THE VALUE OF THE NO_3-N SOIL TEST IN WINTER WHEAT PRODUCTION

BY

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CHAPTER I

INTRODUCTION

Nitrogen fertilization is playing an increasing role in profitable wheat production. However, the cost per unit of return necessitates the efficient use of N fertilizers. The NO_3-N soil test has been developed to measure carry-over fertilizer and mineralized soil N. It has been established that the NO_3-N test is useful if the soil sample is collected just prior to seeding. There is a need to assess available soil N at topdressing time in late winter or early spring. The validity of the NO_3-N test for this purpose has been questionable, and more information is needed to determine its value when taken from a field with growing small grain crops.

The NO_3-N test currently in use has been calibrated for total NO_3-N in the 0-15 and 15-60 cm depths. Efforts have been made to get both surface and subsurface samples taken for assessing the soil N status. Currently about 15% of the samples from wheat fields sent to the Soil Testing Laboratory at Oklahoma State University include the subsoil sample.

The objectives of this study were:

1. To determine the correlation of soil NO_3-N with

yield response of winter wheat to N fertilizer applications.

2. To measure the effect of N rates, sampling date, and sampling depth on the utility of the NO_3-N soil test.

CHAPTER II

LITERATURE REVIEW

Numerous researchers (8,24,25) agree that residual N is mainly found in the NO_3-N form in the soil. White and Pesek (25) found that as much as 90% of the total variations in N yield of oats were accounted for by the multiple regression of N yield on NO_3-N found to a depth of 52 cm. White, Dumenil, and Pesek (24) have found that residual N may account for as much as 49% of the N application rate made to corn in the previous year when a rate of 202 kg N/ha was applied. At rates from 45 to 112 kg N/ha, it was estimated that carryover of initial applications would be 10-15% following wet seasons and 35-40% following dry seasons. These researchers seem to make it apparent that with increased use of N fertilizer there is a need to determine the residual NO_3-N in the soil and thus adjust the fertilizer application for the coming cropping season accordingly. Herron et al. (8) found that in order to utilize the residual NO_3-N in Nebraska soils it may be necessary to reduce N fertilizer rates at three- to four-year intervals to prevent NO_3-N from leaching out of the root zone.

Since the NO_3-N soil test is important for establishing guidlines for fertilizer N application rates, the literature review includes the following topics:

1. Correlation of soil NO_3-N with N response of field crops.
2. Effect of plant growth or sampling date on NO_3-N levels in the soil.
3. Effect of sampling depth on the value of the NO_3-N soil test for predicting N response.

Correlation of Soil NO_3-N with N Response of Field Crops

Soil N levels have long been used to predict N response. Use of initial NO_3-N in soil has recently been accepted as a method for assessing N needs. Many researchers (3,4,5,10, 15,18,20,26) have incorporated N levels in soils into equations with soil and climatic factor variables along with N applications to predict yields of various crops.

Cook, Warder, and Doughty (1) in some early work correlated initial soil NO_3-N levels plus NO_3-N accumulation by incubation with yield response of wheat in some Saskatchewan soils and obtained a correlation coefficient of $r = 0.75$. Continued research on Manitoba soils by Soper, Sims, and Peaslee (16) and Soper and Huang (17) over a six-year span gave similar results. The results indicated that the amount of N barley extracts from the soil could be predicted from initial NO_3-N at seeding time. They pointed out that NO_3-N should not be ignored when making fertilizer recommendations.

Grunes et al. (7) showed that values of soil NO_3-N correlated highly with several parameters of N availability to plants. The various parameters of N availability were: 1) percent yield (dry weights), 2) total mg N in non-N plots, and 3) percent yield (total mg N absorbed). These values, when correlated with initial NO_3-N found in the soil, gave the highest correlation coefficient ($r = 0.96$) of all methods of determining N availability. Other methods in their respective order of predicting N availability were NO_3-N produced in three-week incubation, NO_3-N produced in six-week incubation, and NO_3-N in incubated plus initial NO_3-N in non-incubated soil. This study was done in the greenhouse with spring barley, using soils over a wide geographic area.

Ryan, Sims, and Peaslee (16) found differing results in that initial NO_3-N at sampling did not correlate with N uptake of sorghum in a greenhouse experiment. This work supported biological methods of determining N uptake. The summary stated that initial mineral N is an unreliable index of N availability in plants.

Peterson, Attoe, and Ogden (15) found poor correlation of initial soil NO_3-N with N availability in field experiments with tobacco. The results were correlated with only the surface 15 cm of soil, which may explain the poor correlations. Sampling depth will be covered in another section of the literature review.

In work by Waring and Teakle (22) no relationship was found between initial NO_3-N and yield of wheat. This work, however, was with soils containing levels of residual NO_3-N which exceeded the need for more N.

Many different crops were used to establish relationships between soil tests and available N in western states by Spencer, MacKenzie, and Viets (19). They used corn, sugar beets, sorghum, and cotton to assess the reliability of a N soil test with field responses to additional N. In all cases the correlations of soil N tests were based on N uptake of the crop with no additional N added. In general, the initial NO_3-N in the soil at seeding and nitrifiable N by incubation gave the best estimates of N uptake of all four crops. They pointed out that with further correlation work, initial NO_3-N may be useful in predicting N fertilizer needs in desert soils low in organic matter. This would be applicable because differences in available N are due to past fertilization and management practices.

Leggett (10) showed a relationship of available N and yield of winter wheat from 62 experimental sites in eastern Washington dryland areas in the following equation:

$$Y = 793 + 23.39\ (NO_3\text{-N} + \text{Fertilizer N}) \quad (r = 0.74) \qquad (2.1)$$

Leggett (10) pointed out that it takes approximately 4 kg of N to produce 100 kg of grain to a level of 180 kg N/ha in this experiment. He also pointed out that the NO_3-N in the soil can be interchanged with fertilizer N applied. Onken and Sunderman (13) support this work in stating that they found residual and applied N were interchangeable in the regression equation for their data.

Geist (4), in a study with barley, found that initial NO_3-N + NH_4-N present in the soil to 60 cm at seeding time plus the fertilizer applied were the primary factors that influenced grain yield and protein content. With an increase of fertilizer N plus NO_3-N in the soil, grain yields increased sharply until the total available N reached 100-112 kg/ha. Higher levels of available N were found to decrease yields due to some lodging. Other work with barley by Gasser and Williams (3) supported the use of initial NO_3-N + NH_4-N content of the surface soil samples to predict the barley grain N levels of unfertilized field plots.

Greene (6), working with Oklahoma soils over a period of three years, found the NO_3-N test feasible for assessing N fertilizer needs. Nitrate-nitrogen accumulation was noted on plots receiving 90-180 kg N/ha for more than two years previous to sampling. No correlations or regression equations were developed from this work.

Work on Oklahoma wheatland soils by Webb (23) showed differences in N response on stubble mulched vs. clean tilled plots. In this study it was found that 45 kg N/ha was needed to maximize yields with stubble mulching, while 22 kg N/ha was needed in clean tilled plots. The clean tilled plots consistently gave higher NO_3-N readings at the fall sampling dates.

Work on correlating NO_3-N with winter wheat grain yields and protein content seems limited in Oklahoma, suggesting the need for further investigations on this topic.

Effect of Plant Growth or Sampling Date on NO_3-N in the Soil

Research work concerning NO_3-N as a means of predicting N fertilizer needs has been limited to sampling just prior to seeding time. Little work has associated sampling date with the level of NO_3-N in the soil. Nitrate-nitrogen is known to vary greatly in the soil over time. With a better understanding of the effect of plant growth or sampling date on the level of NO_3-N in the soil, fertilizer N needs of a crop could be more closely predicted.

Ward (21) points out that the level of NO_3-N varies in the soil during the year. Soil samples for winter grains should be taken within six weeks of planting time. He states that this may be one shortcoming of the NO_3-N test. In later work, Ward (20) found NO_3-N was significantly different for sampling date on corn in two of three areas studied in eastern South Dakota. The study was conducted with sampling dates at the beginning, middle, and end of the growing season. The middle sampling date gave the lowest NO_3-N values. These sites had N applied for a period of three years previous to this study, with rates up to 358 kg N/ha.

Soper and Haung (17) made a similar study with barley on nine locations in Manitoba. Samples were taken to 120 cm at seeding, heading, and harvest time to determine the extent of removal of NO_3-N from the soil. The results showed that seven of the nine plots were virtually depleted of NO_3-N at harvest time. Highest levels were found at seeding. The two soils still containing substantial amounts of NO_3-N at harvest time contained in excess of 112 kg N in the 0-120 cm root zone at seeding. All other soils contained from 17 to 81 kg N in a similar root zone. This may suggest that more N was available to the crop at those two sites than was needed. Soper and Haung pointed out that NO_3-N depletion was not closely related to moisture depletion in the root zones.

Work by many researchers (5,9,14,20) supports the points brought out by Ward (20,21) and Soper and Huang (17).

In relating sampling date to winter wheat production, Leggett (10) found that the soil NO_3-N is generally low following a previous crop that had made good growth and yield if N fertilization was not high. He pointed out that if sampling is delayed until spring, the soil NO_3-N will be low, especially with considerable growth in the fall and winter.

Webb (23) found generally lower NO_3-N levels in the root zone (0-60 cm) in the February sampling than in the October sampling on both clean tilled and stubble mulched plots on a Pond Creek silt loam in Oklahoma. The NO_3-N dropped more rapidly in the 0-15 cm sampling depth than in lower depths.

Greene (6) conducted a more extensive study of sampling date on Oklahoma wheatland soils. The soil types in this study included Vanoss loam, Carey silt loam, Hollister silty clay loam, Altus sandy loam, Grant silt loam, and Kingfisher silt loam. Rates of N applied ranged from 0 to 180 kg/ha. The first year generally showed the highest concentration of NO_3-N in November and lowest in February. The next two years' data showed evidence of NO_3-N accumulation on plots with 90-180 kg N/ha applied previously. The NO_3-N again was highest at a fall sampling and decreased thereafter. One soil did not follow this pattern. Vanoss loam remained high throughout the growing season until harvest. This was attributed to drainage characteristics and rainfall.

Effect of Sampling Depth on the Value of the NO_3-N Test for Predicting N Response

Sampling depth is important when considering the levels of NO_3-N available to the crop. Nitrate-nitrogen is readily soluble in water and therefore moves in the rooting zone much the same as does water. Ward (21) pointed out that NO_3-N leaching is not a problem west of a line from International Fall, Minnesota to near Oklahoma City and on south into Texas. This would make the NO_3-N soil test more valuable in these areas. Nitrate-nitrogen would be available to the crop throughout the growing season without fear of it leaching out of the rooting zone.

Many researchers (1,2,4,5,10,12,17,18) support the importance of deep sampling as a more accurate measurement of NO_3-N for predicting N response. Giest (4) reported that initial NH_4-N + NO_3-N present in the soil to a 60-cm depth plus fertilizer N was the primary soil-N factor influencing yield and protein of barley grain.

Work by Soper and Haung (17) showed the best correlations of yield response to N was with NO_3-N when samples were taken to a depth of 120 cm ($r = 0.95$). It is quite likely that the level of NO_3-N in the 0-15 cm depth of soil will vary greatly over short periods of time.

Later Soper, Racz, and Fehr (18) correlated various depths of Manitoba soils with response of barley to N. The sampling depths considered were 0-15, 15-30, 30-60, 60-90, and 90-120 cm. Correlation coefficients increased from $r = 0.56$ for the 0-15 cm depth to the highest $r = 0.92$ for the 0-60 cm increment. The regression equation for N taken up by the barley and NO_3-N in the soil from 0-60 cm was the following:

$$Y = 2.03 + 2.57\ X - 0.016\ X^2 \qquad (2.2)$$

where Y is the total N in the above-ground portion of the barley and X is the kg NO_3-N/ha in the 0-60 cm root zone. These results indicate that the amount of N that a crop such as barley can extract from the soil can be reasonably predicted from initial NO_3-N, providing sampling depth is sufficient. This is in agreement with Leggett (10), Herron et al. (8), White and Pesek (25), and Young et al. (26), who have found that the accuracy of NO_3-N as a measure of available soil N increased with sampling depth.

Interesting work by Onken and Sunderman (13) showed a strong relationship with the amount of NO_3-N found in the top portion of the rooting zone and the amount found in the next increment ($r = 0.90$). A lower correlation ($r = 0.65$) was found using the surface 15 cm to predict the total amount in a 60-cm increment. They found sampling to 30 cm was adequate in two locations in the high plains of Texas for predicting grain yield of sorghum. It was shown that only 20-30% of the total NO_3-N in a soil profile to 90 cm was in the surface 15 cm for plots receiving from 0-180 kg N/ha. Peterson, Attoe, and Ogden (15), however, found poor correlation with NO_3-N in the 0-15 cm layer and N availability to tobacco on 37 sites in Wisconsin. They suggested using deeper sampling.

Greene (6) and Webb (23) found no apparent zones of accumulation for NO_3-N on Oklahoma soils. However, both studies point out a need for deep sampling to at least 60 cm. Webb (23) points out that NO_3-N accumulation was generally lower in the 0-15 cm increment. The 15-30 and 30-60 cm depths contained higher levels of NO_3-N in the spring sampling of winter wheat. Fall sampling generally gave the inverse, with 0-15 cm depth containing the greatest amount of NO_3-N. This work was on a Pond Creek silt loam near Cherokee, Oklahoma.

CHAPTER III

MATERIALS AND METHODS

This study was conducted at nine farmer-cooperator sites and at five continuing fertility trials established by Dr. Billy Tucker of the Agronomy Department. Winter wheat was grown on all sites.

Location, cooperator, and soil classification are listed for each site in Table I. Sites will hereafter be denoted by the corresponding number found in Table I and Figure 1. Sites 1 and 11 were irrigated.

Field Studies

Cooperator Sites

Sites 1 through 9 are farmer-cooperator sites. These sites were established in a randomized, complete block design with four replications. Treatments consisted of 0, 45, 90, and 135 kg N/ha. The N was applied as NH_4NO_3 (34-0-0). Plot size was 4.8 x 22.5 meters. The NH_4NO_3 was applied in the fall at the first soil sampling date.

Soil sampling dates, percent ground cover by the winter wheat at a given soil sampling date, and harvest date are outlined in Table II. Percent ground cover was designated as 0%, being bare soil, to 100%, being a lush, thick growth

TABLE I

EXPERIMENT SITES AND SOIL CLASSIFICATION

Exp. No.	Location	Cooperator	Soil Classification
1	Texas County SW¼,Sec 10, T1N, R13E	L & H Farms	Ustollic Calciorthid Potter Silt Loam
2	Harper County SW¼, Sec 17, T27N, R22W	Max Barth	Pachic Argiustoll St. Paul Silt Loam
3	Grant County NW¼, Sec 7, T25N, R4W	Don Kirby	Alfic Ustipsamment Derby Loamy Sand
4	Noble County NW¼, Sec 11, T22N, R1W	John Steichen	Udertic Paleustoll Kirkland Silt Loam
5	Washita County NW¼, Sec 36, T11N, R17W	George Klaasen	Typic Paleustoll Tillman Silt Loam
6	Washita County SW¼, Sec 2, T9N, R17W	George Klaasen	Typic Ustochrept Vernon Very Fine Sandy Loam
7	Jackson County NW¼, Sec 29, T2N, R20W	Hatton McMahon	Typic-Pachic Paleustoll Tillman-Hollister Clay Loam
8	Cotton County NW¼, Sec 3, T3S, R11W	Lee Langford	Typic Natrustoll Foard Silt Loam
9	Stephens County NW¼, Sec 9, T1S, R4W	Ringer Estate	Cumulic Haplustoll Port Fine Sandy Loam
10	Irrig. Res. Sta. Altus, OK	Exp. No. 407	Typic-Pachic Paleustoll Tillman-Hollister Clay Loam
11	Irrig. Res. Sta. Altus, OK	Exp. No. 406	Typic-Pachic Paleustoll Tillman-Hollister Clay Loam
12	N.C. Exper. Sta. Lahoma, OK	Exp. No. 502	Pachic Agriustoll Pond Creek Silt Loam
13	Agron. Res. Sta. Stillwater, OK	Exp. No. 222	Udertic Paleustoll Kirkland Silt Loam
14	Canadian Co. Farm El Reno, OK	Richard Sestak	Pachic Haplustoll Dale Silt Loam

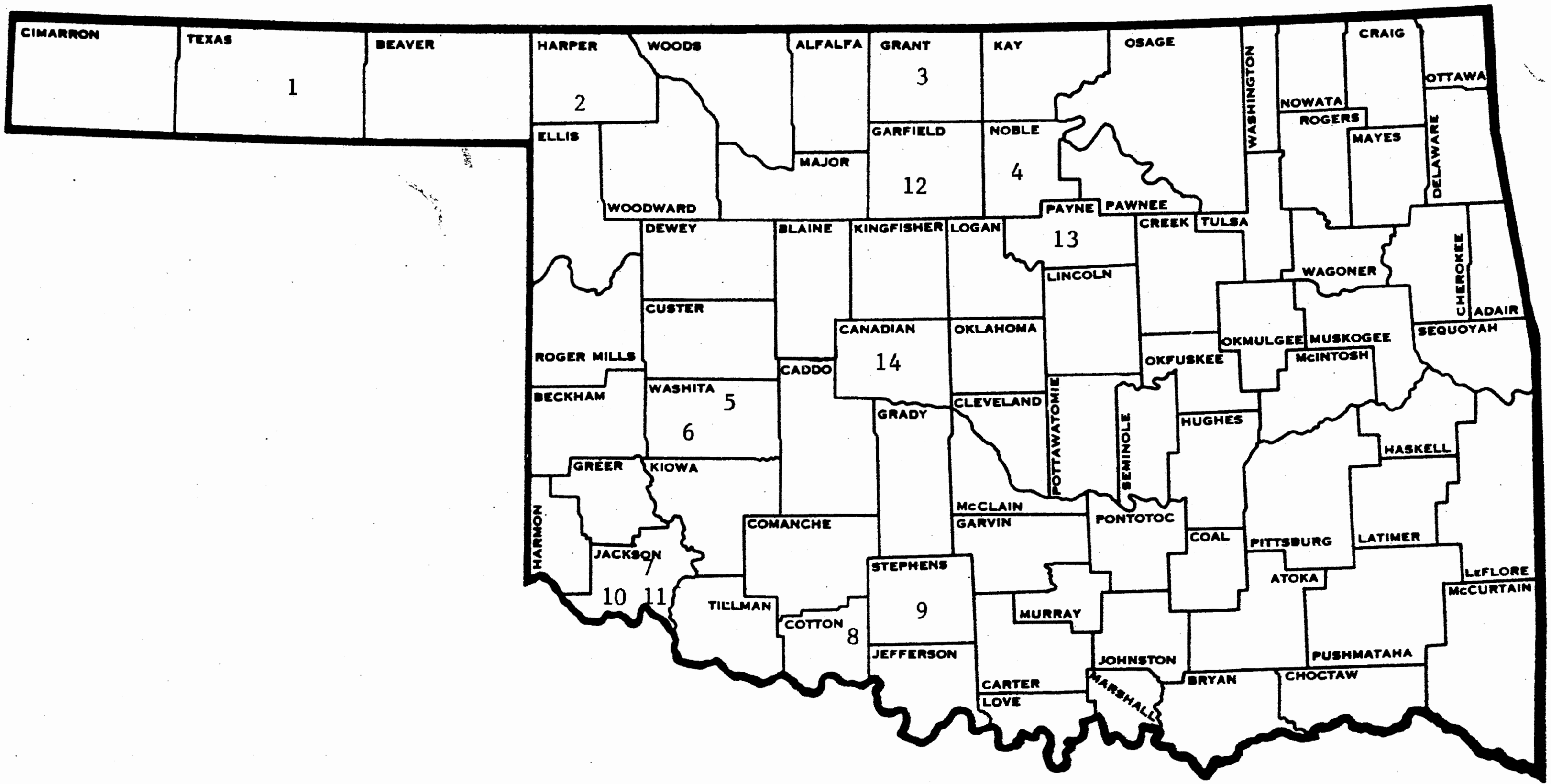

Figure 1. Locations of N Fertilizer Tests Outlined in Table I.

TABLE II

SOIL SAMPLING DATES, PERCENT CROP COVER, AND HARVEST DATE

Exp. No.	Date 1	% Cover	Date 2	% Cover	Date 3	% Cover	Date 4	Date 5	Harvest
1	11/20/75	20		Grazed		60	6/28/76		6/28/76
2	11/20/75	50		Grazed	2/21/76	80	6/28/76		6/28/76
3	11/20/75	30		Grazed	2/21/76	40			Grazed
4	12/11/75	80		Grazed		100	6/26/76		6/18/76
5	11/27/75	70			2/28/76	100	6/26/76		6/18/76
6	11/27/75	40		Grazed	2/28/76	30			Grazed
7	11/28/75	80			3/02/76	100	7/21/76		6/12/76
8	11/28/75	30		Grazed	3/03/76	70	6/24/76	7/24/76	6/17/76
9	12/11/75	40		Grazed	3/03/76	90	6/24/76		6/17/76
10			12/12/75	70	3/01/76	100	7/21/76		6/12/76
11			12/12/75	70	3/02/76	100	7/21/76		6/12/76
12	9/17/75	10	11/14/75	70	2/20/76	100	7/02/76		6/22/76
13	9/10/75	10	12/09/75	70	3/04/76	100	7/01/76		6/23/76
14					3/04/76	70	7/03/76		6/21/76

with good canopy cover. An intermediate value such as 40% would be with three to four leaves and a medium stand.

On soil sampling date 1 the check plots were sampled on the cooperator sites. At date 3, all treatments and replications were sampled. At dates 4 and 5, check and 135 kg N/ha treatments were sampled. Total sampling depth was 120 cm. The damples were divided by depths into 0-15, 15-30, 30-60, 60-90, and 90-120 cm increments. Two cores were taken per plot and composited.

Experiment Station Sites

Site numbers 10 through 14 are experiment station sites.

Sites 10 and 11, at the Altus Experiment Station, were initiated in 1964. The 0, 45, and 90 kg N/ha plots were sampled from site 10, and the 0, 45, 90, 135, and 180 kg N/ha plots were sampled from site 11. Both sites had six replications.

Site 12, at Lahoma, was initiated in 1970, with the 0, 45, 90, and 112 kg N/ha plots being sampled. Site 13, at Stillwater, was initiated in 1968, with the 0, 45, 90, and 135 kg N/ha plots being sampled. Site 14, at El Reno, was initiated in 1973, with the 0, 34, 67, 101, and 135 kg N/ha plots being sampled. All three of these sites were replicated four times.

Soil sampling dates can be noted in Table I. All treatments were sampled on all dates. Sampling was similar to cooperator sites as to depth increments and frequency per plot.

Laboratory Procedures

Soil samples were dried within two days of sampling in a forced air oven slightly above room temperature. Once dried, the samples were ground to pass a 20-mesh sieve and stored at room temperature, awaiting NO_3-N analysis.

Nitrate analysis was completed by extracting a 10-gram soil sample with 25 ml of a saturated calcium sulfate solution. This procedure is outlined by Mack and Sanderson (11) and currently used by the Soil Testing Lab at Oklahoma State University. The Orion NO_3-N electrode was used to determine the concentration of NO_3-N in the sample. The minimum detectable level by the Orion NO_3-N meter is one part per million NO_3-N. With a 2.5 dilution of soil to extract, the minimum detectable level is 2.5 ppm in the soil sample, or by calculation in a 15-cm sample increment, 6 kg/ha, and 30-cm sample increment, 10 kg/ha NO_3-N. It was decided for statistical purposes that when no NO_3-N was detectable in a 15-cm increment, an arbitrary value of 3 kg/ha NO_3-N would be used, and in a 30-cm increment 5 kg/ha. Therefore, in a 0-120 cm soil core when no NO_3-N was detected at any increment, the total NO_3-N would be considered 21 kg/ha, a 0-60 cm probe would have a minimum of 11 kg/ha, etc.

Total N in the grain was run by a micro-kjeldahl procedure, using a Technicon Auto-analyzer.

Data was analyzed statistically by the Statistical Analysis System developed by North Carolina State University and available as a programming system by the Computer Services and Oklahoma State University.

CHAPTER IV

EFFECT OF SAMPLING DATES AND TREATMENT LEVELS ON SOIL NO_3-N

Cooperator Sites

Comparisons of sampling dates and treatment levels for soil NO_3-N was made on check plots and 135 kg N/ha rates. Analysis of variance was run on individual sites to determine significance for dates and treatment levels. Only spring and harvest dates were used in the analysis.

Five sites were analyzed, and the soil NO_3-N levels in the 0-120 cm depth for the 0 and 135 kg N/ha rates are shown in Figure 2.

It was noted that there was a significant difference in levels of soil NO_3-N by date. Harvest (date 4) consistently gave the lowest soil NO_3-N levels. Harper County (site 2) is the only site containing appreciable amounts of NO_3-N in the check plots at spring sampling (date 3).

Soil NO_3-N dropped in all soils from fall (date 1) to spring (date 3) on the check plots except in Stephens County (site 9). Significance of the decline was not tested statistically. Nitrate-Nitrogen levels at site 9 increased from a completely nondetectable level. Least significant differences (LSD) listed above each corresponding graph are

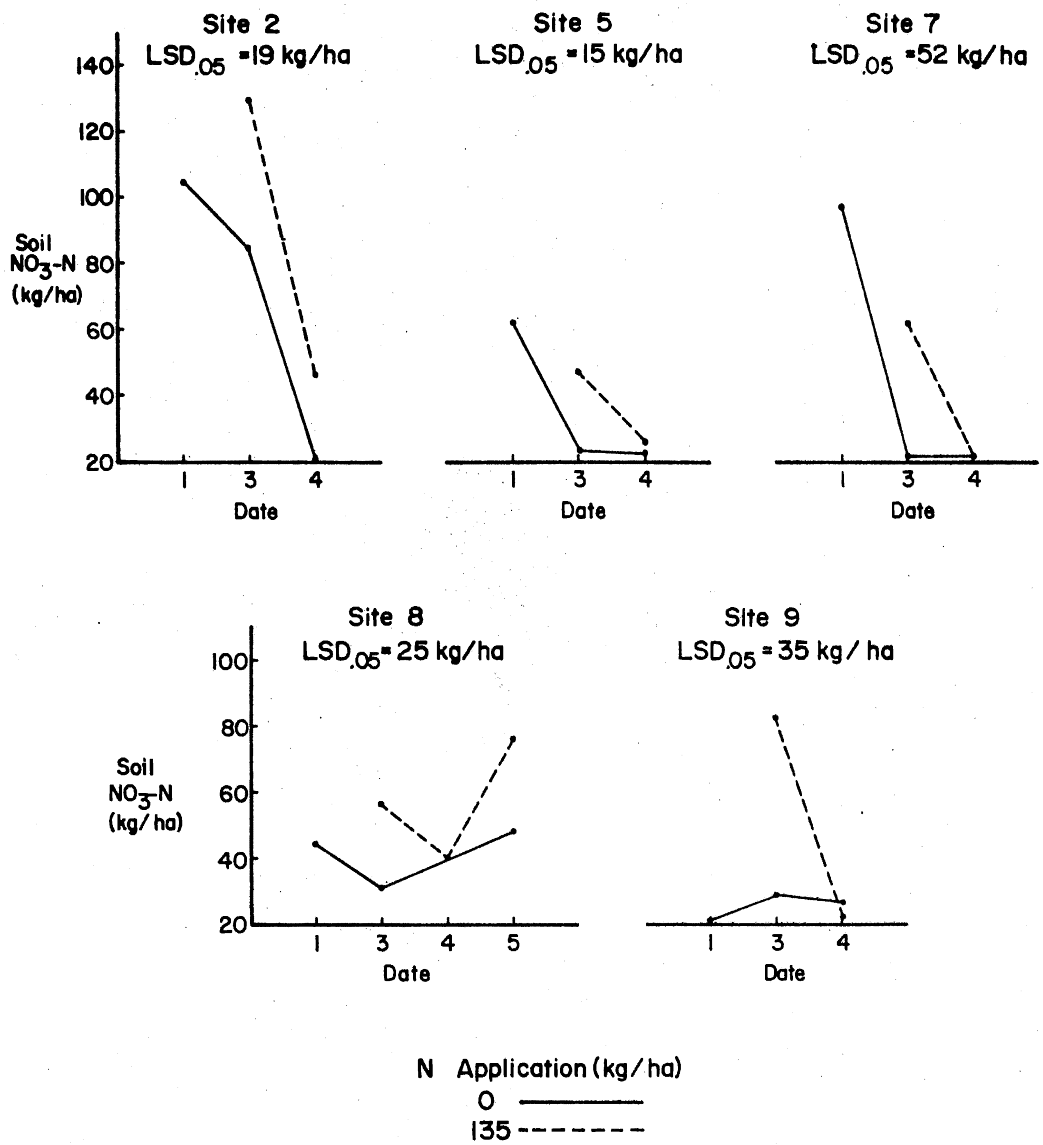

Figure 2. Soil NO_3-N Levels as Affected by Date and N Treatment (0-120 cm Depth)

significant differences between date 3 and date 4 within a treatment level and differences due to treatment levels within a date. Only site 2 showed a significant change in the check plot from date 3 to date 4, dropping from 84 kg/ha to a nondetectable level of NO_3-N. Check plots in all other sites were so low in NO_3-N that changes could not be detected.

The 135 kg N/ha plots showed statistically significant decreases in soil NO_3-N from date 3 to date 4 with the exception of Jackson County (site 7), which dropped to a nondetectable level, but was not enough to make it significant.

Soil NO_3-N differences due to N fertilizer treatments at date 3 were significant at all sites except site 7. There was great variation in the data at site 7, causing the nonsignificance of N treatment on soil NO_3-N. At date 4, N treatment increased NO_3-N significantly at one location, site 2. Cotton County (site 8) included a late July (date 5) sampling taken about one month after date 4. With date 4 showing no difference in treatments, date 5 again showed statistically significant differences due to N treatments. Date 5 was not part of the planned experiment and, therefore, was not taken on any other sites.

Experiment Station Sites

Lahoma (site 12) and Stillwater (site 13) were sampled four times throughout the season on all treatment levels. Both sites increased at nearly all treatment levels from date 1 to date 2 (Figure 3). It was determined that the N fertilizer had been applied between sampling dates 1 and 2.

Date and treatment level differences for the three sites in Figure 3 are similar to cooperator sites. The effect of N treatment on soil NO_3-N at different sampling dates for sites 12, 13, and 14 in Figure 3 are similar to cooperator sites shown in Figure 2.

When comparing dates of sampling, the Altus sites (sites 10 and 11) remained relatively stable in NO_3-N levels throughout the growing season, as shown in Figure 4, while other sites decreased in NO_3-N. These sites have been in continuous wheat under N fertilizer treatments for 12 years. It was hypothesized that the N mineralization rate of these soils was changed to a rapid rate because of continued N fertilization, and thus NO_3-N was produced at a rapid rate equal to crop uptake. The relatively high average levels of NO_3-N in the soil at each treatment level are shown in Figure 4.

The decrease of detectable NO_3-N follows inversely to the need for N by the crop as growth and maturity progress. The results of this study suggest a need to possibly correlate fall (date 1 or 2) NO_3-N with yields of the crop and also spring (date 3) NO_3-N may be usable as a means of determining N needs for topdressing winter wheat. Date 4 or at harvest time is a poor date for sampling. Prior to harvest, N needs for winter wheat are great, and thus NO_3-N diminishes from the soil. July sampling (date 5) on site 8 showed that with time, replenishment occurs. There appears to be a need

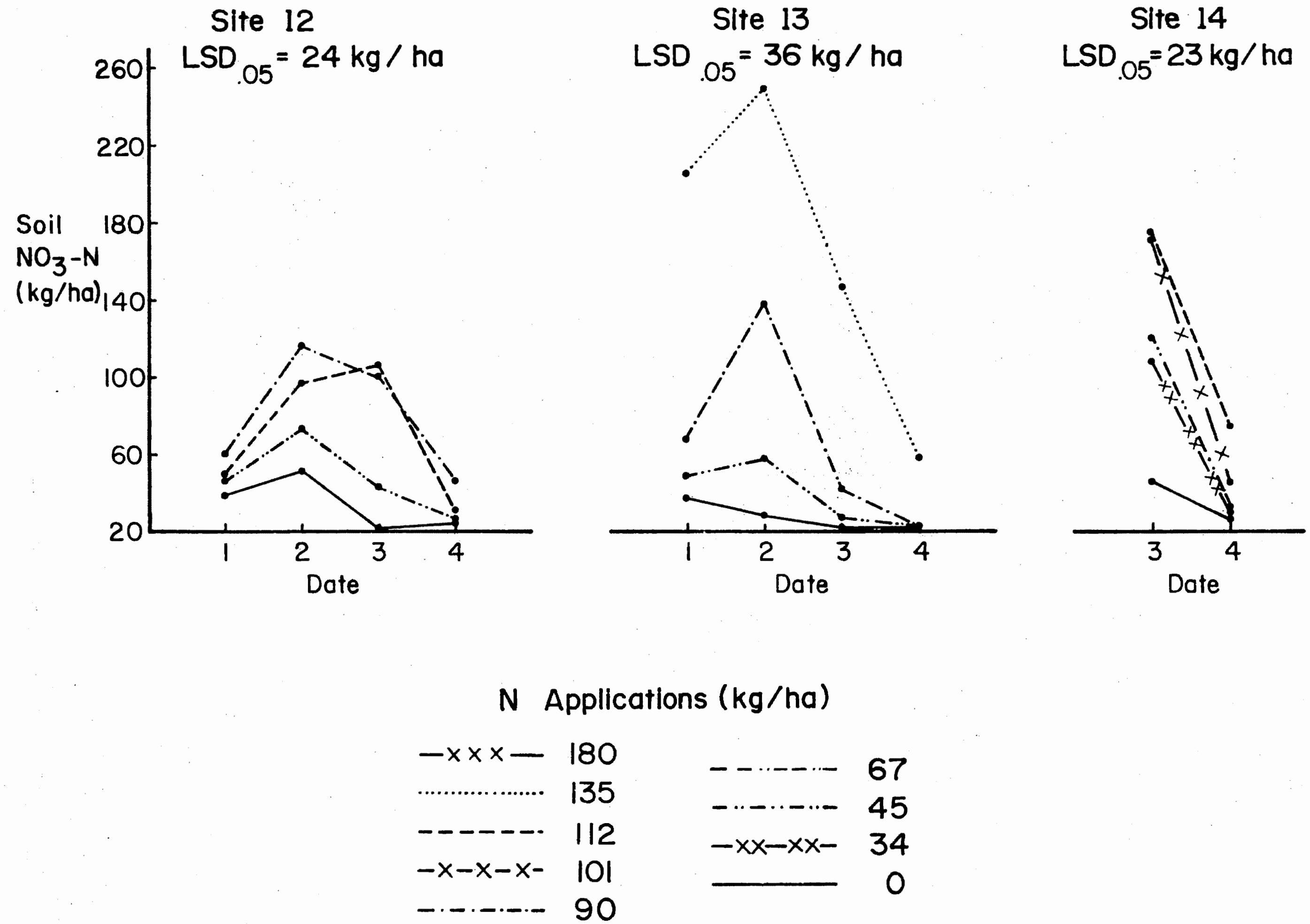

Figure 3. Soil NO_3-N Levels as Affected by Date and N Treatment (0-120 cm Depth)

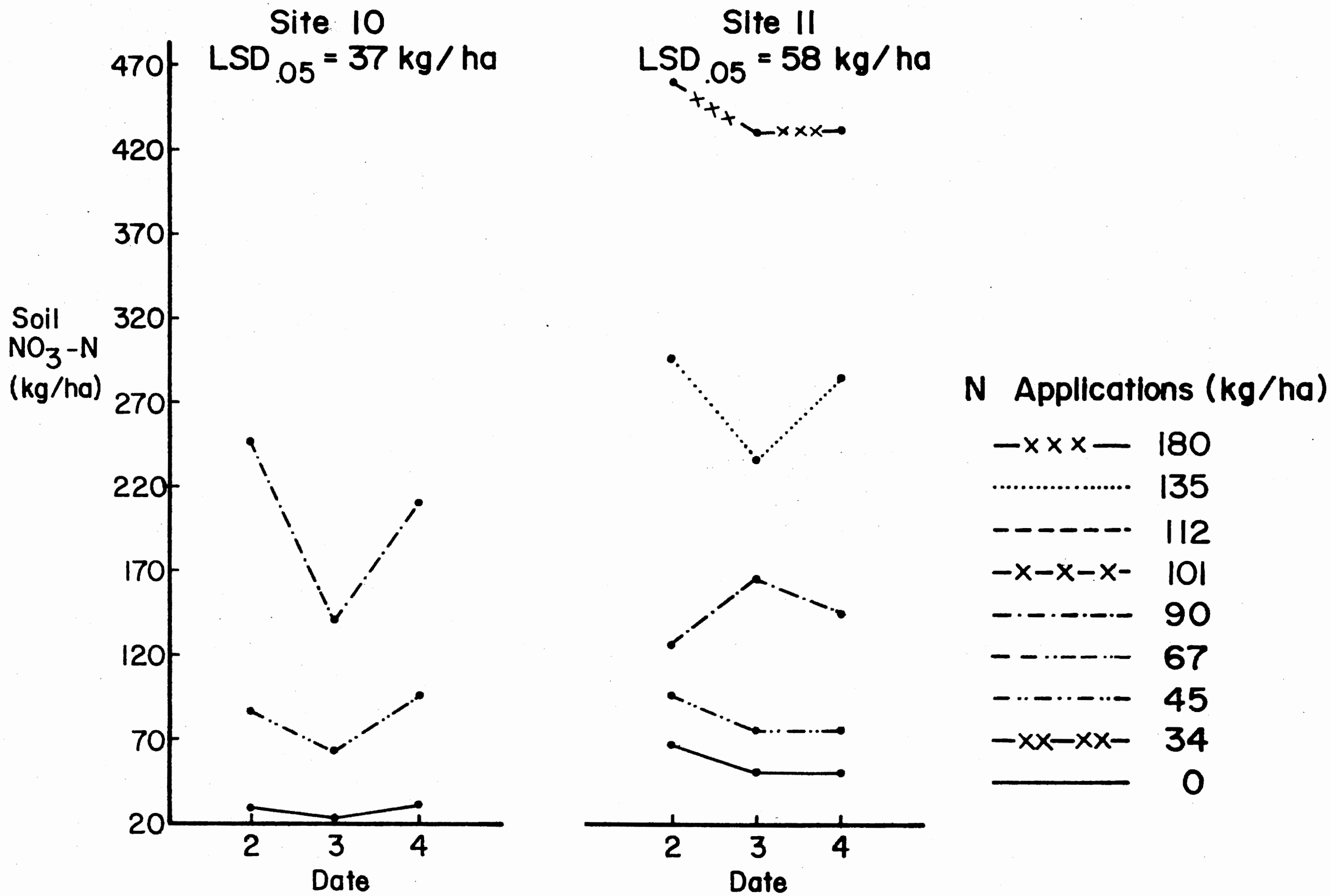

Figure 4. Soil NO_3-N Levels as Affected by Date and N Treatment (0-120 cm Depth)

in future studies to continue sampling through the summer to determine when the NO_3-N reaches an equilibrium plateau. This would appear to be the ideal time to sample to determine N fertilizer needs for winter wheat.

CHAPTER V

EFFECT OF SAMPLING DEPTH ON PREDICTING NO_3-N IN THE SOIL ROOTING ZONE

Correlating Sampling Depth Increments

In studying the effect of sampling depth on the amount of NO_3-N expected at lower depths, correlations were run on all sites at spring (date 3) sampling. The method used in the correlations was correlating depths 0-15, 0-30, 0-60, 0-90, and 0-120 cm increments with each other. The r values (correlation coefficient) shown in Table III were calculated across treatment levels.

Nitrate-Nitrogen in one depth increment can be predicted for other depth increments when considered within a site (Table 3). The r values were calculated from Harper, Washita, Jackson, Cotton, and Stephens Counties (sites 2, 5, 7, 8, and 9, respectively).

Lahoma, Stillwater, and El Reno (sites 12, 13, and 14) gave r values within the ranges given for the five cooperator sites when analyzed for date 3. These sites, under N fertilization for three to six years, gave similar results with sites fertilized one year with N.

The two sites at Altus (sites 10 and 11) gave r values from .60 to .98. The wider range of r values may be due to

TABLE III

CORRELATION COEFFICIENT VALUES FOR NO_3-N AT VARIOUS DEPTH INCREMENTS AT FIVE COOPERATOR SITES ON DATE 3*

Depth (cm)	0-30 cm High	0-30 cm Low	0-60 cm High	0-60 cm Low	0-90 cm High	0-90 cm Low	0-120 cm High	0-120 cm Low
0-15	1.00^{7}	$.96^{2}$	1.00^{7}	$.94^{2}$	1.00^{7}	$.91^{8}$	1.00^{7}	$.82^{5}$
0-30			1.00^{5}	$.97^{8}$	1.00^{5}	$.98^{8}$	1.00^{7}	$.82^{5}$
0-60					1.00^{5}	$.98^{8}$	1.00^{7}	$.82^{5}$
0-90							1.00^{7}	$.82^{5}$

*Superscript is site number

12 years of continuous N fertilization creating some accumulation of NO_3-, especially in the 90-120 cm increment.

Percent NO_3-N at Sampling Depth Increments

The average percent of total NO_3-N in a 120-cm soil depth, when broken down by the given increments, is shown in Figure 5. The points are an average of the nine cooperator sites on date 1. Approximately 34% of the NO_3-N on the nine sites sampled was found to be in the top 15 cm of soil when sampled in the fall. Sixty percent of the total NO_3-N was in the 0-30 cm depth, 80% to a 60-cm depth, and the remaining two increments add approximately 10% each. Table IV summarizes the data for four experiment stations at all dates and the average for all cooperator sites on date 1.

The data in Figures 6 and 7 and Table IV is averaged over treatments and, therefore, treatments may have an effect on depth of NO_3-N. In all cases the treatment X depth of NO_3-N interaction was statistically significant. This is most apparent when considering the number of years at which N treatments have been applied on the experiment station sites. Site 12 has only been established for three years and compares quite closely with the cooperator sites. Site 13 has been established for six years, and sites 10 and 11 for 12 years. This seems to explain the increasing percent of NO_3-N found in the lower portion of the rooting zone. Site 13 appears as an intermediate between sites 12 and 10.

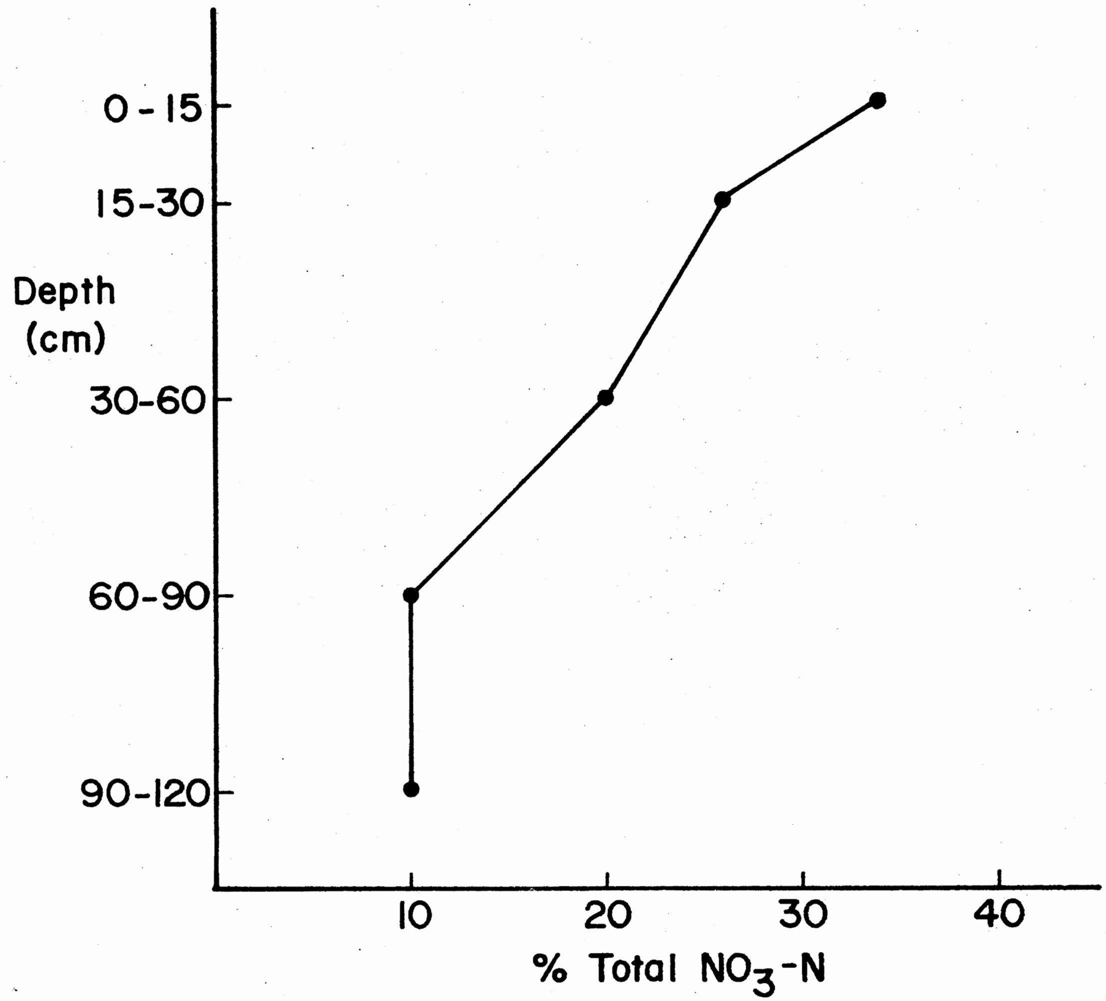

Figure 5. Percent NO_3-N Found in Each Depth Increment Averaged Over All Cooperator Sites (Date 1)

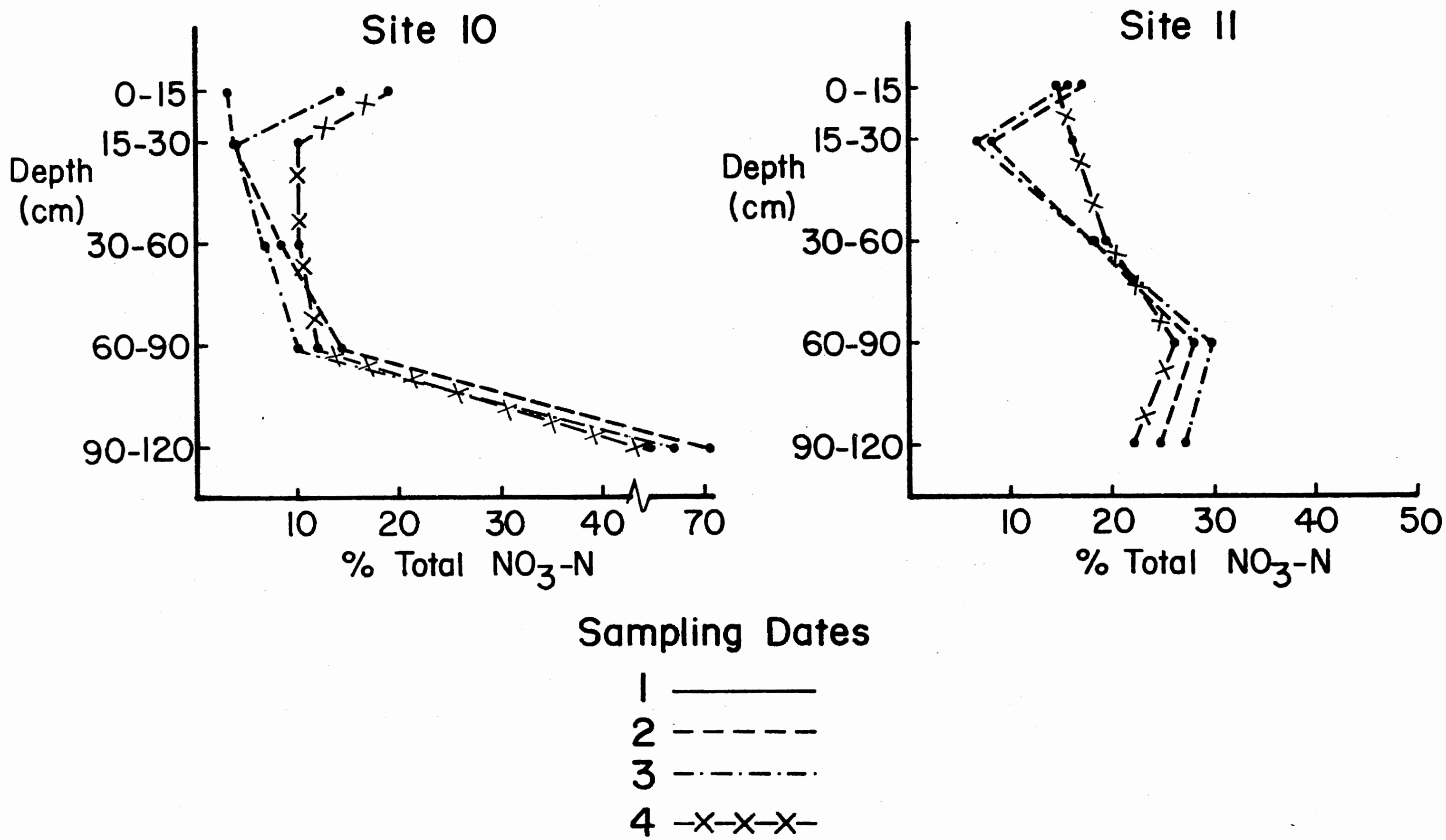

Figure 6. Percent NO_3-N Found in Each Depth Increment

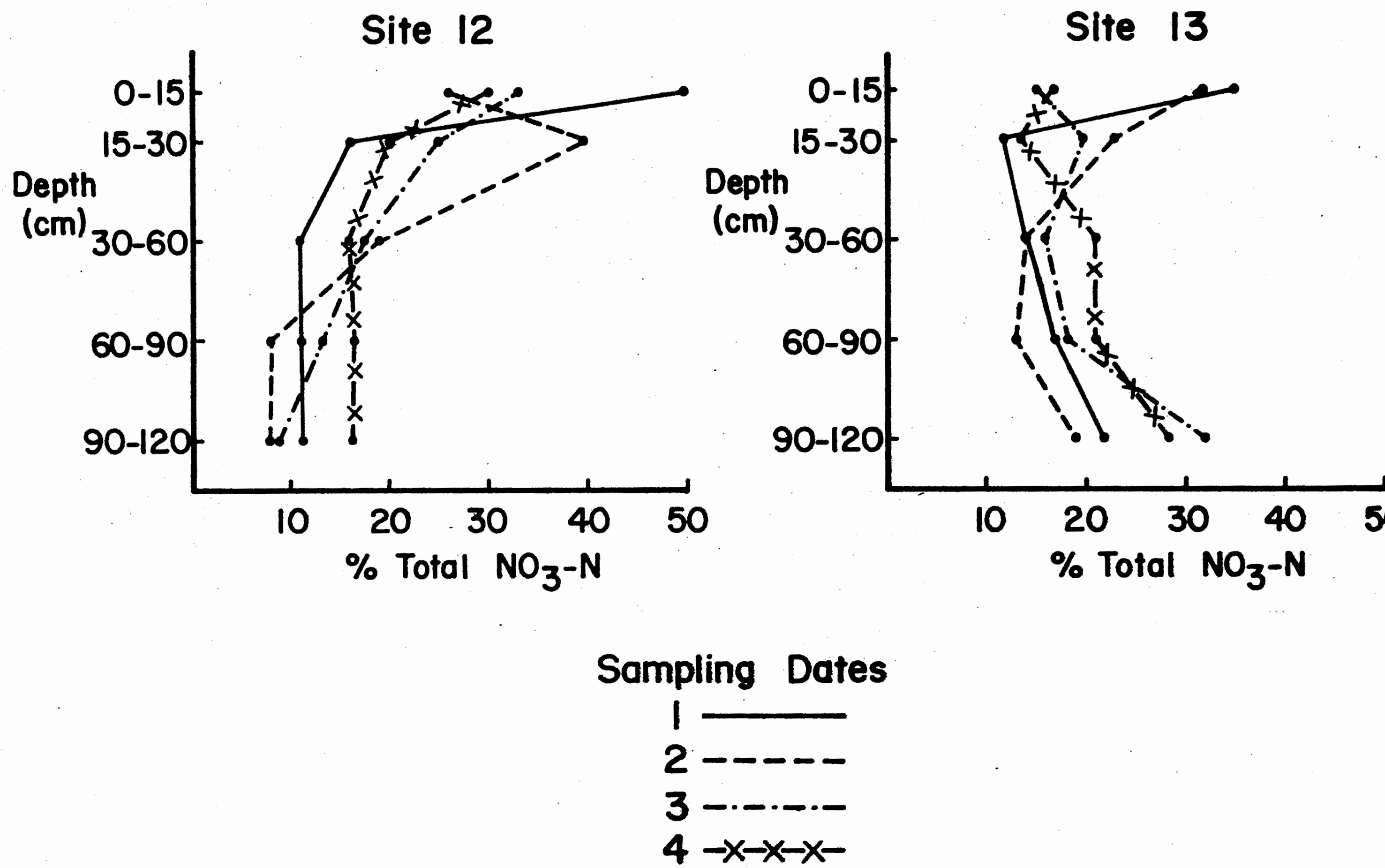

Figure 7. Percent NO_3-N Found in Each Depth Increment

TABLE IV

PERCENT NO_3-N IN 120 CM DEPTH REPRESENTED BY EACH GIVEN DEPTH INCREMENT (DATE 1 FOR COOPERATOR SITES AND AVERAGED OVER DATE FOR OTHER SITES)

Depth (cm)	Site 10 (%)	Site 11 (%)	Site 12 (%)	Site 13 (%)	Site Cooperator (%)
0-15	12	17	35	24	34
0-30	18	37	60	41	60
0-60	26	46	76	56	80
0-90	38	75	88	74	90
0-120	100	100	100	100	100

This may suggest that continued N fertilization plays a significant role in the percent of NO_3-N in a given increment of the rooting zone. This should be a consideration when predicting NO_3-N in a lower depth increment from the top 15 or 30 cm.

CHAPTER VI

CORRELATIONS OF YIELD AND TOTAL N UPTAKE WITH SOIL NO_3-N

Correlating Yield Response with Soil NO_3-N

In studying yield response due to additional N fertilization, it was found that the best predictor of yield response was with soil NO_3-N. Other important factors were depth of sampling, rate of N applied, and economics of maximizing returns or profits on the fertilizer investment.

In order to incorporate all these factors into a meaningful connotation the assumptions needed were:

1. Cost of N fertilizer = \$.44/kg (\$.20/lb)
2. Price for wheat = \$.11/kg (\$3.00/bu)

Yield response was determined for each increment of added N. For example, to determine the yield response from adding 45 kg N/ha to a soil that had already received 45 kg N/ha, the yield response would equal the yield of the 90 kg N/ha plot minus the yield of the 45 kg N/ha plot. The soil NO_3-N used for the regression analysis was taken from the 45 kg N/ha plot in this example. This type of analysis was run only on the cooperator sites. The analysis was averaged over seven cooperator sites with fall sampling (date 1) and over five cooperator sites with spring sampling (date 3).

Lists of the regression equations for each sampling depth and the amount of fertilizer N added to the soil are shown in Table V. The soil NO_3-N values from the check plots were used. Correlation coefficients are given for each equation. The equations were all found to be significant except for the regression of 0-15 cm soil NO_3-N with the 45 kg N/ha treatment for both dates.

All r values improved as soil sampling increased to 60 cm for every rate at date 1. This suggests that soils should be sampled for NO_3-N to 60 cm for the best prediction of yield response. The r values did not improve for sampling depths greater than 60 cm.

The regression equation can be used to calculate maximum dollar returns from N fertilizer. Using the equation:

$$Y = 374 - 3.70X \qquad (6.1)$$

where Y equals yield response and X equals kg NO_3-N in the soil to solve for X, returns can be estimated. If a farmer analyzed a soil sample from a depth of 60 cm, he could, using Equation 6.1, get a profitable yield response by the addition of 45 kg N/ha if his soil test was less than 99 kg NO_3-N/ha. In explanation of this calculation, it would cost \$19.80/ha to apply 45 kg of N fertilizer. This would take a yield response of 180 kg/ha of grain to offset the fertilizer cost. This would suggest a total need of 144 kg of soil NO_3-N plus fertilizer N.

TABLE V

YIELD RESPONSE EQUATIONS CALCULATED AT EACH RATE AND ALL SAMPLING DEPTHS FROM RESIDUAL NO_3-N IN CHECK PLOTS (AVERAGED OVER SITES)

Sampling Date	Sampling Depth (cm)	Rate of N (kg/ha)	Predicted Yield Response Regression Equation	Correlation Coefficient (r)
1	0-15	45	Not Significant[¶]	.33
1	0-30	45	Y*= 404 - 2.69X[†]	.39
1	0-60	45	Y = 434 - 2.56X	.42
1	0-90	45	Y = 452 - 2.53X	.42
1	0-120	45	Y = 466 - 2.45X	.42
1	0-75	90	Y = 740 - 8.07X	.48
1	0-30	90	Y = 801 - 5.82X	.56
1	0-60	90	Y = 855 - 5.37X	.59
1	0-90	90	Y = 892 - 5.29X	.59
1	0-120	90	Y = 924 - 5.14X	.59
1	0-15	135	Y = 886 - 8.24X	.39
1	0-30	135	Y = 962 - 6.21X	.48
1	0-60	135	Y = 1028 - 5.86X	.52
1	0-90	135	Y = 1068 - 5.78X	.52
1	0-120	135	Y = 1098 - 5.55X	.51
3	0-15	45	Not Significant	.42
3	0-30	45	Y = 472 - 12.55X	.46
3	0-60	45	Y = 487 - 6.95X	.47
3	0-90	45	Y = 527 - 6.92X	.47
3	0-120	45	Y = 573 - 6.89X	.46
3	0-15	90	Y = 926 - 40.24X	.52
3	0-30	90	Y = 938 - 21.46X	.56
3	0-60	90	Y = 957 - 11.62X	.55
3	0-90	90	Y = 1022 - 11.46X	.55
3	0-120	90	Y = 1110 - 11.78X	.55
3	0-15	135	Y = 1209 - 52.29X	.60
3	0-30	135	Y = 1216 - 27.10X	.62
3	0-60	135	Y = 1248 - 15.03X	.62
3	0-90	135	Y = 1336 - 15.01X	.63
3	0-120	135	Y = 1462 - 15.71X	.64

*Yield response (kg/ha)
[†]kg/ha of NO_3-N in soil
[¶]Tested at the .05 significance level

From similar calculations, in order to profit from adding 90 kg N/ha, a soil test of 92 kg NO_3-N/ha in the 0-60 cm soil depth or a total of 182 kg of soil NO_3-N plus fertilizer N could not be exceeded. To profit from adding 135 kg N/ha from the same sample the soil test would need to be 83 kg NO_3-N/ha or less or a total of less than 218 kg of soil NO_3-N plus fertilizer N. Similar computations could be made on other depths.

The regression of yield response vs. soil NO_3-N in the 0-60 cm increment for the 90-kg N/ha treatment is shown in Figure 8.

Regression equations and r values for the yield response to soil NO_3-N in the check plots on sampling date 3 are listed in Table V. The actual yield response in the data came from the plots receiving 45, 90, and 135 kg N/ha in the fall. The data is similar to that of sampling date 1 except that a 30-cm sample seemed sufficient to attain the highest r values. The date 1 sampling suggests a need for a 60-cm sample.

Regression of yield response vs. soil NO_3-N to the 60-cm depth for the 90-kg treatment on date 3 is shown in Figure 9. Note that many of the points of the scatter diagram are very near the vertical axis. This was due to the very low or non-detectable NO_3-N in the soil at date 3 on the check plots.

Regression equations for yield responses from 45- and 90-kg N/ha over the first 45-kg N increment to soil NO_3-N levels in the 45-kg N/ha treatment sampled in the spring are shown

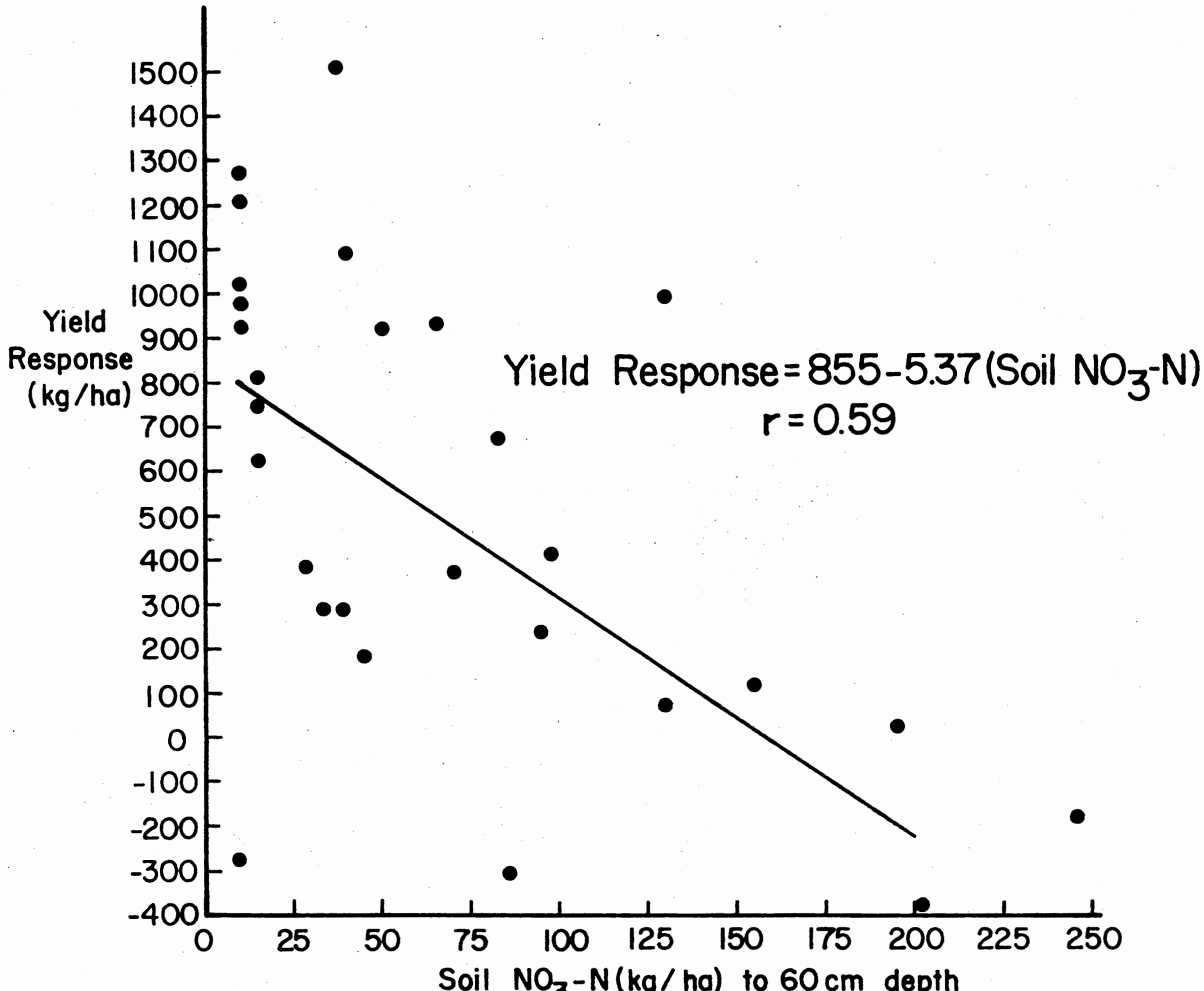

Figure 8. Yield Response as Affected by Soil NO_3-N When 90 kg N/ha is Added to the Soil (Sampling Date 1, Averaged Over 7 Cooperator Sites)

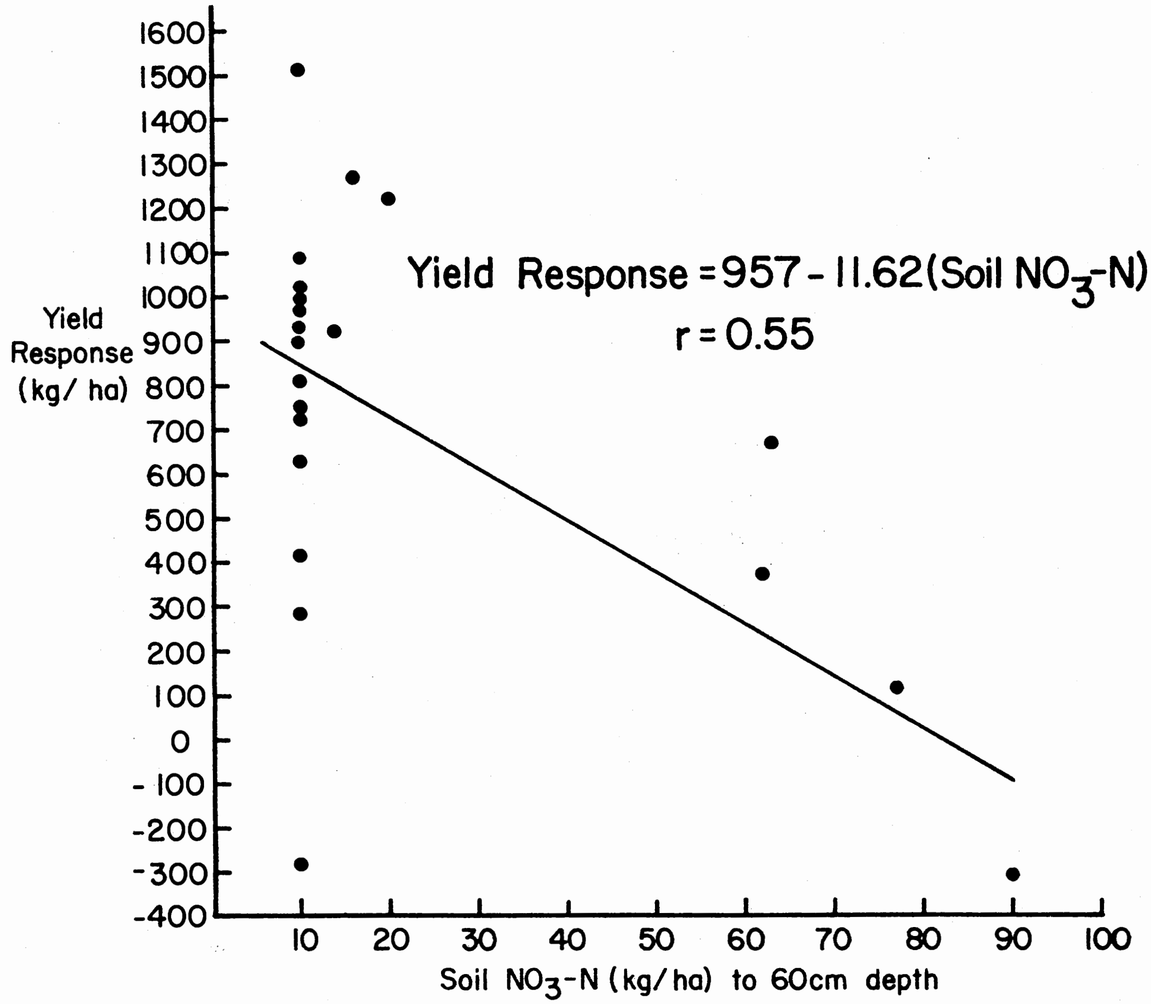

Figure 9. Yield Response as Affected by Soil NO_3-N When 90 kg N/ha is Added to the Soil (Sampling Date 3, Averaged Over 5 Cooperator Sites)

in Table VI. This would, therefore, be a response from an additional 45 and 90 kg N/ha.

It should be noted that there were no significant equations for predicting yield responses when 45 kg N was applied in addition to 45 kg N applied initially. However, 90 kg N applied on top of 45 kg N produced yield responses that were statistically related to soil NO_3-N levels. An analysis was also made for the yield response from 45 kg N applied above a 90 kg N treatment. Soil NO_3-N levels on date 3 from the 90-kg N/ha treatment were used for the analysis. None of the equations were significant and, therefore, are not shown.

Use of the soil NO_3-N test for predicting yield response to additions of N works best when samples are taken in the fall to a 60-cm depth. The best equation for predicting yield response was obtained by correlating soil NO_3-N to 60-cm depth with yield response from 90 kg N/ha. Date 3 sampling needs further analysis due to the low NO_3-N levels in most sites.

Correlation of Total Grain N With Soil NO_3-N at Sampling Date 3

Total N in kg/ha was determined in the grain in order to study the correlation of total N uptake in the grain and soil NO_3-N on sampling date 3. The r values for 0-15, 0-30, and 0-60 cm soil depths NO_3-N analysis and total N uptake are listed in Table VII. Lower depths are not shown because no further improvement of the r values was obtained. This

TABLE VI

YIELD RESPONSE EQUATIONS CALCULATED AT 90 AND 120 KILOGRAM RATES FROM NO_3-N IN THE 45-KILOGRAM RATE SOILS (AVERAGED OVER SITE)

Sampling Date	Sampling Depth (cm)	Rate of N (kg/ha)	Predicted Yield Response Equation	Correlation Coefficient (r)
3	0-15	90	Not Significant¶	.39
3	0-30	90	Not Significant	.40
3	0-60	90	Not Significant	.39
3	0-90	90	Not Significant	.36
3	0-120	90	Not Significant	.40
3	0-15	135	$Y^{*} = 736 - 16.30X^{\dagger}$	.49
3	0-30	135	$Y = 736 - 9.11X$	.50
3	0-60	135	$Y = 760 - 6.32X$	.54
3	0-90	135	$Y = 797 - 6.13X$	.54
3	0-120	135	$Y = 870 - 6.94X$	.60

*Yield response (kg/ha)

†kg/ha NO_3-N in 45 kgN rate soil

¶Tested at the .05 significance level

TABLE VII

TOTAL N UPTAKE AS AFFECTED BY SOIL NO_3-N LEVELS (SAMPLING DATE 3)

Site	Sampling Depth (cm)	Predicted Total Grain N Regression Equation	Correlation Coefficient (r)
2	0-15	Y* = 29.0 + 0.32X†	.70
2	0-30	Y = 21.2 + 0.32X	.80
2	0-60	Y = 14.8 + 0.28X	.73
5	0-15	Y = 53.2 + 2.06X	.71
5	0-30	Y = 48.3 + 2.09X	.74
5	0-60	Y = 37.9 + 2.09X	.74
7	0-15	Y = 68.1 + 0.48X	.53
7	0-30	Y = 66.8 + 0.44X	.55
7	0-60	Y = 65.2 + 0.41X	.54
8	0-15	NOT SIGNIFICANT¶	.43
8	0-30	NOT SIGNIFICANT	.38
8	0-60	NOT SIGNIFICANT	.32
9	0-15	NOT SIGNIFICANT	.42
9	0-30	Y = 43.5 + 0.29X	.49
9	0-60	Y = 39.8 + 0.32X	.55
10	0-15	NOT SIGNIFICANT	.10
10	0-30	NOT SIGNIFICANT	.19
10	0-60	NOT SIGNIFICANT	.25
11	0-15	Y = 63.8 + 0.32X	.43
11	0-30	Y = 60.7 + 0.27X	.46
11	0-60	Y = 64.6 + 0.12X	.34
12	0-15	Y = 33.5 + 0.36X	.57
12	0-30	Y = 31.5 + 0.25X	.62
12	0-60	Y = 30.2 + 0.22X	.63
13	0-15	Y = 33.2 + 1.46X	.74
13	0-30	Y = 34.6 + 0.55X	.66
13	0-60	Y = 33.6 + 0.41X	.64
14	0-15	Y = 32.5 + 0.22X	.56
14	0-30	Y = 31.8 + 0.14X	.57
14	0-60	Y = 30.9 + 0.12X	.57

*Total grain N (kg/ha)
†Soil NO_3-N (kg/ha)
¶Tested at .05 significance level

analysis was done for each site, and no pooling was attempted for the sites. All plots are included in the analysis for the sites.

Regression equations for determining the total N uptake from the date 3 sampling are reported in Table VII. Total N uptake in plants increased with increasing fertilizer N rates, but yield or protein content may not be increased.

Using site 13 as an example, it would take 0.68 kg NO_3-N in the soil test to produce a 1-kg increase in total grain N if the sample were taken from the 0-15 cm increment. In a 0-30 cm sample the soil test for NO_3-N would need to increase 1.8 kg/ha to expect a 1-kg increase in total grain N. About 2.4 kg soil NO_3-N in 0-60 cm sample would raise the total grain N 1 kg.

The equations vary widely between sites, suggesting further studies of total grain N as a dependent variable due to soil NO_3-N being needed. Sites 8 and 10 showed non-significant results for the prediction of total N in the grain using soil NO_3-N as the predictor.

CHAPTER VII

SUMMARY AND CONCLUSIONS

The NO_3-N test correlates well with yield response and provides a means for predicting fertilizer N needs. A need for evaluation of soil NO_3-N at various crop growth stages initiated the concern to undertake this study of Oklahoma wheatland soils.

The NO_3-N soil test shows a positive response to fertilizer N applications when the fertilizer is applied in the fall and soil samples taken in early spring. As growth of the winter wheat progresses to harvest, the ability to differentiate N treatments is lost. The peak of NO_3-N levels is in the fall. Decline of NO_3-N in the soil occurs in the spring through harvest.

Excellent correlations exist in most soils between the NO_3-N in a given soil increment and that of a deeper soil increment. The data points out that approximately 34% of the soil NO_3-N can be found in the top 15 cm, and nearly 80% is in the top 60 cm. These values can vary greatly due to past fertilization of the winter wheat.

Yield response of winter wheat to N fertilization correlates well with the soil NO_3-N test when samples are taken in the fall. The best correlation is when NO_3-N from the top

60 cm of soil is correlated with yield response. Spring sampling shows promise for predicting yield responses to additional N fertilizer. Correlations were not as high with spring sampling. A 0-30 cm depth seemed adequate for the spring predictions.

Prediction of total grain N by soil test NO_3-N levels in the spring shows some promise. Good correlations were achieved at individual sites; however, no attempt was made to pool sites to get an estimate of grain N across sites.

Future studies in the evaluation of the NO_3-N soil test should include a larger number of sites for evaluation. Sampling depths should be limited to 60 cm, and more frequent sampling dates that extend into the summer months need to be evaluated. The importance of adequate N fertilization cannot be overlooked. Continued study to improve predictions of N fertilizer needs is imperative to provide farmers with a useful tool in maximizing their profitable returns.

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