_2)_2CO$ and NH_4NO_3 were applied with a modified Allis-Chalmers grain drill. $(NH_2)_2CO$ and NH_4NO_3 were broadcast over the soil surface in all experiments. Several random soil samples for moisture determination were taken from each location following each fertilizer application. These data along with the fertilization and clipping dates for each experiment are presented in Table II of the Appendix.

Field plots were 9' x 20' with a 20-foot border between each replication to facilitate the handling of the NH_3 applicator. Yields of bermuda grass hay were obtained by harvesting a 3' x 20' swath through the center of each plot. Subsamples were collected from each plot and analyzed for per cent nitrogen by a modified micro-kjeldahl procedure. The yield of nitrogen was calculated by multiplying the yield of dry matter by the per cent nitrogen. Yields of dry matter and nitrogen were expressed in pounds per acre. All three variables were analyzed statistically to aid in the interpretation of the results.

Results and Discussion

Experiments I, II

Rates of $(NH_2)_2CO$, NH_4NO_3, and anhydrous NH_3 were compared when topdressed to bermuda grass sod at two locations in the summers of 1964 and 1965. Experiments were located on the Eastern Oklahoma Pasture Research Station at Muskogee and on the Agronomy Research Farm at Stillwater. Rates of 0, 50, 100, 200, and 400 pounds of nitrogen per acre were used in these experiments. The 400 pound rate was applied as a split application of 200 pounds each. The yields of dry matter, per cent nitrogen, and yield of nitrogen for each clipping were determined and analyzed statistically.

Three clippings were taken from the experiment located at Stillwater in 1964 and 1965. The yield, per cent nitrogen and yield of nitrogen, and the analysis of variance for each clipping and yearly totals are reported in Tables IV through XI of the Appendix.

The yields from the first clipping at Stillwater are presented in Figure 1. It can be seen that the three

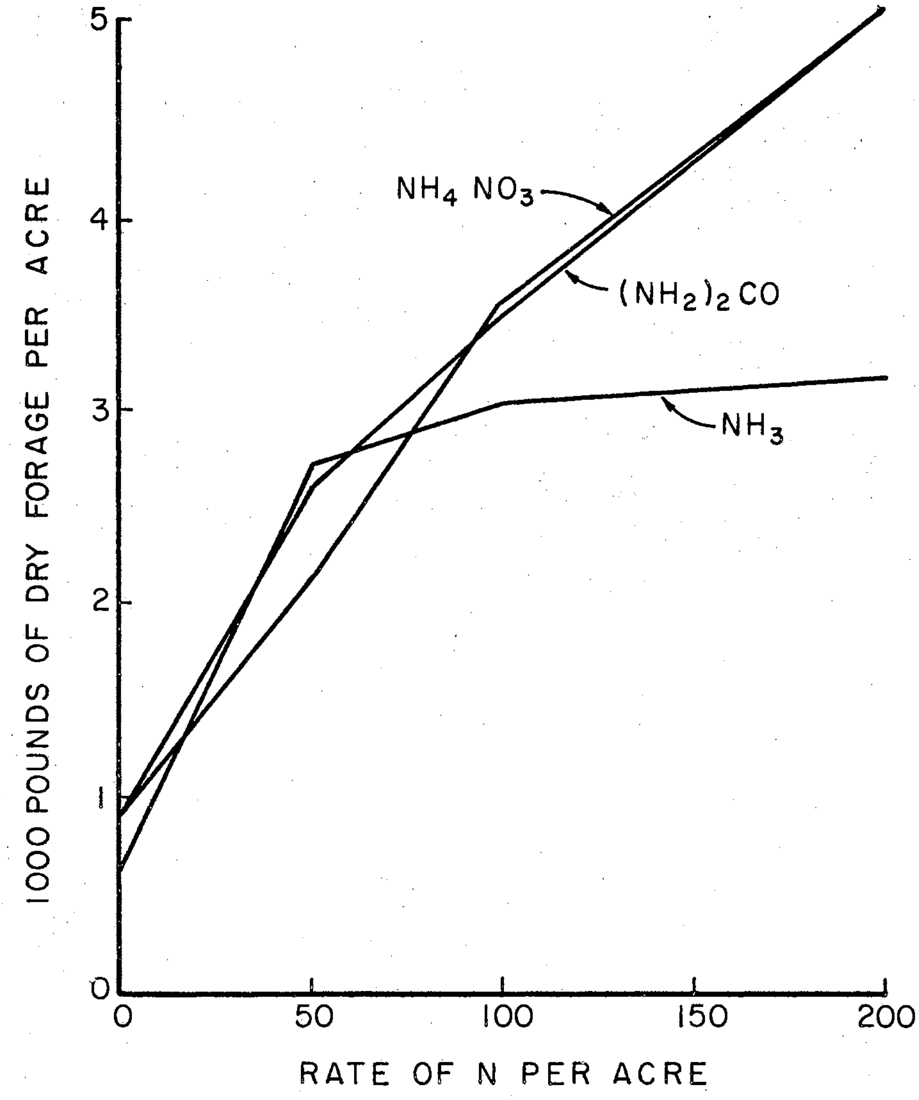

Figure 1. Yields of Dry Bermuda Grass Hay as Affected by Rates and Sources of Nitrogen. Stillwater, First Clipping, 1964

sources were equally effective at the 50 and 100 pounds of nitrogen per acre rates. As the rate of nitrogen increased to 200 pounds of nitrogen per acre the yields from anhydrous NH_3 were lower than those from $(NH_2)_2CO$ and NH_4NO_3. Yields for the second clipping (Figure 2) show that again no differences were present at the lower rates of nitrogen. However, yields from anhydrous NH_3 at the 200 pound rate were greater than those obtained from $(NH_2)_2CO$ or NH_4NO_3. No differences were found from the split application of 400 pounds of nitrogen per acre. No significant differences in yield responses were found in the third clipping.

The analyses of the total yield from the three clippings in 1964 are shown in Figure 3. Again yields were not different except at the higher rates where the solid sources slightly out produced anhydrous NH_3. The average yield, per cent nitrogen, and yield of nitrogen for the three clippings was 1997 pounds of dry matter per acre, 1.89 per cent nitrogen, and average yield of 47 pounds of nitrogen per acre respectively.

The yields of bermuda grass obtained from $(NH_2)_2CO$ and NH_4NO_3 at the Stillwater location in 1965 are extremely low compared to those obtained from anhydrous NH_3 as can be seen in Tables VII, VIII, IX, and XI of the Appendix.

Results of the experiment at Muskogee are presented in Tables XII through XVIII of the Appendix. The experiment was clipped twice in 1964 and three times in 1965. Yields from the individual clippings showed the same general

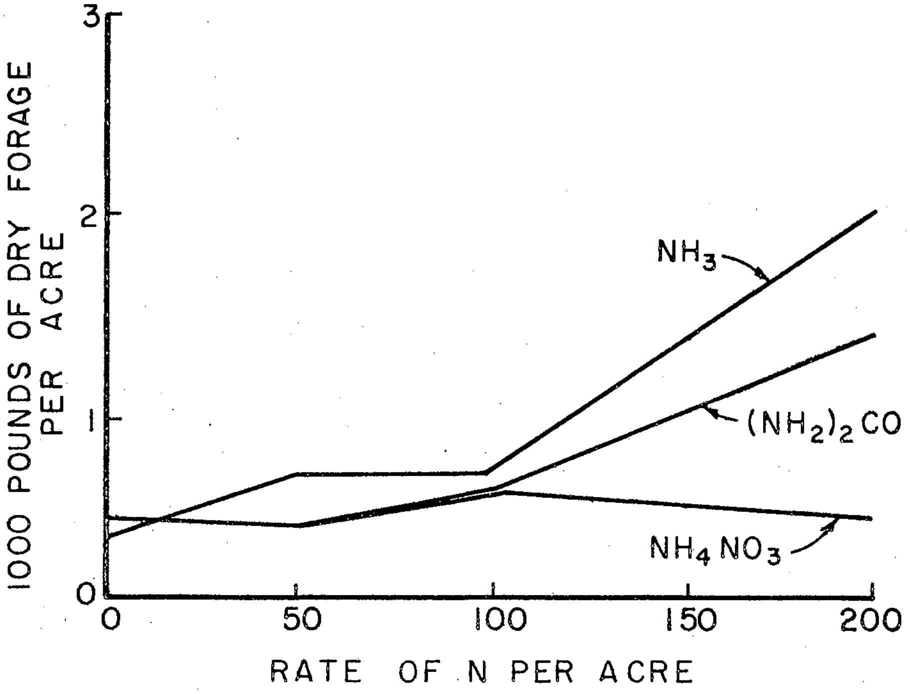

Figure 2. Yields of Dry Bermuda Grass Hay as Affected by Rates and Sources of Nitrogen. Stillwater, Second Clipping, 1964

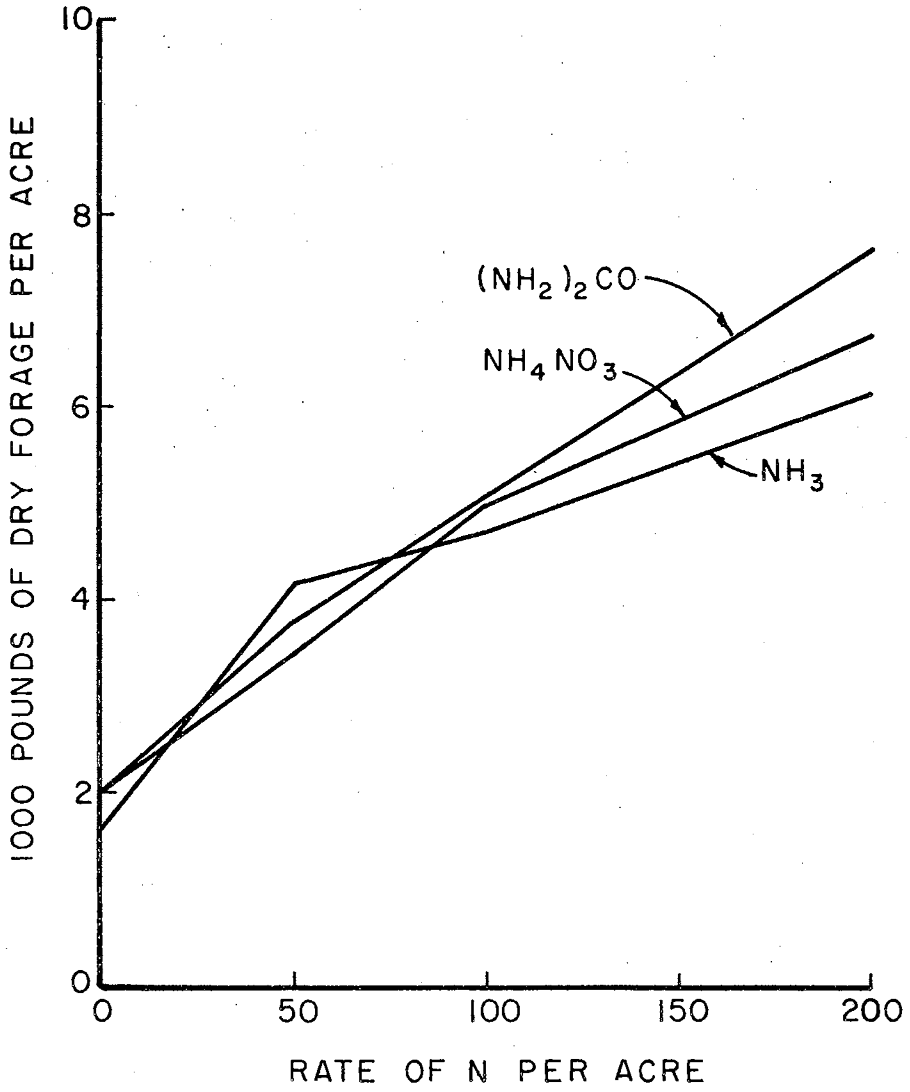

Figure 3. Yields of Dry Bermuda Grass Hay as Affected by Rates and Sources of Nitrogen. Stillwater, Sum of Three Clippings, 1964

trends as those for the Stillwater experiment. Yields from anhydrous NH_3 were consistently lower in the first clipping and higher in subsequent clippings and a total yield slightly below that produced from $(NH_2)_2CO$ and NH_4NO_3. The total yields for the 1964 and 1965 growing seasons are illustrated in Figures 5 and 6.

A characteristic first clipping response curve of bermuda grass to anhydrous NH_3 was established in these experiments and could be described as shown in Figure 4.

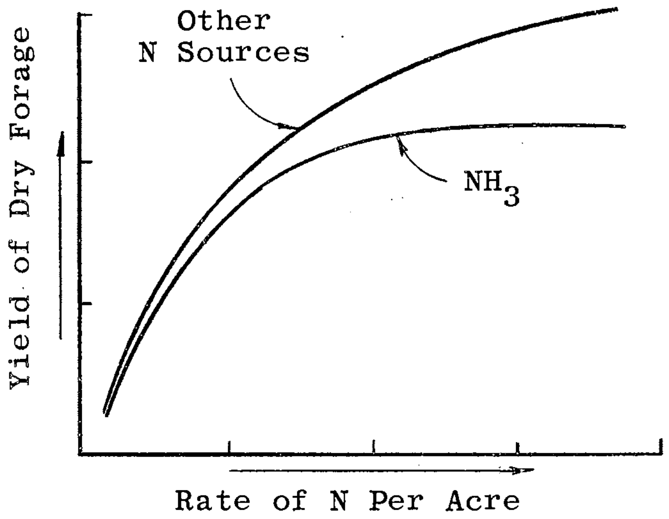

Figure 4. Relative Response of Dry Bermuda Grass Hay to Sources of Nitrogen

Several explanations could be offered for these results. Burton and Jackson (12) obtained a similar type of response where there was a lag in the response of bermuda grass to anhydrous NH_3. They attributed this to poor distribution of the applied nitrogen. Slow nitrification of the NH_3 has also been proposed as the reason for the lag in

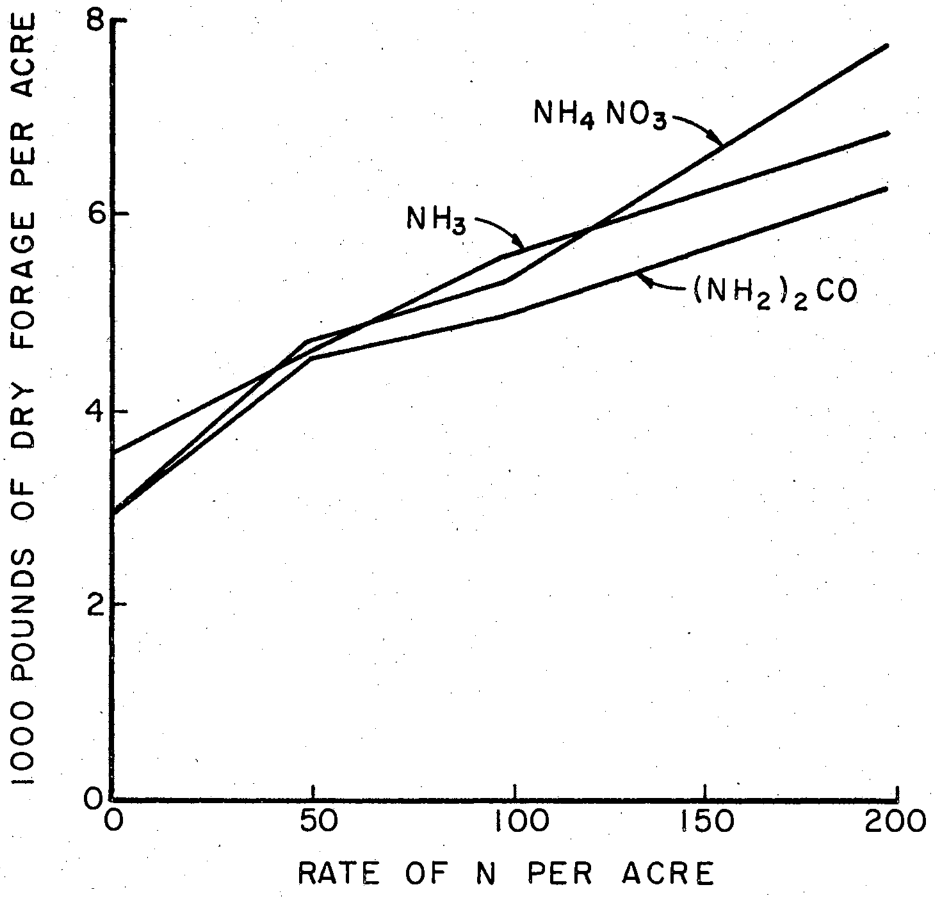

Figure 5. Yields of Dry Bermuda Grass Hay as Affected by Rates and Sources of Nitrogen. Muskogee, Sum of Two Clippings, 1964

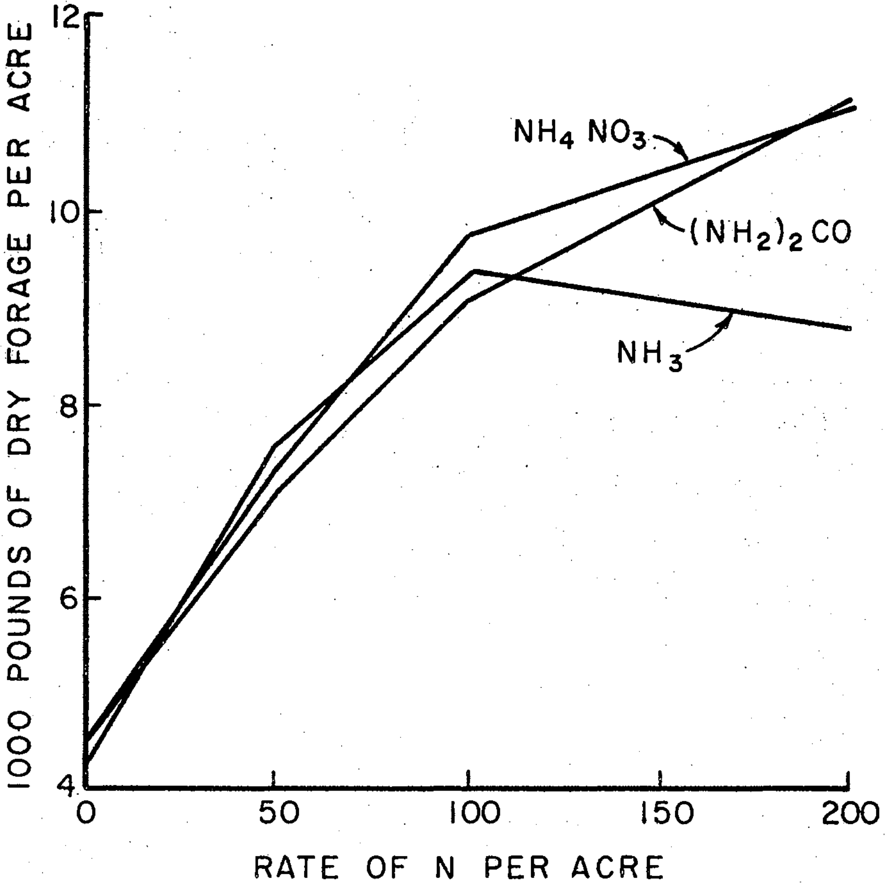

Figure 6. Yields of Dry Bermuda Grass Hay as Affected by Rates and Sources of Nitrogen. Muskogee, Sum of Three Clippings, 1965

growth. However, in experiments I and II there was no lag in production at the low rates of NH_3 application and $(NH_2)_2CO$ treatments did not exhibit the lag in growth. Therefore, because of this, the lag in growth cannot be completely attributed to poor fertilizer distribution or slow nitrification.

In these experiments a burn type of damage was observed when anhydrous NH_3 was applied to the bermuda grass sod. The burn became more apparent as the rate of nitrogen increased. In some instances, an almost complete kill of the sod was obtained at the 200 pound per acre rate. This burn damage would account for the lag in growth and the loss of NH_3 that caused the burn would attribute to the lower total yield as was observed in these experiments.

Experiment III

Four rates of anhydrous NH_3 were applied with three applicator knife spacings. Spacings of 8, 12, and 16 inch centers were used in this experiment. The effect of reducing the applicator knife spacings is to reduce the amount of NH_3 released per linear foot of travel for a specific rate of nitrogen per acre as shown in Figure 7. It was theorized that by reducing the rate of flow of NH_3 from the applicator knives that the efficiency of the applied nitrogen could be increased. This increased efficiency would be a result of increased NH_3 retention and less sod damage by free NH_3.

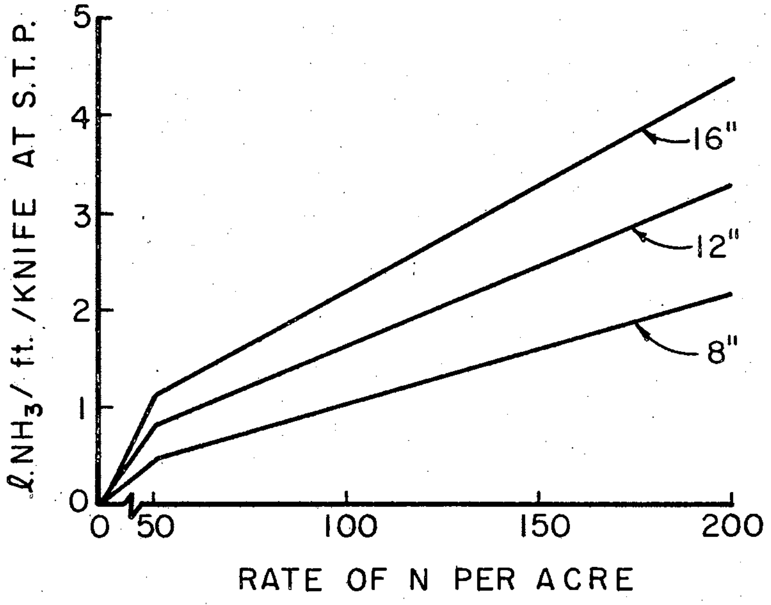

Figure 7. Rate of Release of Anhydrous Ammonia per Applicator Knife at the Various Knife Spacings and Rates of Nitrogen

The yield of dry bermuda grass hay, per cent nitrogen of dry forage, and yield of nitrogen as affected by rates of anhydrous NH_3 and spacings of the applicator knives are presented in Tables XIX through XXII of the Appendix. Results from the first clipping are illustrated in Figure 8. Yields of dry bermuda grass hay were not significantly affected by the narrower knife spacings at the 50 and 100 pound of nitrogen per acre rates. However, as the rates were increased, the narrow spacings tended to produce higher yields. This increased efficiency is again apparent in the yield of nitrogen and is illustrated in Figure 9.

Yield responses in the second and third clippings show the same type of response. The total yield of dry matter and yield of nitrogen for the three clippings are shown in Figures 10 and 11. The total yields of dry matter and nitrogen for the 8-inch spacing was increased over either the 12 or 16-inch spacings. However, rate and knife spacing interactions were not significant except for the total yield of nitrogen.

The results of this experiment support the assumption that a sod damage of some sort is responsible for the lag in production of bermuda grass treated with relatively high rates of anhydrous NH_3.

Summary

Several experiments concerned with the effects of topdressing anhydrous NH_3 to bermuda grass sod were conducted

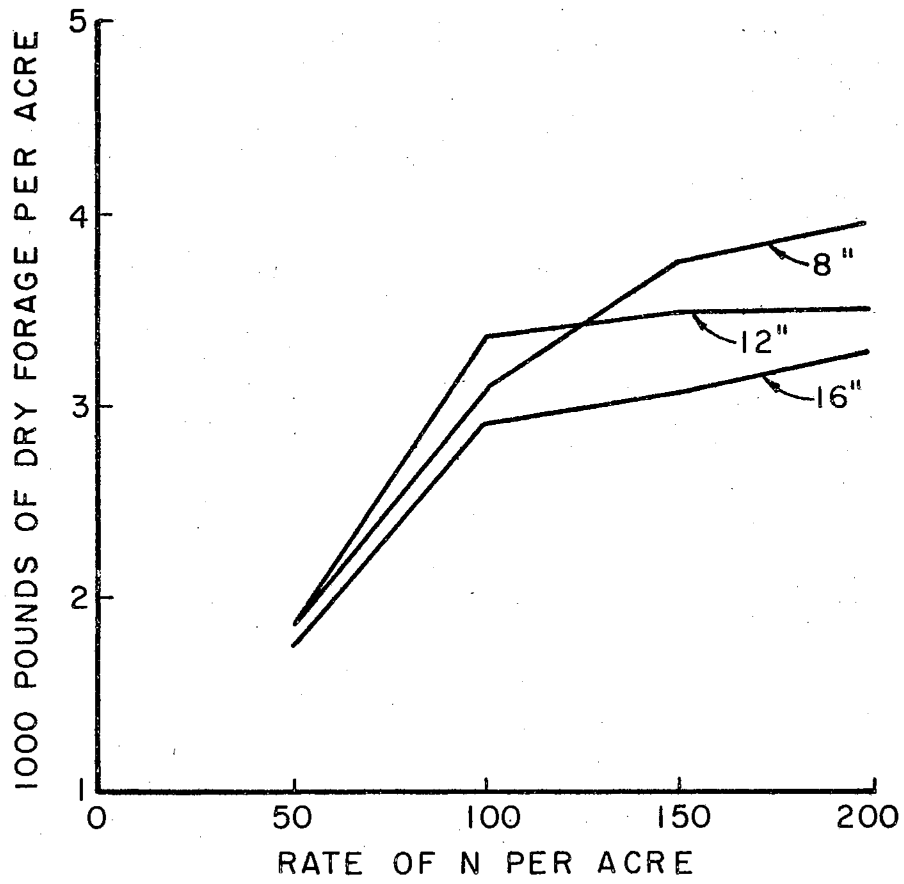

Figure 8. Yields of Dry Bermuda Grass Hay as Affected by Rates of Anhydrous Ammonia Applicator Knife Spacings. Stillwater, First Clipping, 1965

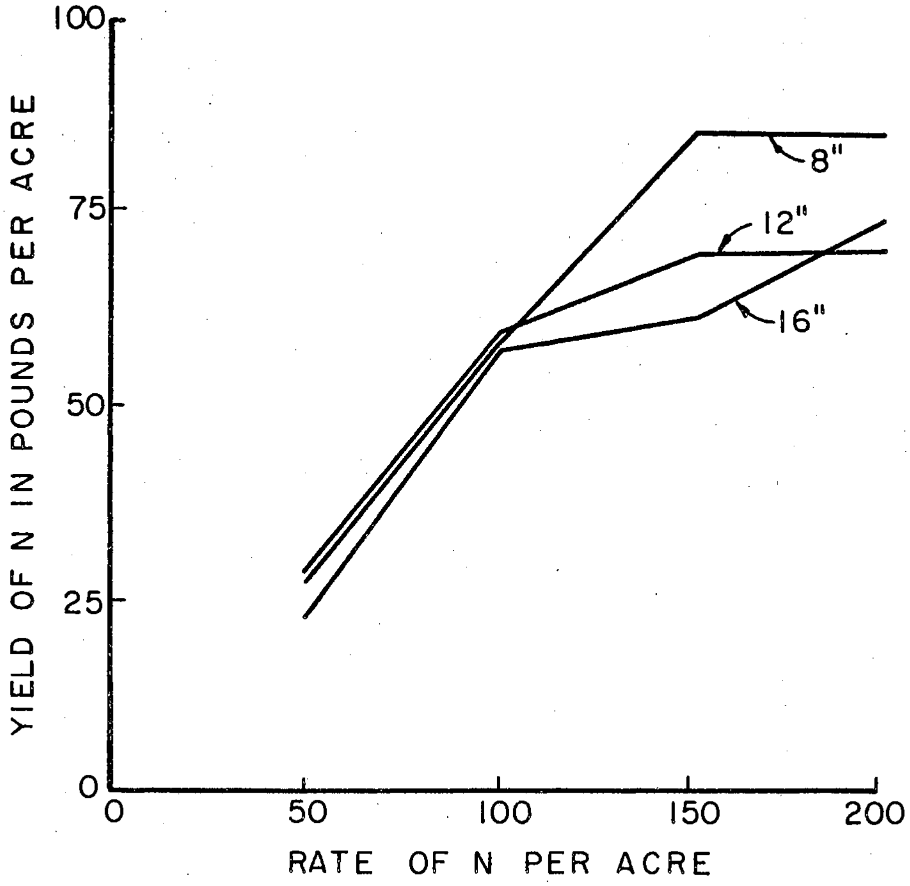

Figure 9. Yields of Nitrogen as Affected by Anhydrous Ammonia Applicator Knife Spacings. Stillwater, First Clipping, 1965

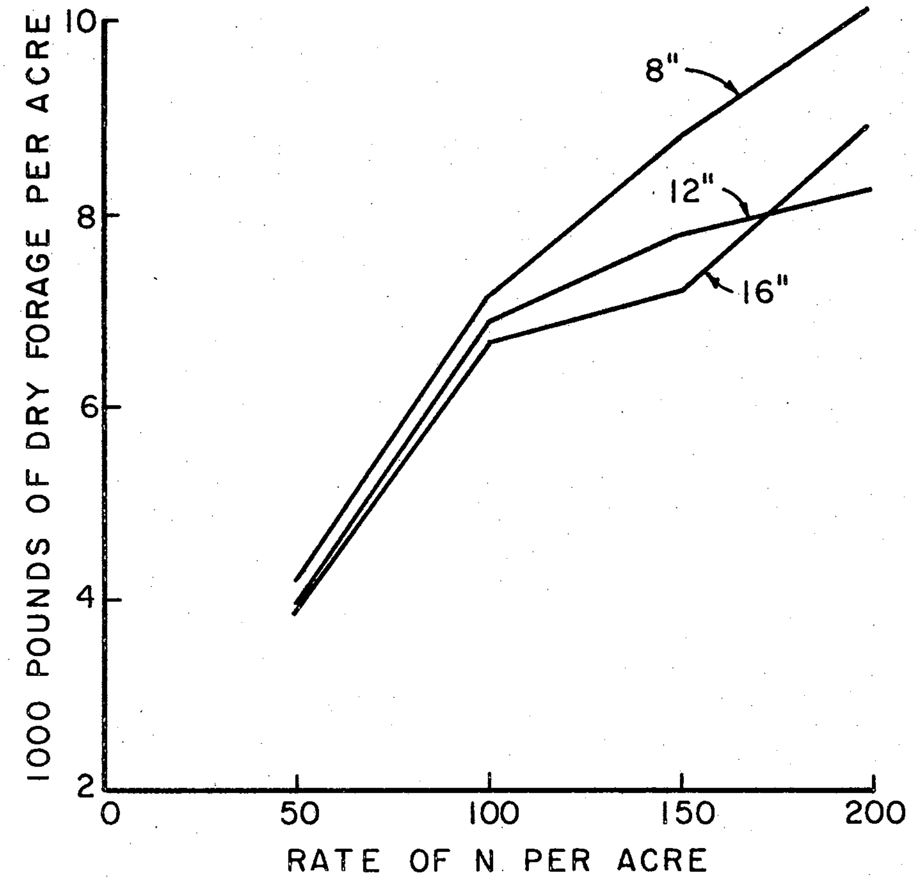

Figure 10. Influence of Anhydrous Ammonia Applicator Knife Spacings and Rates of Nitrogen as Anhydrous Ammonia on Yields of Dry Bermuda Grass Hay. Stillwater, Sum of Three Clippings, 1965

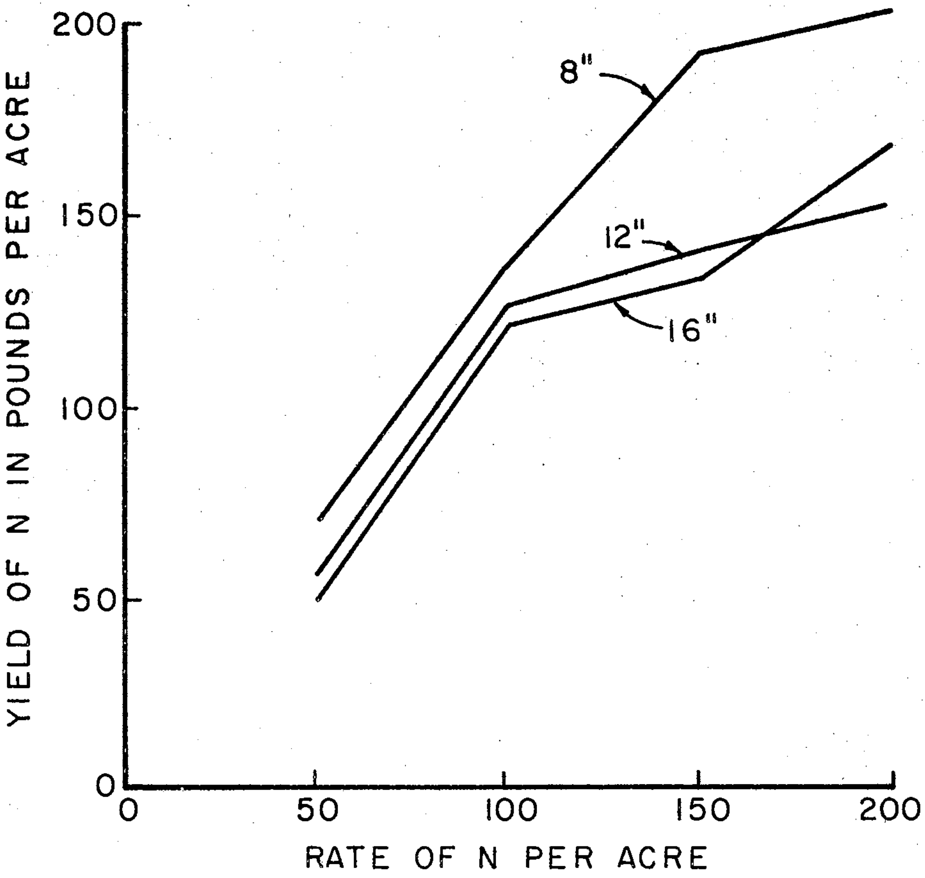

Figure 11. Influence of Anhydrous Ammonia Applicator Knife Spacings and Rates of Nitrogen as Anhydrous Ammonia on Nitrogen Content of Dry Bermuda Grass Hay. Stillwater, Sum of Three Clippings, 1965

during the summers of 1964 and 1965.

Bermuda grass was found to give a characteristic type of yield curve from rates of anhydrous NH_3. Bermuda grass gave a similar response to the low rates of nitrogen regardless of the source used. When compared to $(NH_2)_2CO$ and NH_4NO_3 at high rates of nitrogen application, anhydrous NH_3 consistently produced lower yields in initial clippings and higher yields in subsequent clippings and a lower total yield. These results were attributed to NH_3 burn of the sod, resulting from poor retention of the applied NH_3. When the applicator knife spacing was reduced, the degree of sod damage was decreased and the efficiency of the NH_3 was increased. The yield of nitrogen and per cent nitrogen in the forage followed the same general trends as the yield of dry matter.

CHAPTER IV

WHEAT FERTILITY

Methods and Materials

Field experiments with winter wheat were established on the Agronomy Research Farms at Perkins, Stillwater, and Cherokee. The location, soil type, and chemical data for each experimental site are presented in Table I of the Appendix. The experiments at Cherokee and Stillwater were primarily concerned with the effect of rates and dates of application of anhydrous NH_3 on the yield of winter wheat, whereas the experiment at Perkins was concerned with the damage to the wheat stand by methods of ammonia application.

Experiment I

The fertility treatments at Stillwater were combinations of four rates of nitrogen (0, 20, 40, and 80 pounds per acre) applied as a preplant on September 15, and as a topdressing on November 15, January 15, and March 15. Rates of $(NH_2)_2CO$ and NH_4NO_3 were applied as a topdressing on January 15. Concho wheat was seeded in 10-inch drill rows on October 1, 1964.

Experiment II

A similar experiment was established at Cherokee in 1964. Rates of 20, 40, and 80 pounds of nitrogen per acre as anhydrous NH_3 and NH_4NO_3 were applied as a preplant in the fall and later as a topdressing in the spring. Kaw wheat was seeded on the 7th of October in 14-inch drill rows. The experiments at Stillwater and Cherokee were randomized complete blocks with four replications.

Experiment III

The experiment at Perkins consisted of comparisons of two methods of topdressing anhydrous NH_3 and NH_4NO_3 to winter wheat. The methods consisted of (1) applying the materials perpendicular to drill rows, and (2) applying the materials parallel to the drill rows. The experiment was organized into a randomized complete block with split plots. The methods of application comprised the splits. The five treatments were:

(1) 60 pounds N/A as NH_4NO_3
(2) 60 pounds N/A as NH_4NO_3, plus cultivation with NH_3 applicator knives
(3) 60 pounds N/A as NH_3
(4) control
(5) cultivation with applicator knives.

Concho wheat was seeded on October 1, 1964.

All fertilizer applications were made with the equipment described for the bermuda grass fertility experiments.

Several random soil samples for moisture determination were taken from each location following each fertilizer application. These data along with fertilization and harvesting dates are presented in Table III of the Appendix.

Field plots were 14' x 100' at Stillwater and 14' x 60' at Perkins and Cherokee. Yields of wheat were obtained by harvesting an 8-foot swath through the center of each plot. Grain yields were taken for nitrogen analysis; the same method as for the bermuda grass samples was used. The variables were analyzed statistically to aid in interpretation of the data.

Results and Discussion

Experiment I

Four rates (0, 20, 40, and 80 pounds) of nitrogen as anhydrous NH_3 were compared when applied as a preplant and when applied as a topdressing at three different stages of growth. Equivalent rates of $(NH_2)_2CO$ and NH_4NO_3 were applied as a topdressing on January 15 and were compared to the anhydrous NH_3 applied at that time.

The 1964-65 growing season at this location was extremely wet as is shown in Figure 12. The soil moisture content remained at approximately the 1/3 atmosphere moisture percentage throughout the winter months. Consequently, the fertilizer applications could not be applied according

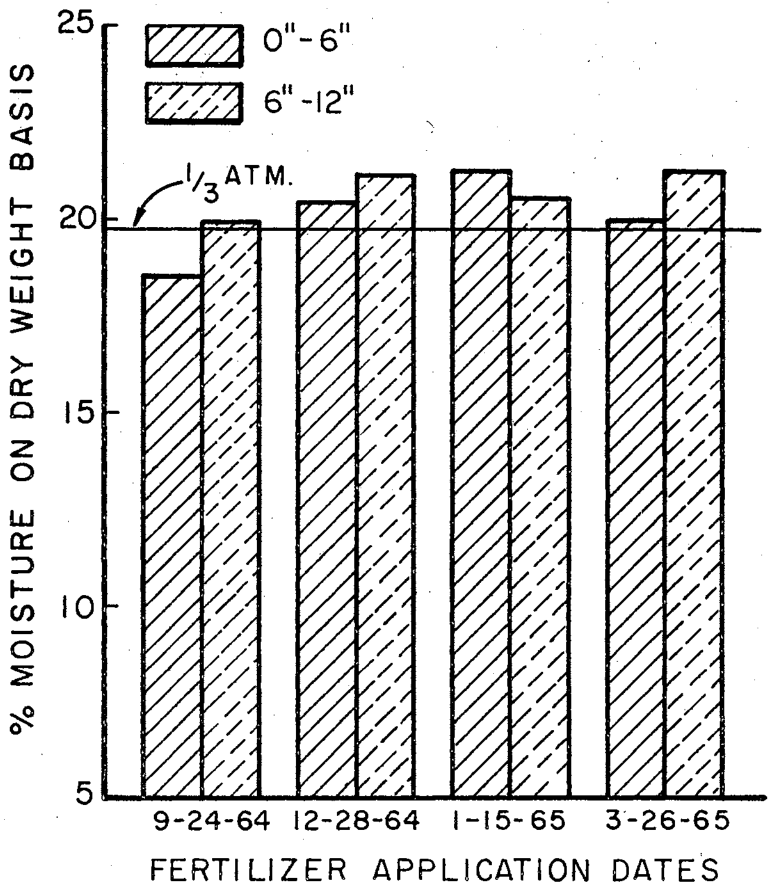

Figure 12. Soil Moisture Conditions During 1964-65 Growing Season. Stillwater

to the treatments. The fertilizer applications were made on the following dates: September 24, 1964; December 28, 1964; January 16, 1965; and March 26, 1965. The fertilizer applications were applied under excessively high moisture conditions. As a result, the stands of wheat suffered considerable damage from cultivation by the applicator knives, and the damage was intensified by an infestation of leaf rust.

Because of the environmental conditions surrounding this experiment, yields were variable and probably do not represent an accurate estimate of the treatment effects that might occur under normal conditions.

The yield of grain, per cent nitrogen in the grain and yield of nitrogen, and the analysis of variance are presented in Table XXIII of the Appendix. The average yield of grain was 25.6 bushels per acre; the average per cent nitrogen was 1.81; and the yield of nitrogen was 27.9 pounds per acre.

The greatest response to the nitrogen applications was found in the preplant application of anhydrous NH_3. The response from the topdressing applications was always smaller when compared to the preplant application. This is readily apparent when the grain yields as presented in Figure 13 are analyzed. A small response from the rates of anhydrous NH_3 applied on December 28 was found. Also a similar response was found with the rates of $(NH_2)_2CO$ and NH_4NO_3 applied on January 15. No significant response was

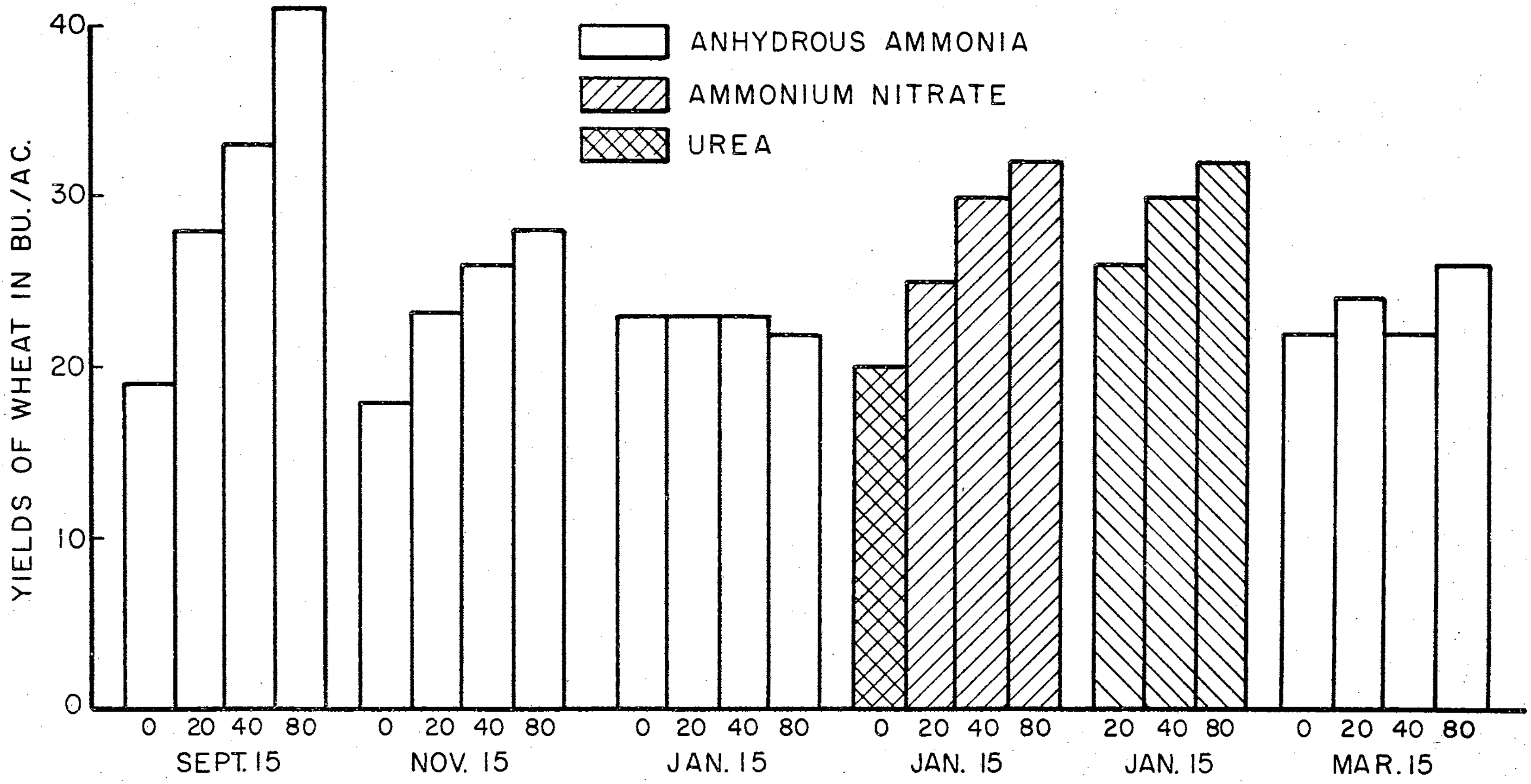

Figure 13. Yields of Winter Wheat as Affected by Rates, Dates, and Sources of Nitrogen Fertilizers. Stillwater, 1965

obtained from the January and March applications of anhydrous NH_3. The only explanation that can be offered for the results obtained in this experiment probably lies in the damage by cultivation and the damage by the rust infestation.

Experiment II

Rates of anhydrous NH_3 and NH_4NO_3 were applied as a preplant application in the fall and as a topdressing in the spring. The yield of grain, grain nitrogen, and yield of nitrogen are presented in Table XXIV of the Appendix. Figure 14 shows the yields of winter wheat as affected by the various treatments. There was no significant response to the rates of nitrogen at this location in 1965, although previous experiments had shown a response to applications of nitrogen. The average yield of grain was 42.6 bushels per acre, containing an average of 2.06 per cent nitrogen. The average yield of nitrogen on a per acre basis was 53 pounds.

Damage to the wheat stand as a result of the NH_3 application was evidently not present as indicated by the yield data. Moisture conditions were favorable for the spring topdressing and, therefore, cultivation by the NH_3 applicator knives was not significant.

Experiment III

Two methods of applying anhydrous NH_3 were compared at the Perkins location in 1965. The methods consisted of

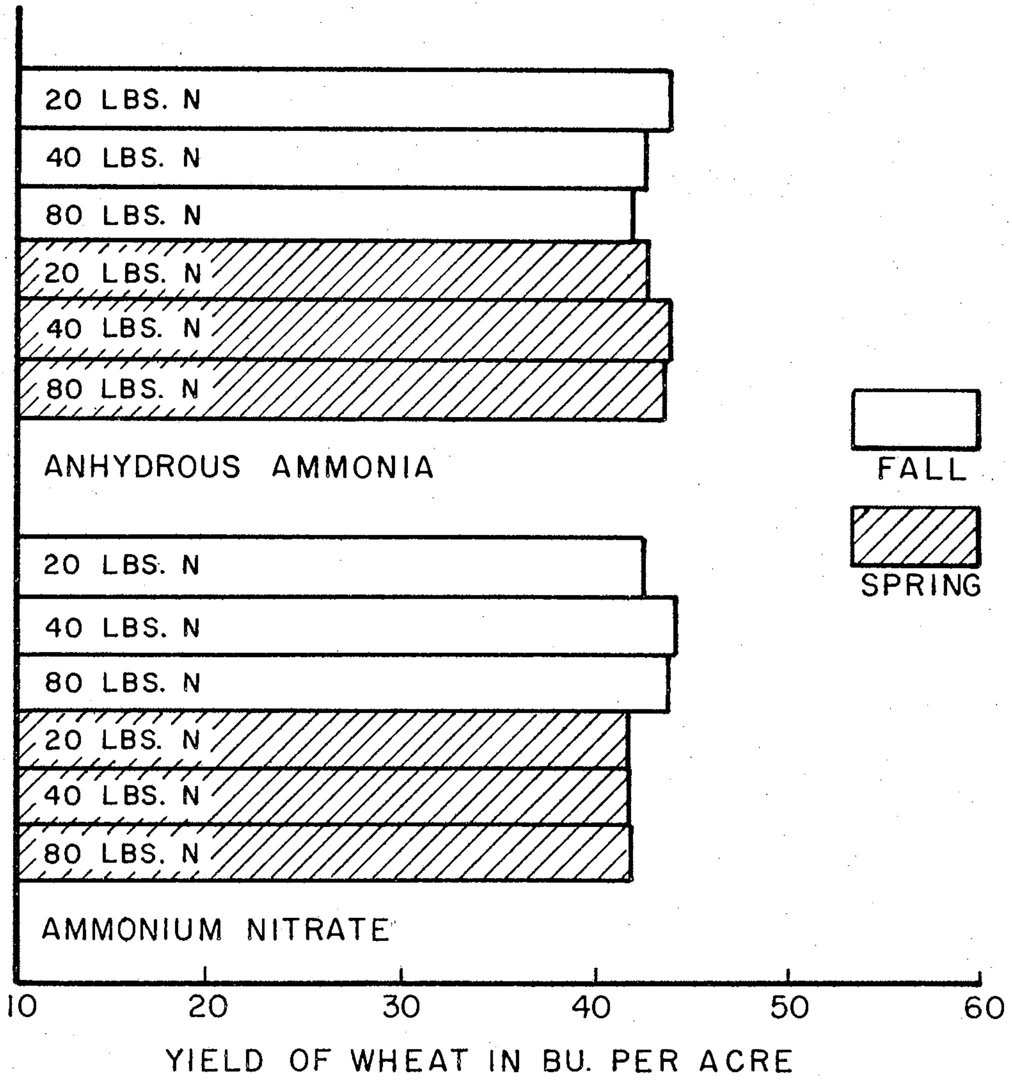

Figure 14. Yields of Winter Wheat as Affected by Rates, Dates, and Sources of Nitrogen. Cherokee, 1965

applying the anhydrous NH_3 either parallel or perpendicular to the drill rows. The extent of damage to wheat stands due to the use of each method was investigated. Treatments as previously described were applied within each method of application.

The yield of grain, grain nitrogen in per cent, and yield of grain nitrogen in pounds per acre are presented in Table XXV of the Appendix. The yields of nitrogen, per cent nitrogen, or yield of nitrogen were not significantly affected by the methods of NH_3 application. The yield of grain is reported in Figure 15. Treatments within the methods were significant as indicated by the F (.05) test. Yields were not consistently reduced by cultivation with the applicator knives except at the zero rate of nitrogen where the materials were applied parallel to the drill rows. The yields were consistently about 3 bushels per acre lower where the applicator knives were used at the zero nitrogen level. Per cent nitrogen and yield of nitrogen were significantly increased by the 60 pound rate of anhydrous NH_3 when compared to the 60 pound rate of NH_4NO_3.

Summary

Field experiments concerned with topdressing anhydrous NH_3 to winter wheat were established and conducted during the 1964-65 growing season.

At Stillwater a normal type response curve was found when the nitrogen was applied as a preplant, but yields

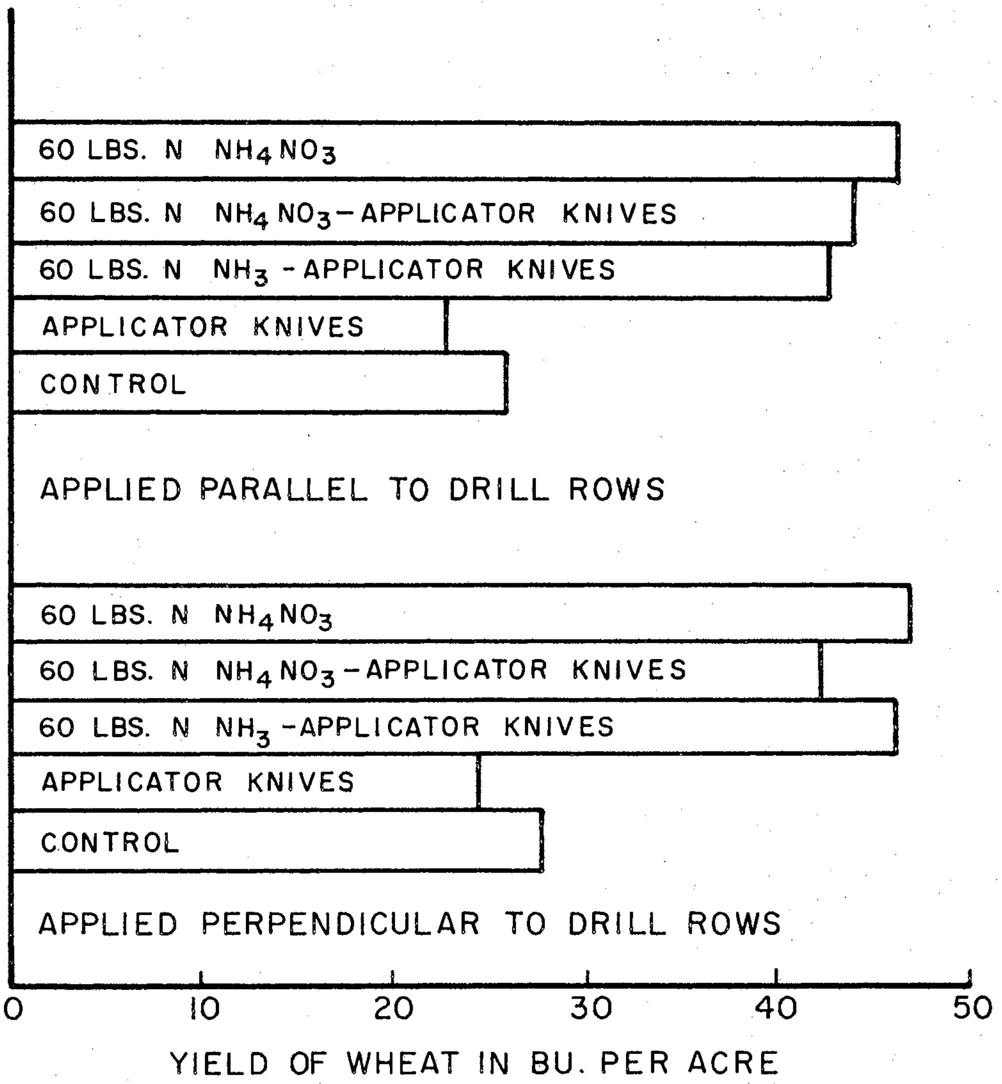

Figure 15. Yields of Winter Wheat as Affected by 60 Pound Rates of Nitrogen as Ammonium Nitrate and Anhydrous Ammonia, and Tillage by Applicator Knives. Perkins, 1965

were reduced when anhydrous NH_3 was topdressed, regardless of the date of application. This reduction in yield was attributed to physical damage to the stand incurred as a result of the cultivation by the ammonia applicator at high moisture conditions, and to a severe infestation of leaf rust.

A similar result was observed at Perkins, however, the magnitude of yield reduction was much lower and was not consistent. The methods of NH_3 application had no effects on the yield of winter wheat. Also the sources of nitrogen had no significant effects on the yield of winter wheat. No significant differences were found between sources of nitrogen or date of application at Cherokee.

LITERATURE CITED

1. Anderson, O. E., "The Effect of Low Temperatures on Nitrification of Ammonia in Cecil Sandy Loam," *Soil Sci. Soc. Amer. Proc.*, 24:286-289. 1960.

2. Baker, J. H., "The Fate of Ammonium Applied to Soils," Diss. Abst., Cornell Univ., 1959. (Abst.) *In* Soils and Fertilizers, 23:128 (796). 1960.

3. Baker, J. H., Peech, M., and Musgrave, R. B., "Determination of Application Losses of Anhydrous Ammonia," *Amer. Soc. of Agron. Jour.*, 51:361-362. 1959.

4. Birecka, H., Duda, J., and Kuzminska, K., "Experiments on the Influence of Ammonia on the Soil Microflora and the Rate of Nitrification," Rocznik Nauk Rolniczych, 69A, 57-64. (Abst.) *In* Soils and Fertilizers, 18:39 (179). 1955.

5. Blue, W. G. and Eno, C. F., "Distribution and Retention of Anhydrous Ammonia in Sandy Soils," *Soil Sci. Soc. Amer. Proc.*, 18:420-425. 1954.

6. Blue, W. G. and Eno, C. F., "The Effect of Anhydrous Ammonia on Nitrification and the Microbiological Population in Sandy Soils," *Soil Sci. Soc. Amer. Proc.*, 18:178-181. 1954.

7. Blue, W. G. and Eno, C. F., "The Comparative Rate of Nitrification of Anhydrous Ammonia, Urea, and Ammonium Sulfate in Sandy Soils," *Soil Sci. Soc. Amer. Proc.*, 21:392-396. 1957.

8. Blue, W. G., Eno, C. F., and Good, J. M., Jr., "The Effect of Anhydrous NH_3 on Nematodes, Fungi, Bacteria and Nitrification in Some Florida Soils," *Soil Sci. Soc. Amer. Proc.*, 19:55-58. 1955.

9. Brewer, C. A. and Fermin, H. A., "Anhydrous Ammonia and Other Nitrogenous Fertilizers on Rice in Acadia Parish," Rice Jour., 56 No. 2, 32, 34, 1953. (Abst.) *In* Soils and Fertilizers, 16:310. 1953.

10. Brown, J. M. and Bartholomew, W. V., "Sorption of Anhydrous Ammonia by Dry Clay Systems," Soil Sci. Soc. Amer. Proc., 26:258-262. 1962.

11. Brown, J. M. and Bartholomew, W. V., "Sorption of Gaseous Ammonia by Clay Minerals as Influenced by Sorbed Aqueous Vapor and Exchangeable Cations," Soil Sci. Soc. Amer. Proc., 27:160-164. 1963.

12. Burton, Glenn W. and Jackson, James E., "Effect of Rate and Frequency of Applying Six Nitrogen Sources on Coastal Bermudagrass," Agron. Jour., 54:40-43. 1962.

13. Campbell, J. A., "Anhydrous Ammonia as a Source of Nitrogen for Cabbage, Tomatoes and Beans," Proc. Amer. Soc. Hort. Sci., 56:253-256. 1950.

14. Chang, S. C., "A Preliminary Study on Ammonia Solution as a Fertilizer for Rice," Agric. Res., 1:23-29. 1950.

15. Cummings, R. W., Krantz, B. A., Mehlich, A., Nelson, W. L., Rankin, W. H., and Weaver, D. S., "Solution '32' as a Source of Nitrogen for Direct Application," Agron. Jour., 50:581-583. 1959.

16. Cummins, D. G. and Parks, W. L., "The Germination of Corn and Wheat as Affected by Various Fertilizer Salts at Different Soil Temperatures," Soil Sci. Soc. Amer. Proc., 25:47-49. 1961.

17. Ech, H. V., Stewart, B. A., and Boatwright, G. O., "Comparisons of Anhydrous Ammonia and Ammonium Nitrate as Fertilizers for Wheat in Central Oklahoma," Oklahoma Agr. Exp. Sta. Bull., B493:1-15. 1957.

18. Ghosh, A. B., "Ammonia in Irrigation Water as a Fertilizer for Paddy and Wheat," Jour. Indian Soc. Soil Sci., 7:37-41. 1959.

19. Govinda, R. S. V. and Venkata, R. B. V., "Anhydrous Ammonia as a Fertilizer. Its Retention in Soils and Value as a Fertilizer," Jour. Indian Soc. Soil Sci., 5:133-140. 1957.

20. Grissom, P. H., "Corn Fertilization in the Yazoo-Mississippi Delta," Miss. Agr. Exp. Sta. Bull., pg. 13. 1948.

21. Hammons, J. G., "The Efficiency of Anhydrous Ammonia as a Source of Nitrogen on Fall-Planted Oats for

Forage and Grain Production," Soil Sci. Soc. Amer. Proc., 12:266-269. 1948.

22. Hansen, C. M., Mortland, M. M., and Robertson, L. S., "A Technique to Determine Volatilization Losses in the Application of Fertilizers Which Contain Free Ammonia," Mich. Agr. Exp. Sta. Quart. Bull., 39:495-499. 1957.

23. Innes, R. F., Chinloy, T., and Thompson, H. M., "Aqueous Ammonia as a Source of Nitrogen on the Sugar Cane Soils of Jamaica," Proc. Brit. W. Ind. Sug. Tech., 193-204. 1957. (Abst.) In Soils and Fertilizers, 22:230 (1428). 1959.

24. Jackson, M. L. and Chang, S. C., "Anhydrous Ammonia Retention by Soils as Influenced by Depth of Application, Soil Texture, Moisture Content, pH Value, and Tilth," Jour. Amer. Soc. Agron., 39: 623-633. 1947.

25. Jackson, T. L., Reisenauer, H. M., and Horner, G. M., "Nitrogen Recommendations for Wheat Production in Eastern Washington," Wash. Agr. Exp. Sta. Circ. 179. 1952.

26. Jameson, H. R., "Liquid Nitrogenous Fertilizers," Jour. Agric. Sci., 53:333-338. 1959.

27. Laughlin, Winston M., "Bromegrass Response to Rate and Source of Nitrogen Applied in Fall and Spring in Alaska," Agron. Jour., 55:62. 1963.

28. Loomis, R. S., Brickey, J. A., Broadbent, F. E., and Worker, G. F., Jr., "Comparisons of Nitrogen Source Materials for Midseason Fertilization of Sugar Beets," Agron. Jour., 52:97-101. 1960.

29. Lowrey, G. W., Olson, R. A., and Ehlers, P. L., 64th Ann. Rept. Neb. Agr. Exp. Sta., pg. 25. May 1951.

30. MacIntire, W. H., Winterberg, S. H., Dunham, H. W., and Clements, L. B., "Response of Sudan Grass to Ammonium Hydroxide in Pot Cultures," Soil Sci. Soc. Amer. Proc., 8:205-210. 1943.

31. McDowell, L. L. and Smith, G. E., "The Retention of Anhydrous Ammonia on Different Soil Types," Soil Sci. Soc. Amer. Proc., 22:38-42. 1958.

32. McIntosh, T. H. and Frederick, L. R., "Distribution and Nitrification of Anhydrous Ammonia in a Nicollet Sandy Clay Loam," Soil Sci. Soc. Amer.

Proc., 22:402-405. 1958.

33. Okuda, A. and Takahashi, E., "On the Germination Injury Due to Free Ammonia," Jour. Sci. Soil Tokyo, 30:243-246. 1959. (Abst.) In Soils and Fertilizers, 24:35 (207). 1961.

34. Peterson, N. K., "Anhydrous Ammonia as a Source of Nitrogen for Wheat," Unpublished Thesis (Masters degree), Purdue Univ. June 1952.

35. Robertson, L. S. and Hansen, C. M., "Losses of Ammonia from Surface and Shallow Applications of a Low Pressure Fertilizer Nitrogen Solution," Mich. Agr. Exp. Sta. Quart. Bull., 42:47-51. 1959.

36. Smirnov, P. M. and Fedicheva, E. I., "Dynamics of Nitrogen in Soil When Aqueous Ammonia is Applied," Dokl. s.-kh. Akod. Timiryaziva, No. 47:65-70. (Abst.) In Soils and Fertilizers, 24:140 (934). 1961.

37. Smith, G. E., "Soil Fertility and Corn Production," Missouri Agr. Exp. Sta. Bull., 583, pp. 46-50. June 1952.

38. Stanley, F. A. and Smith, G. E., "Effect of Soil Moisture and Depth of Application on Retention of Anhydrous Ammonia," Soil Sci. Soc. Amer. Proc., 20: 557-561. 1956.

39. Tiedjens, V. A. and Robbins, W. R., "The Use of Ammonia and Nitrate Nitrogen by Certain Crop Plants," New Jersey Agr. Exp. Sta. Bull., 526. 1931.

40. Tyler, K. B., Broadbent, F. E., and Kondo, V., "Nitrogen Movement in Simulated Cross Sections of Field Soil," Agron. Jour., 50:626-628. 1958.

41. Wyche, R. H., Cheaney, R. L., and Moncrief, J. B., "Anhydrous Ammonia as a Nitrogenous Fertilizer for Rice," Rice Jour., 55, No. 3, 19-20. 1952. (Abst.) In Soils and Fertilizers, 15:421 (2165). 1952.

42. Anonymous, "Anhydrous Ammonia," Rice Jour., 55, No. 3, 9, 40. 1952. (Abst.) In Soils and Fertilizers, 15:421 (2164). 1952.

APPENDIX

TABLE I

SOIL AND CHEMICAL ANALYSIS

Exp. No.	Location	Soil Type	pH 0-6"	% O.M. 0-6"	P lbs/Ac	K lbs/Ac	C.E.C. 0-6"	Sand %	Silt %	Clay %
				Bermuda Grass Fertility						
I	Muskogee	Parsons s.l.	5.7	3.46	39	160	9.28	21	61	17
II	Stillwater	Port s.l.	5.7	1.56	19	160	7.99	47	38	15
III	Stillwater	Port s.l.	5.7	1.73	41	160	8.71	35	44	21
				Winter Wheat Fertility						
I	Cherokee	Pond Creek s.l.	5.7	1.45	49	520	7.28	23	62	15
II	Perkins	Norge s.l.	5.4	1.11	41	160	5.28	55	32	13
III	Stillwater	Bethany-Kirkland Complex	5.8	1.47	60	240	11.71	29	50	21

TABLE II

FERTILIZATION APPLICATION DATES, PER CENT MOISTURE, AND CLIPPING DATES FOR BERMUDA GRASS

Location	Exp. No.	Date Fertilized	% Moist. 0-6"	Date Clipped
Muskogee	I	June 24, 1964	21.8	July 22, 1964
Muskogee				Sept. 24, 1964
Muskogee	I	April 20, 1965	31.6	June 12, 1965
Muskogee	I	June 30, 1965	25.5	Aug. 6, 1965
Muskogee	I			Oct. 15, 1965
Stillwater	II	June 27, 1964	14.0	July 21, 1964
Stillwater	II			Aug. 29, 1964
Stillwater	II			Oct. 16, 1964
Stillwater	II	May 5, 1965	17.4	June 15, 1965
Stillwater	II	June 25, 1965	16.8	July 29, 1965
Stillwater	II			Oct. 8, 1965
Stillwater	III	May 3, 1965	16.0	June 15, 1965
Stillwater	III	June 28, 1965	13.2	July 27, 1965
Stillwater	III			Oct. 8, 1965

TABLE III

FERTILIZER APPLICATION DATES, PER CENT MOISTURE, AND HARVEST DATES FOR WINTER WHEAT FERTILITY EXPERIMENTS

Location	Exp. No.	Application Date	% Moist. 0-6"	Date Harvested
Stillwater	I	Sept. 24, 1964	18.2	June 7, 1965
	I	Dec. 28, 1964	20.3	
	I	Jan. 16, 1965	20.8	
	I	March 26, 1965	19.6	
Cherokee	II	Sept. 23, 1964	15.8	June 19, 1965
	II	Feb. 26, 1965	14.1	
Perkins	III	Feb. 19, 1965	13.0	June 16, 1965

TABLE IV

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, FIRST CLIPPING, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	906	1.30	12
Urea	50	2628	1.94	51
Urea	100	3479	2.46	87
Urea	200	5046	3.36	171
Urea	400*	5045	3.00	151
Ammonium Nitrate	50	2121	1.63	35
Ammonium Nitrate	100	3541	2.10	73
Ammonium Nitrate	200	5047	2.97	149
Ammonium Nitrate	400*	5097	2.64	134
Anhydrous Ammonia	0	628	1.30	8
Anhydrous Ammonia	50	2681	2.50	68
Anhydrous Ammonia	100	3010	2.38	72
Anhydrous Ammonia	200	3132	2.94	91
Anhydrous Ammonia	400*	3330	3.31	110
	L.S.D. (.05)	656	.46	24
	% C.V.	14.00	13.22	19.15

*Split Application

Analysis of Variance

Source	df	Mean Squares		
		Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	8508339.00*	.00018846*	10582.12*
Source	2	4977422.17*	.00009000*	3542.20*
Rate	3	10995552.09*	.00032000*	21107.50*
S x R	6	1558054.48*	.00002333	207.38
O vs. others	2	29159289.40*	.00058500*	27348.24*
Error	39	209093.74	.00001025	271.38

*Denotes significance at the 5% level

TABLE V

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, SECOND CLIPPING, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	370	1.13	4
Urea	50	358	1.28	5
Urea	100	636	1.32	9
Urea	200	1355	1.65	23
Urea	400*	2416	2.62	63
Ammonium Nitrate	50	356	1.25	4
Ammonium Nitrate	100	558	1.44	8
Ammonium Nitrate	200	391	1.64	6
Ammonium Nitrate	400*	2628	2.30	63
Anhydrous Ammonia	0	315	1.16	4
Anhydrous Ammonia	50	628	1.22	8
Anhydrous Ammonia	100	652	1.44	9
Anhydrous Ammonia	200	1924	1.72	33
Anhydrous Ammonia	400*	2356	3.25	78
	L.S.D. (.05)	630	.41	18
	% C.V.	41.76	17.39	55.43

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	3096732.34*	.00015692*	2761.91*
Source	2	661495.82*	.00002500	543.95*
Rate	3	10054382.22*	.00053000*	10166.48*
S x R	6	643361.54*	.00002333*	175.74*
O vs. others	2	2455606.76*	.00013000*	1631.52*
Error	39	198606.78	.00000846	148.72

*Denotes significance at the 5% level

TABLE VI

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, THIRD CLIPPING, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	728	1.05	8
Urea	50	798	1.07	9
Urea	100	1027	1.15	12
Urea	200	1206	1.36	16
Urea	400*	1154	1.60	19
Ammonium Nitrate	50	970	1.08	10
Ammonium Nitrate	100	1097	1.20	13
Ammonium Nitrate	200	1080	1.27	14
Ammonium Nitrate	400*	1494	1.58	23
Anhydrous Ammonia	0	698	1.09	8
Anhydrous Ammonia	50	971	1.16	11
Anhydrous Ammonia	100	1042	1.10	12
Anhydrous Ammonia	200	1112	1.28	14
Anhydrous Ammonia	400*	1538	1.66	25
L.S.D.	(.05)	345	.31	6
	% C.V.	22.48	17.04	29.69

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	239523.46*	.00001769*	120.53*
Source	2	72781.19	.00000000	13.99
Rate	3	491714.89*	.00006333*	358.88*
S x R	6	55320.92	.00000166	15.94
O vs. others	2	580091.21*	.00001500*	183.34*
Error	39	57329.56	.00000461	17.28

*Denotes significance at the 5% level

TABLE VII

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, FIRST CLIPPING, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	593	0.99	6
Urea	50	1014	1.07	11
Urea	100	2848	1.12	32
Urea	200	4122	1.64	68
Urea	400*	5233	1.64	84
Ammonium Nitrate	50	1180	1.00	13
Ammonium Nitrate	100	2456	1.33	34
Ammonium Nitrate	200	4054	2.20	91
Ammonium Nitrate	400*	5095	1.88	96
Anhydrous Ammonia	0	443	1.28	6
Anhydrous Ammonia	50	2760	1.96	54
Anhydrous Ammonia	100	3519	2.10	73
Anhydrous Ammonia	200	3583	2.69	94
Anhydrous Ammonia	400*	4000	2.72	108
	L.S.D. (.05)	901	.32	18
	% C.V.	21.49	13.06	23.00

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	10225830.05*	.00014153*	5597.68*
Source	2	293493.56	.00044000*	4797.14*
Rate	3	21628862.96*	.00020333*	12832.69*
S x R	6	2249734.31*	.00000833	388.33*
O vs. others	2	26981904.49*	.00015000*	11173.76*
Error	39	394214.02	.00000487	160.14

*Denotes significance at the 5% level

TABLE VIII

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, SECOND CLIPPING, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	435	0.76	3
Urea	50	1301	0.93	12
Urea	100	2682	0.98	25
Urea	200	4396	1.19	52
Urea	400*	3900	1.30	51
Ammonium Nitrate	50	2536	1.01	25
Ammonium Nitrate	100	4053	1.37	55
Ammonium Nitrate	200	4744	1.98	94
Ammonium Nitrate	400*	4300	1.89	81
Anhydrous Ammonia	0	371	1.01	4
Anhydrous Ammonia	50	2248	1.23	27
Anhydrous Ammonia	100	2869	1.59	46
Anhydrous Ammonia	200	3092	1.75	54
Anhydrous Ammonia	400*	3478	1.95	66
	L.S.D. (.05)	922	.22	13
	% C.V.	22.26	11.23	21.14

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	7978928.13*	.00006769*	3064.71*
Source	2	4527545.10*	.00013500*	3340.60*
Rate	3	10333405.43*	.00011000*	5588.69*
S x R	6	1019544.25*	.00001166*	352.13*
O vs. others	2	28776746.72*	.00010500*	7140.62*
Error	39	412768.69	.00000230	82.67

*Denotes significance at the 5% level

TABLE IX

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, THIRD CLIPPING, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	744	0.64	5
Urea	50	779	0.62	5
Urea	100	881	0.62	5
Urea	200	1323	0.66	9
Urea	400*	1324	0.69	9
Ammonium Nitrate	50	906	0.64	6
Ammonium Nitrate	100	1130	0.79	9
Ammonium Nitrate	200	2138	0.69	15
Ammonium Nitrate	400*	2271	0.83	19
Anhydrous Ammonia	0	636	0.67	4
Anhydrous Ammonia	50	1194	0.59	7
Anhydrous Ammonia	100	1655	0.75	12
Anhydrous Ammonia	200	2571	0.78	20
Anhydrous Ammonia	400*	2467	0.64	16
	L.S.D. (.05)	579	.20	6
	% C.V.	28.21	20.75	40.57

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	1817191.94*	.00000230	118.29*
Source	2	3243933.49*	.00000500	201.34*
Rate	3	3559045.37*	.00000333	223.48*
S x R	6	220920.62	.00000167	28.06
O vs. others	2	2566734.18*	.00000000	148.14*
Error	39	162772.08	.00000205	16.46

*Denotes significance at the 5% level

TABLE X

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, SUM OF THREE CLIPPINGS, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen Ave.	Yield Nitrogen lbs/Ac
----	0	2004	1.16	24
Urea	50	3783	1.43	63
Urea	100	5142	1.64	108
Urea	200	7608	2.12	210
Urea	400*	8616	2.41	234
Ammonium Nitrate	50	3447	1.32	48
Ammonium Nitrate	100	5196	1.58	93
Ammonium Nitrate	200	6519	1.96	168
Ammonium Nitrate	400*	9219	2.18	219
Anhydrous Ammonia	0	1641	1.19	18
Anhydrous Ammonia	50	4278	1.63	87
Anhydrous Ammonia	100	4704	1.64	93
Anhydrous Ammonia	200	6168	1.98	138
Anhydrous Ammonia	400*	7224	2.74	213
	L.S.D. (.05)	596	.39	18
	% C.V.	23.60	15.69	30.72

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	7066489.73*	.00026153*	7434.04*
Source	2	683293.99*	.00007000*	750.01*
Rate	3	15238316.20*	.00068000*	19544.54*
S x R	6	846562.32*	.00003166*	834.87*
O vs. others	2	19851727.54*	.00051500*	15749.84*
Clippings	2	90118763.32*	.00192000*	88155.22*
T x C	26	2389052.89*	.00005076*	3015.26*
S x C	4	3573323.00*	.00001500	2386.76*
R x C	6	3310300.65*	.00012500*	6575.93*
S x R x C	12	678518.66*	.00001416	719.29*
O vs. others x C	4	4954513.86*	.00008500*	5190.68*
Error	123	180319.88	.00000780	158.66

*Denotes significance at the 5% level

TABLE XI

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. STILLWATER, SUM OF THREE CLIPPINGS, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen Ave.	Yield Nitrogen lbs/Ac
----	0	1773	0.79	5
Urea	50	3093	0.87	9
Urea	100	6411	0.90	21
Urea	200	9840	1.16	43
Urea	400*	10455	1.21	48
Ammonium Nitrate	50	4620	0.88	14
Ammonium Nitrate	100	7638	1.16	33
Ammonium Nitrate	200	10935	1.63	67
Ammonium Nitrate	400*	11664	1.53	65
Anhydrous Ammonia	0	1449	0.99	4
Anhydrous Ammonia	50	6201	1.26	29
Anhydrous Ammonia	100	8043	1.48	44
Anhydrous Ammonia	200	9246	1.74	56
Anhydrous Ammonia	400*	9945	1.77	63
	L.S.D. (.05)	803	.26	14
	% C.V.	23.73	15.23	27.69

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	15563787.47*	.00013615*	6114.43*
Source	2	2270805.01*	.00033500*	4367.47*
Rate	3	29816079.97*	.00021667*	13260.86*
S x R	6	1439942.98*	.00001167*	475.10*
O vs. others	2	49849864.10*	.00019000*	14059.70*
Clippings	2	40569808.49*	.00145000*	29944.72*
T x C	26	2229081.52*	.00003769*	1333.13*
S x C	4	3456038.22*	.00008000*	1420.61*
R x C	6	3411489.63*	.00006667*	3219.58*
S x R x C	12	718833.00*	.00000667*	102.10
O vs. others x C	4	3759258.18*	.00004500*	2109.06*
Error	123	327510.63	.00000357	99.40

*Denotes significance at the 5% level

TABLE XII

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, FIRST CLIPPING, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	1492	1.82	27
Urea	50	2544	1.90	48
Urea	100	2872	2.11	60
Urea	200	3382	2.55	86
Urea	400*	3673	2.25	82
Ammonium Nitrate	50	2620	1.96	51
Ammonium Nitrate	100	3111	2.08	65
Ammonium Nitrate	200	3690	2.47	90
Ammonium Nitrate	400*	3574	2.68	94
Anhydrous Ammonia	0	1860	1.72	32
Anhydrous Ammonia	50	2357	2.31	54
Anhydrous Ammonia	100	2584	2.35	61
Anhydrous Ammonia	200	2236	2.91	65
Anhydrous Ammonia	400*	2213	2.78	62
	L.S.D. (.05)	511	.52	15
	% C.V.	13.06	15.86	17.14

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	1883878.52*	.00005461*	1627.87*
Source	2	3794040.91*	.00006500*	853.58*
Rate	3	1098123.46*	.00009667*	2294.34*
S x R	6	517124.96*	.00001000	359.48*
O vs. others	2	5252609.41*	.00011500*	5207.67*
Error	39	126965.18	.00001307	116.59

*Denotes significance at the 5% level

TABLE XIII

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, SECOND CLIPPING, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	1361	1.19	16
Urea	50	1973	1.13	22
Urea	100	2072	1.08	22
Urea	200	2923	1.10	32
Urea	400*	4487	1.56	71
Ammonium Nitrate	50	2102	1.31	27
Ammonium Nitrate	100	2219	1.13	25
Ammonium Nitrate	200	4123	1.12	46
Ammonium Nitrate	400*	5191	1.76	91
Anhydrous Ammonia	0	1764	1.04	18
Anhydrous Ammonia	50	2123	1.07	23
Anhydrous Ammonia	100	3145	1.18	37
Anhydrous Ammonia	200	4726	1.29	60
Anhydrous Ammonia	400*	4270	1.77	76
	L.S.D. (.05)	654	.29	13
	% C.V.	15.15	15.94	22.92

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	6519509.81*	.00002461*	2381.36*
Source	2	2170851.39*	.00000500	672.53*
Rate	3	17359350.50*	.00008667*	7595.44*
S x R	6	997454.91*	.00000333	232.39*
O vs. others	2	11174571.80*	.00001500*	2716.00*
Error	39	211347.64	.00000410	84.08

*Denotes significance at the 5% level

TABLE XIV

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, FIRST CLIPPING, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	1682	1.48	25
Urea	50	2735	1.38	38
Urea	100	3498	1.86	65
Urea	200	4676	1.80	85
Urea	400*	4404	1.84	81
Ammonium Nitrate	50	2718	1.63	44
Ammonium Nitrate	100	4163	1.88	78
Ammonium Nitrate	200	5968	2.30	137
Ammonium Nitrate	400*	4096	2.58	106
Anhydrous Ammonia	0	1689	1.45	24
Anhydrous Ammonia	50	3492	1.81	63
Anhydrous Ammonia	100	4270	2.10	90
Anhydrous Ammonia	200	4235	2.49	105
Anhydrous Ammonia	400*	3206	2.82	88
	L.S.D. (.05)	687	.38	17
	% C.V.	13.17	13.66	16.32

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	5491545.74*	.00007846*	4232.66*
Source	2	951962.49*	.00014000*	2602.40*
Rate	3	7499399.82*	.00013667*	7379.31*
S x R	6	1829693.81*	.00001500*	756.12*
O vs. others	2	18004903.78*	.00012000*	11572.53*
Error	39	228792.79	.00000717	141.92

*Denotes significance at the 5% level

TABLE XV

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, SECOND CLIPPING, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	2296	0.90	20
Urea	100*	3775	0.92	34
Urea	200*	4677	0.99	46
Urea	200	3331	0.80	27
Urea	400*	5418	1.23	67
Ammonium Nitrate	100*	4158	0.88	36
Ammonium Nitrate	200*	4854	1.05	51
Ammonium Nitrate	200	4631	0.78	36
Ammonium Nitrate	400*	4941	1.45	71
Anhydrous Ammonia	0	2088	0.97	20
Anhydrous Ammonia	100*	3286	0.96	31
Anhydrous Ammonia	200*	4156	1.26	52
Anhydrous Ammonia	200	4827	0.77	37
Anhydrous Ammonia	400*	4221	1.60	67
	L.S.D. (.05)	700	.16	8
	% C.V.	12.04	10.88	13.66

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	3939211.71*	.00002538*	1131.62*
Source	2	1132383.12*	.00001000*	105.69*
Rate	3	2243762.18*	.00009000*	3031.53*
S x R	6	1457956.56*	.00000367*	27.44
O vs. others	2	16732980.13*	.00001000*	2620.20*
Error	39	237655.47	.00000128	34.51

*Denotes significance at the 5% level

TABLE XVI

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, THIRD CLIPPING, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
----	0	456	0.84	4
Urea	100*	516	0.76	4
Urea	200*	868	0.89	8
Urea	200	560	0.83	5
Urea	400*	1340	0.88	12
Ammonium Nitrate	100*	484	0.71	3
Ammonium Nitrate	200*	751	0.87	7
Ammonium Nitrate	200	810	0.90	7
Ammonium Nitrate	400*	1507	1.04	14
Anhydrous Ammonia	0	584	0.92	5
Anhydrous Ammonia	100*	662	0.83	6
Anhydrous Ammonia	200*	862	0.93	8
Anhydrous Ammonia	200	950	0.87	8
Anhydrous Ammonia	400*	1282	1.24	16
	L.S.D. (.05)	549	.19	5
	% C.V.	46.06	14.87	40.68

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	451061.09*	.00000692*	61.59*
Source	2	55919.39	.00000500	23.03
Rate	3	1355897.80*	.00001667*	199.47*
S x R	6	126032.04	.00000333	10.09
O vs. others	2	464034.90*	.00000500	47.86*
Error	39	146517.97	.00000179	10.79

*Denotes significance at the 5% level

TABLE XVII

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, SUM OF TWO CLIPPINGS, 1964

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen Ave.	Yield Nitrogen lbs/Ac
----	0	2852	1.51	44
Urea	50	4516	1.51	70
Urea	100	4944	1.59	82
Urea	200	6304	1.82	118
Urea	400*	8160	1.90	154
Ammonium Nitrate	50	4722	1.63	78
Ammonium Nitrate	100	5330	1.61	90
Ammonium Nitrate	200	7812	1.79	136
Ammonium Nitrate	400*	8766	2.22	186
Anhydrous Ammonia	0	3624	1.38	50
Anhydrous Ammonia	50	4480	1.69	78
Anhydrous Ammonia	100	5728	1.76	98
Anhydrous Ammonia	200	6960	2.10	124
Anhydrous Ammonia	400*	6484	2.28	138
	L.S.D. (.05)	571	.42	14
	% C.V.	14.12	16.72	19.47

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	6061119.73*	.00005923*	3323.83*
Source	2	1354495.51*	.00005000*	583.41*
Rate	3	13222992.12*	.00014333*	8260.14*
S x R	6	953717.16*	.00001167	305.08*
O vs. others	2	15347143.26*	.00008500*	7716.02*
Clippings	1	2607750.66*	.00287000	13888.46*
T x C	13	2342268.11*	.00002000*	685.40*
S x C	2	3972385.79*	.00001000	1157.53*
R x C	3	5823759.97*	.00005333*	1510.07*
S x R x C	6	674414.00*	.00000667	255.34*
O vs. others x C	2	493475.12	.00002000	266.46
Error	81	165620.55	.00000876	102.57

*Denotes significance at the 5% level

TABLE XVIII

YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY AS AFFECTED BY RATES AND SOURCES OF NITROGEN. MUSKOGEE, SUM OF THREE CLIPPINGS, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen Ave.	Yield Nitrogen lbs/Ac
----	0	4434	1.07	48
Urea	100*	7026	1.02	75
Urea	200*	9042	1.25	117
Urea	200	8568	1.15	117
Urea	400*	11160	1.32	159
Ammonium Nitrate	100*	7359	1.07	84
Ammonium Nitrate	200*	9768	1.26	135
Ammonium Nitrate	200	11409	1.32	180
Ammonium Nitrate	400*	10545	1.70	189
Anhydrous Ammonia	0	4362	1.11	51
Anhydrous Ammonia	100*	7440	1.20	99
Anhydrous Ammonia	200*	9288	1.43	150
Anhydrous Ammonia	200	10011	1.38	150
Anhydrous Ammonia	400*	8709	1.88	180
	L.S.D. (.05)	628	.28	11
	% C.V.	15.78	15.35	19.79

*Split Application

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	13	6445677.85*	.00007230*	2885.36*
Source	2	1337882.39*	.00010000*	1386.64*
Rate	3	5185817.11*	.00016000*	4406.79*
S x R	6	1817732.77*	.00001833*	480.70*
O vs. others	2	27327099.81*	.00007500*	9315.92*
Clippings	2	171355634.38*	.00186000*	60645.77*
T x C	26	1718073.38*	.00001923*	1277.18*
S x C	4	1149451.00*	.00002000*	633.60*
R x C	6	2913714.63*	.00004333*	3103.77*
S x R x C	12	1232925.00*	.00000583	191.62*
O vs. others x C	4	1948678.98*	.00002250*	2437.56*
Error	123	200383.92	.00000398	65.86

*Denotes significance at the 5% level

TABLE XIX

INFLUENCE OF AMMONIA APPLICATOR KNIFE SPACINGS AND RATES OF ANHYDROUS AMMONIA ON YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY. STILLWATER, FIRST CLIPPING, 1965

Knife Spacing	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
16 inches	50	1742	1.30	23
16 inches	100	2904	1.98	57
16 inches	150	3049	1.99	61
16 inches	200	3267	2.28	74
12 inches	50	1888	1.46	28
12 inches	100	3340	1.78	59
12 inches	150	3485	2.00	70
12 inches	200	3485	1.98	69
8 inches	50	1888	1.41	27
8 inches	100	3049	1.86	57
8 inches	150	3703	2.32	86
8 inches	200	3920	2.16	85
	L.S.D. (.05)	617	.36	17
	% C.V.	14.60	13.16	21.01

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	11	2054239.77*	.00004272*	1738.30*
Rate	3	6978271.72*	.00014000	5985.92*
Spacing	2	448719.80*	.00000500	233.24
R x S	6	127397.12	.00000667	116.17
Error	33	185024.90	.00000606	143.42

*Denotes significance at the 5% level

TABLE XX

INFLUENCE OF AMMONIA APPLICATOR KNIFE SPACINGS AND RATES OF ANHYDROUS AMMONIA ON YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY. STILLWATER, SECOND CLIPPING, 1965

Knife Spacing	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
16 inches	50	1234	1.78	22
16 inches	100	2614	2.06	54
16 inches	150	2686	2.24	60
16 inches	200	2977	2.50	74
12 inches	50	1162	1.79	21
12 inches	100	2396	2.47	59
12 inches	150	2759	2.21	61
12 inches	200	3049	2.22	68
8 inches	50	1597	2.38	38
8 inches	100	3049	2.32	71
8 inches	150	3122	2.85	89
8 inches	200	2977	3.00	89
	L.S.D. (.05)	400	.50	13
	% C.V.	11.32	15.19	15.44

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	11	1993232.99*	.00005272*	1940.09*
Rate	3	6797239.01*	.00007666*	5766.21*
Spacing	2	452644.64*	.00012000*	1789.13*
R x S	6	104759.42	.00001833	77.34
Error	33	77674.90	.00001242	80.17

*Denotes significance at the 5% level

TABLE XXI

INFLUENCE OF AMMONIA APPLICATOR KNIFE SPACINGS AND RATES OF ANHYDROUS AMMONIA ON YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY. STILLWATER, THIRD CLIPPING, 1965

Knife Spacing	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
16 inches	50	1016	0.51	5
16 inches	100	1162	0.59	7
16 inches	150	1452	0.62	9
16 inches	200	2686	0.62	17
12 inches	50	944	0.50	5
12 inches	100	1234	0.51	6
12 inches	150	1525	0.44	7
12 inches	200	1742	0.64	11
8 inches	50	726	0.57	4
8 inches	100	1089	0.54	6
8 inches	150	2105	0.71	15
8 inches	200	3194	0.85	27
	L.S.D. (.05)	712	.28	7
	% C.V.	31.32	20.82	46.10

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	11	2200807.82*	.00000454*	179.42*
Rate	3	6154882.74*	.00000667*	418.51*
Spacing	2	728345.30	.00001000*	136.93*
R x S	6	714591.16*	.00000167	74.04*
Error	33	245789.85	.00000151	21.26

*Denotes significance at the 5% level

TABLE XXII

INFLUENCE OF AMMONIA APPLICATOR KNIFE SPACINGS AND RATES OF ANHYDROUS AMMONIA ON YIELDS OF DRY MATTER AND NITROGEN CONTENT OF BERMUDA GRASS HAY. STILLWATER, SUM OF THREE CLIPPINGS, 1965

Knife Spacing	Nitrogen Rate lbs/Ac	Yield Dry Matter lbs/Ac	Per Cent Nitrogen Ave.	Yield Nitrogen lbs/Ac
16 inches	50	3992	1.20	50
16 inches	100	6680	1.54	118
16 inches	150	7187	1.62	130
16 inches	200	8930	1.80	165
12 inches	50	3994	1.25	54
12 inches	100	6970	1.59	124
12 inches	150	7769	1.55	138
12 inches	200	8276	1.61	148
8 inches	50	4211	1.45	69
8 inches	100	7187	1.57	134
8 inches	150	8930	1.96	190
8 inches	200	10091	2.00	201
	L.S.D. (.05)	605	.38	13
	% C.V.	18.12	16.58	21.13

Analysis of Variance

		Mean Squares		
Source	df	Yield of Dry Matter	Per Cent Nitrogen	Yield of Nitrogen
Treatments	35	3270073.24*	.00025285*	3298.44*
Rate	3	17971632.86*	.00017333*	9617.20*
Spacing	2	1020902.45*	.00008500*	1536.18*
R x S	6	258216.50	.00001333	215.62*
Clippings	2	22860736.43*	.00386500*	36504.73*
R x C	6	979381.16*	.00002667*	1276.72*
S x C	4	304405.75	.00002500*	311.56*
R x S x C	12	344264.83*	.00000750	25.96
Error	105	178188.33	.00000695	78.74

*Denotes significance at the 5% level

TABLE XXIII

YIELDS OF WINTER WHEAT AND GRAIN NITROGEN AS AFFECTED BY RATES AND DATES OF APPLICATION AND SOURCES OF NITROGEN. STILLWATER, 1965

Nitrogen Source	Date	Nitrogen Rate lbs/Ac	Grain Yield Bu/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
Anhydrous Ammonia	Jan. 15	0	21.4	1.77	23
Anhydrous Ammonia	Jan. 15	20	21.5	1.78	23
Anhydrous Ammonia	Jan. 15	40	19.5	1.98	23
Anhydrous Ammonia	Jan. 15	80	18.9	1.96	22
Ammonia & Urea	Jan. 15	0	21.3	1.55	20
Ammonium Nitrate	Jan. 15	20	25.4	1.65	25
Ammonium Nitrate	Jan. 15	40	28.2	1.78	30
Ammonium Nitrate	Jan. 15	80	28.4	1.85	32
Urea	Jan. 15	20	27.8	1.56	26
Urea	Jan. 15	40	28.6	1.74	30
Urea	Jan. 15	80	27.4	1.96	32
Anhydrous Ammonia	Sept. 15	0	22.2	1.46	19
Anhydrous Ammonia	Sept. 15	20	29.5	1.60	28
Anhydrous Ammonia	Sept. 15	40	31.6	1.73	33
Anhydrous Ammonia	Sept. 15	80	34.9	2.00	42
Anhydrous Ammonia	Nov. 15	0	16.2	1.83	18
Anhydrous Ammonia	Nov. 15	20	20.8	1.87	23
Anhydrous Ammonia	Nov. 15	40	23.2	1.86	26
Anhydrous Ammonia	Nov. 15	80	22.4	2.05	28
Anhydrous Ammonia	Mar. 15	0	20.3	1.79	22
Anhydrous Ammonia	Mar. 15	20	21.7	1.82	24
Anhydrous Ammonia	Mar. 15	40	20.0	1.84	22
Anhydrous Ammonia	Mar. 15	80	20.6	2.12	26
L.S.D. (.05)			4.4	.21	5
% C.V.			12.28	8.04	12.04

Analysis of Variance

		Mean Squares		
Source	df	Yield of Grain	Per Cent Nitrogen	Yield of Nitrogen
Treatments	22	262926.96*	.0000109	108.81*
Rate	3	203953.23*	.0000300	218.22*
Date	3	638664.22*	.0000167	77.78*
R x D	9	87248.72*	.0000033	38.04*
O vs. others	7	353043.18*	.0000100	166.23*
Error	66	35602.29	.00000212	13.08

*Denotes significance at the 5% level

Analysis of Variance

		Mean Squares		
Source	df	Yield of Grain	Per Cent Nitrogen	Yield of Nitrogen
Treatments	9	194174.99*	.00000778*	62.53*
Rate	2	612031.82*	.00001000*	104.69*
Source	2	9087.03	.00002000	75.61*
R x S	4	20208.78	.00000250	15.64
O vs. others	1	392502.12*	.00000000	139.63*
Error	27	41528.56	.00000222	10.61

*Denotes significance at the 5% level

TABLE XXIV

YIELDS OF WINTER WHEAT AND GRAIN NITROGEN AS AFFECTED BY RATES AND DATES OF APPLICATION AND SOURCES OF NITROGEN. CHEROKEE, 1965

Nitrogen Source	Date	Nitrogen Rate lbs/Ac	Grain Yield Bu/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
Anhydrous Ammonia	Fall	20	43.4	1.96	51
Anhydrous Ammonia	Fall	40	42.4	2.12	54
Anhydrous Ammonia	Fall	80	41.9	2.46	62
Anhydrous Ammonia	Spring	20	42.5	1.89	48
Anhydrous Ammonia	Spring	40	43.8	2.12	56
Anhydrous Ammonia	Spring	80	43.1	2.12	55
Ammonium Nitrate	Fall	20	42.3	1.82	46
Ammonium Nitrate	Fall	40	43.9	1.91	50
Ammonium Nitrate	Fall	80	43.7	2.36	62
Ammonium Nitrate	Spring	20	41.5	1.95	49
Ammonium Nitrate	Spring	40	41.7	2.01	50
Ammonium Nitrate	Spring	80	41.5	1.95	49
	L.S.D. (.05)		3.5	0.14	13
	% C.V.		3.66	47.79	16.81

Analysis of Variance

Source	df	Mean Squares Yield of Grain	Per Cent Nitrogen	Yield of Nitrogen
Treatments	11	12542.34	.00001454	116.44
Source	1	7676.02	.00001000	129.69
Rate	2	3731.90	.00004000	276.72
Date	1	21126.02	.00003000	273.13
S x R	2	4858.14	.00000000	5.34
S x D	1	65195.02	.00000000	60.08
R x D	2	3287.90	.00002000	120.57
S x R x D	2	10106.40	.00000000	6.37
Error	33	20975.68	.0000969	79.33

*Denotes significance at the 5% level

TABLE XXV

YIELDS OF WINTER WHEAT AND GRAIN NITROGEN AS AFFECTED BY 60 POUNDS OF AMMONIUM NITRATE AND ANHYDROUS AMMONIA AND TILLAGE BY APPLICATOR KNIVES. PERKINS, 1965

Nitrogen Source	Nitrogen Rate lbs/Ac	Tillage	Grain Yield Bu/Ac	Per Cent Nitrogen	Yield Nitrogen lbs/Ac
	Parallel to Drill Rows				
Ammonium Nitrate	60	---	45.6	1.79	49
Ammonium Nitrate	60	Applicator knives	43.6	1.81	47
Anhydrous Ammonia	60	Applicator knives	42.5	2.44	62
----	0	---	25.4	1.54	23
----	0	Applicator knives	22.2	1.70	23
	Perpendicular to Drill Rows				
Ammonium Nitrate	60	---	46.8	1.82	51
Ammonium Nitrate	60	Applicator knives	41.7	1.82	46
Anhydrous Ammonia	60	Applicator knives	45.7	2.20	60
----	0	---	27.3	1.76	29
----	0	Applicator knives	24.7	1.57	23
		L.S.D. (.05)	3.0	.36	8
		% C.V.	5.78	13.59	13.21

Analysis of Variance

Source	df	Mean Squares Yield of Grain	Per Cent Nitrogen	Yield of Nitrogen
Method	1	70308.22	.00000000	14.04
Error a	3	200881.81	.00000333	50.35
Treatments	4	3336028.90*	.00006250*	2145.61*
T x M	4	26831.34	.00000500	16.12
Error b	24	16088.64	.00000625	29.07

*Denotes significance at the 5% level

VITA

Walter E. Hill

Candidate for the Degree of

Master of Science

Thesis: THE EFFECTS OF TOPDRESSING ANHYDROUS AMMONIA ON WINTER WHEAT AND BERMUDA GRASS SOD

Major Field: Agronomy

Biographical:

Personal Data: Born September 3, 1941, in Liberal, Kansas, the son of Robert R. and Mildred O. Hill.

Education: Attended the primary and secondary public schools of Turpin, Oklahoma, in Beaver County; graduated from Turpin High School in 1959; received the Bachelor of Science degree in Agronomy from Panhandle A & M College, Goodwell, Oklahoma in May, 1964; completed the requirements for the Master of Science degree in May, 1966.

Professional Experience: Worked as farm laborer until graduation from high school in 1959. Worked as a field plot technician for the Oklahoma Agricultural Experiment Station at Goodwell, Oklahoma during undergraduate study and during the summer of 1963. Served as half-time graduate research assistant while completing the requirements for the Master of Science degree during the academic years of 1964-65 and 1965-66; full-time employee of the Agronomy Department at Oklahoma State University during the summers of 1964 and 1965.

Professional Organizations: Member of the American Society of Agronomy and the Soil Science Society of America.