INVESTIGATIONS OF SOIL NITROGEN LEVELS, AND NITROGEN FERTILIZATION OF HARD RED WINTER WHEAT

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

→ The use of nitrogenous fertilizers in wheat production is on the increase. High yielding, good quality wheat is dependent upon many things, one of which is an adequate supply of soil nitrogen.

Being able to recommend the amount of nitrogen required to obtain a good yield is one of the multitude of problems confronting today's agronomist. Any information which could help to elucidate this problem would be extremely beneficial to the wheat farmer.

It was thought that yield response of wheat to nitrogen fertilization might be dependent upon nitrate content of the soil. With this is mind an investigation of soil nitrate levels at various soil depths during the growing season was undertaken.

Another extremely important facet of wheat production is quality of the wheat obtained. Export and domestic markets for wheat are placing increased emphasis on wheat quality. One of the criteria of wheat quality is protein content of the grain which is measured indirectly as nitrogen content of the grain. Investigators have shown that when yields are quite high large amounts of topdressed nitrogen fertilizers are often required for good quality grain. However, from the producer's standpoint this, in many cases, is uneconomical.

Foliar applications of nitrogenous solutions have shown promise of increasing protein content of grain. In an attempt to find a more economical and efficient method to increase wheat quality, a combination of topdressed and foliar applied nitrogen was utilized. The results of this research are reported in this thesis.

CHAPTER II

LITERATURE REVIEW

Variation in Soil Nitrate Level with Time of Year and Depth of Sampling

Many research workers (5, 7, 3)[1] testing for soil nitrates have sampled only to a depth of 6 or 12 inches. Many times this has been due to the fact that previous experience had shown it was not feasible to sample below this depth. Other times the design of the experiment dictated sampling depth. It appears that sampling depth would depend greatly upon environmental conditions, soil type, and information desired.

Michalyna and Hedlin (16) sampled Canadian clay soils to a depth of 72 inches. On a few plots they found nitrate-nitrogen concentration to be 44 ppm. at a depth of 6 feet. They mention that this is probably due to leaching throughout the year. At depths below 3 feet there was usually a fairly high nitrate content during the entire year on fallow plots. Using various combinations of fallow-wheat rotation it was shown that nitrate-nitrogen content was greater at the 3 foot depth than the 2 foot depth after 1 and 2 years of wheat. However,

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[1]Figures in parenthesis refer to Literature Cited.

after 3 years of wheat there was very little, if any, difference in nitrate content between the 36 and 24 inch depths.

Doughty et al. (8) also working with Canadian clay soils, have shown that nitrate content may be as much as 60 ppm. at a depth of 5 feet in cultivated soils while being 5 ppm. above 5 feet. This has been attributed to leaching.

Investigations in Australia (27) concerning soil nitrate levels have shown that amounts varied from 10 to 20 ppm. in the surface 2 feet and decreased to 0 to 10 ppm. at 2 to 4 feet. The soil samples were obtained at seeding time following 6 to 12 months of fallow. Generally the nitrate content of the soil decreased below a depth of 24 inches.

Van Der Paauw (26) studied the effect of rainfall on the availability of nitrogen in soil. Using two rates of nitrogen topdressing he traced the nitrogen through the soil profile to a depth of approximately 40 inches under two different rainfall regimes. In all treatments nitrogen concentration decreased below 24 inches.

It is also possible that residual nitrogen may be present in the soil, being carried over from the previous years' nitrogen application. White, Dumenil and Pesek (28) of Iowa have stated that as much as 49 percent of the previous years' application of ammonium nitrate nitrogen may be carried over to the following year as nitrate-nitrogen.

Bowan et al. (4) in Washington found that residual nitrogen from ammonium nitrate averaged 44 percent of the original application after 1 year but was insignificant after 2 years.

From the above information it can be seen that soil sampling procedures for nitrate determinations may vary considerably from one locale to another. Also, there is a question as to whether any residual nitrogen is left in the soil from the previous year. This portion of the research was designed to elucidate these two problems.

Yield Response of Wheat to Added Nitrogen Fertilizer

As land is continually cultivated, the nutrients needed to support a good crop are slowly depleted. In 1907 Snyder (24) reported that it was uneconomical to use nitrogen fertilizers on Minnesota soils. His field tests included soils which had been cropped for 25 years. On the soils with a longer cultivation period a slight yield increase was obtained by the use of a complete fertilizer. However, on those soils with less than 25 years of cultivation nitrogen fertilizer added alone or with phosphorous and potash gave no increase in yield over the check.

Working with Australian soils Waring and Teakle (27) have reported that wheat yield is not being affected at many sites by lack of nitrogen. The soils with which they were working had been under cultivation only a few years. They also mention that a substantial yield response was obtained on Australian soils which have been continuously cropped for 70 years.

In 1898 many varieties of wheat in Oklahoma produced yields of more than 30 bushels per acre. This was with no fertilizer on soil which had been in cultivation 8 years (1). After approximately 30 years of cultivation nitrogen fertilizers were still not recommended (18) as soil nitrogen levels were sufficient.

However, in 1944 soil nitrogen was beginning to become limiting in

Oklahoma soils (12) and nitrogen-containing compounds were recommended as fertilizers.

From the above discussion (27, 24, 18, 20) it may be seen that in the early years of cultivation the native soil fertility may have been sufficient for crop needs. Murphy (20) reported that a particular soil used in his research work contained 1420 pounds of nitrogen per acre in the surface 6-2/3 inches. He commented that this soil "...is not unlike the nitrogen content of many wheat soils in Oklahoma."

Because of intensive cultivation, higher yielding varieties, and improved farming practices, the nitrogen level in many soils has decreased to the point where the use of nitrogenous fertilizers is a must. This can readily be seen by a brief review of the literature of the past few years. The judicious use of nitrogen has done much to increase yields reduced by nitrogen deficiencies.

This now brings us to the problem at hand. How much nitrogen should be added to the soil? Is there any way to predict yields so that one might have a way of knowing what amount of nitrogen fertilizer to add? Is there any relationship between soil nitrogen levels and yield response to added nitrogen?

Army et al. (2) studied relationships between precipitation and yield on dryland wheat production in the Southern High Plains. Eleven years of data were obtained for three varieties of hard red winter wheat from three commonly employed cropping sequences. Using coefficients of determination the authors arrived at the conclusion that 55 to 60 percent of the variability in wheat yields was attributable to variation in growing season precipitation. These data are concerned with experiments which evidently were not fertilized because of a low annual rainfall. With a wheat-fallow or wheat-sorghum-fallow cropping sequence more than 10 bushels of grain could be expected 80 percent of the time. Greater than 10 bushels of grain more than 50 percent of the time could be expected from a continuous cropping sequence of wheat.

Crop yield probabilities in the Great Plains were studied by Newhall et al. (21). This study was concerned with four cropping systems on many different soils in a six state area. The locations were situated in eastern New Mexico, the panhandles of Texas and Oklahoma, eastern Colorado, western Kansas, and southwestern Nebraska. Data from 36 years on continuous wheat at Dalhart, Texas indicate that a yield greater than 20 bushels of wheat per acre can be expected only 10 percent of the time. At North Platte, Nebraska a wheat yield greater than 20 bushels per acre in a cropping system of continuous wheat can be expected 70 percent of the time.

The relationship of soil nitrate accumulation and yield response to added nitrogen was investigated by Cook et al. (7). Nitrate accumulation was determined by the procedure of Stanford and Hanway (25). Primarily this consists of incubating moist soil in a humid atmosphere at 30°C. for two weeks and then determining the nitrate accumulation. Soils were brought into the laboratory for the soil nitrate accumulation study. Concurrently with this, field fertilizer tests were performed on the same soils to obtain yield data. On soils cropped the previous year a correlation coefficient of 0.846 was found between nitrate accumulation and the wheat yield ratio. The yield ratio used was that suggested by Bray (6) which is:

$$\frac{\text{yield in bushels/acre from 20 lb. } P_2O_5 \text{ treatment}}{\text{yield in bushels/acre from 20 lb. } P_2O_5 + 20 \text{ lb. N treatment}} \times 100$$

For wheat following fallowed soils the correlation between nitrate accumulation and yield ratio was 0.830. Both of these correlation coefficients were statistically significant at the 1 percent level. It was shown that cereal crops in Sasketchewan will respond to nitrogen when the nitrate accumulation value was under 50 ppm. for soils cropped the previous season and 40 ppm. for fallowed soils.

Much research has been performed by incubating soils and correlating nitrate accumulation with nitrogen fertilizer needs (7, 25, 11, 17). More articles of this nature were found in the literature than those relating to the nitrogen concent of the soil at planting time or during the growing season. Cook et al. (7) have stated that the nitrate concent of the 0 to 6 inch depth of soil at seeding time was not significantly related to the yield ratio response of Bray (6). However, lower depths in the soil profile were not studied.

Waring and Teakle (27) also found no relationship between the amount of nitrate to a depth of 6 feet and yield of a wheat crop. However, their work was concerned with soil which was high in nitrate-nitrogen.

Effect of Nitrogen Fertilization on Wheat Quality

In 1907 it was reported from Minnesota that "...increasing the amount of nitrogen in the soil, increases the amount of nitrogen in the wheat grain..." (24).

Murphy (19) stated in 1930 that "...the protein content of the grain rises as the amount of nitrogen in the fertilizer is increased."

McNeal and Davis (15) conducted a variety-fertility study on nine varieties of spring wheat using nitrogen rates of 0, 50, and 100 pounds of nitrogen per acre. Increasing the rate of applied nitrogen increased the yield as much as 30 bushels per acre. The 50 pound nitrogen application tended to decrease protein content of the grain as compared to the check. The 100 pound nitrogen rate increased protein content as compared with the 50 pound rate but did not reach the same levels as the check. The protein content of the grains from the middle spikelets was higher than protein content of grains from the top spikelets. Also, lateral kernels were higher in protein than central kernels. The above information indicates that the first formed kernels obtain the major portion of available nitrogen. Also, the 50 pound nitrogen rate increased yield but decreased nitrogen content of the grains. The 100 pound nitrogen rate, while increasing yield, also increased protein content of the grain. Their data confirm the well-known principle that high nitrogen availability late in the growth period is essential for maximum protein content.

There are many papers in the literature which attest to the above facts. Since these were established much emphasis has been placed on time and method of application of nitrogen. Long and Sherbakoff (14) topdressed soft red winter wheat with two rates of nitrogen, 25 pounds and 50 pounds per acre, on three different dates. From their results they concluded that higher nitrogen applications, especially when applied late, yielded higher nitrogen wheat. At the time of seeding, October 22, all plots received 24 pounds of nitrogen per acre.

Topdressing with 25 and 50 pounds of nitrogen per acre was done either on November 20, March 8, or May 4. The 50 pound nitrogen rate top-dressed on November 20 gave a higher yield than the 25 pound nitrogen rate but did not increase protein content of the grain. The March 8 and May 4 topdressing dates showed no differences in yield but the 50 pound rate increased the protein content at each date.

Seth and co-workers (23) studied nitrogen utilization in high and low protein wheat varieties. In both field and greenhouse tests nitrogen was either applied as a solid to the soil or sprayed on to the aerial portions of the plant as urea or calcium nitrate. The foliar sprays applied after heading of the wheat resulted in grain with the highest protein content.

Finney et al. (10) sprayed Pawnee winter wheat with urea solutions and examined its effect on yield and quality. The wheat was sprayed at various times before flowering and after flowering. The number of sprayings varied from one to fifteen with the rates of nitrogen being equivalent to 10, 30 and 50 pounds of nitrogen per acre. No nitrogen was topdressed on the experiment plots. All added nitrogen was in the form of urea solutions sprayed on to the crop. High concentrations of urea before flowering increased yield. Spraying with urea didn't affect test weight. However, numerous increases in protein content were obtained by single sprayings with urea. The most effective time of spraying was at flowering with a single application of urea, the increase in protein content being 4.4 percent. Grain from the plots which received no nitrogen had a protein content of 10.8 percent while grain from plots sprayed 2 days after flowering at a rate of 50 pounds of nitrogen per acre had a protein content of 15.8 percent.

CHAPTER III

SOIL NITRATE ACCUMULATION IN WHEATLAND SOILS OF OKLAHOMA

Robert E. Greene and Billy B. Tucker[1]

Introduction

The use of nitrogenous fertilizers in wheat farming has increased tremendously in Oklahoma in recent years. Yields as well as quality of grain have increased due to fertilization practices. However, the need for nitrogen fertilization on wheatland soils in Oklahoma fluctuates from season to season depending upon yields made possible by soil moisture and climatic conditions. Nitrogen determinations have not been used in Oklahoma in the past to assess needs for nitrogen fertilization. Currently, organic matter determinations are made and nitrogen needs are then estimated. This publication reports studies that were made in an effort to develop procedures for assessing nitrogen needs by determination of soil nitrates.

Literature Review

Nutrient deficiencies in many Oklahoma soils do not appear until

[1]The authors are respectively: former Graduate Assistant and Associate Professor of Agronomy, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.

after many years of cultivation. As early as 1898 many varieties of wheat grown in Oklahoma produced yields of more than 30 bushels per acre on soils which had received no fertilizer treatment. However, these soils had been in cultivation only eight years (1). After approximately 30 years of cultivation nitrogen fertilizers were still not recommended as soil nitrogen levels were sufficient (18). However, in 1944 soil nitrogen was beginning to become limiting in Oklahoma soils (12) and nitrogen-containing compounds were recommended as fertilizers. Because of intensive cultivation, higher yielding varieties, and improved farming practices, the nitrogen level in many soils has decreased to the extent that use of nitrogenous fertilizers is essential for high yielding, good quality wheat.

Nitrate concentration in the soil has been investigated by many research people. Michalyna and Hedlin (16) sampled Canadian clay soils to a depth of 72 inches and on a few plots found nitrate-nitrogen concentration to be 44 ppm. at a depth of 6 feet. They mention that this is probably due to leaching throughout the year.

Investigations in Australia (27) concerning soil nitrate levels have shown that amounts varied from 10 to 20 ppm. in the surface 2 feet, decreasing to 0 to 10 ppm. at 2 to 4 feet. Generally the nitrate content of the soil decreased below a depth of 24 inches.

Van Der Paauw (26) studied the effect of rainfall on availability of nitrogen in soil. Using two rates of nitrogen topdressing he traced the nitrogen through the soil profile to a depth of approximately 40 inches under two different rainfall regimes. In all treatments nitrogen concentration decreased below a depth of 24 inches.

It is also possible that residual nitrogen may be present in the soil, being carried over from the previous years' nitrogen application. White, Dumenil and Pesek (28) of Iowa have stated that as much as 49 percent of the previous year's application of ammonium nitrate nitrogen may be carried over to the following year as nitrate-nitrogen. Bowan et al. (4) in Washington found that residual nitrogen from ammonium nitrate averaged 44 percent of the original application after one year but was insignificant after 2 years.

The relationship of soil nitrate accumulation and yield response to added nitrogen was investigated by Cook et al. (7). Nitrate accumulation was determined by the procedure of Stanford and Hanway (25). Essentially this consists of incubating moist soil in a humid atmosphere at 30°C. for 2 weeks and then determining the nitrate accumulation. Concurrently with this, field fertilizer tests were performed on the same soils to obtain yield data. On soils cropped the previous year a correlation coefficient of 0.846, significant at the 1 percent level, was found between nitrate accumulation and the wheat yield ratio. The yield ratio used was that suggested by Bray (6) which is:

$$\frac{\text{yield in bushels per acre from 20 lb. } P_2O_5 \text{ treatment}}{\text{yield in bushels per acre from 20 lb. } P_2O_5 + \text{20 lb. N treatment}} \times 100$$

Much research has been performed by incubating soils and correlating nitrate accumulation with nitrogen fertilizer needs (7, 25, 11, 17). More articles of this nature were found in the literature than those relating to the nitrogen content of the soil at planting time or during the growing season. Cook et al. (7) have stated that the nitrate content of the 0 to 6 inch depth of soil at seeding time was not significantly related to the yield response procedure of Bray (6). However, lower depths were not studied.

Waring and Teakle (27) also found no relationship between amount of nitrate to a depth of 6 feet and yield of a wheat crop. However, their work was concerned with soil which was high in nitrate-nitrogen.

This investigation was undertaken to study variation in nitrate levels at various depths within the soil and to investigate the possibility of the relationship between soil nitrate levels and yield response to added nitrogenous fertilizer.

Materials and Methods

Soil samples were collected from four widely different soils where nitrogen fertility studies were being conducted on wheat in 1960-61. Samples were taken from the plots which received no fertilizer. The locations were: Perkins (Vanoss loam), Hobart (Hollister silty clay loam), Custer City (Carey silt loam), and Mangum (Altus sandy loam). Fields where these experiments were located had been in continuous wheat for many years and all were clean tilled except the Mangum experiment which was stubble mulched. There were five sampling dates: November 12, 1960, November 30, 1960, January 31, 1961, March 10, 1961, and May 12, 1961.

During 1961-62 and 1962-63 five locations were sampled, these being two different locations at Cherokee, one clean tilled and the other stubble mulched, and one location each at Okeene, Altus and Mangum, Oklahoma. These plots were clean tilled except those at Mangum which were stubble mulched. The sampling dates were approximately November 1, 1961 and 1962, and February 10, 1962 and 1963. The five above-mentioned locations have been in wheat since 1960, 1960, 1962, 1958, and 1958 respectively. All experiments were originally designed as nitrogen fertility studies and all treatments were sampled. All samplings were obtained previous to the spring topdressing date.

Depths of sampling were 0 to 6, 6 to 12, 12 to 24, 24 to 36, and 36 to 48 inches. Within 48 hours after sampling the soil was air dried, ground to pass a 9 mesh sieve, and stored at 0°C. Nitrates were determined by the phenoldisulfonic acid method as outlined by Jackson (13).

Each experiment of 1960-61 was a split plot design with dates as the main plot treatments and depths as subplots. The experiment consisted of four replications. The 1961-62 and 1962-63 experiments were factorial arrangements of depths and previous nitrogen treatments as main plot units in a randomized complete-block design of four replications with dates as sub-units. In the statistical analysis locations and years were not pooled. Each location for each year was analyzed separately.

Results and Discussion

1960-61

Locations and soils sampled are outlined in Table I and Figure 1. No data are reported for sampling depths of 24 to 36 and 36 to 48 inches because nitrate concentrations at these depths were negligible as compared to the other depths.

This was the initial phase of a 3-year study. Its purpose was to determine the practicability of soil nitrate determinations on field samples and the date and depth of maximum nitrate accumulation on wheat producing soils of Oklahoma.

TABLE I

DATA CONCERNING SAMPLING SITES

Location No.	Location	Soil Type	Average Annual Rainfall	Drainage
1	Perkins, Oklahoma	Vanoss loam	34.1"	Slow to moderate
2	Custer City, Okla.	Carey silt loam	27.2"	Moderate
3	Hobart, Oklahoma	Hollister silty clay loam	24.6"	Slow
4	Mangum, Oklahoma	Altus sandy loam	23.0"	Moderate to moderately rapid
5	Cherokee, Oklahoma	Grant silt loam	25.9"	Moderate
6	Okeene, Oklahoma	Kingfisher silt loam	24.6"	Slow to moderate
7	Altus, Oklahoma	Hollister silty clay loam	23.6"	Slow

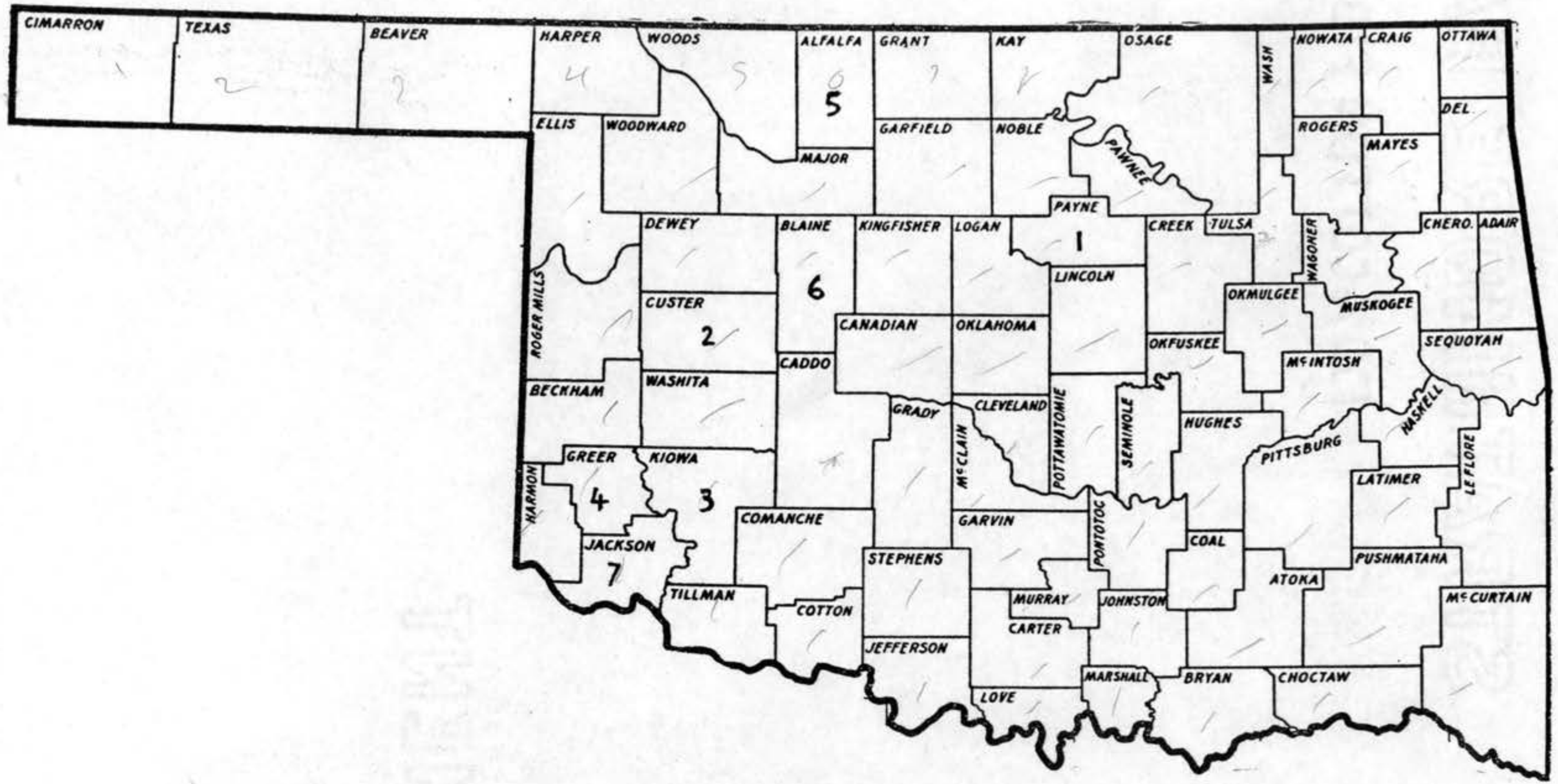


Figure 1. Location of Sampling Sites Identified in Table I.

Data concerning soil nitrate concentrations at the four locations sampled in 1960-61 appear in Figures 2, 3, 4, and 5. In Figure 2 nitrate means for depths and dates were separated by Duncan's multiple-range test at the 10 percent level.

At Perkins on Vanoss loam (Figure 2) the 0 to 6 inch depth was significantly lower in nitrate than the 6 to 12 inch and 12 to 24 inch depths. The nitrate content of the soil on date five was significantly lower than the other four dates. A detectable amount of nitrates was found to a depth of 24 inches. Between the 24 inch and 48 inch depths the nitrate concentration decreased rapidly. There was a continual increase in soil nitrate concentration throughout the growing season from November 10 until February 2.

After March 10, during the period of rapid growth and maturation of the wheat plant, the nitrate concentration of the soil decreased rapidly. This fact is illustrated very well in Figure 3 where one can also see the general increase in nitrate concentration at all three depths until March 10.

The lowest concentration of soil nitrates in the Carey silt loam at Custer City was found in the 0 to 6 inch depth while the highest was in the 12 to 24 inch depth with the 6 to 12 inch depth intermediate (Figure 2). With regard to sampling dates, nitrate concentration was greatest on November 10 and least on February 2 with concentrations at the other dates being intermediate. These trends are more easily seen in Figure 4. There was a rapid decrease in nitrate concentration from November 10 to November 30. This decrease leveled off until February 2. By March 10 there had been an increase in nitrate nitrogen and then a gradual decrease during the period from March 10 to May 12.

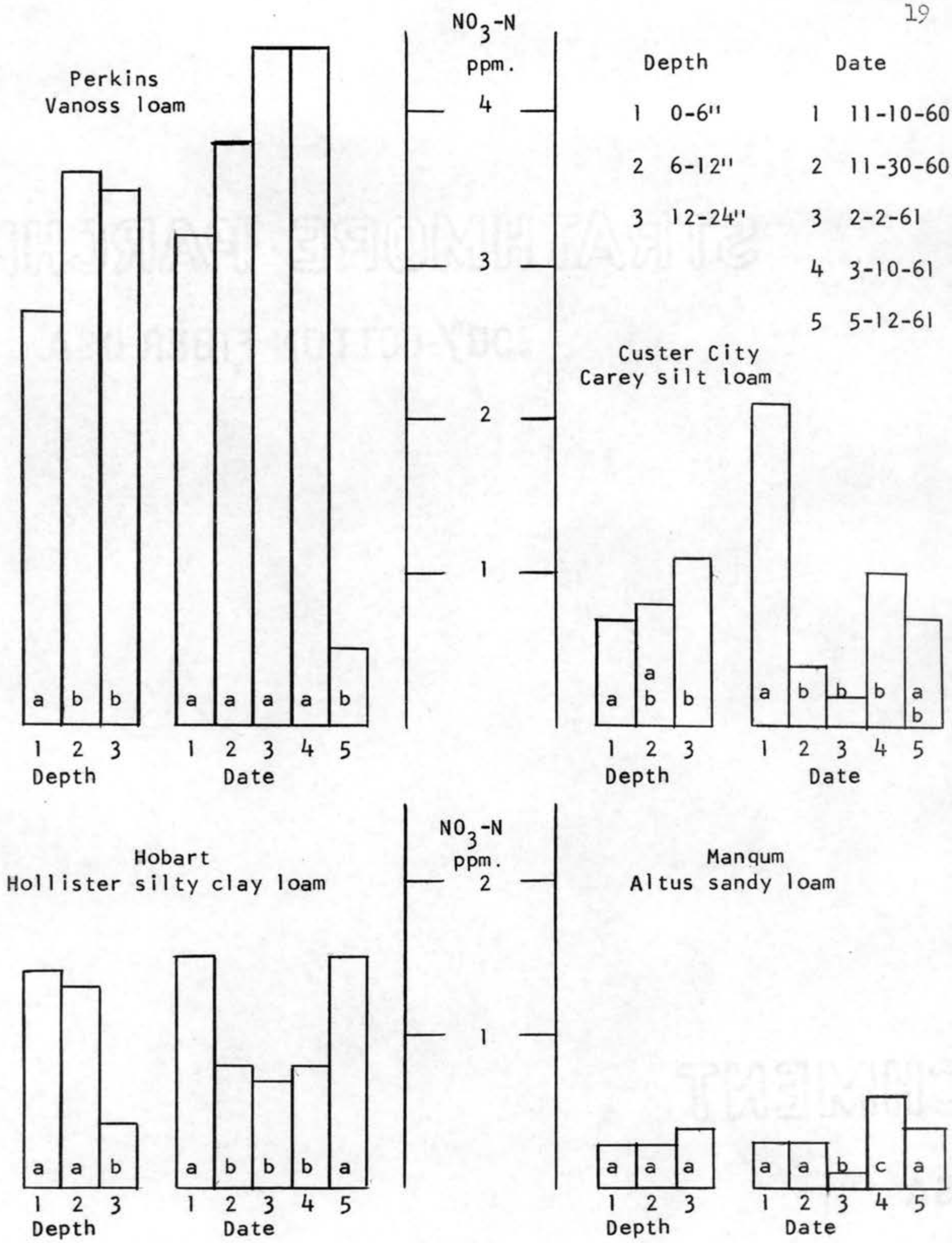


Figure 2. Nitrate Concentrations at Various Soil Depths and Dates. (Each depth value is the average for five dates. Each date value is the average for three depths. Bars with the same letters within a group belong to same population as tested by Duncan's Multiple Range Test at the 10% level.)

Date

1 11-10-60

2 11-30-60

3 2-2-61

4 3-10-61

5 5-12-61

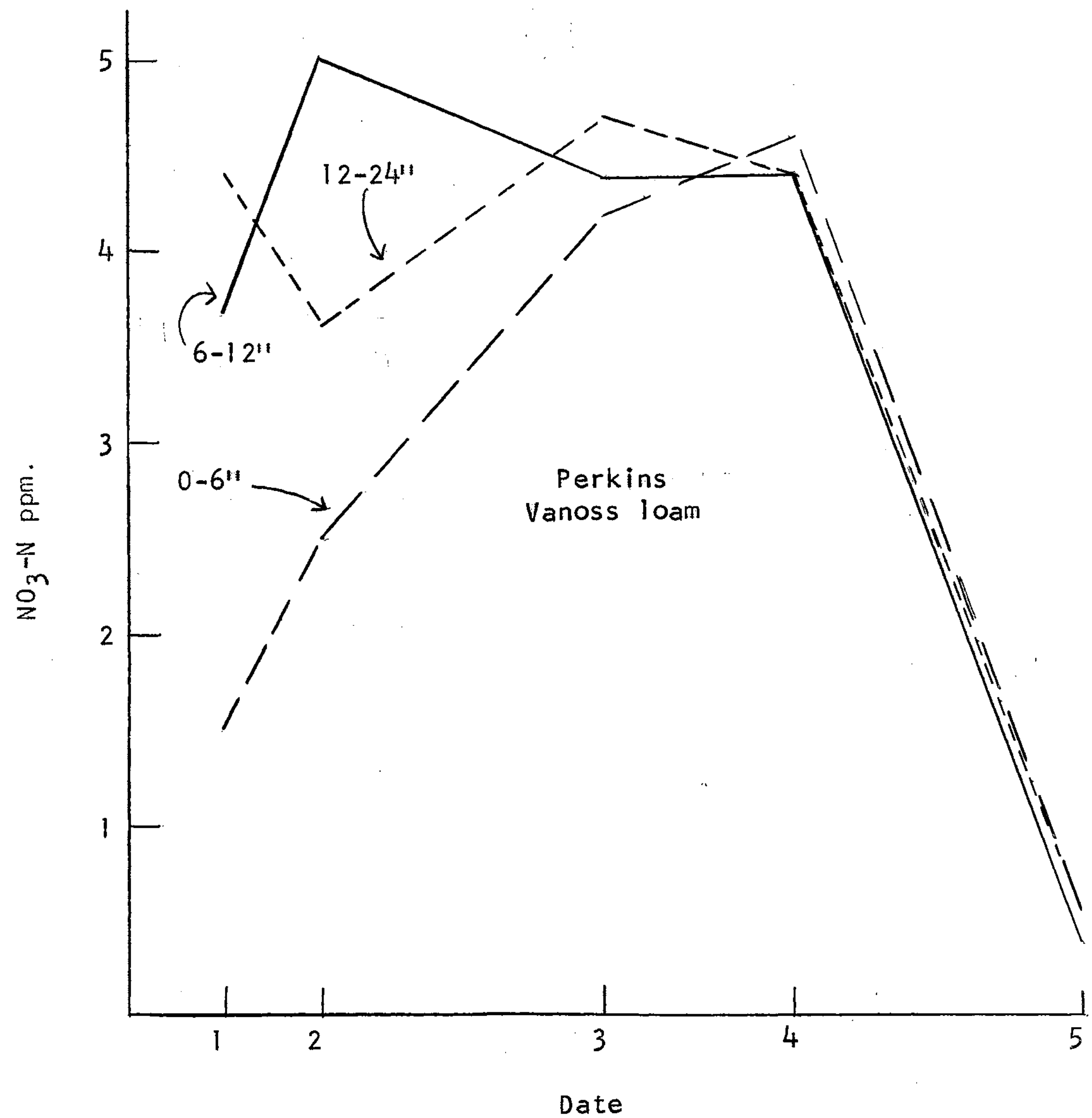


Figure 3. Nitrate Concentrations of Various Soil Depths Throughout the Growing Season at Perkins.

Date

1 11-10-60

2 11-30-60

3 2-2-61

4 3-10-61

5 5-12-61

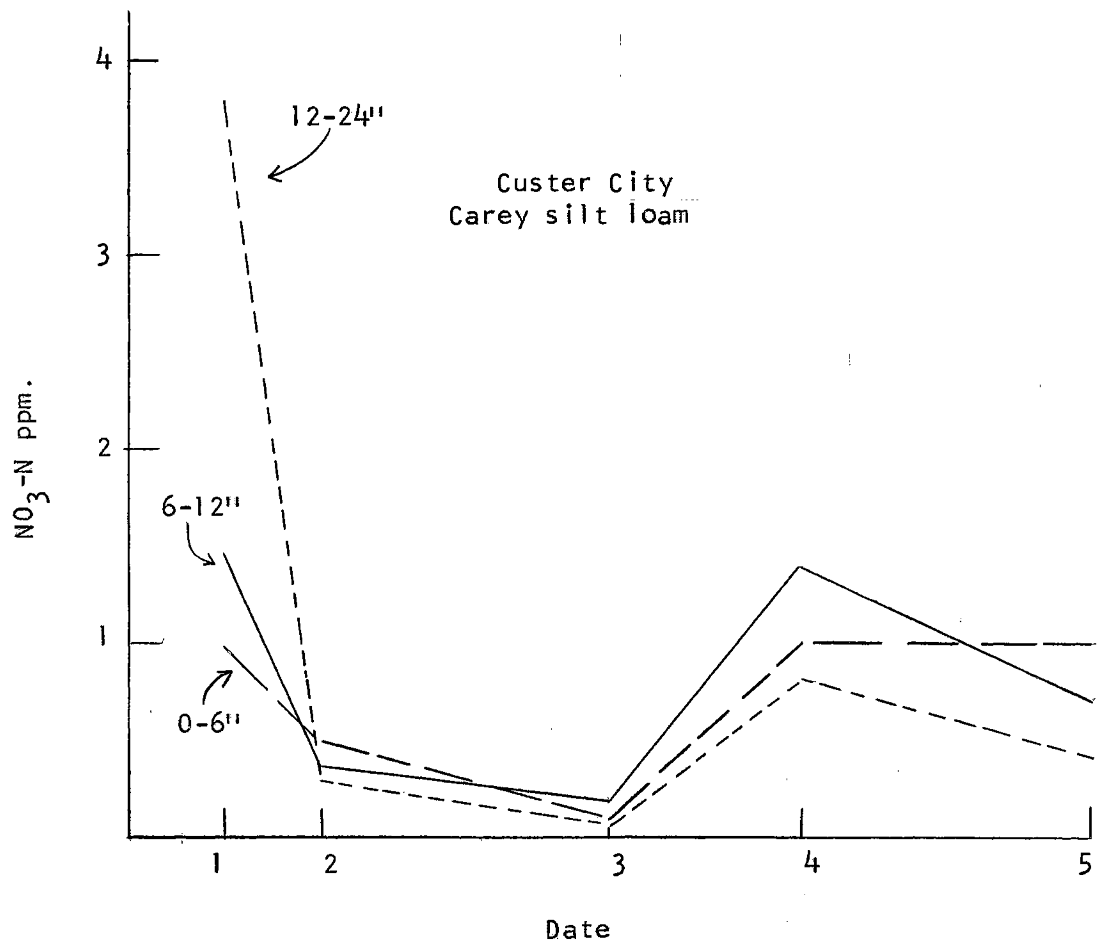


Figure 4. Nitrate Concentrations of Various Soil Depths Throughout the Growing Season at Custer City.

On the Hollister silty clay loam at Hobart (Figure 2) the 0 to 6 inch and 6 to 12 inch depths had higher nitrate concentrations than the 12 to 24 inch depth. On November 10 and May 12 nitrate concentrations were greater than at the other dates. Figure 5 shows the change in nitrate concentration at the various depths throughout the growing season. A general decrease in nitrate concentration occurred from November 10 to February 2. From February 2 to May 12 an increase in the concentration of nitrate nitrogen was observed.

The Altus sandy loam of Mangum did not contain much nitrate nitrogen. There was no significant difference between sampling depths (Figure 2). On the March 10 sampling date nitrate concentration was the highest with the February 2 date being the lowest. All other dates were intermediate between these two. Upon examination of Figure 5 it can be seen that the soil nitrate concentration was very low at all dates and depths at Mangum.

Soil nitrate concentrations at the Custer City, Hobart, and Mangum sampling sites all behaved in a similar manner. The nitrate concentration decreased from November 10 until February 2. After February 2 there was a general increase in soil nitrate concentration. These three locations differed from the Perkins location, especially between the November 10 and November 30 sampling dates. At Perkins the soil nitrate concentration increased from November 10 until March 10 whereupon the nitrate concentration decreased markedly. This difference in behavior might be attributed to one or more factors such as soil type, soil temperature, drainage, organic matter, nitrifying organisms and rainfall.

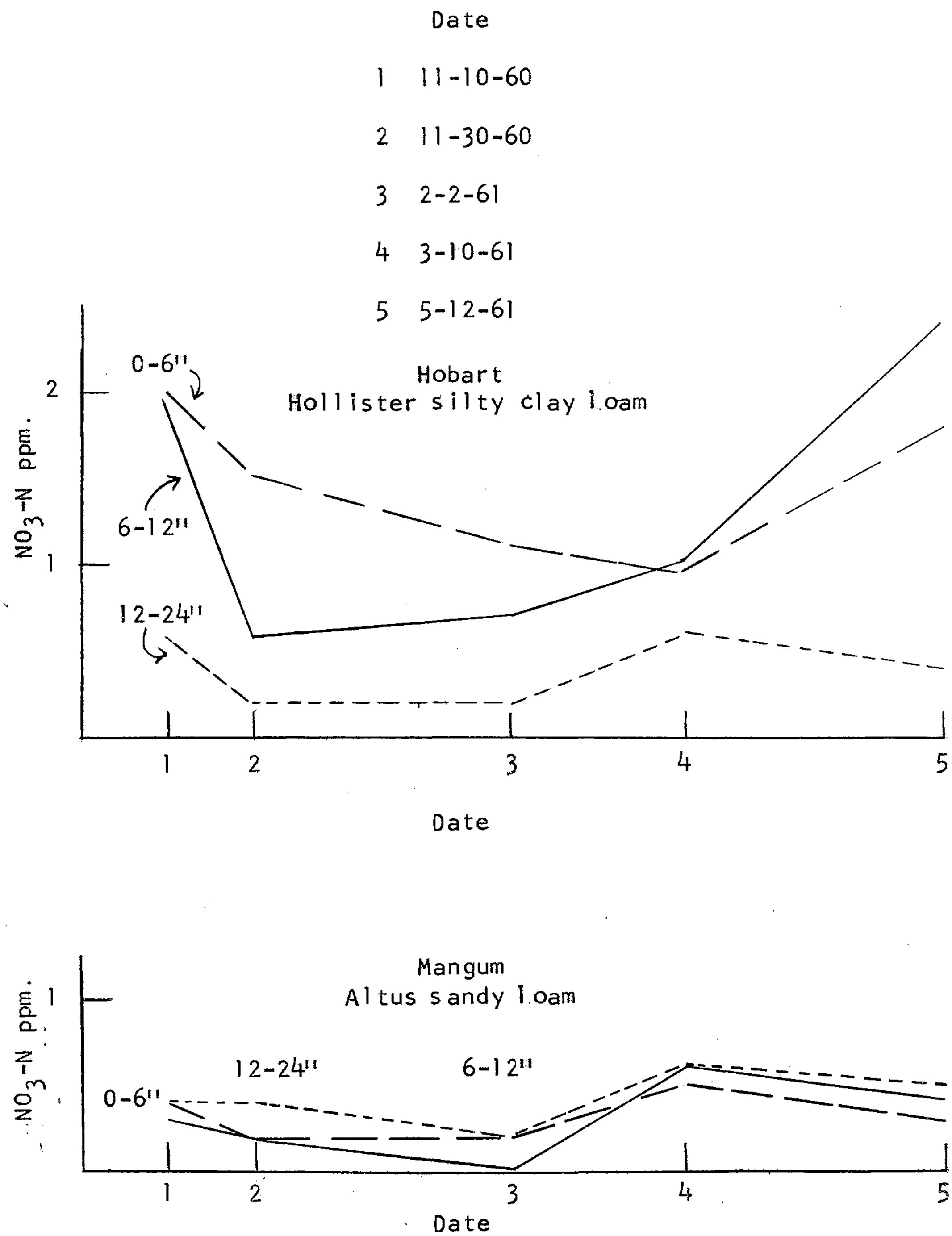


Figure 5. Nitrate Concentrations of Various Soil Depths Throughout the Growing Season at Hobart and Mangum.

The Vanoss loam at Perkins has a slow to moderate drainage as compared to slow for Hollister silty clay loam, moderate on Carey silt loam and moderately rapid on the Altus sandy loam. In October all sites received a plentiful amount of precipitation varying from 6.1 inches on the Hollister silty clay loam to 8.4 inches on the Carey silt loam. Due to the drainage characteristics of the soils and the amount of October precipitation it is possible that some of the nitrates at Perkins were leached out of the 24 inch sampling range. From Figure 3 it can be seen that a general increase in nitrates occurred from November 10 until March 10, especially in the 0 to 6 inch depth. Due to the slow drainage characteristics of the Hollister silty clay loam it appears that leaching into the 24 inch depth and beyond the 24 inch depth was not appreciable. However, in the moderately drained Carey silt loam leaching of nitrates into the 12 to 24 inch depth was very noticeable. The Altus sandy loam of Mangum is classed as moderately rapid with respect to drainage. The 7.5 inches of precipitation which fell on this sampling site in October apparently leached what nitrates were present beyond the sampling depth of 24 inches. As mentioned previously, all of the soils were sampled to 48 inches but no appreciable amount of nitrates was found below 24 inches at any location. If nitrates were present to any extent at Mangum they might have been leached beyond the 48 inch depth which is unlikely due to clay content of the soil at that depth.

1961-62

Data presented in the histogram concerning the 1961-62 data (Figures 6 and 7) have been analyzed statistically and subjected to

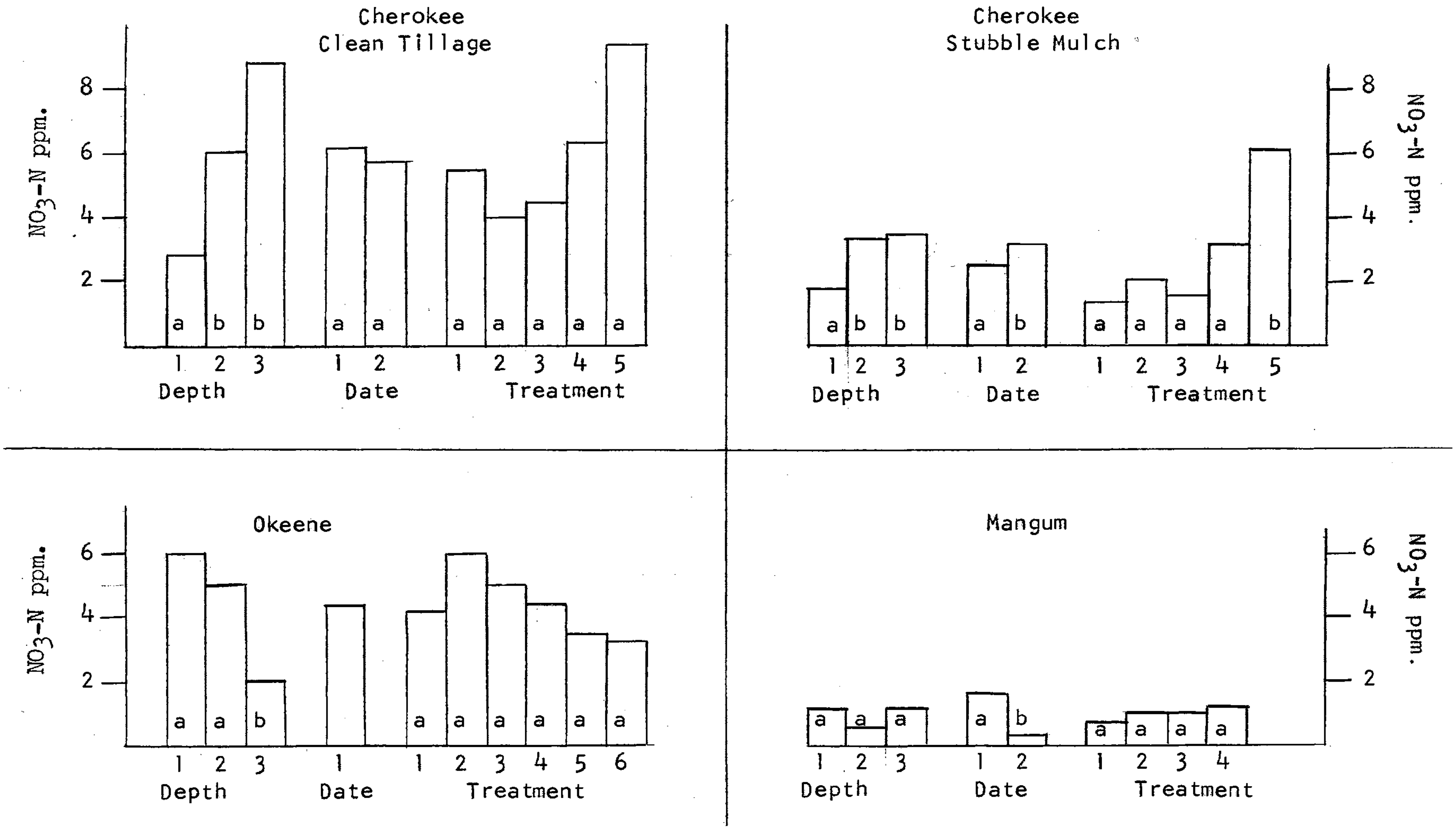


Figure 6. Nitrate Concentrations of Various Soil Depths, Dates, and Treatments at Different Locations for 1961-62 Crop Year. (Bars with same letter within a group belong to same population as tested with Duncan's Multiple Range Test at 10% level.)

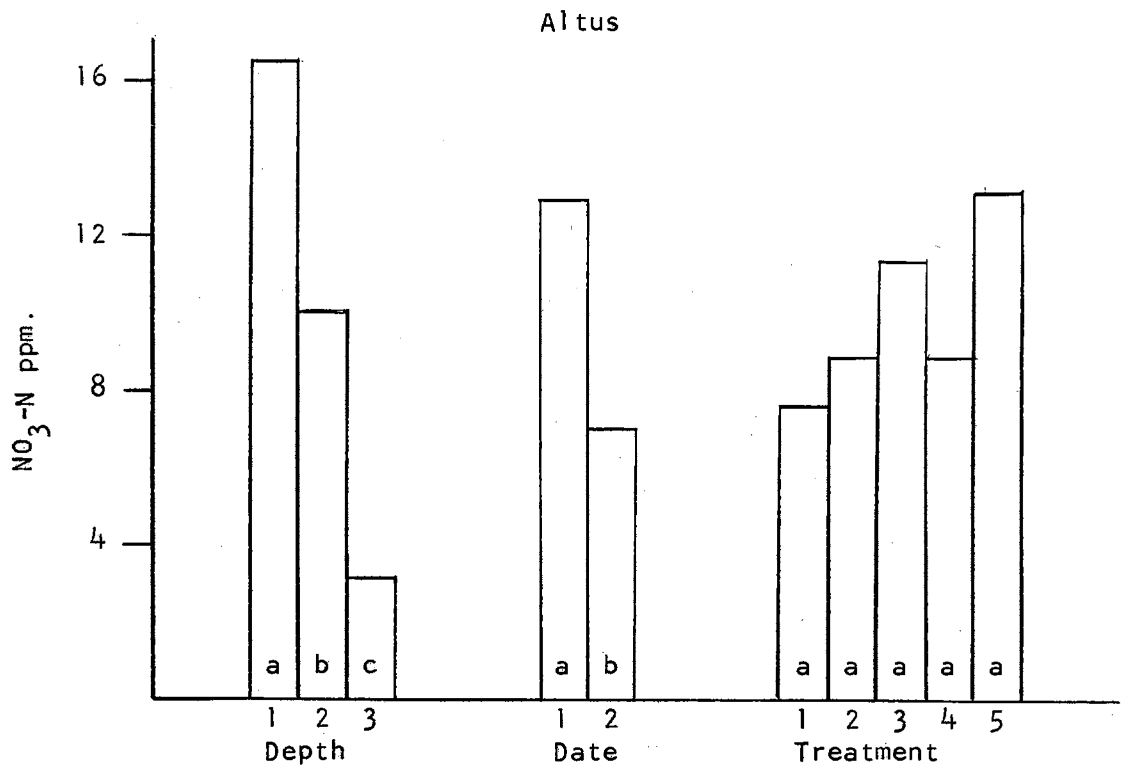


Figure 7. Nitrate Concentrations of Various Soil Depths, Dates, and Treatments for 1961-62 Crop Year at Altus. (Bars with same letter within a group belong to some population as tested with Duncan's Multiple Range Test at 10% level.)

Duncan's multiple-range test at the 10 percent level. Figures 1 and Table I describe locations and soil types sampled. Information concerning locations, sampling depths, sampling dates, and previous years' nitrogen treatment is presented in Table II. The soil at Cherokee was Grant silt loam; at Okeene, Kingfisher silt loam; at Mangum, Altus sandy loam; and at Altus, Hollister silty clay loam. At Cherokee samples were taken from plots which were subjected to clean tillage and to stubble mulching. Soil nitrate concentration increased with depth at Cherokee on both tillage practices (Figure 6). There was no difference in nitrate concentration on sampling dates for the clean tilled plots, but soil obtained on the second sampling date from stubble mulched plots had the highest nitrate concentration. At the Cherokee location only treatment 5, 160 pounds of nitrogen per acre topdressed in the spring of the previous crop year on the stubble mulched plots, was significantly different than the soil nitrate concentrations of the other treatments. Although there was similarity in soil nitrate concentration levels at both Cherokee sampling sites, the amount of nitrate nitrogen in the stubble mulched plots was noticeably less. This is certainly not an unexpected occurrence as one would expect a greater amount of extractable nitrogen where nitrogen was not being utilized in the decomposition of organic matter.

Data are available only for the first sampling date at Okeene. The 0 to 6 inch and 6 to 12 inch depths had a greater soil nitrate concentration than the 12 to 24 inch depth (Figure 6). No difference was detected in nitrate concentrations of soil samples obtained from the various plots designated to receive different nitrogen treatments.

TABLE II

LEGEND IDENTIFICATION FOR FIGURES 7, 8, 11 AND 12

Location	Sampling Depth No.	Depth Inches	Sampling Date No.	Sampling Date	Treat. No.	Treat. # N/A
Cherokee	1	0- 6	1	11- 1-61	1	0
	2	6-12	2	2-10-62	2	20
	3	12-24	1	10-24-62	3	40
			2	2- 6-63	4	80
					5	160
Okeene	1	0- 6	1	11- 1-61	1	0
	2	6-12	2	No samples taken	2	20
	3	12-24	1	11- 2-62	3	40
			2	2-10-63	4	60
					5	80
					6	160
Mangum	1	0- 6	1	11- 1-61	1	0
	2	6-12	2	2-10-62	2	20
	3	12-24	1	11-15-62	3	40
			2	2- 6-63	4	80
Altus	1	0- 6	1	11-10-61	1	0
	2	6-12	2	2-10-62	2	40
	3	12-24	1	No samples taken	3	80
			2	2-10-63	4	120
					5	160

This was to be expected as the experiment was initiated the same year and had received no previous nitrogen topdressing.

Nitrate concentrations at Mangum (Figure 6) were extremely low in all categories, and the only difference detected was in sampling dates. The soil at Mangum is rather sandy with moderately rapid drainage and very little organic matter. This might account for the extremely low nitrate concentrations. The experiment, with respect to nitrogen applications, was begun in 1958.

Figure 7 contains data concerning the Altus location. This soil is a dark colored silty clay loam and contained more nitrate than soils of the other locations. A high nitrate concentration was detected in the 0 to 6 inch depth with a comparatively low nitrate concentration in the 12 to 24 inch depth. Soil from the first sampling date contained more nitrates than that from the second sampling date. No significant difference in soil nitrate concentrations was found among treatments. The experiment was originally initiated in 1958.

Data presented in Figures 6 and 7 were subjected to statistical analysis as outlined in "Materials and Methods."

Information of a more specific nature is recorded graphically in Figures 8, 9, 10 and 11. This specific information is useful in data interpretation but has not been subjected to statistical analysis.

Data from both sampling dates are presented for the Cherokee, Altus and Mangum locations. There is no specific presentation of data from Okeene as it would merely be a duplication of the data in Figure 6. Cherokee data are presented in Figures 8 and 9 illustrating the contrast between the two management practices employed. On clean tilled plots wheat stubble is turned under shortly after harvest.

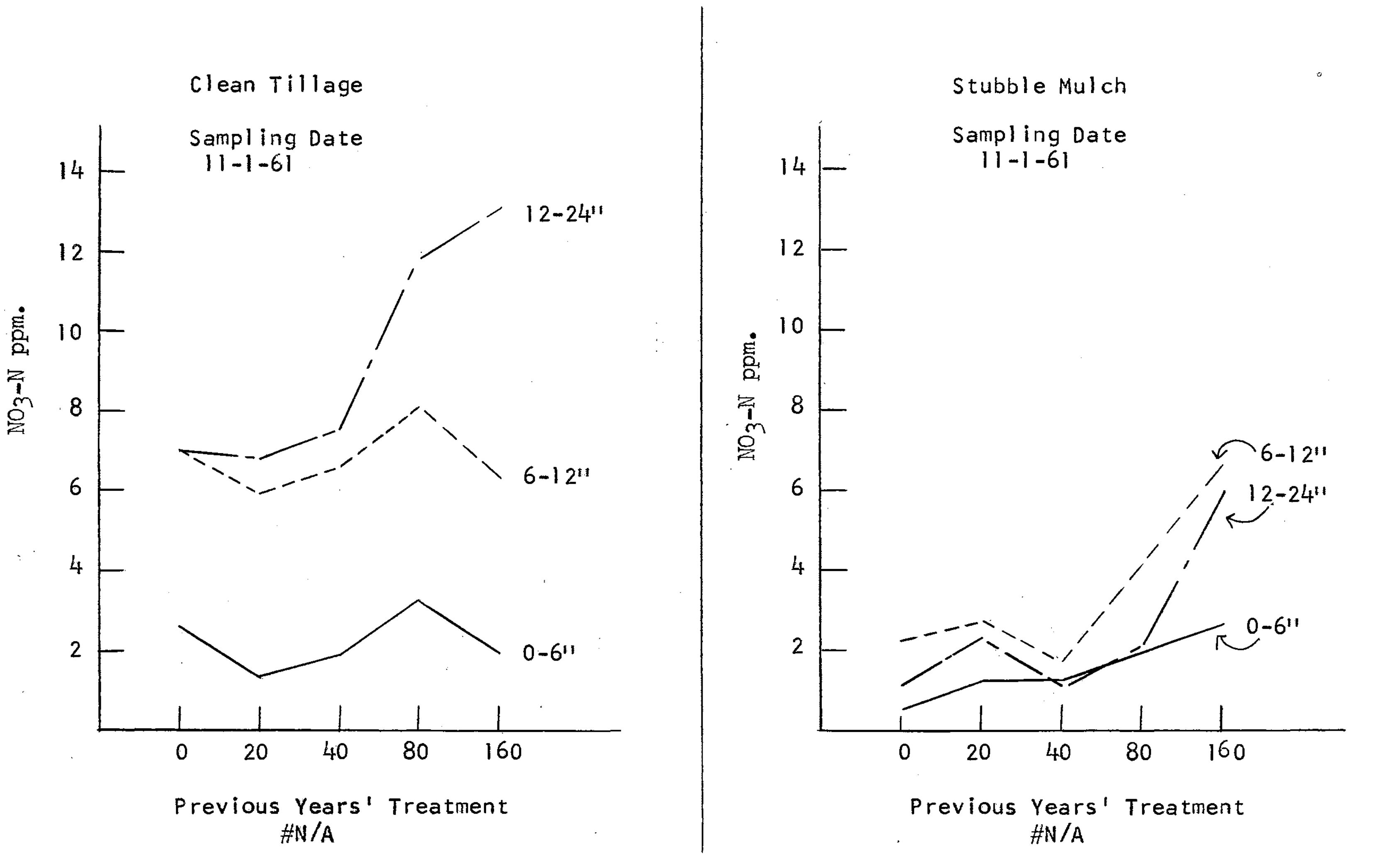


Figure 8. Nitrate Concentrations of Various Soil Depths at Cherokee, 1961

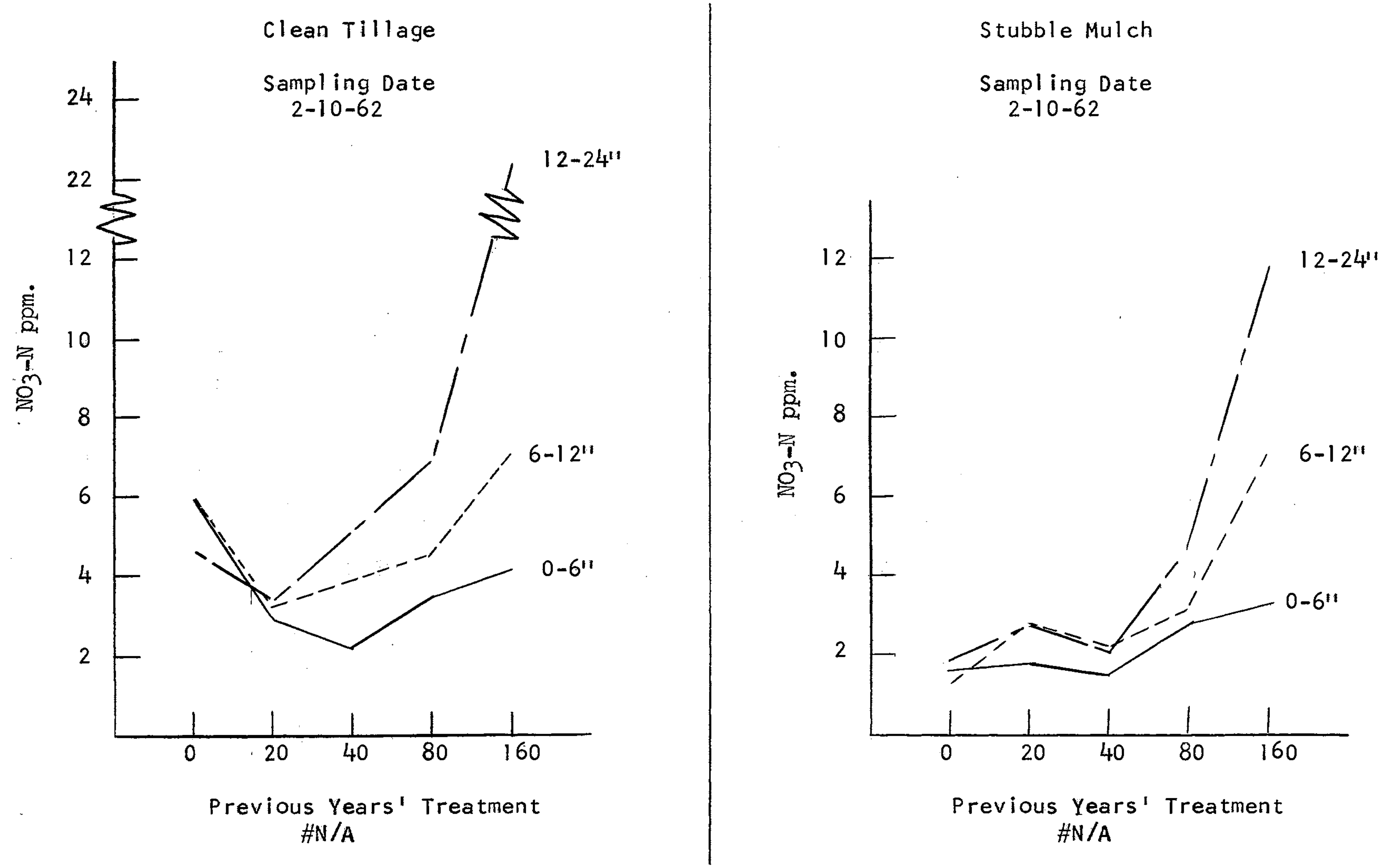


Figure 9. Nitrate Concentrations of Various Soil Depths at Cherokee, 1962.

Wheat stubble is left on the surface for stubble mulched plots. On both sampling dates a higher nitrate concentration was observed in soil from the clean tilled plots. This may be due to a more rapid decomposition of organic matter in the clean tilled plots caused by more even distribution of the stubble through a greater volume of soil. There is also a possibility that the C:N ratio may have been extremely large in the stubble mulched plots causing a decrease in extractable nitrates due to the nitrogen needs of the microbial population. Also apparent from the material presented is the larger nitrate concentrations in soil from treatments which received 80 and 160 pounds of nitrogen per acre. This suggests that at higher nitrogen applications there is a nitrogen carry-over from year to year.

At the Altus location, which has a soil drainage classed as moderately slow, there was a high concentration of soil nitrates in the 0 to 6 inch depth on the first sampling date. The nitrate concentration of the 6 to 12 inch depth was intermediate, the 12 to 24 inch depth being low in nitrates (Figure 10). On the second sampling date there was little difference between depths in soil nitrate concentration. Because of the moderately slow drainage of the soil at Altus it seems that leaching would not remove nitrates to any great degree. It is more likely that the decrease in soil nitrate concentrations between sampling dates was due to utilization by the wheat plants. At Altus there appears to be little available nitrogen carry-over from the previous years' nitrogen treatment.

Nitrate concentrations in the soil at Mangum were extremely low (Figure 11) on both sampling dates. This soil is sandy and has a moderately rapid drainage. Nitrates that are formed readily leach

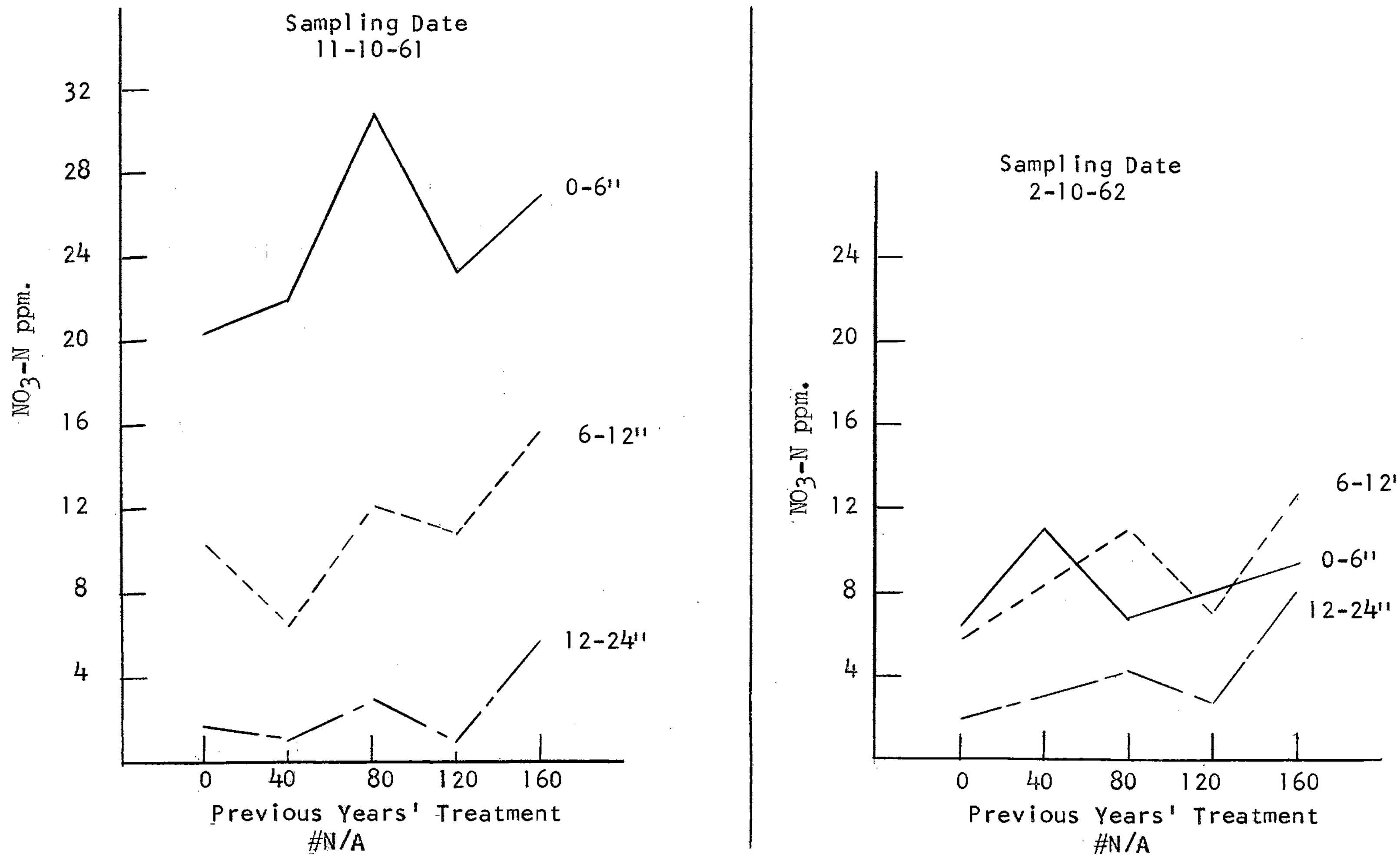
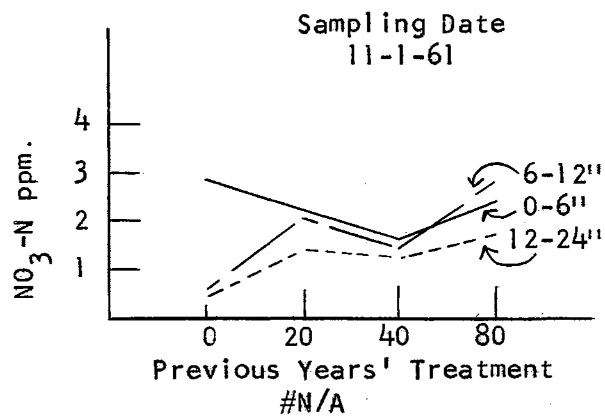


Figure 10. Nitrate Concentrations of Various Soil Depths at Altus, 1961-62.



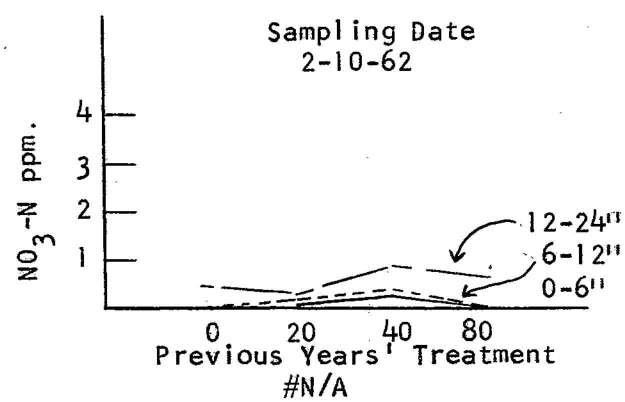


Figure 11. Nitrate Concentrations of Various Soil Depths at Mangum, 1961-62.

through the soil profile. There was no evidence of nitrogen carry-over from previous applications.

1962-63

Figures 12 and 13 contain data concerning the 1962-63 crop year. Legend identification of these figures is presented in Table II. On the clean tilled plots at Cherokee the 6 to 12 inch sampling depth contained the largest concentration of soil nitrates; the soil nitrate concentration of the first sampling date was greater than the second; treatments 4 and 5 had higher nitrate concentrations than the other treatments. The main difference at this location between 1961-62 and 1962-63 appears in sampling depth. In 1961-62, rainfall for three months preceding the first sampling date was 9.2 inches as compared to 5.3 inches in 1962-63. Leaching could have had great influence in moving soil nitrates to a lower depth in 1961-62. For three months preceding the second sampling date rainfall was 4.7 inches in 1961-62 and 2.9 inches in 1962-63. In 1962-63 a residual effect of previous nitrogen treatments can be detected at the higher nitrogen rates.

At the Cherokee stubble mulch location in 1962-63 no difference was found in soil nitrate concentrations with respect to depth. This differs from findings of the previous year and may be partially attributable to rainfall as mentioned above. Soil from the first sampling date contained more nitrates than from the second date, and treatment 5 showed effects of residual nitrogen due to previous nitrogen treatment. In general, the stubble mulched plots of 1962-63 contained fewer nitrates than the clean tilled plots. This same response was observed in the 1961-62 data and has been discussed previously.

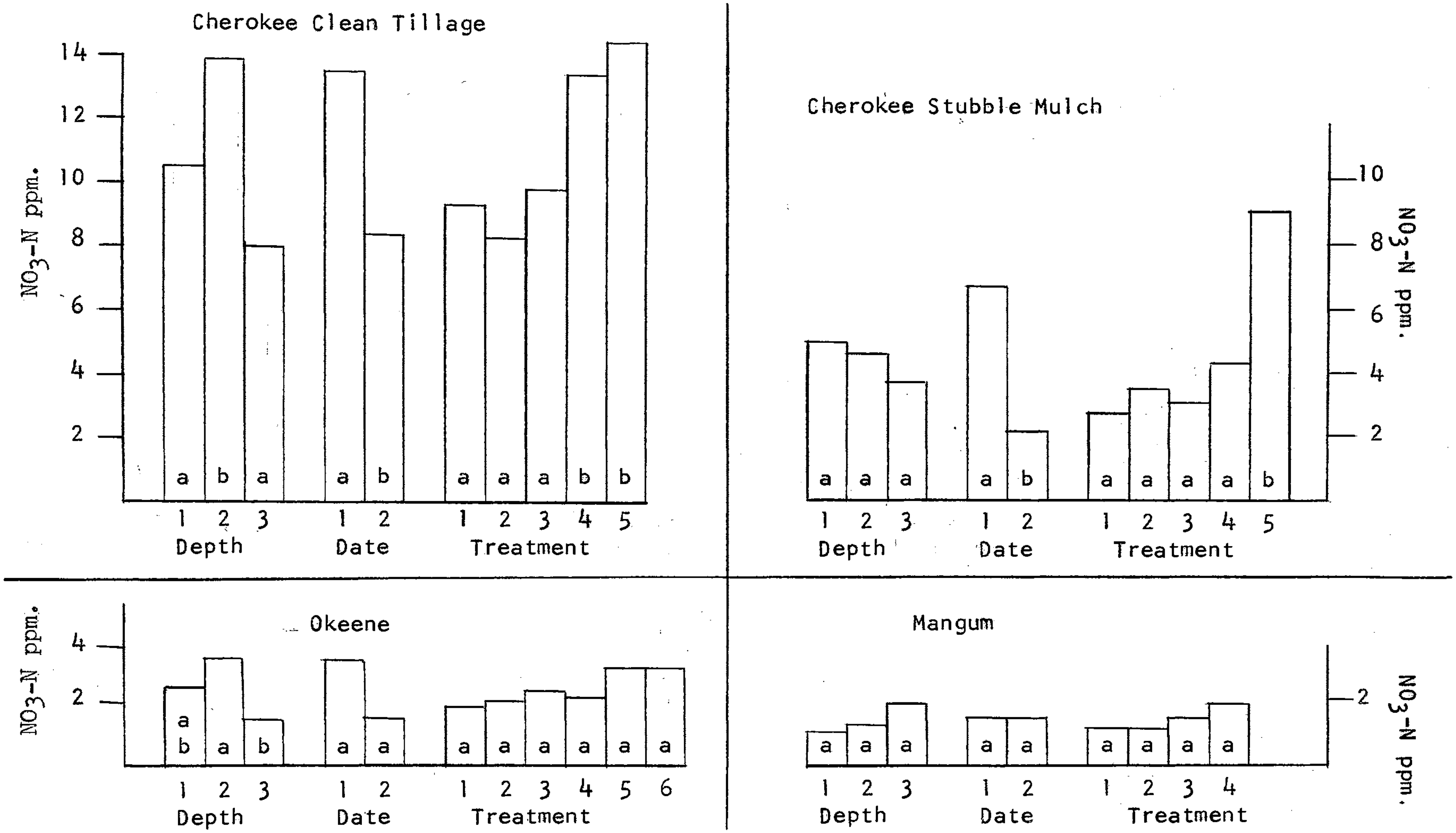


Figure 12. Nitrate Concentrations of Various Soil Depths, Dates and Treatments at Different Locations for 1962-63 Crop Year. (Bars with same letter within a group belong to same population as tested with Duncan's Multiple Range Test at 10% level.)

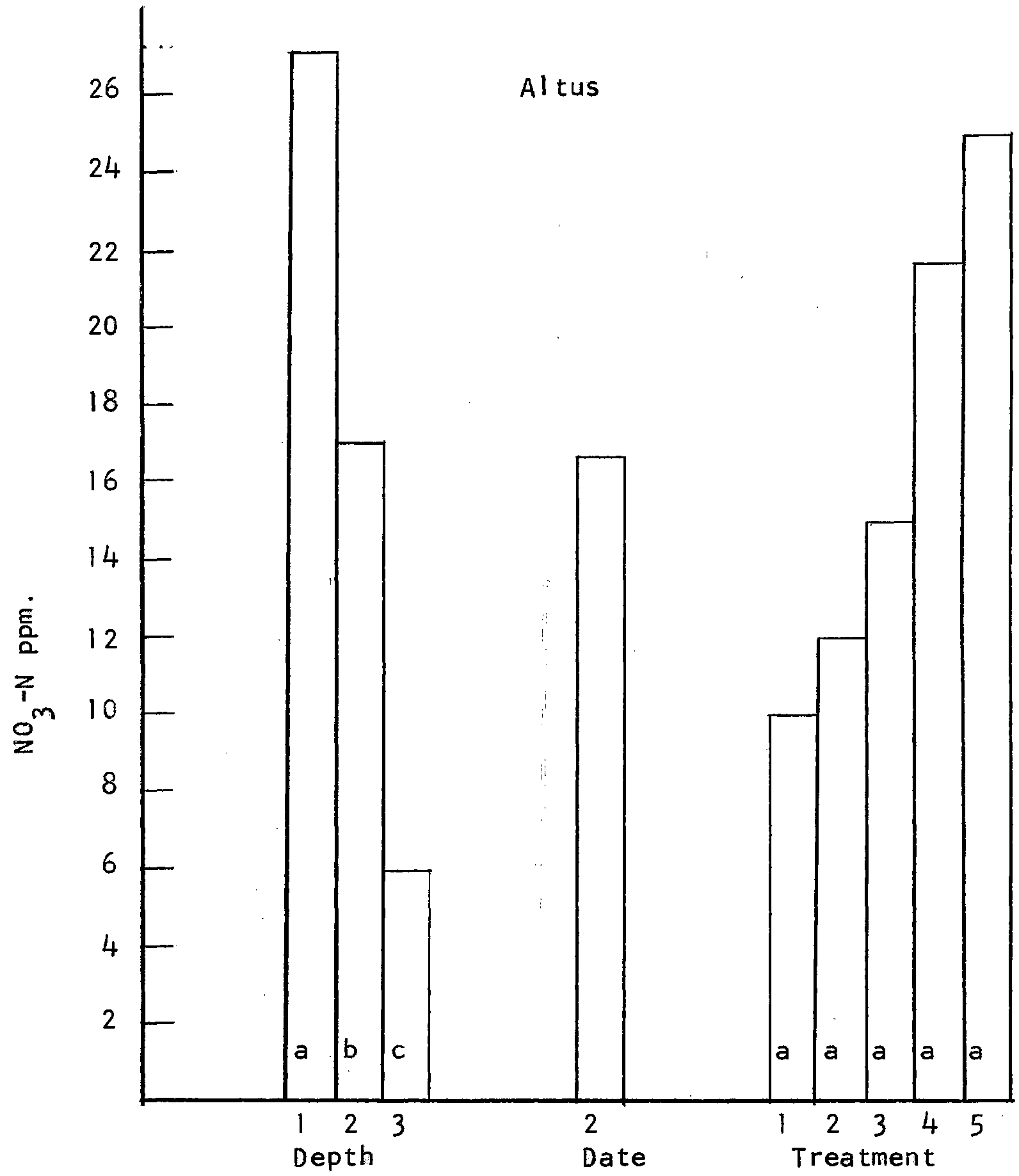


Figure 13. Nitrate Concentrations of Various Soil Depths and Treatments at Altus for Crop Year 1962-63. (Bars with same letter within a group belong to the same population as tested by Duncan's Multiple Range Test at the 10% level.)

Soil at the Okeene and Mangum locations contained a small amount of nitrate, and there was no indication of residual nitrogen effect. At Okeene this is understandable as the nitrogen fertility experiment had been initiated the previous year. This length of time appears inadequate to obtain build-up of nitrogen. As mentioned previously, the soil at Mangum is sandy with a moderately rapid drainage. This may account for the low soil nitrate levels.

Soil nitrate levels at the Altus location are presented in Figure 13. Samples were obtained only on the second sampling date. These data are so similar to the 1961-62 data that no discussion will be made of the results. The reader is referred to the previous discussion.

Additional and more specific information concerning 1962-63 data appears in Figures 14, 15, 16 and 17. These data have not been analyzed statistically. Data from the Cherokee clean tilled and stubble mulched plots appear in Figures 14 and 15. Variation in nitrate concentration was plotted against previous years' nitrogen topdressing treatments for three different depths on the appropriate sampling date. A striking difference in soil nitrate concentrations presents itself between the clean tilled and stubble mulched plots. On the clean tilled plots straw residue is plowed under. This apparently decomposes more rapidly than the surface straw of the stubble mulched plots and nitrogen is therefore not being inactivated by the decomposition process.

Data for the Okeene and Mangum locations are presented in Figures 16 and 17. No definite trend as to carry-over of nitrogen was apparent

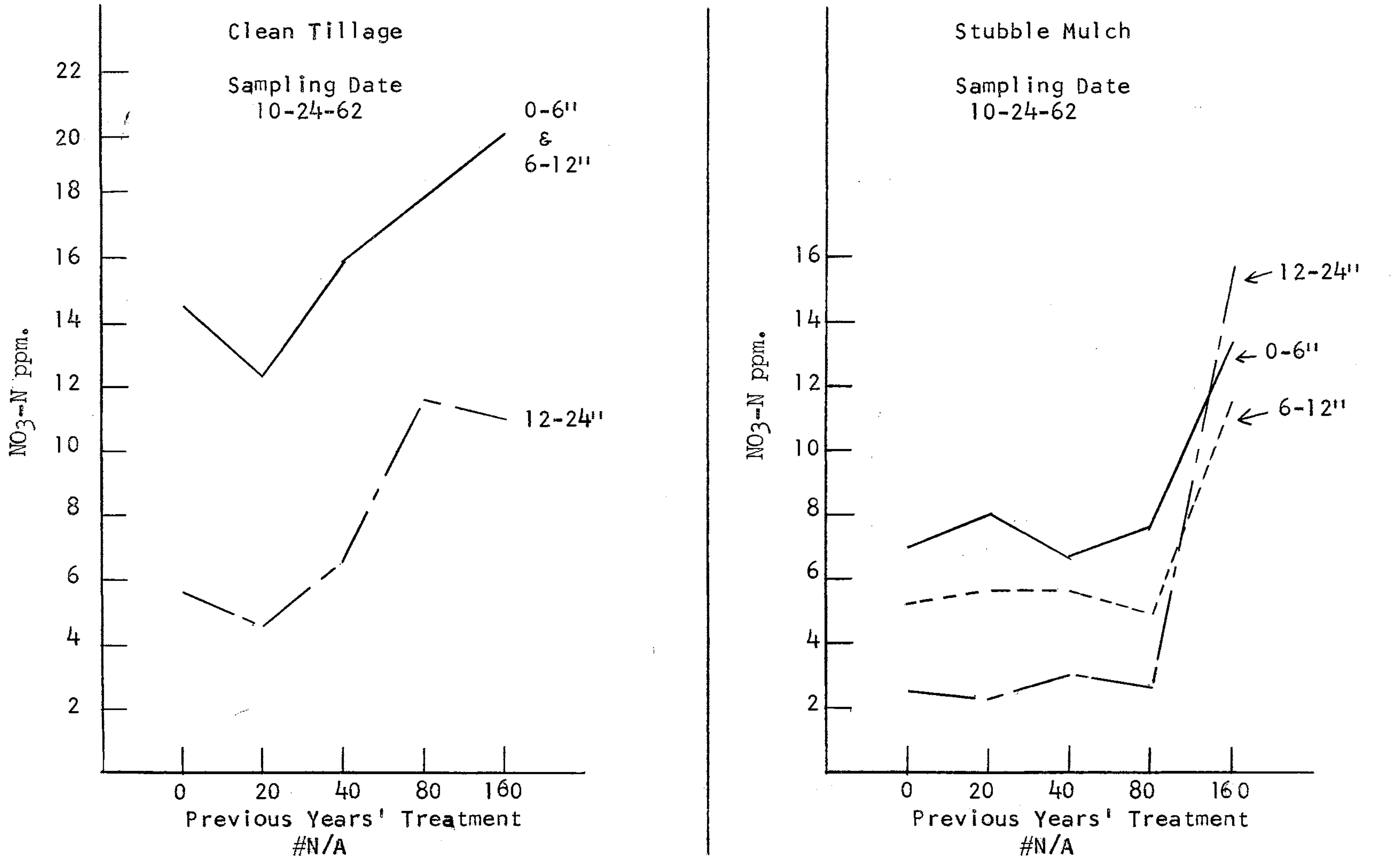


Figure 14. Nitrate Concentrations of Various Soil Depths at Cherokee on the First Sampling Date, 1962-63.

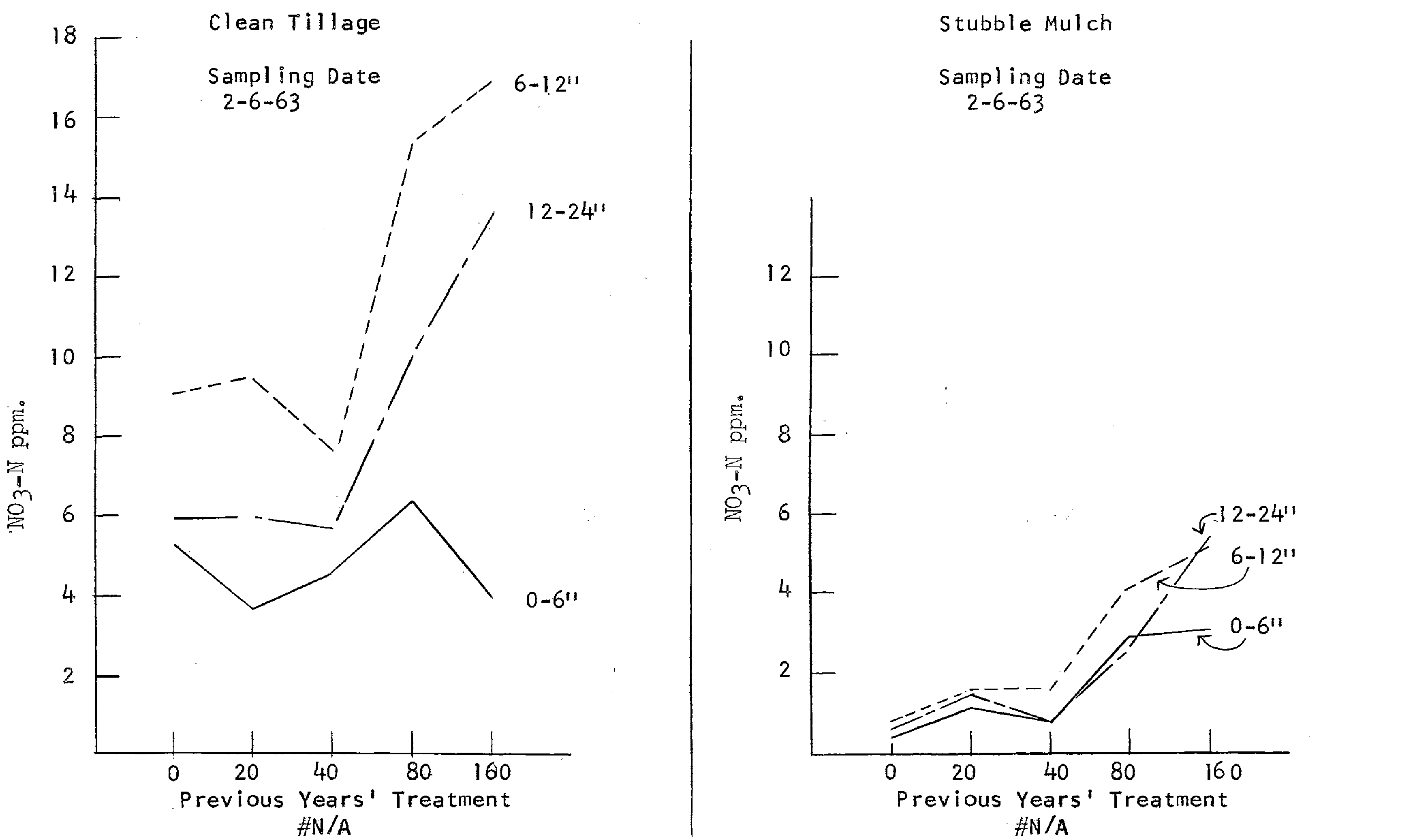


Figure 15. Nitrate Concentrations of Various Soil Depths at Cherokee on the Second Sampling Date, 1962-63.

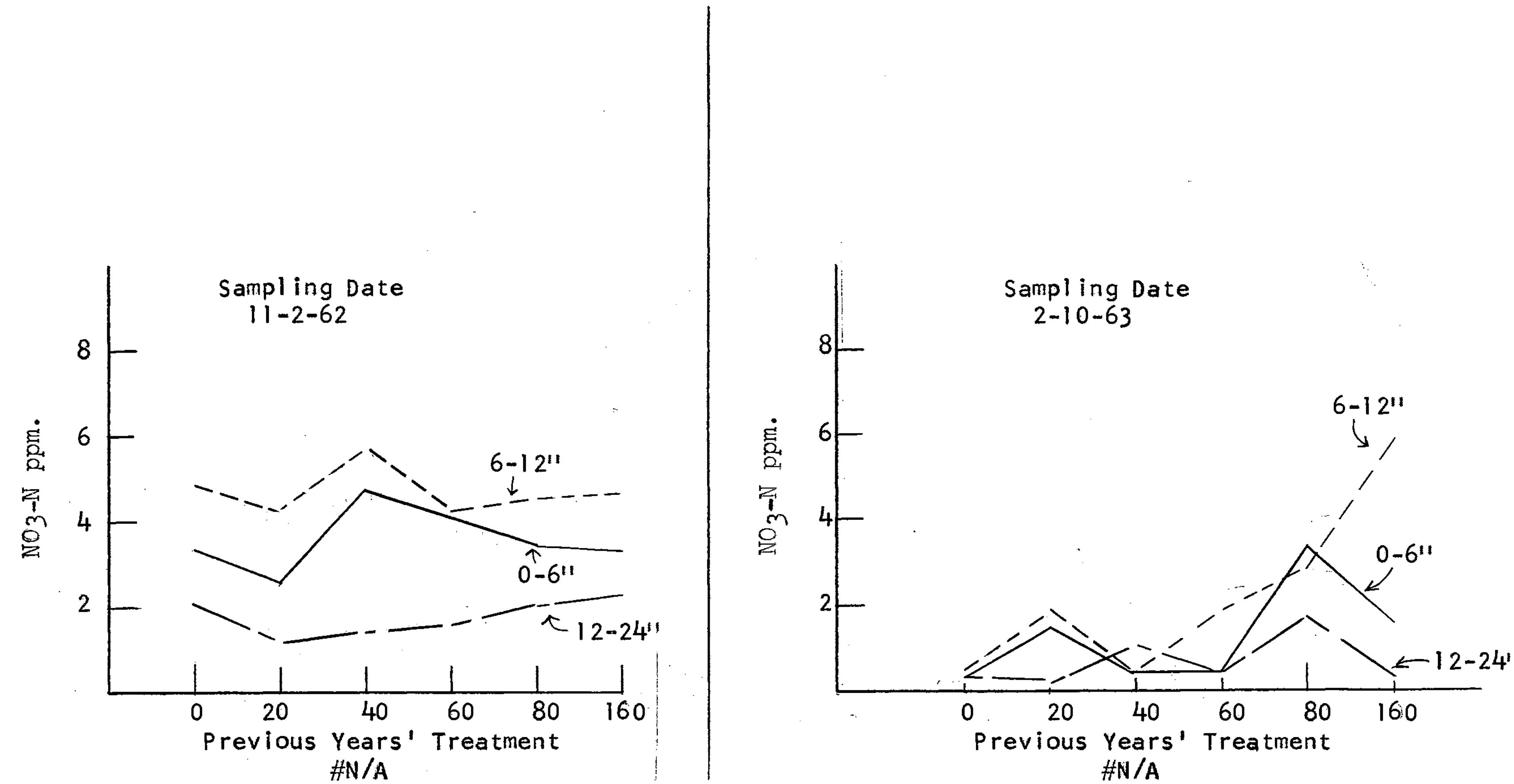


Figure 16. Nitrate Concentrations of Various Soil Depths at Okeene, 1962-63.

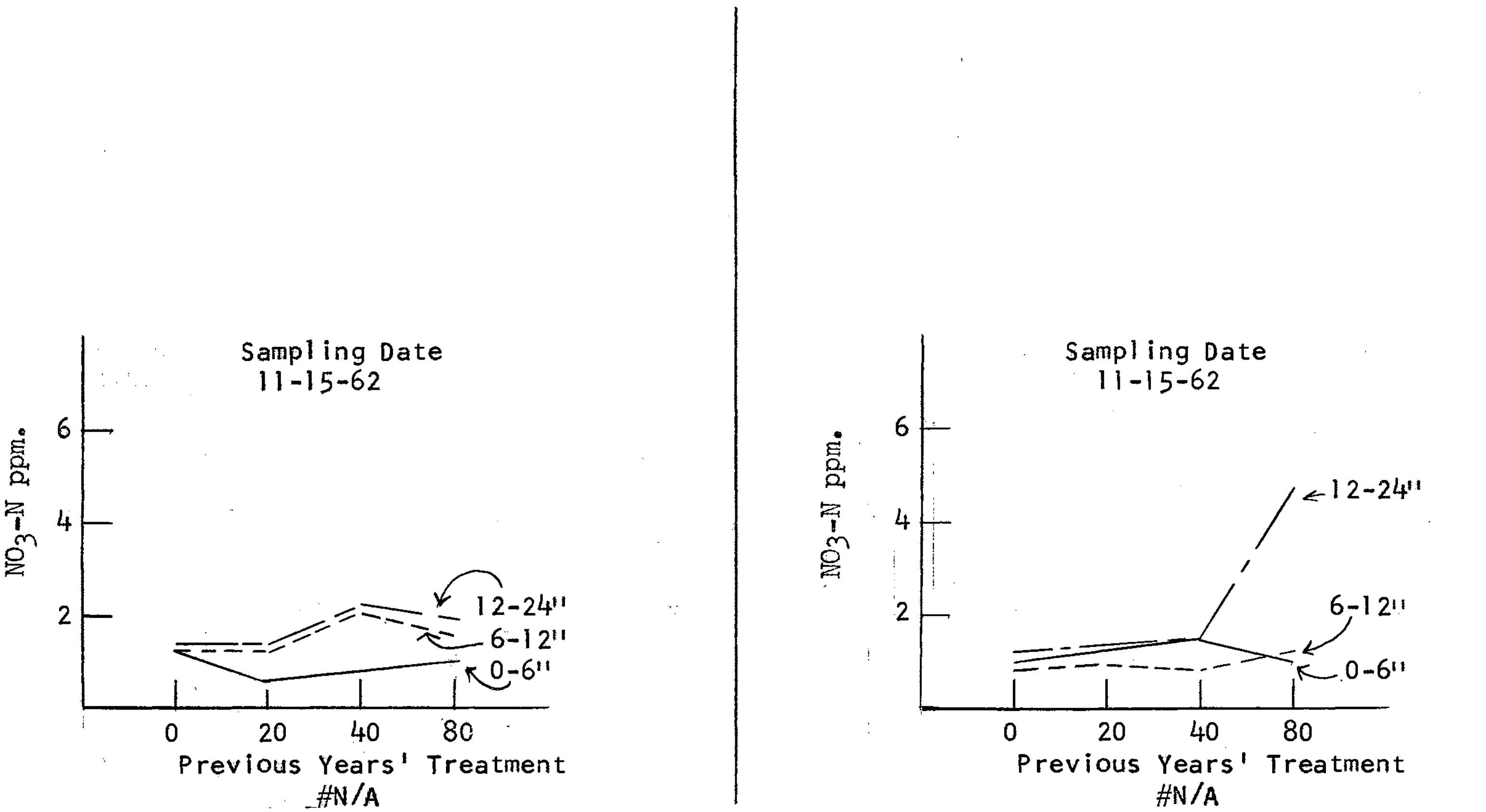


Figure 17. Nitrate Concentrations of Various Soil Depths at Mangum, 1962-63.

at either location. The sandy soils of Mangum were extremely low in nitrates, being similar to the 1961-62 data.

Soil nitrate concentration data concerning the soil at Altus are not presented in a line graph as there was only one sampling date. However, these data are presented in the bar graph of Figure 13.

Summary and Conclusions

From the 1960-61 data it was seen that the detection and measurement of soil nitrates in Oklahoma wheat producing soils were found to be feasible. Three of the soils, namely Carey silt loam, Hollister silty clay loam, and Altus sandy loam behaved similarly throughout the growing season with respect to soil nitrate concentrations. Nitrate concentration of Vanoss loam did not follow the same pattern as the other three soils. It was postulated that this might be attributed to drainage characteristics and rainfall. Generally the maximum nitrate concentration occurred on the first sampling date, November 10, while the minimum occurred on the third sampling date, February 2. From this experiment sampling dates were established for further studies of detecting residual nitrogen on plots with a previous history of nitrogen fertilization.

The 1961-62 and 1962-63 data gave evidence of nitrate accumulation on plots which had been topdressed with 80 to 160 pounds of nitrogen per acre for more than two years previous to sampling. Generally the maximum nitrate concentration was found at the first sampling date. There was no definite pattern of a zone of accumulation for nitrates. Apparently this is governed by many factors including rainfall and temperature.

CHAPTER IV

EFFECT OF FOLIAR NITROGEN APPLICATIONS ON QUALITY OF HARD RED WINTER WHEAT[1]

R. E. Greene, B. B. Tucker, A. M. Schlehuber and Jeff Schlesinger[2]

SYNOPSIS: Spraying wheat at flowering time with urea nitrogen solutions, after an early spring nitrogen topdressing, increased protein content of the grain. Increasing soil nitrogen rates increased protein content of the grain. Increased grain protein contents corresponded to other quality measurements.

As early as 1907 it was reported from Minnesota (24) that "...increasing the amount of nitrogen in the soil increases the amount of nitrogen in the wheat grain." Murphy (19) stated in 1930 that "...the protein content of the grain rises as the amount of nitrogen in the fertilizer is increased."

In 1963 it was reported by Eck et al. (9) that as rate of nitrogen application increased, protein content of the grain increased. In a

[1]This research was partially supported by funds from the Oklahoma Wheat Research Foundation.

[2]Former Graduate Assistant, Associate Professor of Agronomy, and Professor of Agronomy, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma; and Laboratory Director, Union Equity Cooperative Exchange, Enid, Oklahoma.

similar experiment Schlehuber et al. (22) found that wheat quality increased with increasing nitrogen fertilization. This was based on many milling and baking criteria of quality.

For quite some time it has been established that nitrogen fertilization is necessary in order to obtain both high yielding and good quality wheat. At the present time much emphasis is being placed on time and method of nitrogen application. Long and Sherbakoff (14) topdressed two rates of nitrogen at three different dates to soft red winter wheat. They concluded that higher nitrogen applications, especially when applied late, yielded higher nitrogen wheat.

Seth and co-workers (23) studied nitrogen utilization in high and low protein wheat varieties. In both field and greenhouse tests nitrogen in the form of urea or calcium nitrate was applied either as a solid to the soil or sprayed on to aerial portions of the plant. The foliar sprays applied after heading of the wheat resulted in grain with the highest protein content.

Finney et al. (10) sprayed Pawnee winter wheat with urea solutions and determined its effect on yield and quality. Wheat was sprayed at various times before and after flowering. The number of sprayings varied from one to fifteen with rates of nitrogen being equivalent to 10, 30 and 50 pounds of nitrogen per acre. No nitrogen was topdressed to the experiment plots. All added nitrogen was in the form of urea solutions applied as a foliar spray. The use of high concentrations of urea before flowering increased yield, but spraying with urea did not affect test weight. Increases in protein content were obtained by single sprayings with urea. A single spraying at flowering was most effective, increasing protein content 4.4 percent. Grain from plots which received no nitrogen had a protein content of 10.8 percent while grain from plots sprayed 2 days after flowering at a rate of 50 pounds of nitrogen per acre had a protein content of 15.8 percent.

This study was conducted to determine what effect a combination of topdressed and foliar nitrogen would have on yield and quality of wheat with the topdressed nitrogen being applied early in the spring and foliar nitrogen being applied at flowering time.

Materials and Methods

Concho hard red winter wheat (Triticum aestivum L.) was seeded late in the fall of 1961 at the rate of two bushels per acre on Norge fine sandy loam at the Agronomy Research Farm, Paradise, Oklahoma. The experiment was a randomized complete block of three replications with a plot size of 20 by 50 feet. At the time of seeding phosphorous was applied at the rate of 40 pounds of P per acre as concentrated super phosphate and potassium at a 20 pound per acre rate as muriate of potash. On May 12, 1962, which was late in the flowering stage, either urea or ammonium nitrate solutions were sprayed onto the wheat by the use of a Steerman airplane rigged for spraying.[3] These solutions contained 2 pounds of nitrogen per gallon. The plane was calibrated to spray 2 gallons of solution per acre. Enough passes were made to leave the desired amount of nitrogen on the crop. Nitrogen treatments are outlined in Table III.

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[3]The authors are indebted to the Oklahoma Aerial Applicators Association for furnishing the plane and pilot (Frank S. Kimmel, Jr.).

In addition to grain yield, nitrogen and sedimentation values were determined on the harvested grain.

TABLE III

NITROGEN TREATMENTS FOR CONCHO WHEAT GROWN AT PARADISE, OKLAHOMA, 1961-62

Treatment No.	Lbs. N/A	Source of Nitrogen
1	0	-
2	18	Urea
3	36	Urea
4	54	Urea
5	18	Ammonium nitrate
6	36	Ammonium nitrate
7	54	Ammonium nitrate

Tascosa hard red winter wheat (*Triticum aestivum* L.) was seeded in the fall of 1962 at a rate of two bushels per acre on Vanoss loam at the Agronomy Research Farm, Perkins, Oklahoma. At the time of seeding phosphorous was applied at the rate of 50 pounds of P per acre as concentrated super phosphate and potassium at the rate of 70 pounds of K per acre as muriate of potash. The surface soil had a pH of 5.6 and contained 1.85 percent organic matter and 0.110 percent N. The soil was deep and friable.

On March 1, 1963, nitrogen was topdressed at the rate of 0, 40, and 80 pounds per acre as NH_4NO_3. Each nitrogen treatment received additional nitrogen applied as a foliar spray of urea. Rates of foliar application were 0, 18, and 36 pounds of nitrogen per acre. The 18 pound nitrogen rate was applied from a solution which contained 1.2 pounds of nitrogen per gallon. The 36 pound nitrogen rate was applied from a solution containing 2.5 pounds of nitrogen per gallon. All plots were sprayed by two passes with a spray rig attached to a tractor. These rates were applied at flowering time either as a single application on May 1 or as a split application on May 1 and May 2. Soil moisture levels were determined during the growing season, and when moisture approached one-half field capacity, or 7 inches of water in the 48 inch profile, the wheat was irrigated. Irrigations occurred on April 11 and May 9. The experimental design was a split plot of four replications with a factorial arrangement of main plot treatments. Main plots were nitrogen topdressing and method of foliar application. Subplots consisted of rate of foliar application. The wheat was harvested in early June and combine weights were obtained for yield determinations. Protein content of the grain was established by the Kjeldahl method.[4] Test weights were obtained by the usual procedure. The following milling and baking measurements were made: sedimentation value, loaf volume, farinograph peak, and bake quality score.

Due to the expense in running milling and baking tests, analyses were run on composite samples of each treatment.

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[4] Percent nitrogen determined by Kjeldahl method x 5.7 = protein.

Results and Discussion

Yield, protein content and sedimentation values for the Concho wheat are presented in Table IV. This experiment was a preliminary investigation to study the effect of foliar applications of nitrogen on yield and quality of wheat. It should be mentioned that climatic conditions were quite unfavorable. Before, during, and after flowering the wheat was subjected to hot, dry winds. The duration of flowering time was extremely short and the nitrogen applications were made late in the flowering period. Because of the climatic conditions and the lateness of application, the efficiency of nitrogen utilization may have been reduced.

Yield was not affected by foliar applied nitrogen but protein content and sedimentation values increased with larger rates of foliar applied nitrogen. The results of this study encouraged the design of a more intricate experiment the following year. The discussion of the results of this later experiment appears below.

Rate of Topdressed Nitrogen Yield and protein content data for all treatments of the Perkins experiment are presented in Tables V and VI. Where differences were found they were statistically significant at the .005 probability level. There was a statistical difference in yield due to topdressed nitrogen. No difference was detected in yield between the 40 and 80 pound rates of topdressed nitrogen. However, these levels of nitrogen resulted in greater yields than did the untreated plots. The protein content of the grain from the check plots was no different than the grain from plots receiving 40 pounds of nitrogen. The 80 pound rate of nitrogen increased the protein content

TABLE IV

GRAIN YIELD, PROTEIN CONTENT AND SEDIMENTATION VALUES FOR CONCHO WHEAT GROWN AT PARADISE, OKLAHOMA, 1961-62*

Foliar Nitrogen Lbs./Acre	Yield Bu./Acre**	% Protein**	Sedimentation Value**
0	29.4	13.1	48.4
18 Urea	29.4	13.6	55.9
36 Urea	30.0	14.0	64.6
54 Urea	28.1	14.2	67.8
18 Ammonium nitrate	27.1	14.4	77.0
36 Ammonium nitrate	27.8	15.0	71.6
54 Ammonium nitrate	26.9	15.8	72.5

* Each value is average of 3 observations.

** Duncan's Multiple Range Test at .05 probability level.

TABLE V

GRAIN YIELDS AS INFLUENCED BY NITROGEN TREATMENTS

AT PERKINS, OKLAHOMA, 1962-63

Topdressed Nitrogen Lbs/Acre	Grain Yields, Bushels per Acre — Rate of Urea Sprayed (Pounds of N/acre): 0 — Method of Application		18 — Method of Application		36 — Method of Application		Average
	No Split	Split	No Split	Split	No Split	Split	
0	26.6	29.6	26.6	28.8	33.3	32.6	29.6
40	55.2	52.4	55.6	54.4	51.0	59.4	54.7
80	58.7	53.8	60.8	57.0	68.0	57.1	58.0
Average	46.8	45.3	47.7	46.7	48.4	49.7	

Duncan's Multiple Range (.01 probability level)

	Topdressed N*			Foliar N*			Application Method**	
	0	40	80	0	18	36	No Split	Split
Yield Bu./A	29.6	54.7	58.0	46.1	47.2	49.6	47.5	47.2

* Each value is average of 24 observations.

** Each value is average of 36 observations.

TABLE VI

PROTEIN CONTENT OF WHEAT GRAIN AS INFLUENCED BY NITROGEN TREATMENTS AT PERKINS, OKLAHOMA, 1962-63

Topdressed Nitrogen Lbs/Acre	Grain Protein, Percent — Rate of Urea Sprayed (Pounds of N/acre): 0 — Method of Application		18 — Method of Application		36 — Method of Application		Average
	No Split	Split	No Split	Split	No Split	Split	
0	11.7	11.9	12.8	12.9	13.7	14.0	12.8
40	12.1	12.1	12.4	13.0	13.7	13.7	12.8
80	14.0	13.8	14.7	14.6	14.9	15.2	14.6
Average	12.6	12.6	13.3	13.5	14.1	14.3	13.4

Duncan's Multiple Range (.01 probability level)

	Topdressed N*			Foliar N*			Application Method**	
	0	40	80	0	18	36	No Split	Split
Protein (%)	12.8	12.8	14.6	12.6	13.4	14.2	13.3	13.5

* Each value is average of 24 observations.

** Each value is average of 36 observations.

of the grain. It appears that the initial 40 pounds of nitrogen was utilized to increase the yield, whereas the next increment of 40 pounds of nitrogen was utilized to increase protein content of the grain. Forty pounds of nitrogen per acre increased the yield by 20 bushels per acre with no change in protein content (Tables V and VI). Apparently the absolute amount of nitrogen in all the grain produced increased with the 40 pound rate but not enough to increase the concentration of nitrogen in the grain. The 80 pound nitrogen rate did not increase yield over the 40 pound rate but increased the nitrogen concentration in the grain as expressed by percent protein. Pounds of nitrogen removed per acre[5] by the crop at the rates of 40 and 80 pounds of nitrogen per acre were significantly greater than at the 0 nitrogen rate. Test weight was not affected by rate of topdressed nitrogen.

Timing of Application of Foliar Nitrogen Nitrogen as urea was applied as a foliar spray in a single application and a split application. This was done at flowering time, the single application date being May 1, 1963, and the split application occurring on May 1 and May 2, 1963. No difference was found in any of the variables measured due to application procedure. However, there may not have been enough time allowed for absorption before the second application was applied. It is possible with more time between applications more absorption could have occurred.

Rate of Foliar Applied Nitrogen There was no difference in yield due to different rates of foliar applied urea nitrogen except where no

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[5]Pounds of nitrogen removed per acre = yield x test weight x % protein/5.7

topdressed nitrogen was applied. In this case the 36 pound foliar application rate increased yields to a slight extent (Table V). An increase in protein content was obtained from foliar application. A foliar application rate of 18 pounds of nitrogen per acre gave an increase of 0.8 percent in protein content over the check, and the 36 pounds of nitrogen per acre rate increased protein content 0.8 percent (Table VI). Foliar application of nitrogen also had an effect of increasing test weight at the higher nitrogen rates. As might be expected, the pounds of nitrogen removed per acre increased with increasing nitrogen applications.

As mentioned previously, the 40 pounds of nitrogen per acre increased yield with no resulting increase in protein. The 80 pounds of nitrogen per acre rate did not increase yield as compared to the 40 pound rate but did result in a higher protein content of the grain. From previous experiments performed by the authors this was to be expected. This experiment was designed to ascertain whether a smaller amount of foliar applied nitrogen at flowering time would result in the same increase in protein content as could be obtained from higher topdressed nitrogen rates. Upon examination of the data in Tables V and VI it can be seen that the combination of 0 pounds of topdressed nitrogen and 36 pounds of foliar nitrogen per acre did not approach the same yield as the 40 pounds of topdressed nitrogen and 0 pounds of foliar nitrogen per acre, and protein content of the grain was also different. Yields were similar for the rates of 40 and 80 pounds of nitrogen per acre with and without foliar applied nitrogen. However, the protein content at the 80 pound rate was greater. It was thought that when high yields of rather low protein wheat were produced the protein could be substantially increased by foliar nitrogen applications. The data obtained from this study does show that the protein was increased by foliar applications of urea but not to the desired degree.

Baking and Milling Data Baking and milling data are presented in Table VII. These data represent analyses performed on only a composite of each treatment due to the cost of analyses. Because of the compositing no statistical analysis could be performed.

Sedimentation Values Sedimentation values have recently been established to determine premium prices paid for wheat. In this experiment sedimentation values increased when larger amounts of nitrogen were applied to the crop. This was true on the main plot treatments as well as the split plots. Method of application had no effect on sedimentation values. In general, sedimentation values were closely related to grain protein contents.

Loaf Volume Loaf volume has long been regarded by many cereal chemists to be a good criterion of wheat quality, and some believe it to be the best single criterion of wheat quality. In general, loaf volume increased as amount of nitrogen supplied to the crop increased, regardless of whether the nitrogen was applied to soil or sprayed on the plants. This was especially true after the highest yield had been attained.

Farinograph Peak The farinograph peak values are a measurement of inherent dough-mixing characteristics. Generally the greater values are related to better quality characteristics. Peaks were substantially increased by foliar urea applications on plots receiving 0 and 40 pounds of topdressed nitrogen. On plots receiving 80 pounds of soil nitrogen the urea sprayings had little effect on the farinograph peaks. Soil nitrogen was also instrumental in increasing peak values.

Bake Quality Score As bake quality score increases in value so does over-all bread quality. As might be expected from reflections of other quality criteria, bake quality score increased with increased nitrogen rate.

TABLE VII

BAKING AND MILLING DATA OF WHEAT AS AFFECTED BY NITROGEN TREATMENTS AT PERKINS, OKLAHOMA, 1962-63

Topdressed Nitrogen Lbs./Acre	Urea Spray: Method of Application	Urea Spray: Lbs. N/Acre	Sedimentation Value CM.^{3}	Loaf Volume CM.^{3}	Farinograph Peak Minutes	Bake Score
0	No split	0	30	2265	2.0	56
		18	40	2230	6.5	55
		36	60	2415	7.0	73
0	Split	0	34	2195	6.8	48
		18	44	2180	6.5	53
		36	62	2310	6.2	62
40	No split	0	37	2240	2.0	58
		18	44	2275	6.0	62
		36	53	2420	6.0	75
40	Split	0	34	2060	2.2	47
		18	43	2220	5.5	55
		36	54	2195	6.0	54
80	No split	0	52	2525	6.5	77
		18	53	2640	6.5	84
		36	64	2620	6.0	84
80	Split	0	59	2455	6.0	71
		18	62	2530	6.0	79
		36	63	2560	7.0	82

Conclusions

A rate of 40 pounds of nitrogen per acre increased wheat yields as compared with the check but did not increase percent protein in the grain. A rate of 80 pounds of nitrogen per acre did not increase yield with respect to the 40 pound rate but did increase protein content. Additional nitrogen supplied as urea in the foliar spray also increased percent protein of the grain but not to as great an extent as had been reported by other investigators. The timing of application of foliar applied nitrogen affected neither yield nor percent protein of the grain. In general, other quality measurements indicated improvement in wheat quality with increasing nitrogen rates in about the same relationship as protein content.

In this study additional soil nitrogen was instrumental in bringing the protein content to moderate levels, but the spraying of urea on the foliage was not more efficient than the additional soil application. Protein contents were not further increased above the moderate levels by urea spraying at the bloom stage.

CHAPTER V

SUMMARY AND CONCLUSIONS

This research had two objectives. These were: 1. To investigate soil nitrate levels at various depths and dates throughout the growing season; and 2. To investigate the possibility of increasing protein content of hard red winter wheat by the use of foliar applications of a nitrogen solution used in conjunction with topdressed nitrogen. In order to carry out these objectives two different experiments were designed.

The investigation of soil nitrate levels showed that detection and measurement of soil nitrates in Oklahoma wheat producing soils were feasible. The data gave evidence of soil nitrate accumulation on plots which had been topdressed with 80 to 160 pounds of nitrogen per acre for more than two years previous to sampling. Generally the maximum soil nitrate concentrations occurred early in the growing season shortly after planting time.

The second objective showed that a rate of 40 pounds of nitrogen per acre increased wheat yields as compared with the check but did not increase percent protein in the grain. A rate of 80 pounds of nitrogen per acre did not increase yield with respect to the 40 pound rate but did increase protein content. Additional nitrogen supplied as urea in the foliar spray also increased percent protein of the grain but not to as great an extent as had been reported by other investigators. The method of application of foliar applied nitrogen, split or no split, affected neither yield nor percent protein of the grain. In general, other quality measurements indicated improvement in wheat quality with increasing nitrogen rates in about the same relationship as protein content.

In this study additional soil nitrogen was instrumental in bringing the protein content to moderate levels, but the spraying of urea on the foliage was not more efficient than the additional soil application. Protein contents were not further increased above the moderate levels by urea spraying at the bloom stage.

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