ANHYDROUS AMMONIA AS A NITROGEN SOURCE FOR IRRIGATED COTTON

By

LEWIS E. DILLON

Bachelor of Science

Texas College of Arts and Industries

Kingsville, Texas

1958

Master of Science

1960

Submitted to the faculty of the Graduate School
of the Oklahoma State University in partial
fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
May, 1960

ANHYDROUS AMMONIA AS A NITROGEN
SOURCE FOR IRRIGATED COTTON

Thesis Approved:

Robert M. Reed
Thesis Adviser

[signature]

John F. Stone

Charles L. Leinweber

[signature]
Dean of the Graduate School

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the Phillips Chemical Company for furnishing the anhydrous ammonia and to the Continental NH_3 Products Company, Incorporated for furnishing the regulator. The author is also grateful to the Agronomy Department of Oklahoma State University for the financial assistance and facilities which made this study possible and to the Agronomy Department Staff for their helpful advice and criticism.

Special recognitition is due Dr. R.M. Reed, major thesis adviser, whose gudidance throughout this study was invaluable. A vote of thanks to Dr. C.L. Leinweber for his cooperation during this study. The writer also wishes to thank his wife, Margaret, for her patience, understanding, and for typing the manuscript.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I INTRODUCTION

Cotton is one of Oklahoma's leading agricultural crops. Although the acreage was only 3 percent of the total cropped area of Oklahoma in 1958, the receipts from cotton comprised approximately 9 percent of the state's farm income. This makes cotton very important in the economic stability of the state. For the ten year period 1949-1959 the annual income derived from lint cotton averaged over 50 million dollars (5,6)[1]. Cotton seed and oil processing provided additional income. Also, a large number of people are employed in harvesting, ginning, and sales of equipment and materials for the production of cotton. Even though cotton acreage allotments have caused a decrease in the number of planted acres, cotton yields are increasing.

Ever since man has been growing crops, he has been constantly searching for new and better methods of production. A great number of improvements have been made and many more will undoubtedly occur in the future. One of the most recent advances in cotton fertility practices is the use of anhydrous ammonia as a nitrogenous fertilizer. Initially it was important in the field of refrigeration. In the early 1900's some experimenters thought that anhydrous

[1]Figures in parenthesis refer to Literature Cited

ammonia would probably be beneficial in agricultural production since it is rich in nitrogen (82% N). However, early attempts to use this gas in the realm of crop production were abandoned probably because of a lack of knowledge concerning the behavior of the gas in the soil and inadequate metering devices. Recently other investigators have resurrected the ideas of their predecessors and in the past ten years, anhydrous ammonia sales have steadily increased throughout the United States. Several experiment stations and commerical organizations are conducting field tests with anhydrous ammonia as the nitrogen carrier on all phases of crop production. These experiments include both the direct injection of the gas into the soil and the application of the gas through irrigation water.

It was the objective of this investigation to study the effects of times and rates of application of anhydrous ammonia, metered into irrigation water, on yield and quality of lint cotton.

II REVIEW OF LITERATURE

General Morphology of the Cotton Plant

A mature undamaged cotton plant has a prominent erect main stem with an apex or growing tip called a plumule and a taproot system. It is a many branched soft stem shrub and the American varieties are generally from 2 to 6 feet tall. The American varieties act as annuals because of environmental conditions, whereas in its native habitat in India, the cotton plant may obtain heights up to 20 feet and exist as a perennial (10). Cotton has an indeterminate growth habit and a characteristic shedding of small floral buds and bolls (11,13,16). The general shape of the cotton plant ranges from columnar to rounded, and this shape is determined mainly by the length of the branches. Large leaves arise from the stems and are arranged in a pattern. There is a three-eights turn about the stem between successive leaves. Each leaf has two buds or rudiments of buds in its axil. One of these buds is known as the axillary bud and produces the vegetative branches, while the other bud is known as the lateral bud and produces the fruiting branches. About 6 to 8 flower buds are produced on each fruiting branch. The bud first appears as a small green structure known as a square. Flowers will develop approximately 21 days after the appearance of the squares. After the flower blooms, the boll emerges. The boll will be segmented, and these segments of cotton later become known as "locks". Cotton bolls, depending upon climatic conditions, will require about 45 to 65 days to mature.

Physiological Role of Nitrogen in Cotton Production

In more than 150 experiments conducted by the U.S.D.A. with farmer cooperators, the lint yield increases were approximately 40 pounds per 100 pounds of fertilizer. Best results were obtained when one half of the nitrogen was applied in a mixed fertilizer at or before planting, and one half as a nitrogen sidedressing. It has been estimated that 12% of the total seasonal uptake of mineral nutrients for cotton growth occurs from seedling to square stage, 58% from square to boll, and 30% thereafter (29). These uptake rates are in some accordance with the findings of Nelson and Welch (36). They reported uptake values of 4.4% from planting to seedling, 12.8% from seedling to early square, 43.3% from early square to early boll, and 39.5% from early boll to maturity.

Nitrogen is important in reproduction. Eaton (16) found that nitrogen is translocated to the bolls during fruiting. He noted that if the supply of nitrogen is exhausted fruiting stops, yellowing of the leaves occurs, and the size of leaves and internodes is reduced. Crowther (15) stated that the number of flowers initiated is related to or determined by the nitrogen supply.

Brown (10) has shown that cotton has a greater need for nitrogen than any other plant food nutrient. However, none of the essential nutrients can be below an optimum level if normal growth and development is expected. He has also stated that nitrogen balanced with the other essential nutrients may accelerate plant growth, produce a larger plant, cause earlier blooming, and hasten maturity. On the other hand, nitrogen alone in excessive quantities may cause delayed maturity and excessive vegetative growth. Cardozier (11) reported that nitrogen aids in the production of chlorophyll which is associated with a rapid, healthy growth. In addition, an adequate supply of nitrogen reduced drought injury in the plant. Christidis and Harrison (13) stated that nitrogen may increase the number of squares and bolls, boll size, seed weight, lint length and decrease boll shedding. However, they agreed with Brown (10) that an oversupply of nitrogen can be detrimental to production.

Ammonia in the Soil

Mechanisms of Ammonia Sorption

Mortland (35) discussed some of the possible ways in which ammonia is held in the soil. He attributed the holding power of the soil to the chemical and physical forces involved in the colloidal system. Hydrogen ions in the soil may combine with ammonia to form ammonium ions. Chemical sorption occurs when these ammonium ions are exchanged for hydrogen ions on the colloidal surface. In physical sorption, the presence of hydrogen ions is not necessary. The ammonia may be held in much the same way as water is retained. Since the ammonia molecule is tetrahedral, a bond may exist between the oxygen of the clay and hydrogen of the ammonia.

Reaction of Ammonia with Clay Minerals and Organic Matter

Several investigators have studied the sorption of ammonia by clay minerals (18,27,34). Both Mortland (34) and Jenny et al. (27) have been able to show physical sorption as well as chemical sorption. Mortland (34) stated that the amount of ammonia sorbed was inversely related to the soil temperature because of volatilization losses. Mortland (35) also reported that little is known about the exact relationship between ammonia sorption and organic matter in the soil. Some work has been done by Mattson and Koutler-Anderrson (33) on the reaction of ammonia with peat, litter residues, humus, and lignin. They concluded that lignin in organic matter is responsible for ammonia fixation. However, Stevenson (42) suggested that there is not real conclusive proof that such a complex exists in the soil.

Factors of Sorption and Loss of Ammonia as Affected by Moisture, Texture, Tilth, Reaction, and Method of Application

Stanley and Smith (41) in a laboratory experiment noted losses of anhydrous ammonia applied to the soil by the direct injection method. Losses were heavy from both the very wet and very dry soils. Losses from the dry soil were due to the lack of reaction media, whereas the losses from the very wet soils were explained by evaporation from the surface. However, these data are not in complete agreement with the results obtained by Jackson and Chang (26). Under laboratory conditions, they reported a rapid sorption of ammonia and concluded that moisture and depth of application would be of little significance in the retention of ammonia.

The effect of soil texture on the sorption of ammonia is very evident. Several investigators have shown that sorption of ammonia is a function of texture (27,32,41). The coarse-textured soils tend to lose ammonia faster than fine-textured soils.

Very little work has been done on the effects of tilth on the retention of ammonia. Stanley and Smith (41) observed that retention is greater in an air-dry cloddy soil as compared to a air-dry granulated soil.

Soil reaction is another factor which influences the rate of sorption and loss of ammonia from the soil. It has been found that more ammonia is sorbed by acid soils than by alkaline soils (25,27,32).

There are two main methods of application for anhydrous ammonia. One is the direct injection of ammonia into the soil. Small losses of ammonia occur from the soil when it is applied at 4 to 6 inch depths under optimum moisture conditions (22,41,44). The second method is the application of ammonia through the irrigation water. Some investigators agree that little ammonia is lost from the water if the concentration of 110 ppm. is not exceeded (1,28,39). Leavitt (28) found that samples taken from 400 to 800 foot furrows showed equal concentrations of ammonia at the upper and lower end of the furrow. Chapman (12) concluded that the concentration of ammonia in the irrigation water had no effect upon losses from furrow irrigation. Other investigators reported significant losses of ammonia when applied through irrigation water (7,25). Andrews (3) stated that the application of ammonia through the irrigation water is inefficient as compared to the direct injection method. On the other hand, Cook and Hulburt (14) reported that irrigation water may carry fertilizers to the plants, and that such methods of distribution are suitable for supplementary applications of nitrogen and potassium.

Effects of Ammonia in the Soil

The initial effect of ammonia in the soil is an increase of alkalinity (25,41). However, Humbert and Ayers (25) stated that the ultimate influence was an increase of acidity. Some changes in nutrient availability have occurred with applications of ammonia. Investigators have shown a decrease in the availability of calcium and magnesium, but an increase in the amount of available phosphorus (25,41). Anderson (2) found that ammonia applications increased the amount of available potassium.

The actual importance of ammonia in soil structure is still vague. Some experiments have shown beneficial effects while others have shown harmful effects depending on the nature of the soil. According to Humbert and Ayers,(25) ammonia applied directly to the soil caused a drastic reduction of organisms in the band of fertilizer. However, after a period of ten days, nitrification became evident. Eno et al. (17) suggested the possibility of the use of ammonia for the destruction of nematodes.

Effect of Ammonia on Cotton Yields

Only a limited amount of information is available at the present time on the response of cotton to ammonia. Since anhydrous ammonia is still a relatively new fertilizer material, most of the research work is still in the experimental stage.

Thornton and Fisher (43) reported increases in yields of seed cotton from the application of ammonia at both the Prairie View and Ysleta Stations in Texas. At Praire View a two year average showed that ammonia added at the rate of 120 pounds of nitrogen per acre produced an increase of 145 pounds of lint over the check plots and was equivalent to ammonium nitrate applied at the same rate. At the Ysleta Station, ammonia produced an increase of 401 pounds of seed cotton per acre over the check plots, but was inferior to ammonium sulfate or ammonium nitrate when applied at the rate of 94 pounds of nitrogen per acre. Another report from Texas, stated that ammonia applied at the rate of 98 pounds of nitrogen per acre increased the yields of seed cotton by 370 pounds per acre compared to the check plots (31). In cotton yields it exceeded four other types of nitrogenous materials.

At thirty locations in Mississippi, Andrews et al. (4) have shown that ammonia was superior to ammonium nitrate by 44 pounds of seed cotton per acre when both were applied preplant at the rate of 32 pounds of nitrogen per acre. However, ammonium nitrate produced 43 pounds more seed cotton than ammonia in a sidedressing test. In a similar experiment in Mississippi, ammonia increased yields of seed cotton 386 pounds per acre above the check plots while ammonium nitrate increased yields of seed cotton by 305 pounds per acre (36). As a sidedressing there were no particular differences between these two nitrogenous materials. In a summary of several experiments conducted in Louisiana, North Carolina, Alabama, Mississippi, and Georgia it was stated that anhydrous ammonia, ammonium nitrate, and nitrogen solutions were equally effective in increasing yields of seed cotton. On infertile Arizona soils Hamilton et al. (21) reported increases in the yields of seed cotton fertilized at varying rates from 60 to 375 pounds of nitrogen per acre. The 375 pound rate gave the largest increase in yields.

III METHODS AND MATERIALS

This field investigation involved comparisons of the effects of starter versus no starter nitrogen, times of nitrogen sidedressing, and rates of nitrogen sidedressing plus interactions on the lint yields and fiber qualities of irrigated cotton. The field and laboratory techniques for conducting this experiment are found in the subsequent paragraphs.

Soil and Water Analyses

The soil used for this study was a Vanoss loam (profile description found in the Appendix)located on 3800, 3900, 4000, and 4100 series of the Perkins Agronomy farm. The soil was characterized by the following chemical and physical measurements. Cation exchange capacity was determined by replacing the cations with ammonium ions from 1.0 N ammonium acetate (30). A solution of 1.0 N ammonium acetate was also used to displace the exchangeable cations (37). Exchangeable calcium, magnesium, potassium, and sodium were then measured with the Beckman Flame Spectrophotometer. For the pH determination, the soil was moistened with distilled water to a thick paste, allowed to stand for 30 minutes to reach equilibrium, and then the pH was measured with a Beckman Zeromatic pH meter. The organic matter content was obtained by wet oxidation with sodium dichromate in the presence of sulfuric acid (45). The total nitrogen was determined by a modification of of the method recommended by the A.O.A.C. (30), and as suggested by Harper (23), selenium was used as the catalyst. Total phosphorus was ascertained according to Shelton and Harper (4). Available phosphorus was determined by the 0.1 N acetic acid leaching method as outlined by Harper (24). The mechanical analysis of the soil was made using the Bouyoucos method (9). The results of these analyses are recorded in Table I.

A water sample was taken from the well used as the source of irrigation water for this experiment. Total salts, conductivity, and chlorides were determined on this sample (38). The results of these tests are shown in Table II.

TABLE II

IRRIGATION WATER ANALYSES

Analysis	
Total Salts	200 ppm.
Conductivity	384 micromhos/cm.
Chlorides	26 ppm.

TABLE I

SOIL CHARACTERISTICS AS DETERMINED

BY LABORATORY ANALYSES

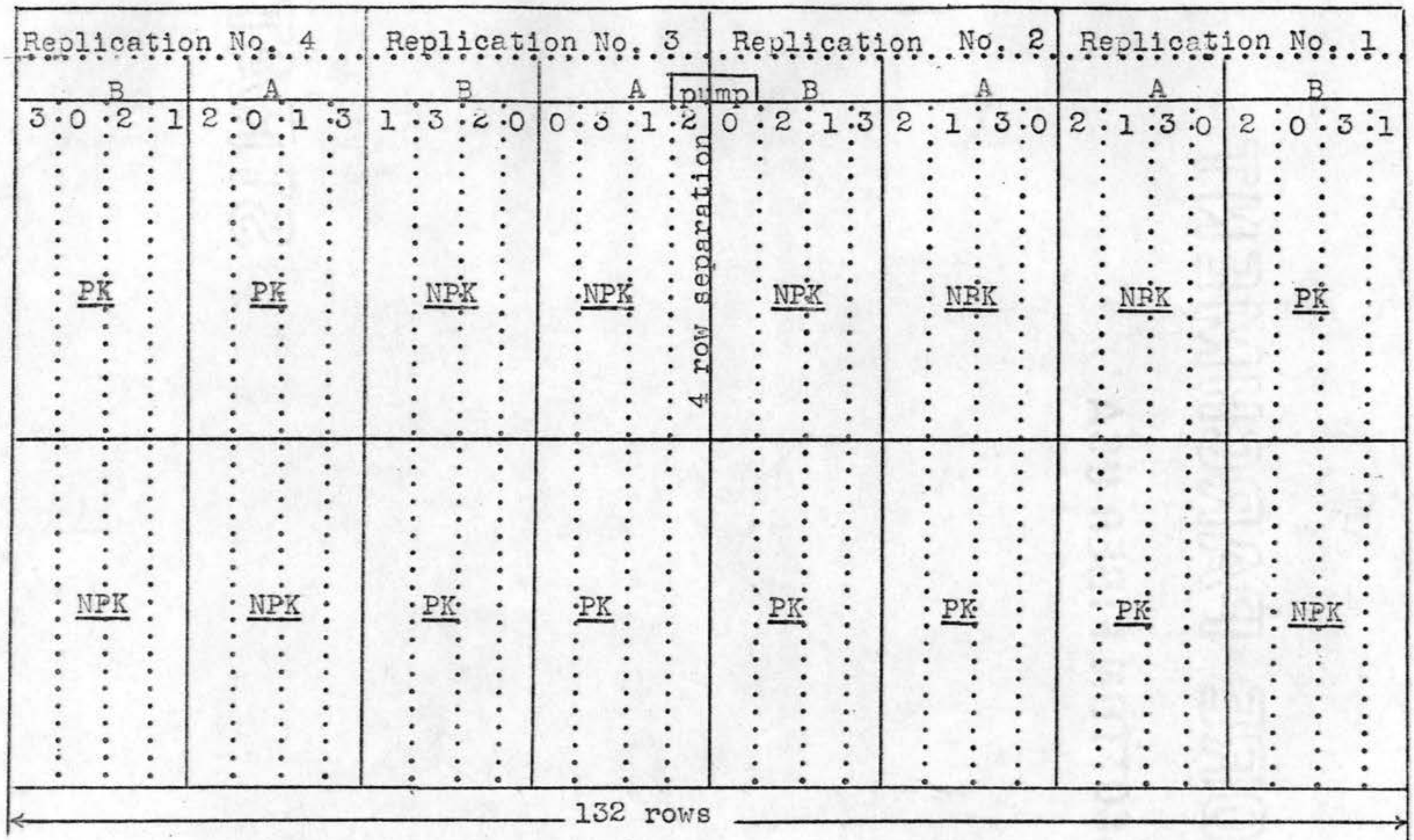
Analysis	0-8"Depth	8-16"Depth
Mechanical Analysis	54% Sand 10% Clay 36% Silt	54% Sand 12% Clay 34% Silt
Textural Class	Sandy Loam	Sandy Loam
Soil Reaction (pH)	6.2	6.2
Percent Organic Matter	1.47	1.45
Percent Total Nitrogen	0.12	0.11
Cation Exchange Capacity (me./100 grams)	8.50	8.90
Exchangeable Calcium (me./100 grams)	4.00	3.00
Exchangeable Magnesium (me./100 grams)	2.67	2.50
Exchangeable Potassium (me./100 grams)	0.82	1.15
Exchangeable Sodium (me./100 grams)	0.04	0.04
Total Phosphorus (pounds/acre)	412.00	360.00
Available Phosphorus (pounds/acre)	30.80	22.30

Fertilizer Treatments

After studying the soil analyses it was decided that a constant rate of phosphorus and potassium should be applied on all plots so that these nutrients would not be limiting and thus affect the responses to the nitrogen treatments. Phosphorus and potassium were applied at planting time at the rate of 80 pounds available P_2O_5, as treble superphosphate, and 40 pounds available K_2O, as muriate of potash. As shown in Figure 1, one-half the plots also received 40 pounds of starter nitrogen in the form of ammonium nitrate at planting time. Thus, a comparison of starter nitrogen versus no starter nitrogen could be made. Hereafter, these two splits will be referred to as NPK and PK respectively.

The main split in this investigation consisted of the two different times of application of anhydrous ammonia as a sidedressing material. The first sidedressing was made during the late square stage of growth on August 4, 1959. The second application was applied on August 24, 1959 when the cotton was in the mid-bloom stage of development. Hereafter, these two stages will be referred to as A and B respectively. These two splits (planting time and sidedressing) could also be compared.

The last phase of the experiment involved four rates of sidedressing of anhydrous ammonia on the two previous splits which have been discussed. The anhydrous ammonia was applied as a gas through the irrigation water at the



Legend	Treatment	Legend	Treatment
PK	0-80-40 at planting	0	No nitrogen sidedress
NPK	40-80-40 at planting	1	40# N sidedress as NH_3
A	Late square stage	2	80# N sidedress as NH_3
B	Mid-bloom stage	3	160# N sidedress as NH_3

Figure 1. Randomized split-plot with strips (4 row plots) design for the irrigated cotton fertility experiment located on the Perkins Agronomy farm.

rates of 0, 40, 80, and 160 pounds of nitrogen per acre. Hereafter, these rates will be referred to as 0, 1, 2, and 3 respectively. These amounts were metered into the irrigation water so that the concentration of the ammonia in the water would be approximately 0, 100, 200, and 400 ppm.

Metering Device

Commerical metering devices which will permit the accurate injection of small amounts of ammonia into irrigation water were not availavle, so a metering device was designed to fulfill the needs of this study. For purposes of clarification, the device will be discussed in conjunction with a series of pictures.

The first phase of the metering device consisted of an ammonia cylinder and attached Continental regulator which are shown in Figure 2. A full cylinder contains 150 pounds of anhydrous ammonia and the regulator was a standard piece of equipment used in connection with the direct injection method of application. Regulator pressure was maintained at 50 psi and the ammonia was divided at that point into three different hoses.

Each hose carried NH_3 to a manometer box (Figure 3). The gas entered the box at the right, and could flow through a check valve or be stopped at this point. If the gas was permitted to flow through the valve a portion of it passed through an aluminum block connected to

Figure 2. Ammonia cylinder with regulator attached

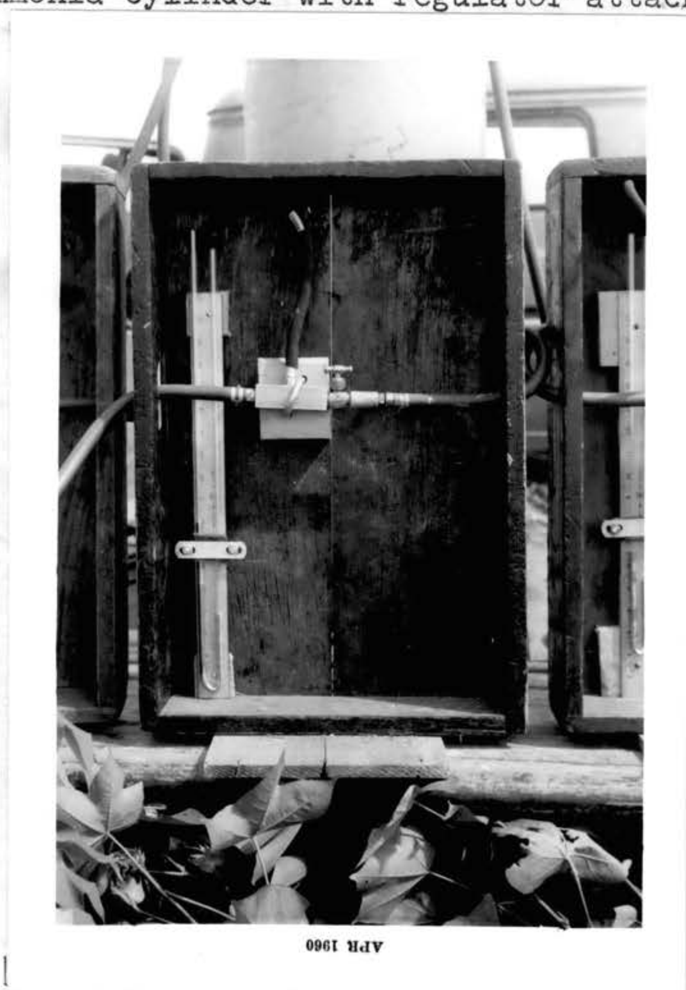


Figure 3. Manometer box

to a mercury manometer. The pressure flow was indicated in this calibrated manometer. The manometer consisted of a U-shaped piece of glass tubing partially filled with mercury.

After the gas left a manometer box, it passed through a gas manifold as illustrated in Figure 4. The NH_3 was again divided into three hoses so that the gas might be injected into the three center furrows of a four row plot. The gas was injected through orifices of known sizes (0.046 inches for the 40 and 80 pound rate and 0.093 inches for the 160 pound rate) into the water at a predetermined depth (Figure5). The orifices were necessary so that each of the three hoses from the manifold would carry equal quantities of ammonia gas. The known depth of the injection into the water was also necessary to insure uniform distribution of NH_3.

Each rate of ammonia application required a metering device so that all three rates of application could be made simultaneously. This made it possible to irrigate and sidedress one whole replication at a time. The transportation of the manometers to different parts of the field is given in Figure 6. A complete picture of the entire metering apparatus is shown in Figure 7.

The calibration of this metering device was performed in the laboratory prior to the field application. The anhydrous ammonia was allowed to flow through the apparatus into a flask of standard sulfuric acid at a certain depth. The acid was then back titrated with standard sodium hydroxide

Figure 4. Gas manifold

Figure 5. Injection site

Figure 6. Field technique

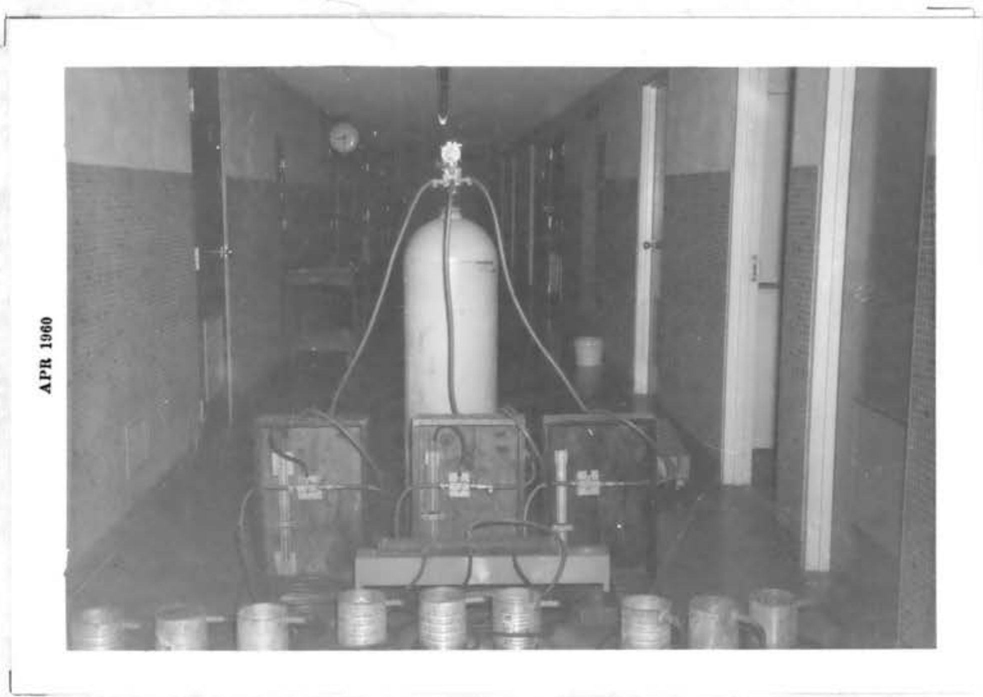


Figure 7. Entire metering apparatus

to an end point using phenolthalein as an indicator. Then through the difference in milliequivalents of acid, the amount of ammonia combined with the acid could be determined. This value was then converted to pounds per acre and compared to the difference in head of the mercury in the manometer tube. Through trial and error the correct number of pounds per acre and the corresponding manometer readings were obtained for each rate of application. From this information, the correct setting could be made on the manometer in the field, and the desired rate of NH_3 could be injected into the irrigation water.

Cultural Practices

On May 20, 1959 the plots were planted in a randomized four row split-plot with strips design. However, several rains occurred in the next few days which caused the soil to form a crust and the seedlings did not emerge. On June 9, the plots were replanted. The Stoneville 62 variety of cotton was chosen for the late planting date because it is an early maturing variety. The plots were thinned on July 10 and 11 to a stand of plants approximately 8 inches apart.

Four cultivations at approximately two-week intervals were used to control weeds and to hill the seedlings. Five tractor applicatons of 5-10-40 (5% BHC-10% DDT-40% sulfur) insecticide at the rate of 25 pounds per acre were used to control boll weevil, boll worm, and other insects. The insect control started while the cotton was

[illegible]

sa

[illegible]

used to convert the field weights of "snaps" to pounds of lint per plot. The ginning percentages for the second harvest were obtained from composite samples of the four replications for each treatment which were ginned at the Cotton Research Station at Chickasha, Oklahoma. These ginning percentages were then used to convert pounds of "snaps" per plot to pounds of lint per plot.

The lint cotton was then analyzed to determine quality. Micronaire instrument was used to determined the density of the cotton fibers. The Fibrograph measured both the mean length as well as the upper mean length of the entire sample. The zero and one-eight inch break on the Stelometer was used to determine fiber strength.

IV RESULTS AND DISCUSSION

Preharvest Boll Counts

Three preharvest boll counts were made on all plots. The bolls were counted on August 22, September 1, and October 22. All of the values are an average of the four replications and are designated as number of bolls per foot of row. The results of these boll counts are graphically illustrated in Figures 8, 9,and 10 (Figure 10 combines the data given in Figures 8 and 9). Figure 8 shows that in the August counts for the PK (no starter nitrogen) plots there was an increase in bolls with sidedressed nitrogen as compared to the plots which had not received nitrogen. However, there was a leveling off in number of bolls produced at the higher rates of sidedressed nitrogen. These increases were generally true regardless of the stage in which the nitrogen was applied. In the September counts the same situation held true. In October the tendency was for a slight reduction in the number of bolls on the higher nitrogen plots while the PK-0 plots were still increasing. During August and September, the NPK (starter nitrogen) plots generally had a greater increase in bolls on the A (early sidedressed) strips compared to the B (late sidedressed) strips (Figure 9).

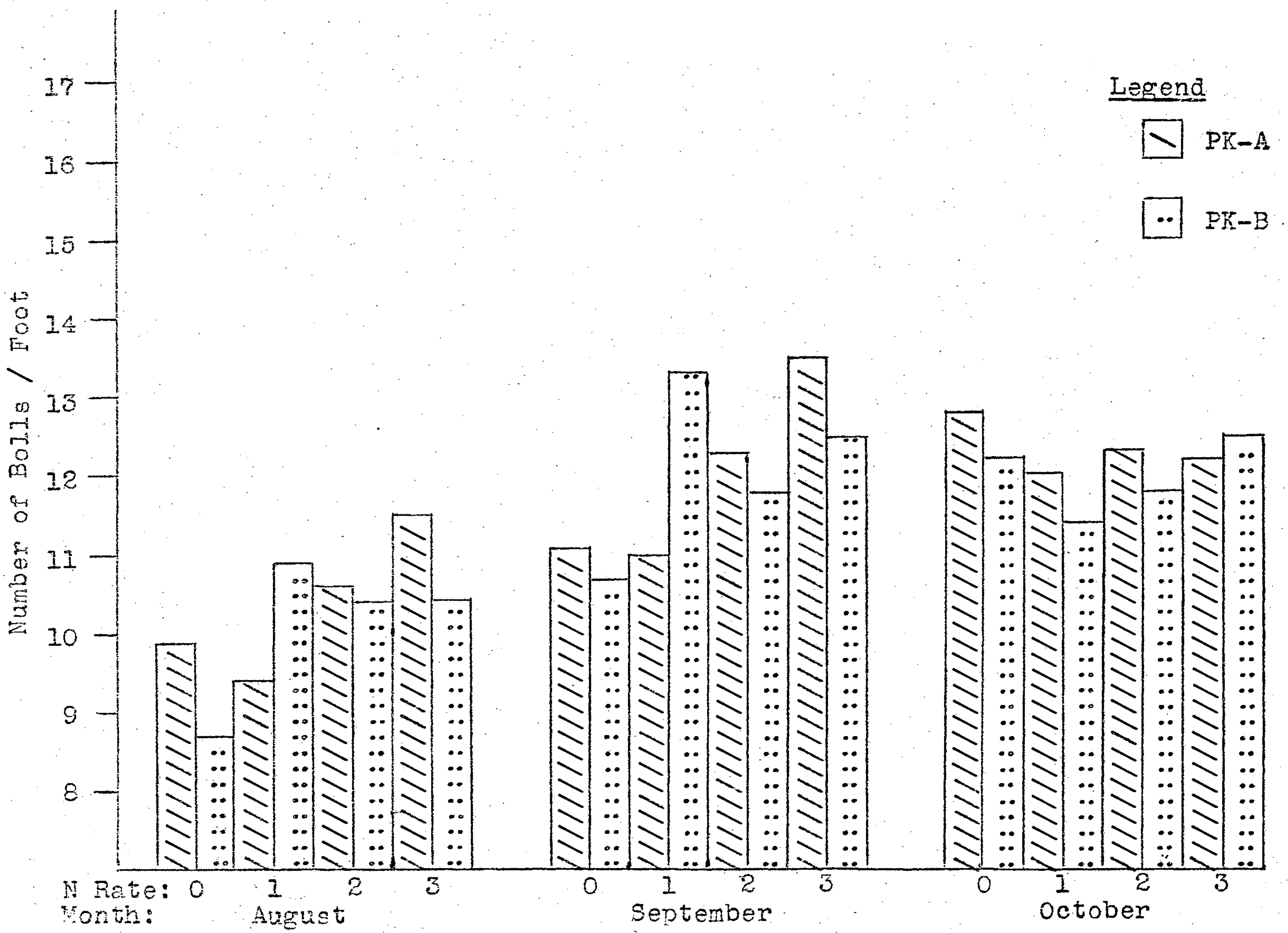


Figure 8. Boll counts for PK plots.

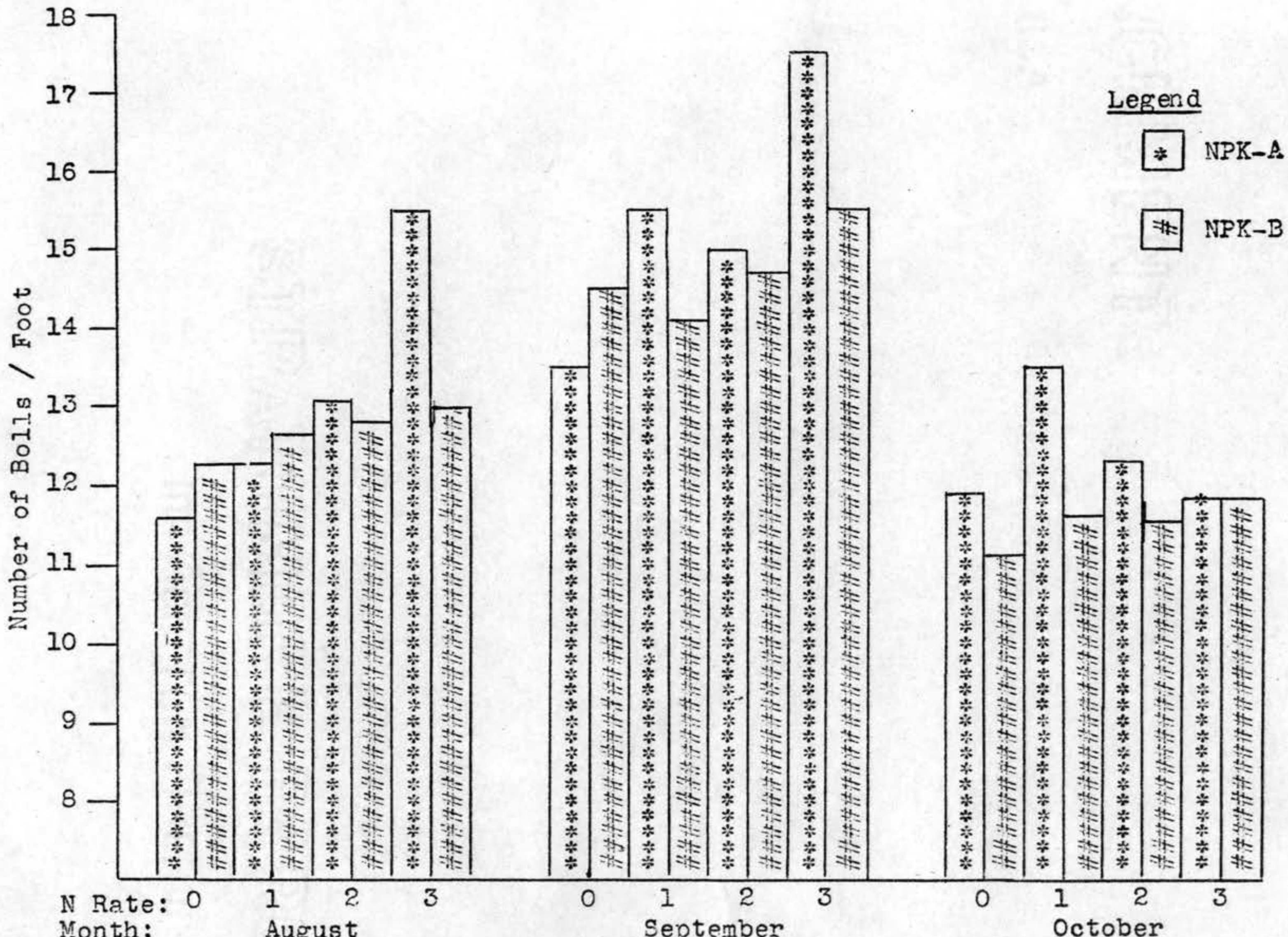


Figure 9. Boll counts for NPK plots.

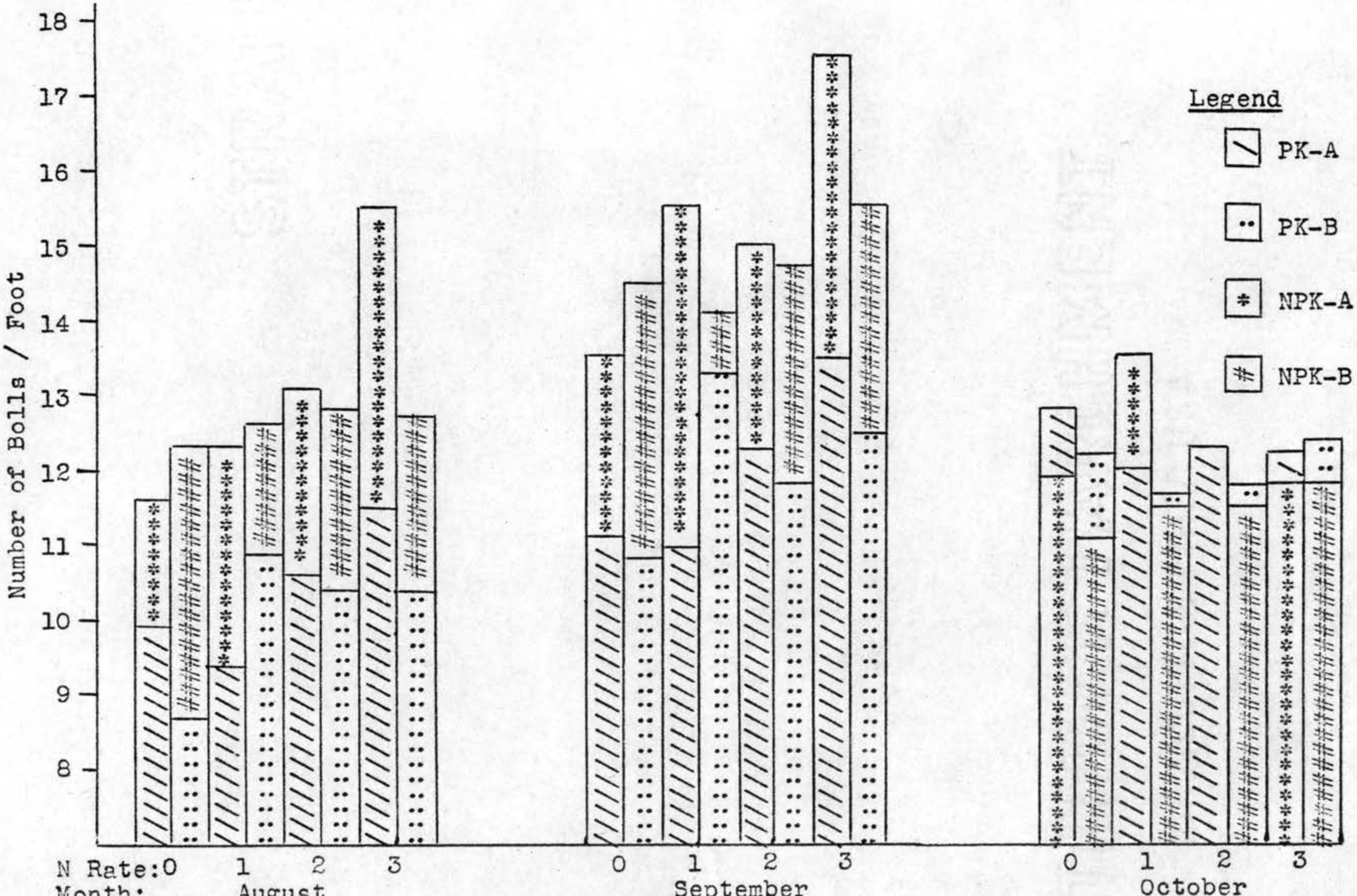


Figure 10. Boll counts for all treatments.

This was especially true at the higher rates of sidedressing. Great boll losses occurred on all NPK plots in October. Figure 10 indicates that boll counts for the NPK plots exceeded those of the PK plots in late August and early September. By October 22 practically all of the NPK plots had shed enough bolls so that the NPK and PK plots were almost equal in boll numbers.

During the period of September 1 to October 22 the following climatic conditions were observed; a wind and hail storm occurred on September 2; 21.35 inches of rainfall were recorded (between the days of the boll counts on September 1 and October 22); and the days were cool and cloudy. According to a review by Hall (20), these conditions are conducive to boll shedding. Thus, the weather conditions may partially explain the sudden decrease in boll number during this period. However, only the NPK plots showed a great tendency to shed. The PK plots with sidedressing displayed only a moderate tendency towards boll loss, but the PK plots without sidedressing showed boll increase. Shedding of bolls seems to be the most plausible explanation for the overall tendency of lower lint yields (discussed in the next section) on the plots which had received nitrogen. Nitrogen generally favored an increase in boll sizes and ginning percentages which is in contrast with lint yield data (Table III). The statistical analyses for boll sizes and ginning percentages are given in Tables IV and V. These data are a furthur indication that the low yields were probably due to

TABLE III

BOLL SIZES AND GINNING PERCENTAGES

Treatment	Boll Size (Grams of Seed Cotton Per Boll)	Ginning ** Percentages (First Harvest)
PK-A-0	6.68*	36.93
PK-A-1	6.90	36.50
PK-A-2	6.83	37.00
PK-A-3	6.71	36.36
PK-B-0	6.60	37.11
PK-B-1	6.82	36.65
PK-B-2	6.80	37.21
PK-B-3	6.64	37.12
NPK-A-0	6.85	37.26
NPK-A-1	6.94	37.06
NPK-A-2	6.82	36.73
NPK-A-3	6.83	37.13
NPK-B-0	6.87	37.35
NPK-B-1	6.80	36.81
NPK-B-2	6.85	37.84
NPK-B-3	6.79	36.83

* Each figure represents an average of 4 replications.

** Ginning percentages are a ratio of lint to seed cotton.

TABLE IV

ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST OF BOLL SIZE (expressed in grams of seed cotton per boll)

Source	d.f.	S.S.	M.S.	F
Total	63	3.92		
Main Plot	7	1.02		
Stages of Growth	1	.04	.04	.80
Replications	3	.82	.27	5.40
Error A	3	.16	.05	
Sub-plots	8	.27		
N	1	.14	.14	.70
N x Stage	1	.00	.00	.00
Error B	6	1.30	.20	
Sub-plot strips	48	.53		
Sidedress	3	.16	.05	1.25
Sidedress x N	3	.13	.04	4.00*
Sidedress x Stage	3	.04	.01	.30
Sidedress x N x Stage	3	.02	.01	.10
Sidedress x Rep.	9	.32	.04	
Sidedress x Stage x Rep.	9	.25	.03	
Sidedress x N x Rep.	9	.09	.01	
Sidedress x N x Stage x Rep.	9	.54	.06	

* Indicates significance at the 5% level of confidence.

MULTIPLE RANGE

Treatments:	PK-0	PK-3	PK-2	NPK-3	NPK-2	NPK-0	PK-1	NPK-1
Means Ranked in Order:	6.63	6.67	6.81	6.81	6.83	6.85	6.86	6.87

Note: Any two means not underscored by the same line are significantly different at the 5% probability level.

TABLE V

ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
OF GINNING PERCENTAGES FOR FIRST HARVEST
(based on ratio of lint to seed cotton)

Source	d.f.	S.S.	M.S.	F
Total	63	46.92		
Main Plot	7	4.31		
Stages of Growth	1	.96	.96	1.00
Replications	3	.47	.16	.10
Error A	3	2.88	.96	
Sub-plots	8	2.17		
N	1	1.11	1.11	.24
N x Stage	1	.10	.10	.01
Error B	6	27.39	4.57	
Sub-plot strips	48	15.10		
Sidedress	3	2.30	.77	3.20
Sidedress x N	3	.16	.02	.08
Sidedress x Stage	3	1.10	.37	1.12
Sidedress x N x Stage	3	1.98	.66	4.71*
Sidedress x Rep.	9	2.27	.24	
Sidedress x Stage x Rep.	9	2.97	.33	
Sidedress x N x Rep.	9	2.07	.23	
Sidedress x N x Stage x Rep.	9	1.26	.14	

* Indicates significance at the 5% level of confidence.

MULTIPLE RANGE

Treatments	Means Ranked in Order
PK-A-3	36.36
PK-A-1	36.50
PK-B-1	36.65
NPK-A-2	36.73
NPK-B-1	36.81
NPK-B-3	36.83
PK-A-0	36.93
PK-A-2	37.00
NPK-A-1	37.06
PK-B-0	37.11
PK-B-3	37.12
NPK-A-3	37.13
PK-B-2	37.21
NPK-A-0	37.26
NPK-B-0	37.35
NPK-B-2	37.84

Note: Any two means not scored by the same line are significantly different at the 5% probability level.

a loss of the bolls prior to harvest.

Lint Yields

The lint yields are given in Table VI and are represented graphically in Figure 11. The statistical analyses of the yields are shown in Table VII. For the A split, the overall trend was towards a decrease in yields with added amounts of nitrogen on both the NPK and PK plots. A different tendency is observed for the B split. The B split on the NPK plots showed an increase in yields over the B split on the PK plots. As was shown in Table III, there was a general increase in boll sizes and ginning percentages in the NPK-B plots as compared to the PK-B plots. This may partially explain the increased yields on the NPK-B plots. In general, the B split on the NPK plots yielded more than the A split. However, the check plots (NPK-A-0 and PK-A-0) out yielded the other treatments in their respective groups. With few exceptions, these results coincided with the October boll counts found in Figure 10. The late sidedressing treatments may have shown even more promise, if there had not been a killing frost on October 30. Only 67 days had elapsed between the late sidedressing application and the killing frost. This did not allow the late bolls an opportunity to fully mature.

Fiber Analyses

Fiber analyses are measurements of the quality of lint.

TABLE VI

COTTON LINT YIELDS
(expressed in pounds per acre)

Treatment	Yield
PK-A-0	745.6*
PK-A-1	627.8
PK-A-2	640.9
PK-A-3	601.7
PK-B-0	627.8
PK-B-1	588.6
PK-B-2	627.8
PK-B-3	614.9
NPK-A-0	693.2
NPK-A-1	627.8
NPK-A-2	614.9
NPK-A-3	575.5
NPK-B-0	654.0
NPK-B-1	640.9
NPK-B-2	680.2
NPK-B-3	614.9

* Each figure represents an average of 4 replications.

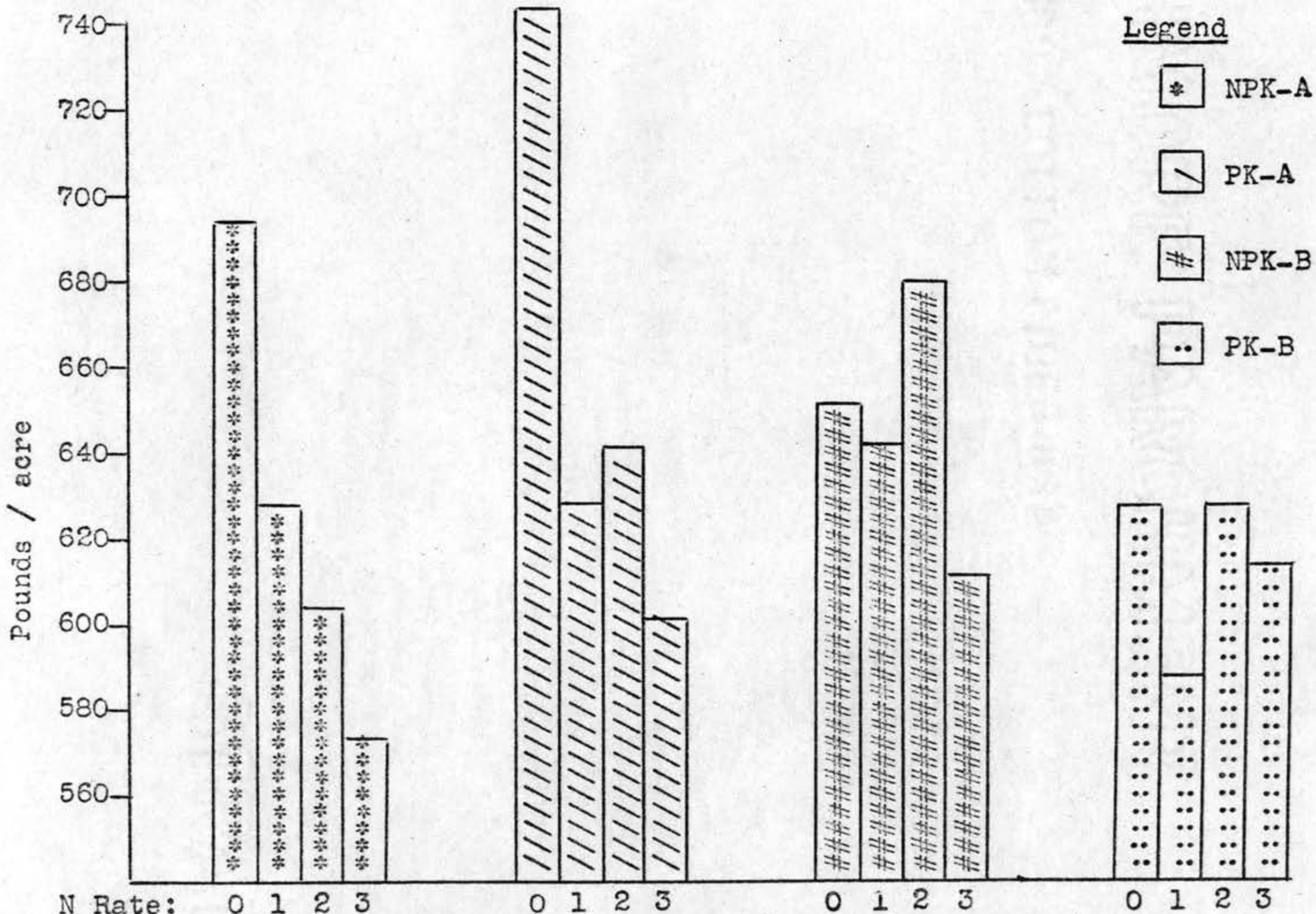


Figure 11. Cotton lint yields(expressed in pounds per acre).

TABLE VII

ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST OF COTTON LINT YIELDS (expressed in pounds of lint per plot)

Source	d.f.	S.S.	M.S.	F
Total	63	17.35		
Main Plot	7	1.60		
Stages of Growth	1	.07	.07	.18
Replications	3	.34	.11	.28
Error A	3	1.19	.39	
Sub-plots	8	.93		
N	1	.03	.03	.09
N x Stage	1	.83	.83	2.37
Error B	6	2.11	.35	
Sub-plot strips	48	6.84		
Sidedress	3	3.44	1.15	4.11*
Sidedress x N	3	.34	.11	.68
Sidedress x Stage	3	1.96	.65	2.60
Sidedress x N x Stage	3	.17	.06	.86
Sidedress x Rep.	9	2.54	.28	
Sidedress x Stage x Rep.	9	2.24	.25	
Sidedress x N x Rep.	9	1.43	.16	
Sidedress x N x Stage x Rep.	9	.66	.07	

* Indicates significance at the 5% level of confidence.

MULTIPLE RANGE

Treatments:	3	1	2	0
Means Ranked in Order:	4.46	4.77	4.89	5.22

(In the printed table, one line underscores 4.77, 4.89 and 5.22; a second line underscores 4.46, 4.77 and 4.89.)

Note: Any two means not underscored by the same line are significantly different at the 5% probability level.

Since fiber properties are primarily genetically controlled, environment should have little effect on the data (8).

The results obtained from the Micronaire (density) follows the genetical line of reasoning (Table VIII). Even though there was a tendency toward higher Micronaire index on the PK, and B splits, the treatments were statistically similar (Table IX).

The Fibrograph measures the upper half mean length and the average mean length of fiber. In general, the PK and A splits had higher upper half mean values as given in Table VIII. The statistical analyses show a significant increase in upper half mean length on the A-0 plots (Table X). The large replication variation of these data is partially responsible for the differences. Only minor differences were obtained in the average mean length on the plots which received varying amounts of nitrogen (Table VIII). Statistically all the treatments were similar (Table XI). The breaking strength of the fiber was measured with a device known as the Stelometer. The one-eighth inch break is valuable information for the cotton mill (Table VIII). The lint from all treatments was similar in strength as indicated by the statistical analysis found in Table XII. However, there was a tendency for a greater Stelometer index on the NPK-0 and the PK-A-1 plots. The variation amoung replications is partially responsible for these differences among plots.

There were large replication variations in the analyses

TABLE VIII

MICRONAIRE, STELOMETER, AND FIBROGRAPH DATA ON LINT SAMPLES

Treatment	Micronaire	Stelometer (1/8 Inch Break)	Fibrograph Mean length	Fibrograph UHM length
PK-A-0	4.60*	1.99	.77	1.00
PK-A-1	4.75	2.02	.77	.97
PK-A-2	4.80	2.00	.75	.96
PK-A-3	4.73	1.96	.75	.98
PK-B-0	4.80	1.92	.76	.96
PK-B-1	4.85	1.96	.77	.97
PK-B-2	4.88	1.97	.75	.96
PK-B-3	4.75	1.99	.75	.97
NPK-A-0	4.70	2.05	.75	.95
NPK-A-1	4.67	1.99	.76	.95
NPK-A-2	4.80	2.00	.74	.93
NPK-A-3	4.80	2.00	.75	.94
NPK-B-0	4.86	1.96	.75	.94
NPK-B-1	4.80	1.99	.76	.95
NPK-B-2	4.80	2.00	.76	.96
NPK-B-3	4.86	1.98	.76	.96

* Each figure represents an average of 4 replications.

TABLE IX

ANALYSIS OF VARIANCE OF THE MICRONAIRE INDEX

Source	d.f.	S.S.	M.S.	F
Total	63	2.76		
Main Plot	7	.80		
Stages of Growth	1	.07	.07	.37
Replications	3	.17	.06	.32
Error A	3	.56	.19	
Sub-plots	8	.07		
N	1	.00	.00	.00
N x Stage	1	.00	.00	.00
Error B	6	.85	.14	
Sub-plot strips	48	.33		
Sidedress	3	.07	.02	1.00
Sidedress x N	3	.10	.03	1.00
Sidedress x Stage	3	.05	.02	1.00
Sidedress x N x Stage	3	.04	.01	.50
Sidedress x Rep.	9	.22	.02	
Sidedress x Stage x Rep.	9	.19	.02	
Sidedress x N x Rep.	9	.23	.03	
Sidedress x N x Stage x Rep.	9	.21	.02	

TABLE X

ANALYSIS OF VARIANCE AND MULTIPLE RANGE TEST
FOR UPPER HALF MEAN LENGTH ON THE FIBROGRAPH
(expressed in inches)

Source	d.f.	S.S.	M.S.	F
Total	63	.005		
Main Plot	7	.009		
Stages of Growth	1	.000	.000	
Replications	3	.008	.0027	9.00
Error A	3	.001	.0003	
Sub-plots	8	.009		
N	1	.008	.008	1.70
N x Stage	1	.001	.001	.21
Error B	6	.028	.0047	
Sub-plot strips	48	.015		
Sidedress	3	.001	.0003	1.50
Sidedress x N	3	.001	.0003	1.00
Sidedress x Stage	3	.004	.0013	4.30*
Sidedress x N x Stage	3	.000	.000	.00
Sidedress x Rep.	9	.002	.002	
Sidedress x Stage x Rep.	9	.003	.0003	
Sidedress x N x Rep.	9	.003	.0003	
Sidedress x N x Stage x Rep.	9	.000	.000	

* Indicates significance at the 5% level of confidence.

MULTIPLE RANGE

Treatments:	A-2	B-0	B-1	B-2	B-3	A-1	A-3	A-0
Means Ranked in Order:	.94	.95	.96	.96	.96	.96	.96	.97

Note: Any two means not underscored by the same line are significantly different at the 5% probability level.

TABLE XI

ANALYSIS OF VARIANCE FOR AVERAGE MEAN LENGTH ON THE FIBROGRAPH
(expressed in inches)

Source	d.f.	S.S.	M.S.	F
Total	63	.058		
Main Plot	7	.013		
Stages of Growth	1	.000	.000	.00
Replications	3	.011	.004	5.71
Error A	3	.002	.0007	
Sub-plots	8	.001		
N	1	.001	.001	.33
N x Stage	1	.000	.000	.00
Error B	6	.017	.003	
Sub-plot strips	48	.005		
Sidedress	3	.001	.0003	1.00
Sidedress x N	3	.002	.0007	2.30
Sidedress x Stage	3	.001	.0003	.80
Sidedress x N x Stage	3	.000	.000	.00
Sidedress x Rep.	9	.003	.0003	
Sidedress x Stage x Rep.	9	.004	.0004	
Sidedress x N x Rep.	9	.003	.0003	
Sidedress x N x Stage x Rep.	9	.013	.0014	

TABLE XII

ANALYSIS OF VARIANCE FOR THE ONE-EIGHTH INCH GAGE STELOMETER INDEX

Source	d.f.	S.S.	M.S.	F
Total	63	.437		
Main Plot	7	.108		
Stages of Growth	1	.015	.015	4.55
Replications	3	.083	.0277	8.39
Error A	3	.010	.0033	
Sub-plots	8	.021		
N	1	.005	.005	2.00
N x Stage	1	.001	.001	.40
Error B	6	.015	.0025	
Sub-plot strips	48	.052		
Sidedress	3	.003	.001	.30
Sidedress x N	3	.006	.002	.30
Sidedress x Stage	3	.016	.0053	.60
Sidedress x N x Stage	3	.006	.002	.20
Sidedress x Rep.	9	.029	.0032	
Sidedress x Stage x Rep.	9	.080	.009	
Sidedress x N x Rep.	9	.069	.007	
Sidedress x N x Stage x Rep.	9	.099	.011	

APPENDIX

of the fiber qualities except in the Micronaire test. An early influx of leaf worms in replication four and a low area which held water in replication three seem to have caused differences in maturity which is a logical explanation for the variations.

V SUMMARY

An irrigated cotton fertility experiment, to compare times and rates of nitrogen sidedressing using anhydrous ammonia with and without starter nitrogen, was conducted on the Agronomy Research Station at Perkins, Oklahoma. At planting time, one-half the plots received a 0-80-40 treatment (PK) and the other one-half a 40-80-40 application (NPK). Anhydrous ammonia was sidedressed at two stages of growth; the late square and mid-bloom stages. The gas was metered into the irrigation water at the rates of 0,40,80, and 160 pounds of nitrogen per acre. Lint yields, ginning percentages, boll sizes, and fiber qualities were determined.

The results of this study may be summarized as follows:

1. Although the early season growth and boll sets were better on the nitrogen treated plots, the final lint yields did not attain these potentials.
2. Due to adverse weather conditions, especially late in the growing season, boll shedding was particularly great on the NPK plots. The loss of bolls from the nitrogen treated plots seems to be the most plausible explanation for their lower lint yields as compared to the plots which did not receive nitrogen. The 160 pound

rate of nitrogen sidedressing gave a significant decrease in lint yields.

3. There was a trend towards slightly larger boll sizes when starter nitrogen and an early side-dressing were applied.

4. Ginning percentages tended to be somewhat higher when starter nitrogen and a late sidedressing were used.

5. The fiber qualities of the cotton were not appreciably influenced by various nitrogen treatments, although some definite trends occurred. This was expected because fiber qualities of cotton are primarily controlled by the genetic constitution of the plant rather than environmental conditions.

VI LITERATURE CITED

1. Aldrich, D.G., Jr. The use of NH_3 in irrigation water. Agricultural Ammonia News. Vol. VI. No. 1. Jan.-Feb. 1956.

2. Anderson, O.I. Thesis. Rutgers University New Brunswick, New Jersey. (Original not seen; cited from M.M. Mortland Adv. in Agron. 10: 325-345. 1958.)

3. Andrews, W. B. Anhydrous ammonia as a nitrogenous fertilizer. Adv. in Agron. 8: 62-123. 1956.

4. Andrews, W. B., Neely, J. A. and Edwards, F. E. Anhydrous ammonia as a source of nitrogen. Miss. Expt. Sta. Bull. 482. 1952.

5. Anonymous. Oklahoma crop and livestock reporting service, and Oklahoma state board of Agriculture Cooperating. Mimeographed Circular. May 1959.

6. Anonymous. Statistics on Cotton and related data. 1920-1956. Statistical Bull. 99. U.S.D.A. Agricultural Marketing Service. Washington, D.C. Revised 1957.

7. Babcock, W. G. Suitability of nitrogen fertilizers for application in irrigation water. Calif. Citrog. 22: 70-75. 1936-1937. (Original not seen; cited from D. G. Aldrich, Jr. Agricultural Ammonia News Vol. VI. No. 1. 1956.)

8. Barker, H. B. Fiber properties and their significance. Adv. in Agron. 2: 60-63. 1950.

9. Bouyoucos, G. J. Directions for making mechanical analysis of soil by the hydrometer method. Soil Sci. 42: 225-229. 1936.

10. Brown, H. B. Cotton. McGraw-Hill Book Company, Inc. New York and London. 1938.

11. Cardozier, V. R. Growing Cotton. McGraw-Hill Book Company, Inc. New York and London. 1957.

12. Chapman, H. D. The distribution of nitrogen materials in irrigation water. Proc. Nat. Joint Com. Fert. Applic. 18-23. 1944.

13. Christidis, B. G. and Harrison, G. J. Cotton Growing Problems. McGraw-Hill Book Company, Inc. New York and London. 1955.

14. Cook, R. L. and Hulburt, W. C. Applying fertilizer. Soil. U.S.D.A. Yearbook of Agriculture. Washington, D.C. 1957.

15. Crowther, F. Nitrogen and flowering. Ann. Bot. (N.S.) 8: 213. 1944.

16. Eaton, F. M. Physiology of the cotton plant. Ann. Rev. Plant Physiol. 6: 299-328. 1955.

17. Eno, F. E., Blue, W. G., and Good, J. M., Jr. The effect of anhydrous ammonia on nematodes, fungi, bacteria and nitrification in some Florida soils. Soil Sci. Soc. Amer. Proc. 19: 55-59. 1955.

18. Erickson, A. E. and Mortland, M. M. Surface reactions of clay minerals. Soil Sci. Soc. Amer. Proc. 20: 476-479. 1956.

19. Galloway, H. M. Detailed Soil Survey. Perkins Farm, Perkins, Oklahoma. Oklahoma State University, Processed Series P-315A. 1959.

20. Hall, Wayne C. Physiology and biochemistry of abscission in the cotton plant. Tex. Agr. Expt. Sta. MP-285. 1958.

21. Hamilton, J., Stanberry, C.O., and Woolton, W. M. Cotton growth and production as effected by moisture, nitrogen, and plant spacing on the Yuma Mesa. Soil Sci. Soc. Amer. Proc. 20: 246. 1955.

22. Hansen, C. M., Robertson, L. S., and Mortland, M. M. Ammonia losses during and after application. Agricultural Ammonia News. Vol. VII. No. 3 May-June. 1957.

23. Harper, H. J. Determination of easily soluble phosphorus in soils. Science. 76: 415-416. 1932.

24. _______________ Soils Laboratory Manual, Oklahoma Agr. Expt. Sta. Soils Laboratory. 1948.

25. Humbert, R. P. and Ayers, A. S. The use of aqua ammonia in Hawaiian sugar industry: II Injection Studies. Soil Sci. Soc. Amer. Proc. 21: 312-316. 1957.

26. 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.

27. Jenny, H., Ayers, A. S. and Hosking, J. S. Comparative behavior of ammonia and ammonia salts in soils. Hilgardia 16: 429-457. 1945.

28. Leavitt, F. H. Fertilizer application through irrigation water. Proc. Nat. Joint Com. Fert. Applic. 35-40. 1949.

29. Leonard, Warren H. and Martin, John H. Principles of Field Crop Production. Macmillan Company. New York. 1949

30. Lepper, H. A. (Chairman of editorial board) Offical and Tentative Methods of Analysis. Sixth Edition. A.O.A.C. Washington, D. C. 1945.

31. Longnecker, D. E. and Lyerly, P. J. Influences of source of nitrogen fertilization on yields of Acala cotton in the El Paso Valley. Tex. Agr. Expt. Stat. 1956 Progress Report. 1957.

32. Martin, J. P. and Chapman, H. D. Volatilization of ammonia from surface fertilized soils. Soil Sci. 71: 25. 1951.

33. Mattson, S. and Koutler-Anderrson. Geochemistry of a raised bog. Lantbruks-Hogskolans Annaler. Vols. 20-22: (In English) 1953-1956.

34. Mortland, M. M. Adsorption of ammonia by clays and mucks. Soil Sci. 80: 11-18. 1955.

35. ________ Reaction of ammonia in the soil. Adv. in Agron. 10: 325-345. 1958.

36. Nelson, W. L. and Welch, C. D. Sources of nitrogen in crop production. North Carolina Agr. Expt. Sta. Tech. Bull. 96. 1952.

37. Peech. M., Alexander, L. T., and Reed, J. F. Methods of soil analyis for soil-fertility investigations. U.S.D.A. Cir 757. 1947.

38. Richards, L. A. (Editor). Saline and Alkali Soils. Agricultural Handbook 60. U.S.D.A. U.S. Government Printing Office. Washington, D. C. 1954.

39. Rosenstein, L. Increased yields obtained from Shell Agricultural Ammonia (NH_3) in irrigated agriculture. Bull. 1. Shell Chemical Co. San Francisco, Calif. (Original not seen; cited from D. G. Aldrich, Jr. Agricultural Ammonia News Vol. VI. No. 1. 1956.)

40. Shelton, W. R. and Harper, H. J. A rapid method for the determination of total phosphorus in soil and plant material. Iowa State College Jour. of Sci. XV. 403-413. 1941.

41. Stanley, F. A. and Smith, G. E. Effect of soil moisture on retention of anhydrous ammonia. Soil Sci. Soc. Amer. Proc. 20: 557-561. 1956.

42. Stevenson, F. J. Distribution of the forms of nitrogen in some profiles. Soil Sci. Soc. Amer. Proc. 21: 280-287, 1957.

43. Thornton, M. K. and Fisher, F. L. Anhydrous ammonia as a fertilizer. Tex Agr. Expt. Sta. L-194.

44. Trickey, N. G. and Smith, G. E. Losses of nitrogen from solution materials. Soil Sci. Soc. Amer. Proc. 19: 222-224. 1955.

45. Walkley, A., and Black, I. A. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 37: 29-38. 1934.

APPENDIX

PROFILE DESCRIPTION OF VANOSS LOAM

Samples were taken from the 3800 series of the Agronomy Farm at Perkins, Oklahoma, which is located in the SW$\frac{1}{4}$ of the SE$\frac{1}{4}$ of the SW$\frac{1}{4}$ of the Section 36, Township 18 N, Range 2 E. The exact site was 550' N and 1250' E of the southwest corner of the Section.

Vanoss loam occupies plane to weakly convex slopes with surface gradients of about $\frac{1}{2}$ percent. The soil has a brown loam surface 14 to 20 inches deep over a brown clay loam sub-soil that grades to a strong brown or reddish yellow sandy caly loam substratum. The substratum becomes more sandy below 36 to 48 inches. This granular, well-drained unit is inherently fertile, reponsive to management and highly productive.

The profile is described as follows:

A_{1p}	0-8"	Brown (7.5 YR 5.3; 3.5/2, moist)* loam or coarse silt loam; weak medium granular; friable; soft and crumbly; permeable; pH 6.0; many pores and pin holes; rests with a shear face on the layer below.
A_1	8-16"	Brown (7.5 YR 4.5/3; 3.5/2, moist) loam or silt loam; moderate medium granular; friable;

* Color designations are based on the standard Munsell color system and refer to the dry soil unless specified moist.

porous and permeable; pH 6.2; the upper 3 inches has tendency to weak coarse platiness and the upper surface has a thin, glazed plow sole; grades to the layer below.

A_3	16-22"	Brown (7.5 YR 4/3; 3/2, moist) heavy loam or light clay loam; moderate medium granular; friable; permeable, pH 6.0; many pin holes; grades to the layer below.
B_{2-1}	22-32"	Brown (7.5 YR 5/3; 4/3, moist) clay loam; compound moderate medium granular and weak fine subanglar blocky; firm; hard when dry; porous and permeable; pH 6.0; grades to the layer below.
B_{2-2}	32-40"	Brown (7.5 YR 5/4; 4/4, moist) sandy clay loam; same as the layer above; pH 6.5: becomes more coarse with depth and grades to the layer below.
B_3	40-50"	Strong brown (7.5 YR 5.5/5; 5/6, moist) sandy clay loam; weak medium subangular blocky; friable to firm; porous and permeable; pH 6.5; grades to the layer below.
C_1	50-60"	Same as the layer above but contains a few, medium distinct yellowish red (5 YR 5/6) mottles; pH 6.5; grades to the layer below.

C_2	60-74"	Reddish-yellow (YR 6/6; 5/6, moist) fine sandy loam with thin lenses of sandy clay loam; very friable; permeable; pH 7.0; grades to the layer below.
C_3	74-90"	Red (2.5 YR 5/6; 4/6, moist) sandy clay loam with seams of pink (7.5 YR 7/14) fine sandy loam; permeable; pH 7.0; breaks out in thin plates on the stratification planes; grades to the layer below.
C_4	90-110+	Much like the layer above but lacks the pink seams; firm; hard when dry; pH 7.0.

The lower three horizons appear to be stratified old alluvium. The upper four horizons are composed of less sandy materials which might comprise a loess cap overlying the older alluvium.

Variations: In areas where wind erosion has removed some of the finer materials, surface textures are fine sandy loams. Locally surface colors are grayish brown. A horizons range 14 to 22 inches deep and B_1 horizons vary from 0 to 6 inches thick. A_3 and B_1 horizons are often difficult to distinguish. Subsoils are predominantly clay loams but range from light clay loams to silty clays. Substrata generally become sandier below 42 to 48 inches. Surfaces become browner or redder, thinner, and more convex as Vanoss grades to Teller.

This profile was described by Galloway with modifications by Smith (19).

VITA

Lewis E. Dillon

Candidate for the Degree

of

Master of Science

Thesis: ANHYDROUS AMMONIA AS A SOURCE OF NITROGEN FOR IRRIGATED COTTON.

Major: Agronomy (Soils)

Biographical:

Personal data: Born August 13, 1936 at Mc Allen, Texas, son of Homer and Ermin Lee Dillon.

Education: Graduated from Donna High School, Donna, Texas, 1954; received the Bachelor of Science degree from Texas College of Arts and Industries with a major in Agriculture and a minor in Education, May, 1958; graduate study at Oklahoma State University, June, 1958 to May, 1960.

Experience: Reared on farm; Graduate Assistant, Oklahoma State University, 1958-1960.

Member of: Alpha Chi, Alpha Tau Alpha, Alpha Zeta, and Who's Who Among Students in American Colleges and Universities.

Date of Final Examination: May, 1960