EFFECT OF AG-LIME AND NITROGEN APPLICATIONS ON

ALUMINUM AND MANGANESE CONCENTRATIONS IN

ACID SOILS AND YIELDS OF WINTER WHEAT

By

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## ACID SOILS AND YIELDS OF WINTER WHEAT

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## ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

Soil acidity is becoming an ever-increasing problem in modern crop production. The decreasing soil pH is a result of increased nitrogen fertilization to obtain higher yields. The processes involved include residual H during the nitrification process of $NH_3$-N, basic cation removal (Ca, Mg, K), leaching, and H ions from plant roots.

Whenever the pH of a soil drops below 5, the Al in soil solution can be high enough to reduce yields (Lee, 1972). Excessive levels of Al and Mn creates deficiencies of some nutrients needed for normal plant growth. For example, high Al concentrations can cause P or Ca deficiencies (Foy, 1964), and high Mn concentrations can induce a number of physiological disorders in plants (Foy et al., 1978).

Acidic soils are commonly found in high rainfall areas where soils are leached and highly weathered. However, acidic soils are not necessarily confined to the more humid regions, but can occur anywhere where rather high yields are obtained, especially under rain-fed conditions.

Some soils in North Central Oklahoma have become quite acidic with soil pH values below 5. It is believed these acidic soils are a result of continuous applications of ammonia nitrogen and resultant removal of high levels of basic cations by high yields.

Because the acidic soil conditions are increasing, this study was initiated. The objectives of the study were: 1) to determine the effect

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of ag-lime and ammonium nitrogen application on the soluble Al and Mn

concentrations in two soils; and, 2) to determine the effect of ag-lime

and nitrogen rates on the yield of winter wheat.

CHAPTER II

REVIEW OF LITERATURE

Role of Aluminum in Soil Acidity

Because of higher rates of fertilizer salts being applied to reach
maximum yield, soils are becoming increasing acidic. This is due in
part to the removal of basic cations, nitrification of $NH_3$ to $NO_3$-N,
leaching, and increased solubility of Al.

Soil acidity is defined as "a systems proton yielding capacity in
going from a given state to a reference state" (Jackson, 1958, p. 6).
As the soil becomes more acidic, the pH decreases and H ions are released
into soil solution until the pH reaches about 5.0. Then Al becomes more
soluble at this low pH and has been suggested as an index of soil acidity
(Miller, 1965; Janghorbani et al., 1975).

When Al ions are displaced from minerals by cations in soil solution,
the hydrolysis products are reabsorbed by clay minerals causing further
hydrolysis. Also, sesquioxide-coated interlayered minerals increases
the hydrolysis of nonexchangable Fe and Al. This results in an increase
in the H ion concentration of the soil solution and a lower pH when
fertilizer salts have been applied (Tisdale and Nelson, 1975).

Figure 1 shows the effect of pH on extractable Al, Fe, and Mn, and
some of the basic cations as well as other ions are shown. At low pH
levels aluminum is in the $Al^{3+}$ ion state, and at a pH above 5.0 aluminum
is in the hydroxy hydrated aluminum state which exist in exchangable

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form. All other ions in the graph, except Fe and Mn, are inhibited by Al at this low pH.
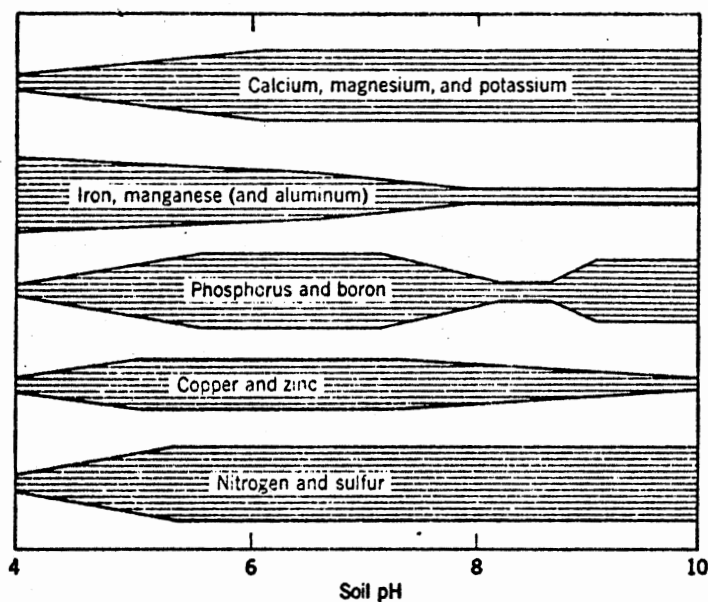


General relationship between soil pH and availability of plant nutrients: the wider the bar, the more available the nutrient.

Source: Foth and Turk (1972, p. 186).

Figure 1. Effect of pH on Ion Availability

## Aluminum in Soils

Aluminum is the third most abundant element in the earth's crust comprising about eight percent (Foth and Turk, 1972). It is the most abundant of the metallic elements and is the main constituent of most common inorganic soil particles (exceptions are quartz sand, chert

fragments, and ferromangiferous concretions). Also, the aluminosilicates are the most common primary and secondary minerals (Jackson, 1961; Rich, 1960; Coleman et al., 1958). Aluminum appears in the exchangeable form as the monomeric $Al^{3+}$ ion, and anything more than a few parts per million is toxic. There are two types of charges associated with Al (permanent and pH dependent). The permanent charges are on the colloidal material and are responsible for the electrostatic bonding present. Electrostatic bonding results from isomorphic substitution. The aluminosilicates gets its bonding from the pH dependent charges on soil colloids. These originate from structural $OH^-$ groups at the corners and edges of the clay lattice. The aluminosilicates may also be coated with amorphous aluminum and iron hydroxy compounds and, at a higher pH value, may hydrolize and unblock exchange sites on the minerals (Reed, 1978).

In soils studied by Foy and Brown (1964), levels of neutral KCl extractable Al ranged from .05 to 2.5me per 100g. Lafever et al. (1977) reported levels of $NH_4OAC$ pH 4.8 extractable Al to be from 3.07me per 100g on unlimed soil to 2.59me per 100g for the high lime rate. When Al saturation exceeded 12 percent of CEC on Ultisols in Pennsylvania, corn yields were reduced to 90 percent of maximum yield (Fox, 1978).

When Al bonds with $O_2$, it forms a wide variety of functional groups. As an oxygen coordinator, aluminum is second only to silicon in soil minerals, analogous to carbon for soil organic matter (Jackson, 1963). Aluminum fits well into the space of an $O_2$ octahedron. This space has an effective radius of $55A^o$. The ions that replace Al are: $Fe^{+2}$, $Mg^{+2}$, and $Mn^{+2}$. They are considerably larger than the space of a tightly fitting $O_2$ octahedron (Reed, 1978). The aluminum-oxygen bond of dimensions in the order $1.9A^o$ units as radius sum of $Al^{+3} + O^{-2} = 0.57 + 1.32A^o$

(Bragg, 1973, p. 31) attaches to various cations which may be outlined according to bonding arrangements in soil mineral structures (X):

(a) Bonding to exchangable cations (M):

$$X \ Al - O^- \ . \ . \ . \ M^{n+}$$
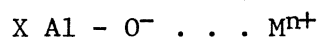
(b) Bonding to structural cation represented by Na (lost through chemical weathering):

$$X \ Al - ONa + H_2O \ \text{———} \ X \ Al - OH + Na^+$$
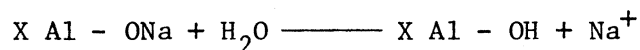
(c) Bonding to protons (exchanged in neutralization, liming):

$$2(X \ Al - O^- \ . \ . \ . \ Y - OH_n) + CaCo_3 \ \text{————}$$
$$Ca(X \ Al - O^- \ . \ . \ . \ Y - OH_{n-1})_2 + CO_2 + H_2O$$
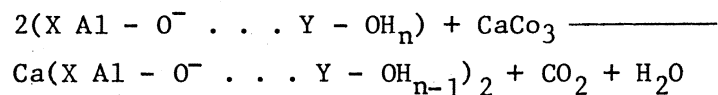
in which Y-O is an inorganic proton-retaining site, including Al-O.

(d) Oxygen shared with radicals (anions exchange and fixation):

$$X \ Al - OPO_3 - Al \ X \ \text{(or)} \ Al - OSO_3 - Al \ X$$
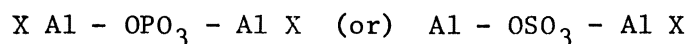
in which one oxygen of the radical probably becomes identified with the 6 coordination of Al;

(e) Held protons forming hydrogen bonds in soil aggregates:

$$X \ Al - OH_2 \ . \ . \ . \ OX \ \text{(and)} \ X \ Al - OH \ ... \ OX$$
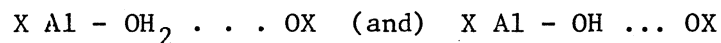
Organic and ferruginous functional groups also have roles in these five categories (Jackson, 1963).

Also, the monomeric alumino hexahydronium is amphiteric (acting both as an acid or a base). Furthermore, Figure 2 shows that when minerals weather, they release Al, which in turn progressively acquires more octahedral or six-fold bonding (Jackson, 1963) (Figure 2).

The most generalized equation of chemical weathering in terms of aluminum bonding is given in Figure 3.
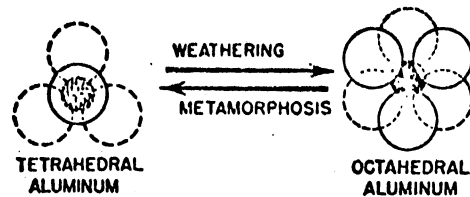
Source: Jackson (1963, p. 4).

Figure 2. Mineral Weathering
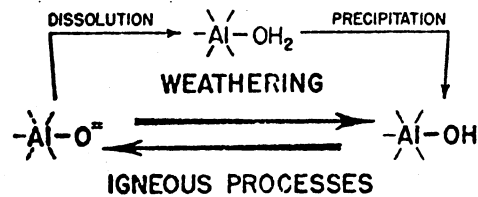


Source: Jackson (1963, p. 4).

Figure 3. General Equation for
Chemical Weathering

Manganese

Manganese ions are held near the negative charged soil surface by electrostatic attraction when Mn enters into cation exchange reactions (Ellis and Knezek, 1972). Ellis and Knezek (1972) also stated that Mn has been suggested to exist in soils primarily as insoluble oxides, and is expected to be adsorbed by clay minerals in exchangable forms under acidic conditions. Manganese becomes more available in strongly acid soils or in waterlogged soils (Murphy and Walsh, 1972).

The availability of Mn is related to soil reaction and increases

markedly when the pH falls below 5.5 (Shickluna and Davis, 1972; Lee, 1972). Under reducing conditions, both Fe and Mn, which can substitute extensively for each other, are known to increase in solubility to a point where they become adsorbed as exchangable ions (Mandal, 1961; Krauskopf, 1972).

Absorption of Mn by plants depends primarily upon the amount of divalent Mn present in the ambient solution of the root system. However, as other salts in solution increase, Mn absorption is decreased. Under most conditions, a few parts per million is all that is needed for symptoms of Mn toxicity to occur (Pearson and Adams, 1967). Organic matter may also have an effect on Mn adsorption (Ellis and Knezek, 1972; Hempstock and Low, 1952).

The mineralogy of Mn is complicated by the large number of oxides and hydroxides formed in which substitution of $Mn^{2+}$ and $Mn^{3+}$ for $Mn^{4+}$ occur extensively. Manganese can be oxidized or reduced without changing positions. These oxides and hydroxides have a high sorption capacity for heavy metals and may control the availability of certain trace elements, some of which are essential to plants and animals (Mckenzie, 1977).

## Manganese in Soils

Since Mn is a lithophile, it occurs dominantly in silicate minerals. In igneous rock, Mn is more abundant in basaltic lavas than in granite. This is possible due to the similarities of ionic radii between Fe and Mn. In sedimentary rock, Mn is most abundant in limestone due to its ease in reduction to Mn and similarity in solubility between $MnCO_3$ and $CaCo_3$ (Krauskopf, 1972). According to Toth and Romney (1954), Mn content of plants is variable, ranging from 9 to 73 parts per million for the

nine vegetables analyzed. Symptoms of Mn toxicity are found more often in a highly reduced or in a poorly aerated soil. Toxic concentrations of Mn normally are not found above pH 6.5 (Murphy and Walsh, 1972).

## Effect on Plant Growth

### Aluminum

Roots. In acidic soils, cationic Al is often present in phytotoxic concentrations and resulting in inhibition of root growth (Sartain and Kamprath, 1975). Clarkson (1965) states that when plants are exposed to toxic levels of Al, the roots are affected first with damage to tops later. Roots develop a brownish cast and lose turgidity. Excessive amounts of Al prevent main roots from growing normally, and they become thick, swollen and distorted (Fleming and Foy, 1969). Lateral roots are initiated but remain as short stubs (Bortner, 1935). Vose and Randall (1962) found that roots of Al-sensitive ryegrass varieties have higher CEC capacities than those of Al-tolerant varieties. The Donnan theory was suggested as a possible basis for explaining the differential tolerance of varieties to Al.

Tops. Whenever plants are growing in soils with toxic levels of Al, the top growth has smaller leaves with thickened and shortened internodes. The foliage generally becomes dark green and sometimes a purplish tinge develops in the leaves or stem bases. Die back is present in some small grains from leaf tips, and mature leaves may become brittle and somewhat yellowish. It is generally thought that above-ground symptoms resemble acute P deficiencies with slower growth rates and deeper coloration being the dominant characteristic rather than severe chlorosis or

necrosis (Foy et al., 1965; Pearson and Adams, 1967). Shoot growth is

not usually affected as soon as root growth (Clarkson, 1965).

## Manganese

Manganese accumulates in the foliage somewhat in proportion to

injury (Foy, 1973; Foy and Fleming, 1978). Plant symptoms of Mn toxi-

city are often detectable at stress levels which produce little or no

reduction in vegetable growth (Foy et al., 1978). According to Pearson

and Adams (1967), symptoms of Mn toxicity may appear differently in

different plant species; e.g., stunted and chlorotic leaves with necrotic

spots are found in tobacco (Bortner, 1935), and alfalfa leaves are

affected with tip and marginal chlorosis (Foy, 1974).

Manganese generally affects plant tops more severely than roots.

In severe cases of Mn toxicity, plant roots turn brown, usually after

the tops have been severely injured (Foy et al., 1978).

## Liming Acid Soils

The literature is replete with information on the effect of liming

acid soils from the standpoint of chemical processes in the soil itself

and the resultant effect upon crop growth.

Many studies have shown that wheat tolerates a rather wide range

of soil pH. It is generally classified in the "medium" acid tolerant

range (Woodruff, 1967). Earlier studies in Oklahoma on soils above pH

values 5.3 showed no increase in wheat yield due to liming (Harper, 1959).

However, in the studies conducted by Lafever et al. (1977), a two-three

fold increase was obtained from liming. Kaufman and Garner (1978) state

that concentrations of Mn in wheat plants decreased as the amount of

lime applied increased. Foy et al. (1974) observed that liming the soil would decrease Al solubility and increase P solubility at the same time. Also, Martini et al. (1977) reported that wheat varieties grown in countries that were susceptible to Al showed a significant yield response to liming. Janghorbani et al. (1975) stated that with increasing lime rates, soil pH increased and exchangable acidity decreased.

The response of liming is due in part to the effectiveness and purity of the limestone (Barber, 1967). It also may be due to the variety grown. Foy and Brown (1964) stated that there are differences in response to lime even among varieties of the same species. In the study on alfalfa clones by Ovellette and Dessureaux (1958), they reported that Ca was believed to act in two ways: 1) by reducing the uptake of Al; and, 2) by immobilizing part of the absorbed Al in the roots, thus preventing translocation to plant tops. Even though lime has an effect on correcting acid soils, considerable time is required for the lime to raise the pH to an optimum level (Pearson and Adams, 1967).

CHAPTER III

MATERIALS AND METHODS

Part I Field Experiments

Two field experiments were conducted in North Central Oklahoma.
Soil types, locations, lime and N treatments are presented in Table I.
The Carrier site, a Pond Creek silt loam, is located 1.6km North and
1.6km East of town in Sec. 12, T.23.N. R.8.W. in Garfield County,
while the Lahoma site, a Meno loamy fine sand, is located 6.4km South
and 0.4km North of the North Central Agricultural Research Station in
S.E. 1/4, Sec. 36, T.21.N. R.9.W. in Major County.

The field layout was set up as four separate experiments at each
site. Four rates of N were applied to strips 121.9 by 22.9 meters.
Five ag-lime rates were randomly applied on each N strip which were
replicated four times. The ag-lime treatments were 22.9m long and
6.1m wide with 6.1m alleys between replicated blocks.

Fields were divided into four quadrants to get initial samples.
Samples were taken from five locations in each quadrant and at five dif-
ferent depths. Depths were 0-15, 15-30, 30-45, 45-60, and 60-90cm. The
monthly soil samples consisted of twenty random cores from each treat-
ment at a depth of 0-15cm which were composited and mixed in the field.
Sampling dates were initially June 10-11, 1978, while monthly samples
were August 24, 1978, September 23, 1978, October 22, 1978, November 28,

1978, for Lahoma.  Due to the incliment weather, it was December 20, 1978, before the Carrier sample could be taken.  The final samples were taken on May 14, 1979.  All samples were air dried, crushed and saved for chemical analysis.

TABLE I

LOCATION, SOIL TYPE, RATES OF LIME AND NITROGEN

|  |  | Treatment Rates | |
| --- | --- | --- | --- |
| Location | Soil Type | Lime (metric tons/ha) | Nitrogen (kg/ha) |
| Carrier | Pond Creek (Udic Argiustoll) | 0 | 0 |
|  |  | 2.69($\frac{1}{4}$x) | 224 |
|  |  | 5.38($\frac{1}{2}$x) | 448 |
|  |  | 10.76(x) | 896 |
|  |  | 21.52(2x) |  |
| Lahoma | Meno (Aquic Arenic Haplustalf) | 0 | 0 |
|  |  | 1.12($\frac{1}{4}$x) | 224 |
|  |  | 2.24($\frac{1}{2}$x) | 448 |
|  |  | 4.48(x) | 896 |
|  |  | 8.96(2x) |  |

Lime requirements were 10.76 and 4.48 metric tons ECCE lime/ha respectively for the Pond Creek and Meno soils, and were determined

using the SMP buffer (Shoemaker et al., 1961). Nitrogen was applied

as urea. Treatments were applied using a Barber spreader and had a

capacity of 0.45 metric tons. Wheat was seeded on October 6, 1978.

Grain samples were harvested by using an A-type Gleaner combine

with a 3.0m header. Grain samples were taken from a 3.0m strip 21.3

meters long from the middle of each plot. Samples were collected in

burlap bags. Straw samples were collected from a 3.0 square meter sec-

tion, from the discharged straw, in the middle of the plots. After

yields were recorded, samples of both grain and straw were taken and

brought to the lab for analysis. Grain and straw yields were taken only

on the Pond Creek soil due to the failure to get a stand on the Meno

soil.

## Part II Laboratory Experiments

### Soil pH

Initial soil pH values were obtained by glass electrode in a 1:1

soil/water ratio, 0.01M $CaCl_2$, and 1 N KCl; monthly soil pH values were

obtained using a glass electrode in a 1:1 soil/water ratio and 0.01M

$CaCl_2$. Soil pH's were determined by the procedure of Mclean (1960).

Ten grams of soil was weighed into a 142g paper cup and twenty ml

of 0.01M $CaCl_2$ was added, stirred and set aside to equilibrate. After

samples had equilibrated, the pH was determined using Orion 700 pH meter.

Standards of 4.0 and 7.0 were used to standardize the pH meter. After

ten samples, the pH meter was restandardized.

Twenty gram soil samples were weighed into a 142g paper cup and

twenty ml of deionized water was added, samples were stirred and allowed

to equilibrate. One to one values were determined the same as for the 0.01M $CaCl_2$ pH's. After 1:1 water pH's were determined, ten ml of 1 N KCl was added and samples were restirred and allowed to equilibrate again, then the pH was determined. The same procedure was used to determine the monthly pH values except 1 N KCl was deleted.

## Flame Analysis (Emission)

Aluminum, Mn, Na, Fe, Cu, and Zn were determined on the initial samples and Al and Mn were determined on the first and fourth month samples. $NH_4OAC$ pH 4.8 was used as the extracting solution in the flame analysis. $NH_4OAC$ was made by using Jackson's method (1963) at pH 5.0. Additional HOAC was added until the pH dropped to 4.8.

Standards were made up from stock solution of 1000 ug/ml except for the Zn standard which was made up from 100 ug/ml. Ten grams of air dried soil was weighed into a 125ml erlenmeyer flask, and 100ml of 1 N $NH_4OAC$ pH 4.8 was added. Samples were shaken for five minutes on a wrist action shaker and then set aside for two hours to equilibrate. After this lag time, samples were filtered by gravity flow using Whatman #2 filter paper and concentrations of the elements were measured on an atomic absorption spectrometer. Due to the dilution ratio of 10/1, all values derived from the flame spectrometer were multiplied by a factor of ten.

## Statistical Analyses

Statistical analyses were determined using the SAS--72 and 76 system. Significant difference was determined by the F test at the 5 percent level. ANOVA's were determined for monthly 1:1 and 0.01M $CaCl_2$ pH's,

Al and Mn values, wheat grain and straw yields at different lime and

N rates.  An ANOVA showing interactions between treatments is in the

Appendix.

# CHAPTER IV

## RESULTS AND DISCUSSION

### Chemical Properties of Experimental Soils

Initial soil pH values for the three pH measuring methods at vary-
ing depths are presented in Table II for each location. Both soils were
quite acidic in the surface, but pH increased with depth. However,
differences between pH measuring methods are present. This can be due
to the fact that 1:1 dissolves carbonates and other soluble salts in
the soil solution. A dilute solution of $0.01M$ $CaCl_2$ provides the pH
that has been suggested to more nearly represent the pH found around
the roots. A solution of 1 N KCl has an effect on the breakdown of
clays and results in extracting the total potential acidity and, hence,
a lower pH results. The difference in location is due to the higher
buffering capacity and CEC on the Pond Creek soil as compared to the
Meno soil.

Concentrations of initial extractable elements at both locations
and depths is tabulated in Table III. On the Pond Creek soil, Mn de-
creased with depth from 79.69 ug/g soil at 0-15cm, to 10.28 ug/g soil
at 60-90cm. Al and Fe were similar in response in that concentrations
of both were high in the soil surface (96.5 and 18.74 ug/g soil respec-
tively), and then a significant drop between 0-15 and 15-30cm for Al
and between 0-15 and 30-45cm for Fe, followed by an increase down to
60-90cm. Sodium concentrations gradually increased from 34.46 ug/g soil

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TABLE II

pH METHODS, DEPTH OF INITIAL SAMPLES
AT BOTH LOCATIONS

| Method | Depth (cm) | Location Carrier (Pond Creek sil) | Lahoma (Meno lfs) |
|---|---|---|---|
| 1 N KCl | 0-15 | 3.92 | 3.88 |
| | 15-30 | 5.00 | 4.17 |
| | 30-45 | 5.48 | 4.76 |
| | 45-60 | 5.72 | 5.28 |
| | 60-90 | 5.83 | 5.79 |
| 1:1 Water | 0-15 | 4.66 | 4.87 |
| | 15-30 | 5.56 | 4.99 |
| | 30-45 | 6.37 | 5.95 |
| | 45-60 | 6.79 | 6.52 |
| | 60-90 | 6.93 | 7.01 |
| 0.01M $CaCl_2$ | 0-15 | 4.80 | 4.06 |
| | 15-30 | 5.08 | 4.18 |
| | 30-45 | 5.59 | 5.05 |
| | 45-60 | 6.26 | 5.66 |
| | 60-90 | 6.40 | 6.13 |

at 0-15cm to 59.87 ug/g soil at 60-90cm depth. When 45-60cm is excluded,
Zn follows the general trend as Al, Na, and Fe with a gradual increase
with increasing depths. Copper concentrations are about the same through-
out the profile. This increase of Al and Fe with depth can be due to

TABLE III

SOME CHEMICAL CONCENTRATIONS OF EXPERIMENTAL SOILS

| Location | Depth (cm) | Al | Mn | Na | Fe | Cu | Zn |
|----------|------------|-----|-----|-----|-----|-----|-----|
| | | | | | | | |
| | | | | Analysis (1 N $NH_4OAC$ 4.8) | | | |
| | | | | (ug/g soil) | | | |
| | | | | | | | |
| Pond Creek | 0–15 | 96.50 | 79.69 | 34.46 | 18.74 | .36 | 21.68 |
| | 15–30 | 27.90 | 37.64 | 34.76 | 2.19 | .43 | 23.72 |
| | 30–45 | 38.35 | 19.33 | 35.09 | 1.40 | .35 | 25.56 |
| | 45–60 | 57.75 | 12.55 | 42.80 | 1.59 | .31 | 20.62 |
| | 60–90 | 68.55 | 10.28 | 59.87 | 2.04 | .31 | 25.78 |
| | | | | | | | |
| Meno | 0–15 | 74.65 | 32.93 | 6.70 | 12.20 | .50 | 9.31 |
| | 15–30 | 64.70 | 35.49 | 6.75 | 9.72 | .45 | 7.76 |
| | 30–45 | 32.65 | 28.17 | 6.81 | 2.98 | .27 | 12.76 |
| | 45–60 | 31.20 | 13.05 | 8.46 | 1.58 | .27 | 15.46 |
| | 60–90 | 40.25 | 7.99 | 10.39 | 1.45 | .49 | 9.06 |

the increasing clay content at the lower depths. The decrease of Mn and the increase of Na is associated with the increase in pH.

On the Meno soil, both Mn and Fe decreased drastically with depth. Aluminum decreased from 74.65 ug/g soil at 0–15cm down to 31.20 ug/g soil at 45–60cm, then increases from 31.20 to 40.25 ug/g soil at 60–90cm. Sodium showed a slight increase from 6.70 ug/g soil at 0–15cm to 10.39 ug/g soil at 60–90cm. Copper was basically unchanged. Zinc values fluctuated with depth.

The increase of Al at the lower depth on the Meno soil could be

due to the presence of a clay layer. Manganese decreased due to the higher pH at the lower depths. Also, the decrease of Fe can be explained as a function of pH, and the higher Na concentrations at the lower depths contributed to the higher pH values. The Zn variability could be due to natural field variability or experimental error.

Generally, the elemental concentrations at Carrier were higher than at Lahoma. The Pond Creek soil has a higher buffering capacity, more exchangable bases, a higher clay content, and a higher lime requirement than the Meno soil.

<div align="center">

### Effect of Ag-Lime Treatments with
### Varying Rates of N - Carrier

</div>

## Soil pH

The effect of ag-lime on subsequent soil pH values for each treatment are shown graphically in Figures 4 through 11. All rates of ag-lime increased the pH of the surface. By the first sampling date after treatment, significant changes in pH values were measured. The greatest increases in pH occurred by the first sampling date. As expected, the higher rates increased pH more than the lower rates. The x and 2x lime rates were required to raise the soil pH to levels above 5.5. There was a trend for the zero lime plots to decrease in pH values.

The effect of N on soil pH is shown in Table IV. By the first sampling date (35 days after application), all rates of ag-lime increased the soil pH by both the 1:1 and 0.01M $CaCl_2$ methods regardless of N treatment. Increases in pH values by ag-lime were affected by N levels. By the end of the growing season (298 days after application), the pH

N=Zero
X=10.76 Metric Tons ECCE/ha

Pond Creek sil

○————○ = 0
◇————◇ = ¼x
△————△ = ½x
□————□ = x
●————● = 2x
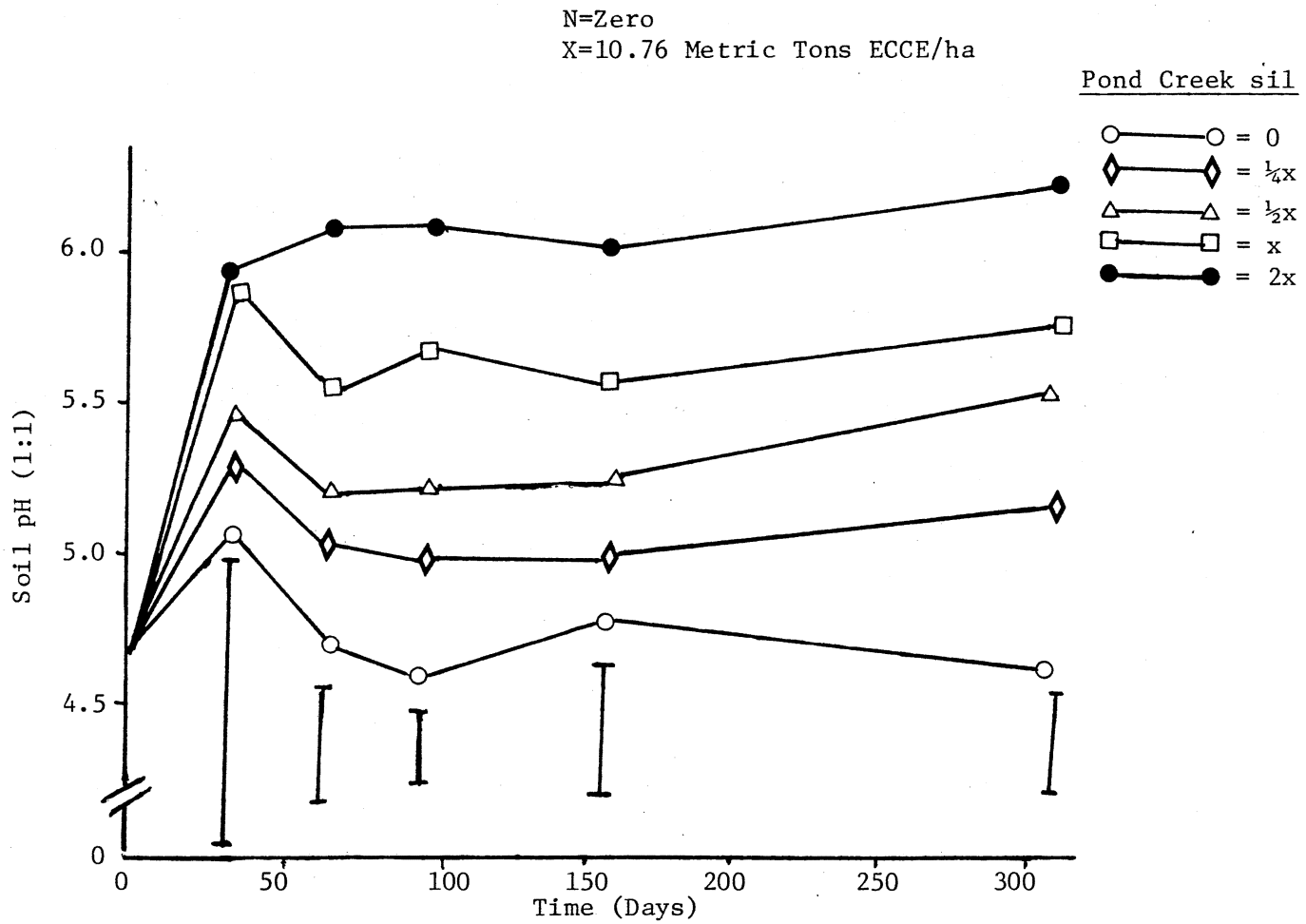
Figure 4. Effects of Ag-Lime on pH (1:1) of Pond Creek
Silt Loam (N=0)
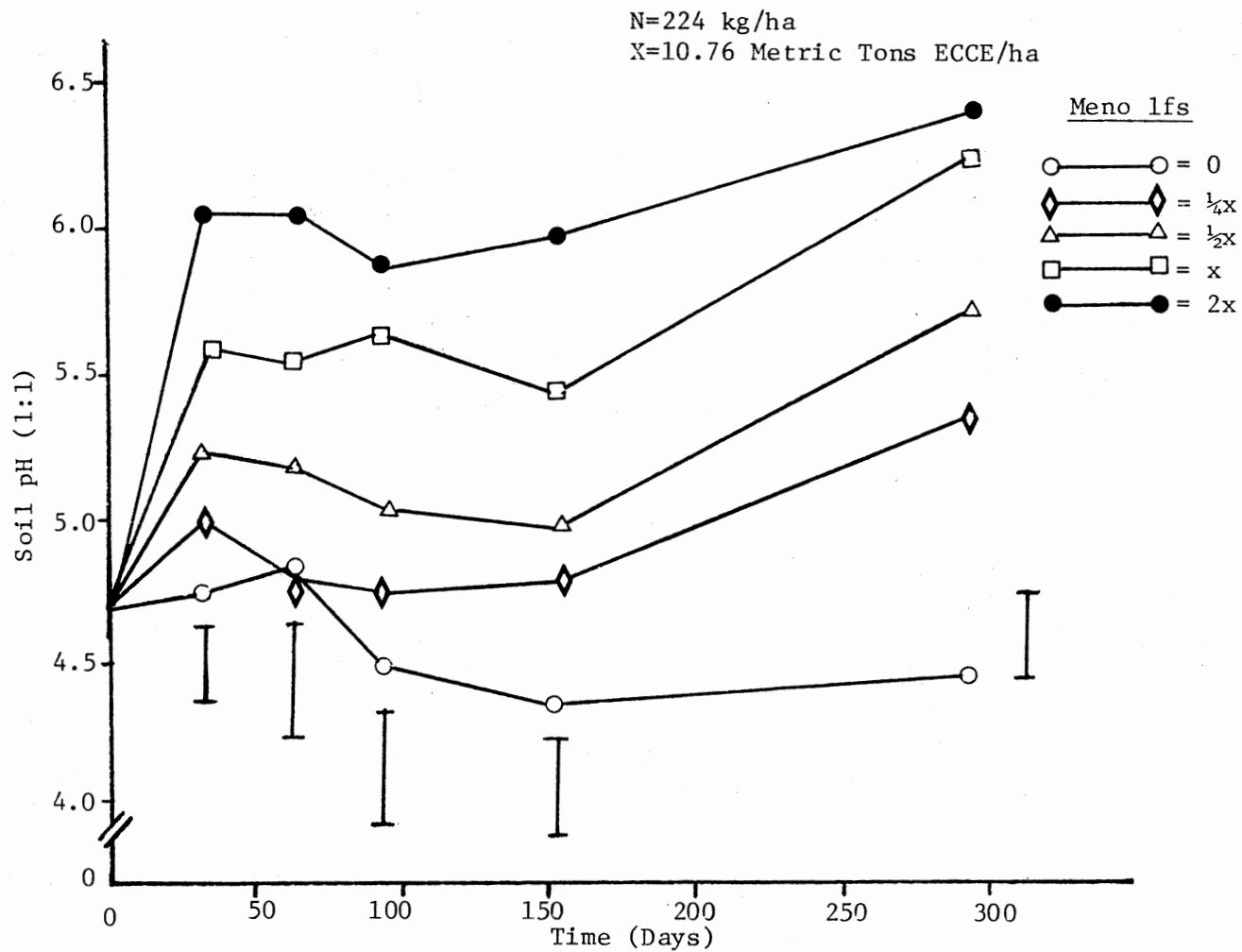
Figure 5. Effects of Ag-Lime on pH (1:1) of Pond Creek Silt Loam
(N=224 kg/ha)
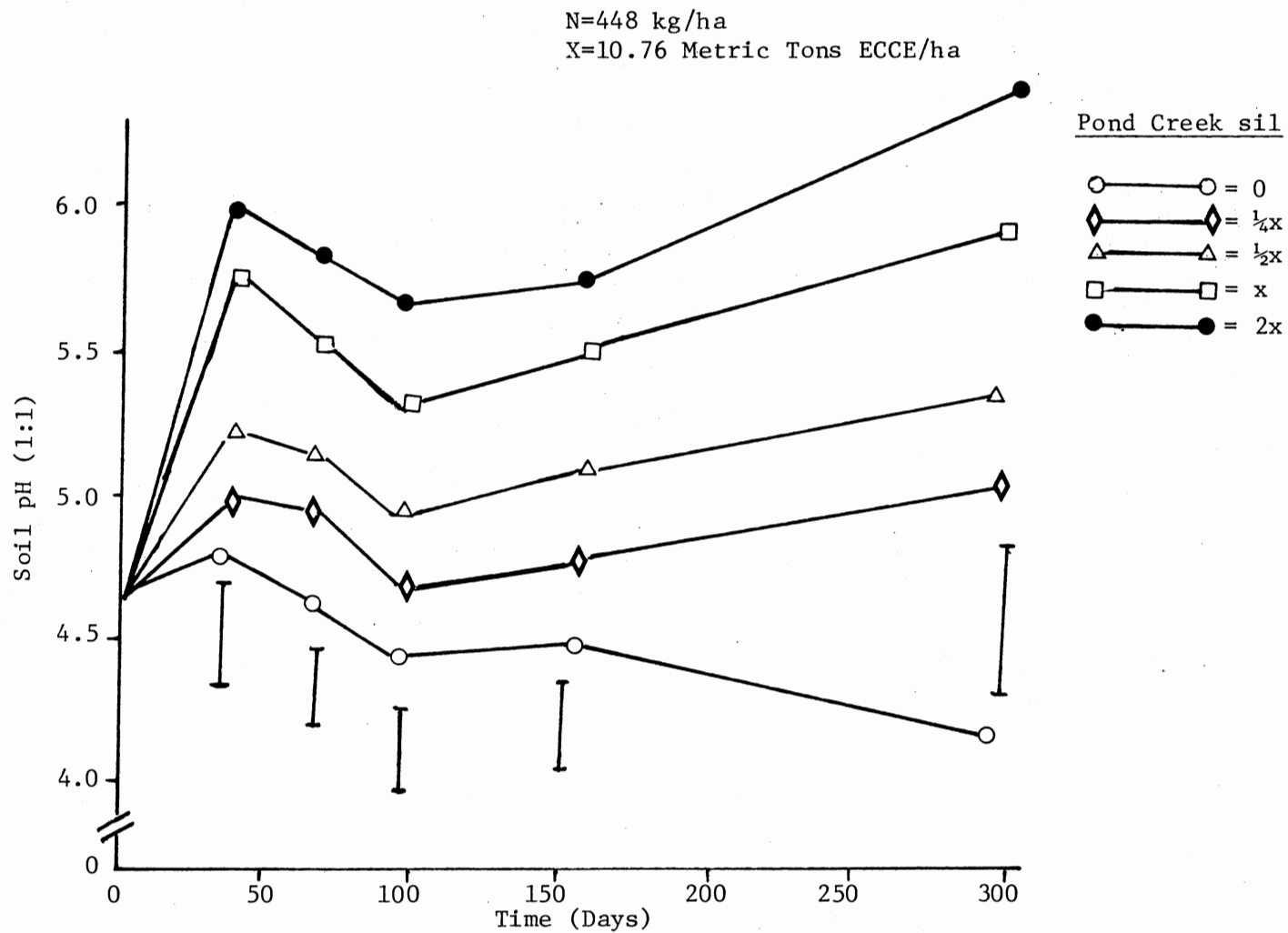
Figure 6. Effects of Ag-Lime on pH (1:1) of Pond Creek
Silt Loam (N=448 kg/ha)

23
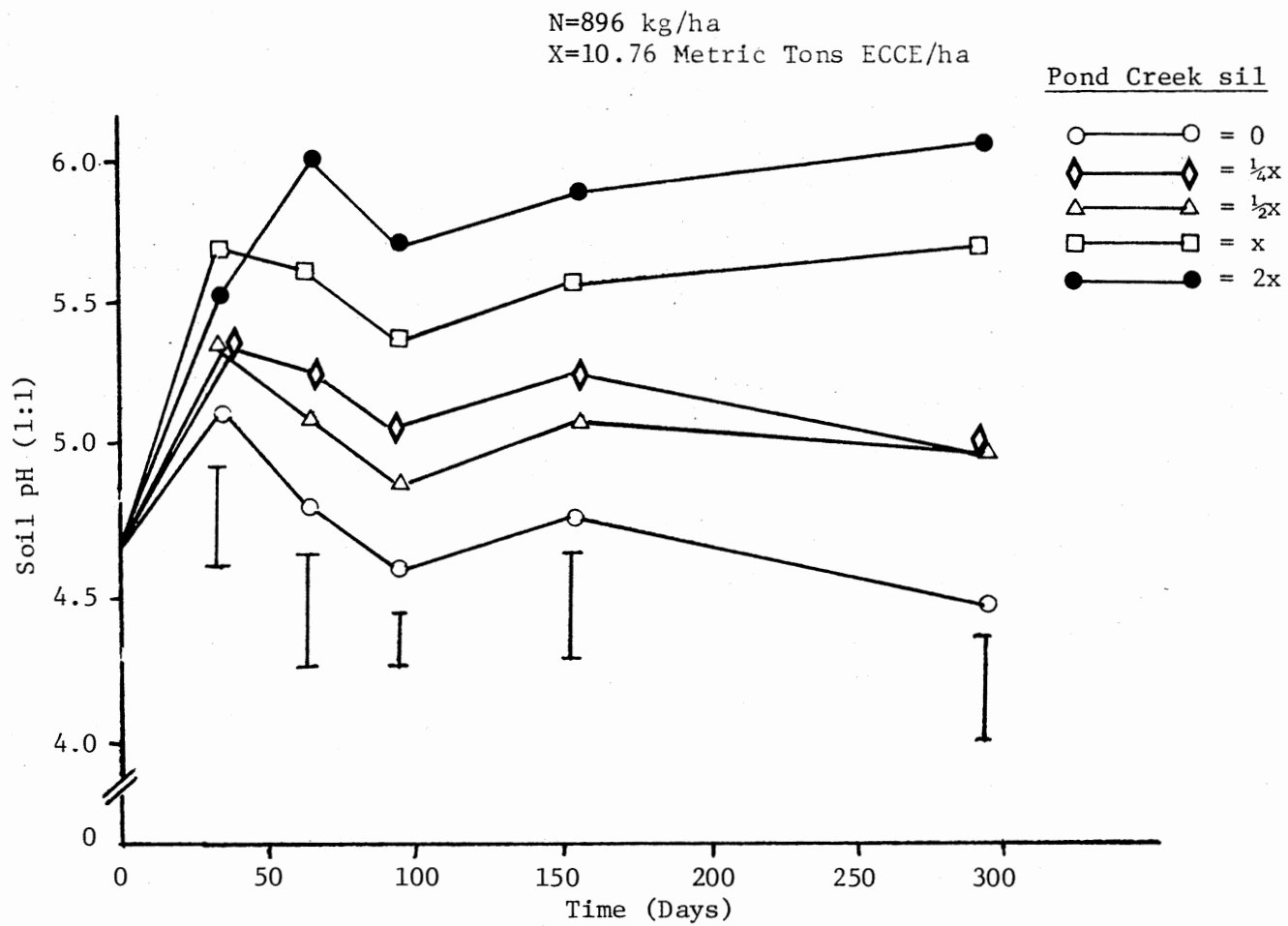
Figure 7. Effects of Ag-Lime on Soil pH (1:1) of Pond Creek
Silt Loam (N=896 kg/ha)
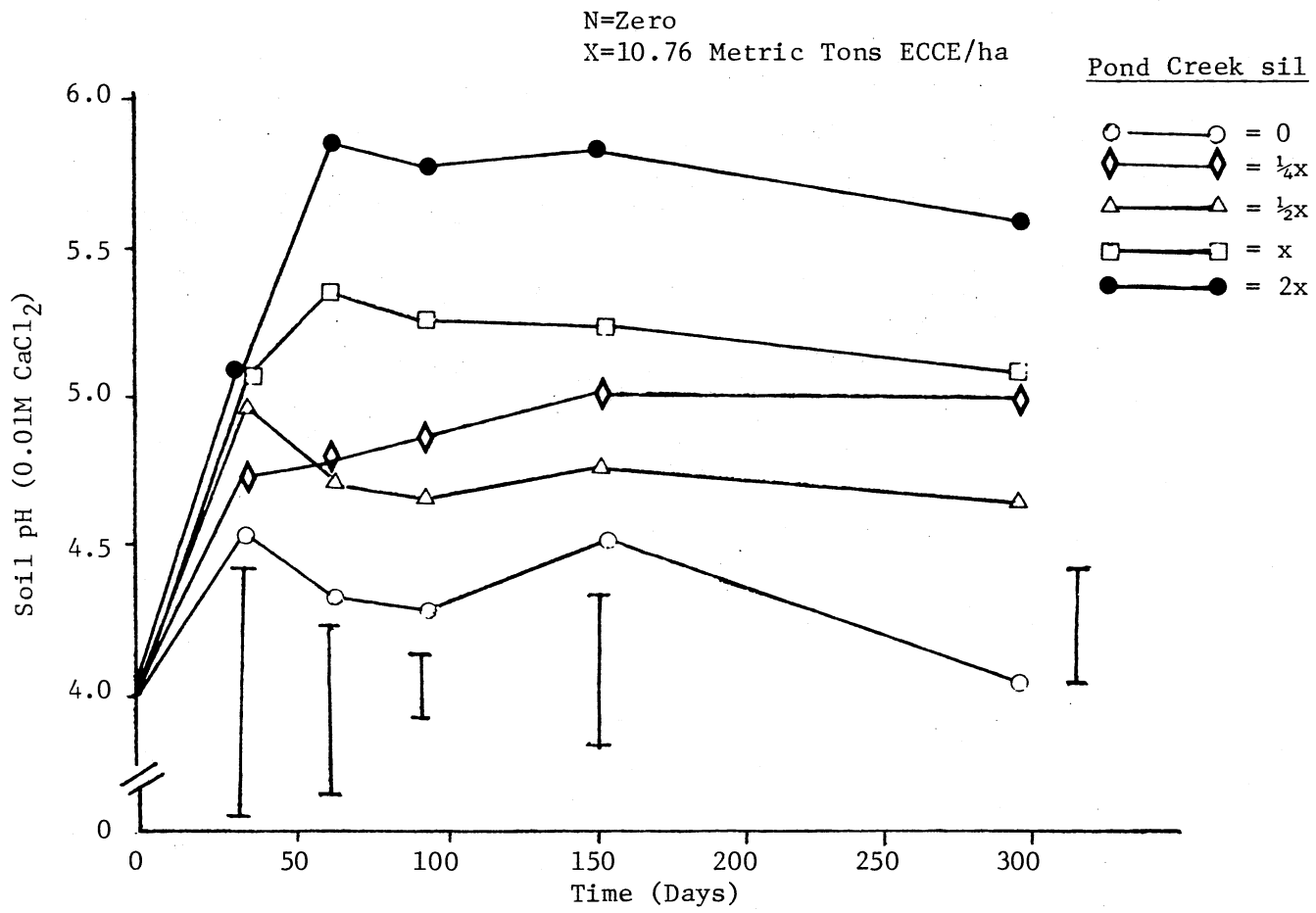
Figure 8. Effects of Ag–Lime on pH (0.01M CaCl$_2$) of Pond Creek
Silt Loam (N=0)
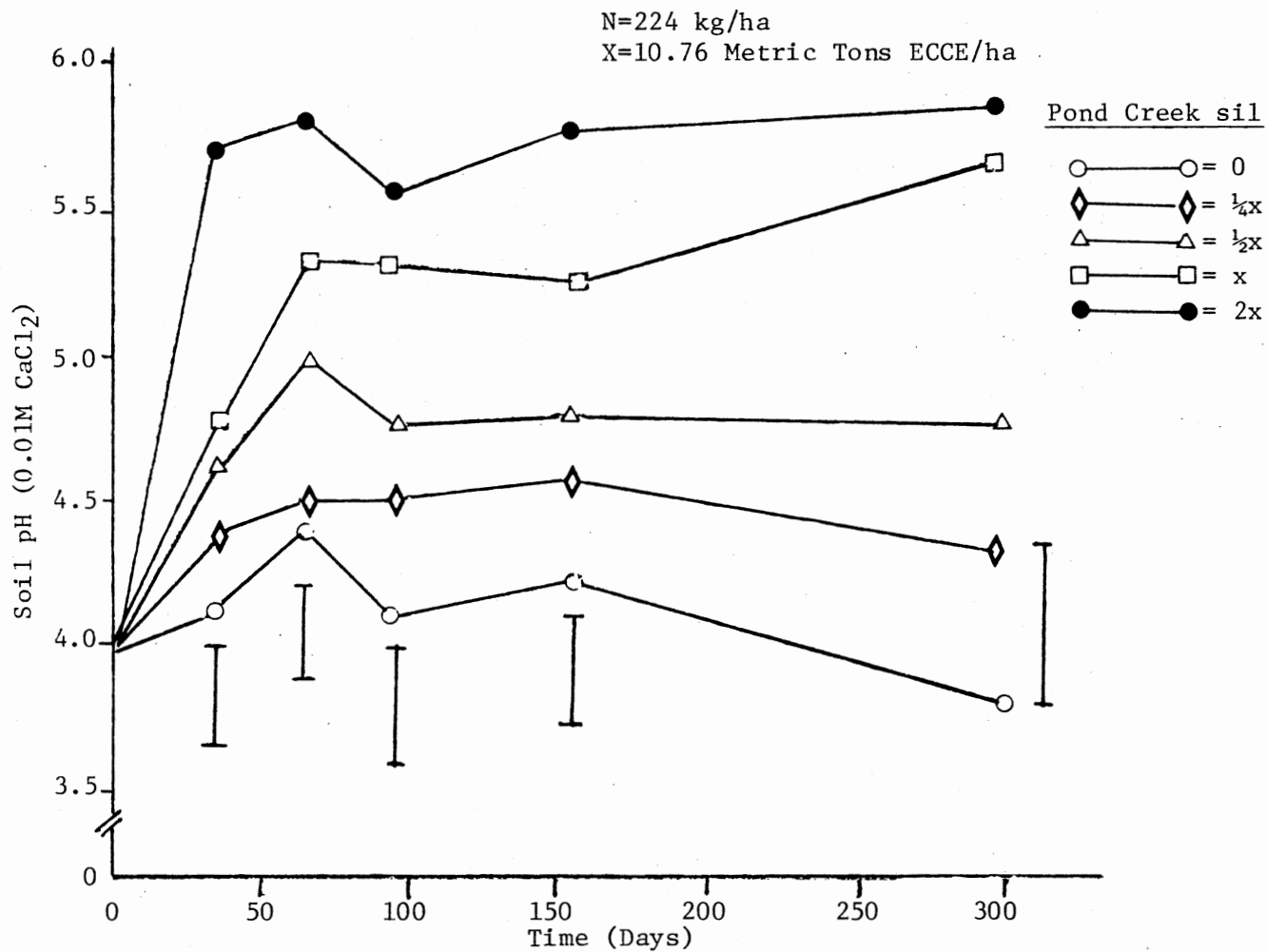
Figure 9.  Effects of Ag-Lime on pH (0.01M CaCl$_2$) of Pond Creek
Silt Loam (N=224 kg/ha)
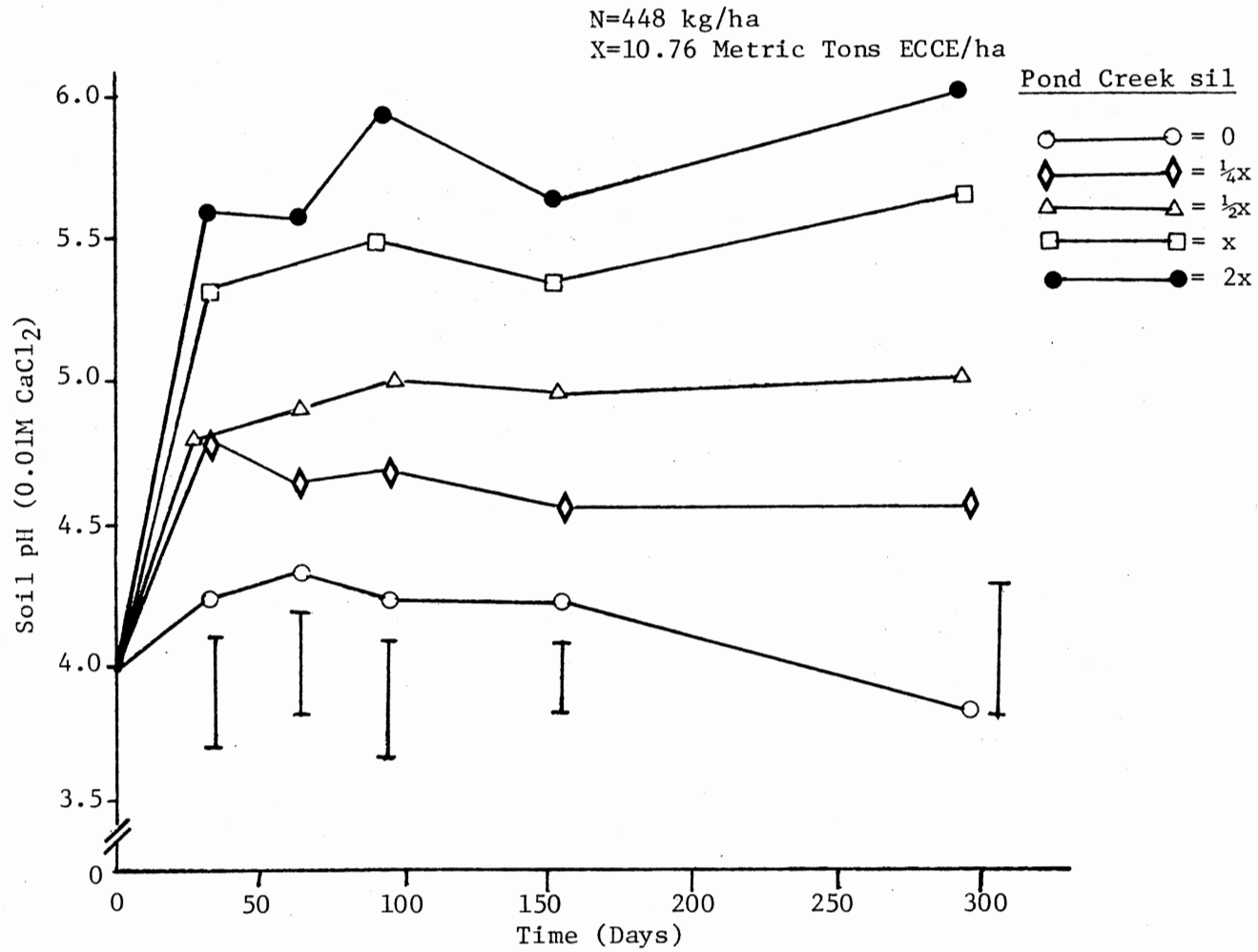
Figure 10.  Effects of Ag-Lime on pH (0.01M $CaCl_2$) of Pond
Creek Silt Loam (N=448 kg/ha)
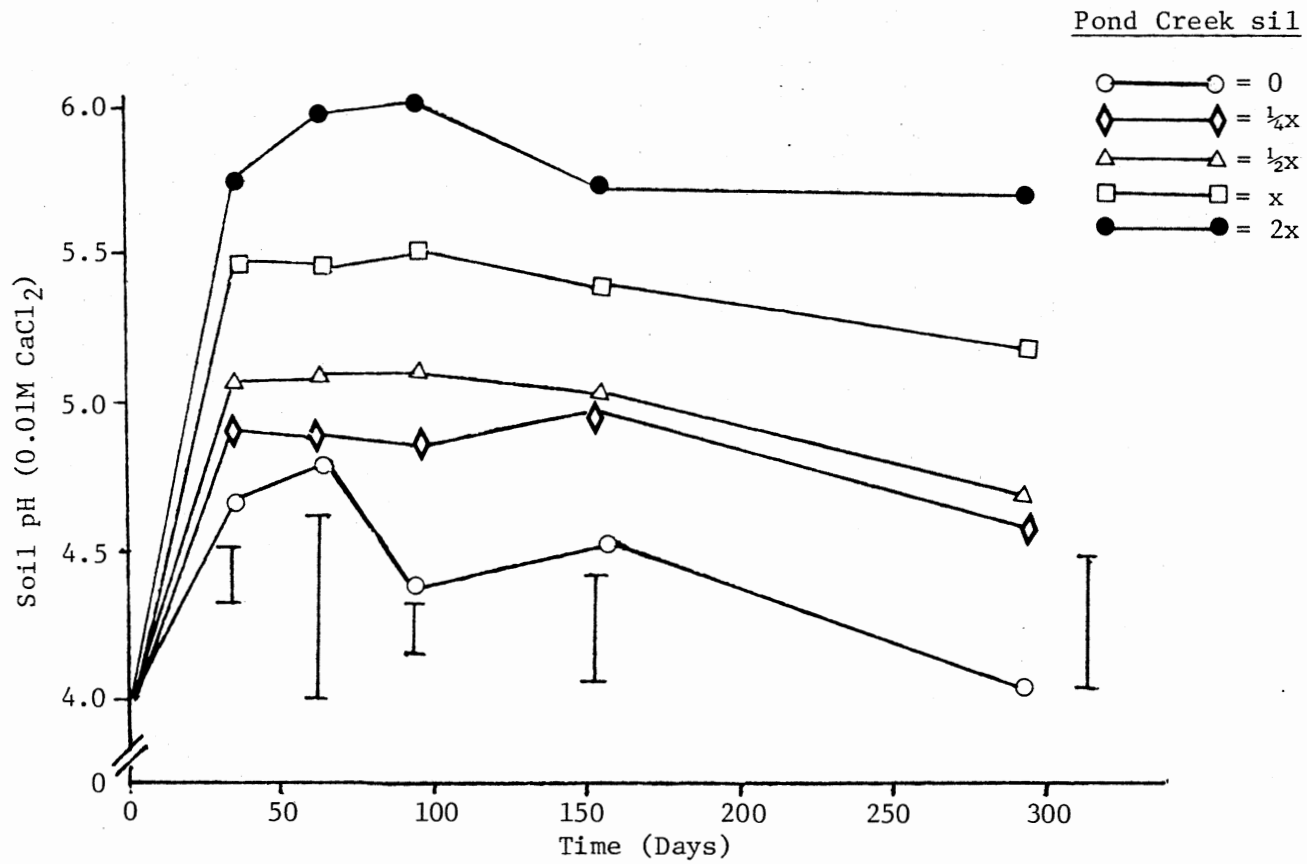
Figure 11.   Effects of Ag-Lime on pH (0.01M $CaCl_2$) of Pond
Creek Silt Loam (N=896 kg/ha)

TABLE IV

THE EFFECTS OF AG-LIME AND NITROGEN RATES
ON SOIL pH ON POND CREEK SILT LOAM

| N Rate (kg/ha) | Lime Rate (Metric Tons ECCE/ha) | | | | | Lime Rate (Metric Tons ECCE/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1/4x | 1/2x | x | 2x | 0 | 1/4x | 1/2x | x | 2x |
| | 1:1 - 35 Days | | | | | 1:1 - 298 Days | | | | |
| 0 | 4.86 | 5.50 | 5.28 | 5.58 | 5.58 | 4.69 | 5.23 | 5.39 | 5.81 | 6.27 |
| 224 | 4.71 | 4.95 | 5.21 | 5.55 | 6.08 | 4.32 | 5.15 | 5.53 | 6.09 | 6.46 |
| 448 | 4.75 | 5.15 | 5.19 | 5.17 | 5.99 | 4.27 | 5.11 | 5.31 | 6.02 | 6.48 |
| 896 | 5.11 | 5.32 | 5.32 | 5.68 | 5.53 | 4.42 | 4.94 | 5.10 | 5.38 | 6.02 |
| | 0.01 M CaCl$_2$ - 35 Days | | | | | 0.01 M CaCl$_2$ - 298 Days | | | | |
| 0 | 4.34 | 4.77 | 4.88 | 5.14 | 5.01 | 4.02 | 4.61 | 4.82 | 5.18 | 5.59 |
| 224 | 4.14 | 4.38 | 4.61 | 4.67 | 5.69 | 3.82 | 4.36 | 4.79 | 5.42 | 5.85 |
| 448 | 4.30 | 4.73 | 4.73 | 5.32 | 5.59 | 3.82 | 4.56 | 5.01 | 5.56 | 6.00 |
| 896 | 4.55 | 5.02 | 5.06 | 5.45 | 5.72 | 4.06 | 4.56 | 4.68 | 5.15 | 5.67 |

values were higher than at the first sampling date at each N level, and
1:1 pH values were all above 6.0. The highest 1:1 pH values were from
the 2x treatment with N=224 and N=448 kg/ha. The x lime treatment at
these N rates were above 6.0.

The 0.01M $CaCl_2$ pH values followed essentially the same trend as
the 1:1 pH values, but the 0.01M $CaCl_2$ values were from 0.5 to 0.9 pH
units lower. On the zero lime plots, N rates seemed to have little
effect on soil pH values. The effect of N on pH changes was expressed
within the ag-lime rates. At the higher N rates (448 and 896 kg/ha),
nitrification from ammonium N is present to intensify the decrease in
pH. The initial increases in pH is due to the release of ammonium N
being applied which eventually results in a decrease in pH. This trend
is present for both pH methods, but is more apparent for the 1:1 pro-
cedure.

Extractable Aluminum and Manganese

The effect of ag-lime and N rates on Al content of the Pond Creek
(Carrier site) is presented in Table V. Ag-lime had no effect on ex-
tractable Al within 35 days after treatment. It may be noteworthy,
however, that the lowest Al concentrations were measured at the highest
N rate.

Ag-lime applications did affect measured Al concentrations on
samples taken 153 days after treatment. In all cases, significantly
lower Al concentrations were measured with increasing rates of ag-lime.
In spite of the fact that N rates tended to decrease soil pH, N rates
decreased soluble Al concentrations at each ag-lime rate.

It will be interesting in future studies on these plots to note

TABLE V

EFFECT OF LIME ON ALUMINUM CONTENT WITH VARYING RATES
OF NITROGEN WITH TIME AT POND CREEK SILT LOAM

| Lime Metric Tons ECCE/ha x=10.76 | Al(ug/g soil) at 35 Days N(kg/ha) | | | | Al(ug/g soil) at 153 Days N(kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 224 | 448 | 896 | 0 | 224 | 448 | 896 |
| 0 | 83.50 | 95.00 | 86.00 | 73.75 | 75.00 | 92.50 | 50.00 | 60.00 |
| 1/4x | 85.00 | 86.00 | 81.00 | 70.00 | 60.00 | 70.00 | 52.50 | 42.50 |
| 1/2x | 87.50 | 85.00 | 88.00 | 77.00 | 63.75 | 57.50 | 47.50 | 37.50 |
| x | 82.00 | 83.25 | 77.75 | 55.75 | 57.50 | 55.00 | 35.00 | 35.00 |
| 2x | 85.75 | 71.00 | 78.75 | 64.00 | 43.75 | 40.00 | 30.00 | 32.50 |
| LSD.05 | 18.04 | 18.58 | 9.88 | 34.21 | 18.64 | 13.76 | 23.16 | 15.04 |

the effects of N levels on soluble Al when the $NH_4$ ion has dissipated.

The effect of ag-lime and N on Mn concentration is presented in Table VI. At 35 days, ag-lime had no effect on Mn concentrations, but the application of 896 kg/ha increased the Mn concentration. Very high levels of Mn were found in all plots.

By 153 days, lower levels of soluble Mn were present in the soil, and the concentrations decreased with increasing rates of ag-lime. Again, N rates increased Mn concentrations.

With Al concentrations decreasing with increasing N applications while Mn concentrations increased as N rates increased, any interpretations of the causative effects of poor wheat yields on acid soil is difficult.

Grain and straw yields from the treatments are shown in Table VII. Grain yields were decreased by N application on zero lime plots. This was to be expected with the high residual soil N levels. Abnormally high rates of N were selected to determine the effects of N on soil chemical properties not on practical levels for proper fertilization.

Because grain yields were not decreased by N application through the 448 kg/ha rate when lime requirement was met suggests an interesting phenomena. It could be concluded that the higher Mn concentration resulting from added N on the zero lime plots was responsible for the decreased yields, whereas the toxic soluble Mn levels was sufficiently depressed with adequate ag-lime.

Straw yields did not follow the same trends as grain yields except ag-lime applications did result in increased yields. However, the highest straw yields were obtained from 448 kg/ha with x and 2x lime applications. It is of interest to note the large increase in straw

## TABLE VI

### EFFECT OF LIME ON MANGANESE CONTENT WITH VARYING RATES OF NITROGEN WITH TIME AT POND CREEK SILT LOAM

| Lime Metric Tons ECCE/ha x=10.76 | Mn(ug/g soil) at 35 Days N(kg/ha) | | | | Mn(ug/g soil) at 153 Days N(kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 224 | 448 | 896 | 0 | 224 | 448 | 896 |
| 0 | 84.75 | 88.00 | 103.25 | 122.75 | 77.25 | 80.00 | 97.50 | 118.75 |
| 1/4x | 83.50 | 86.50 | 99.00 | 119.25 | 60.50 | 60.50 | 73.50 | 116.25 |
| 1/2x | 83.75 | 86.75 | 99.75 | 119.75 | 54.00 | 59.00 | 71.25 | 110.00 |
| x | 89.25 | 88.00 | 105.00 | 117.50 | 50.25 | 47.00 | 56.00 | 97.75 |
| 2x | 96.25 | 92.25 | 109.75 | 124.00 | 53.50 | 46.75 | 58.25 | 87.00 |
| LSD.05 | 18.58 | 11.27 | 13.93 | 9.67 | 17.32 | 10.66 | 13.08 | 21.13 |

TABLE VII

EFFECT OF AG-LIME AND NITROGEN ON YIELD OF
WINTER WHEAT ON A POND CREEK
SILT LOAM SOIL

| Lime (metric tons ECCE/ha) | Grain (kg/ha) | | | | Straw (kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| x=10.76 | | | N level (kg/ha) | | | | | |
| | 0 | 224 | 448 | 896 | 0 | 224 | 448 | 896 |
| 0 | 2769 | 2155 | 2196 | 2592 | 2501 | 2437 | 2354 | 2732 |
| 1/4x | 3184 | 2888 | 2883 | 2854 | 3781 | 3525 | 3488 | 4013 |
| 1/2x | 3190 | 2808 | 2893 | 2968 | 3745 | 3866 | 3183 | 4303 |
| x | 3370 | 3215 | 3276 | 2953 | 3549 | 4256 | 4342 | 3891 |
| 2x | 3155 | 3089 | 3197 | 2853 | 4082 | 4116 | 3988 | 4256 |
| LSD.05 | 508 | 437 | 521 | 346 | 1797 | 2247 | 1933 | 1632 |

yields with the first increment (1/4x) of ag-lime.  Rather small rates
of ag-lime caused considerable improvement in total dry matter produced.

Effects of Ag-Lime Treatments with

Varying Rates of N - Lahoma

## Soil pH

Soil pH on the Meno soil followed the same general trend as the
Pond Creek soil with all rates of ag-lime increasing soil pH of the

surface and the greatest increases in pH occurring by the first date. The higher lime rates (x and 2x) were consistently more effective than the other lime rates in increasing soil pH. The x and 2x lime rates were required to raise the pH to a level above 5.0. There was a trend for soil pH to decrease with time in the zero lime plots. The effects of ag-lime on monthly pH's is shown in Figures 12 through 19. As with the Pond Creek soil, 1:1 values were consistently higher than the 0.01M $CaCl_2$ values.

Effects of N rate on soil pH is presented in Table VIII. By the end of the first sampling date (35 days after application), all rates of ag-lime increased soil pH by both the 1:1 and 0.01M $CaCl_2$ methods regardless of N treatment. Increases in pH values by ag-lime were affected by N treatment only at the low ag-lime rates and the highest N levels. The highest pH levels were from 0 and 224 kg N/ha. This would indicate that as N rates are increased, they have an effect on lowering soil pH. At the higher N rates (448 and 896 kg/ha), there was more nitrification of ammonium N present to intensify the drop in pH.

The 0.01M $CaCl_2$ pH values followed essentially the same trend as the 1:1 pH values, but the 0.01M $CaCl_2$ values were from 0.5 to 0.9 pH units lower. The effect of N on pH changes was expressed within the ag-lime rates. On the zero lime plots, N rates seemed to have little effect on soil pH values. At higher N rates (448 and 896 kg/ha), nitrification from ammonium N is present to intensify the decrease in pH. The initial increase in pH is due to the release of ammonium N being applied which eventually results in a decrease in pH. This trend is present for both pH methods but more so for the 1:1 soil pH procedure.

## TABLE VIII

### THE EFFECT OF AG-LIME AND NITROGEN ON
### SOIL pH ON MENO LOAMY FINE SAND

| N Rate (kg/ha) | Lime Rate (Metric Tons ECCE/ha) | | | | | Lime Rate (Metric Tons ECCE/ha) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1/4x | 1/2x | x | 2x | 0 | 1/4x | 1/2x | x | 2x |
| | 1:1 - 35 Days | | | | | 1:1 - 298 Days | | | | |
| 0 | 5.23 | 5.35 | 5.65 | 5.87 | 6.40 | 4.96 | 5.05 | 5.43 | 5.71 | 6.01 |
| 224 | 5.32 | 5.53 | 5.59 | 5.97 | 6.34 | 4.27 | 4.72 | 5.06 | 5.43 | 5.82 |
| 448 | 5.32 | 5.28 | 5.57 | 5.49 | 5.79 | 3.97 | 4.19 | 4.38 | 5.27 | 5.62 |
| 896 | 5.86 | 6.19 | 6.26 | 6.21 | 6.29 | 4.33 | 4.78 | 4.80 | 5.33 | 5.68 |
| | $0.01$ M $CaCl_2$ - 35 Days | | | | | $0.01$ M $CaCl_2$ - 298 Days | | | | |
| 0 | 4.21 | 4.51 | 4.67 | 4.89 | 5.27 | 4.02 | 4.28 | 4.74 | 4.92 | 5.41 |
| 224 | 4.40 | 4.53 | 4.57 | 5.10 | 5.36 | 3.81 | 4.08 | 4.42 | 4.86 | 5.37 |
| 448 | 4.33 | 4.42 | 4.68 | 4.88 | 5.39 | 3.67 | 3.90 | 3.92 | 4.81 | 5.19 |
| 896 | 4.70 | 5.04 | 5.23 | 5.25 | 5.42 | 3.70 | 3.95 | 4.26 | 4.92 | 5.20 |
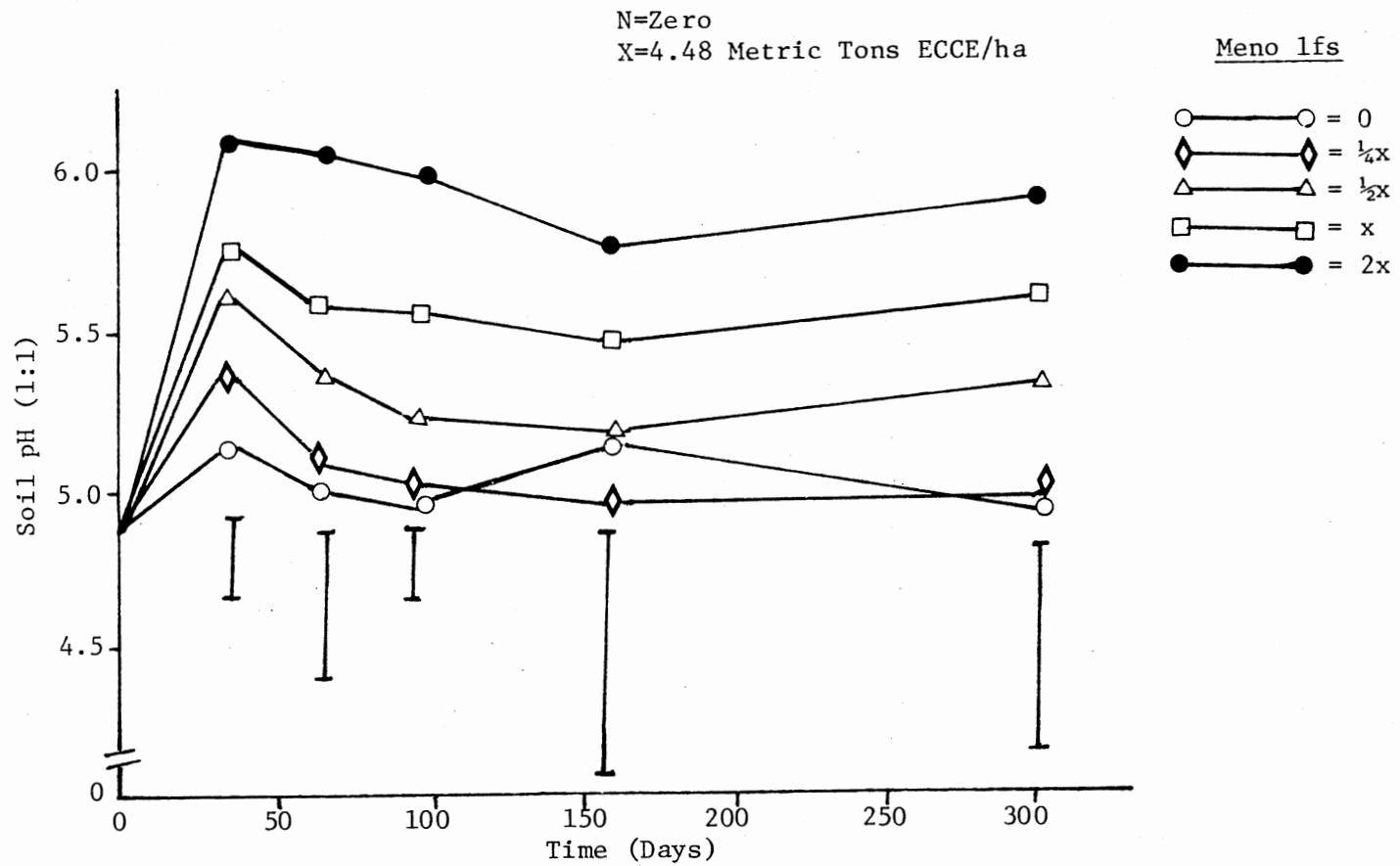
Figure 12. Effects of Ag-Lime on pH (1:1) of Meno Loamy
Fine Sand (N=0)
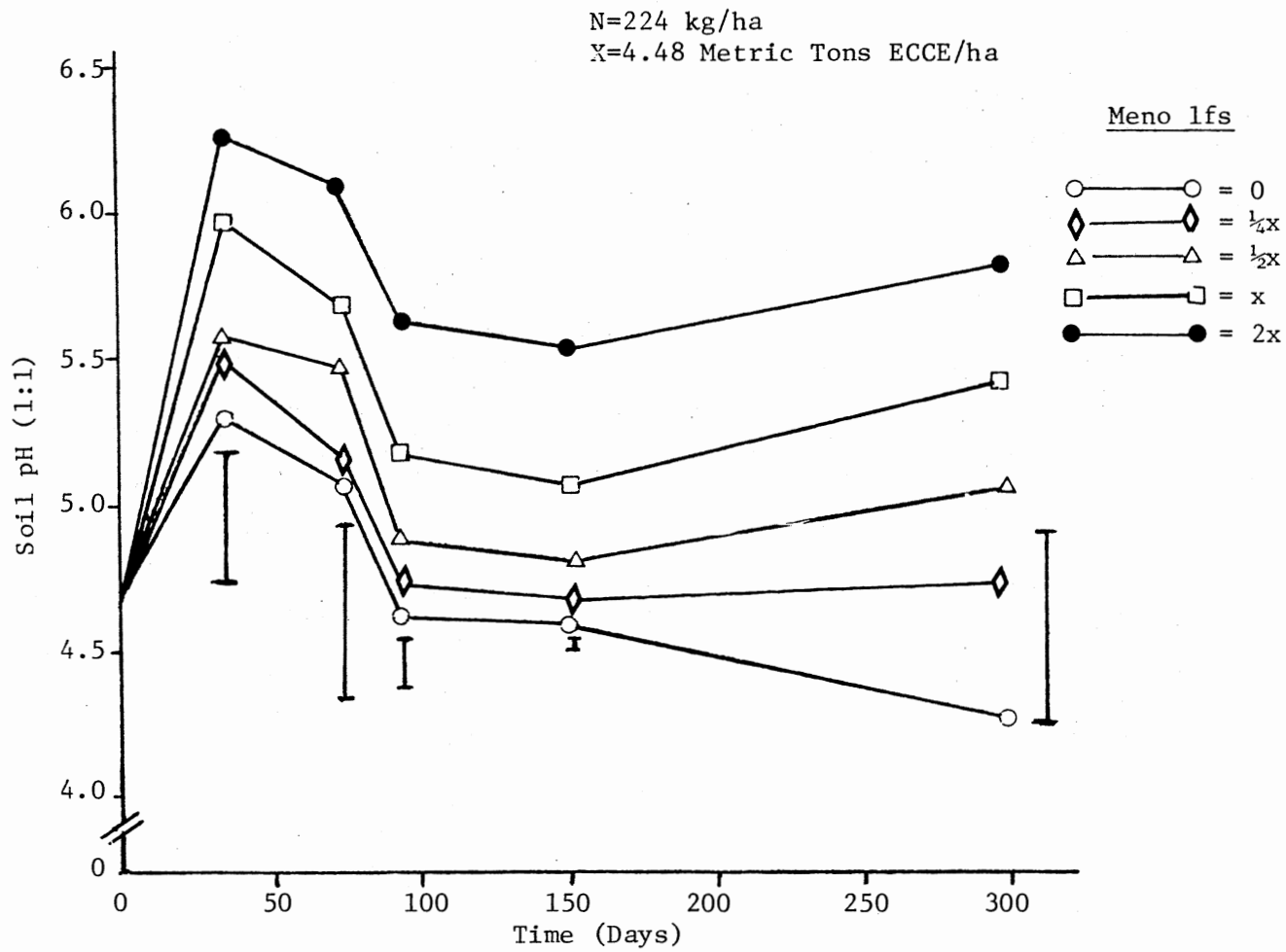
Figure 13.   Effects of Ag-Lime on pH (1:1) of Meno Loamy
Fine Sand (N=224 kg/ha)
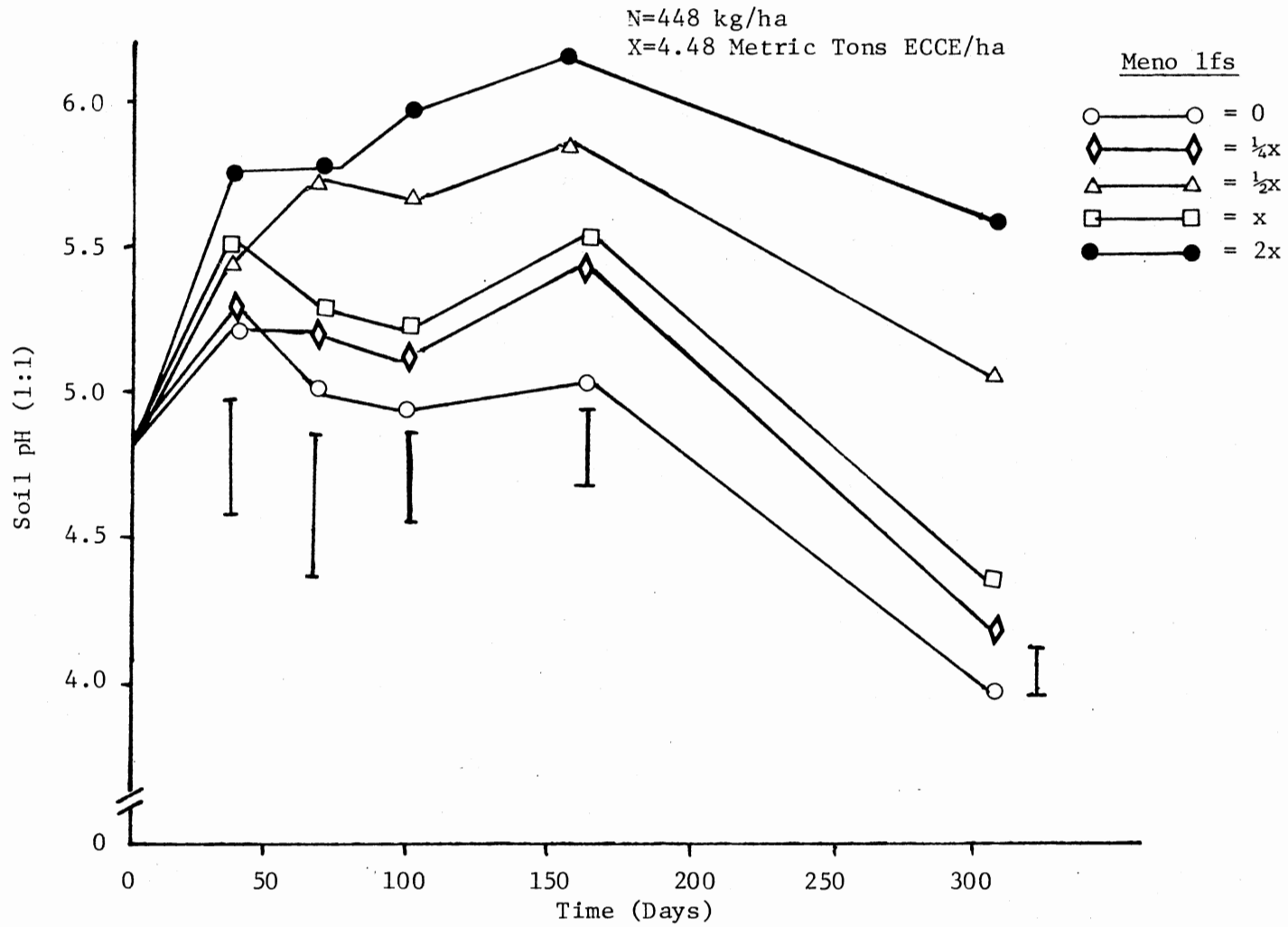
Figure 14.  Effects of Ag-Lime on pH (1:1) of Meno Loamy
Fine Sand (N=448 kg/ha)

Figure 15.  Effects of Ag–Lime on pH (1:1) of
Meno Loamy Fine Sand (N=896 kg/ha)

N=Zero
X=4.48 Metric Tons ECCE/ha

Figure 16.   Effects of Ag-Lime on pH (0.01M $CaCl_2$) of Meno Loamy
Fine Sand (N=0)

Figure 17.  Effects of Ag-Lime on pH ($0.01M$ $CaCl_2$) of
Meno Loamy Fine Sand ($N=224$ kg/ha)

N=448 kg/ha
X=4.48 Metric Tons ECCE/ha

Meno lfs

○────○ = 0
◇────◇ = ¼x
△────△ = ½x
□────□ = x
●────● = 2x

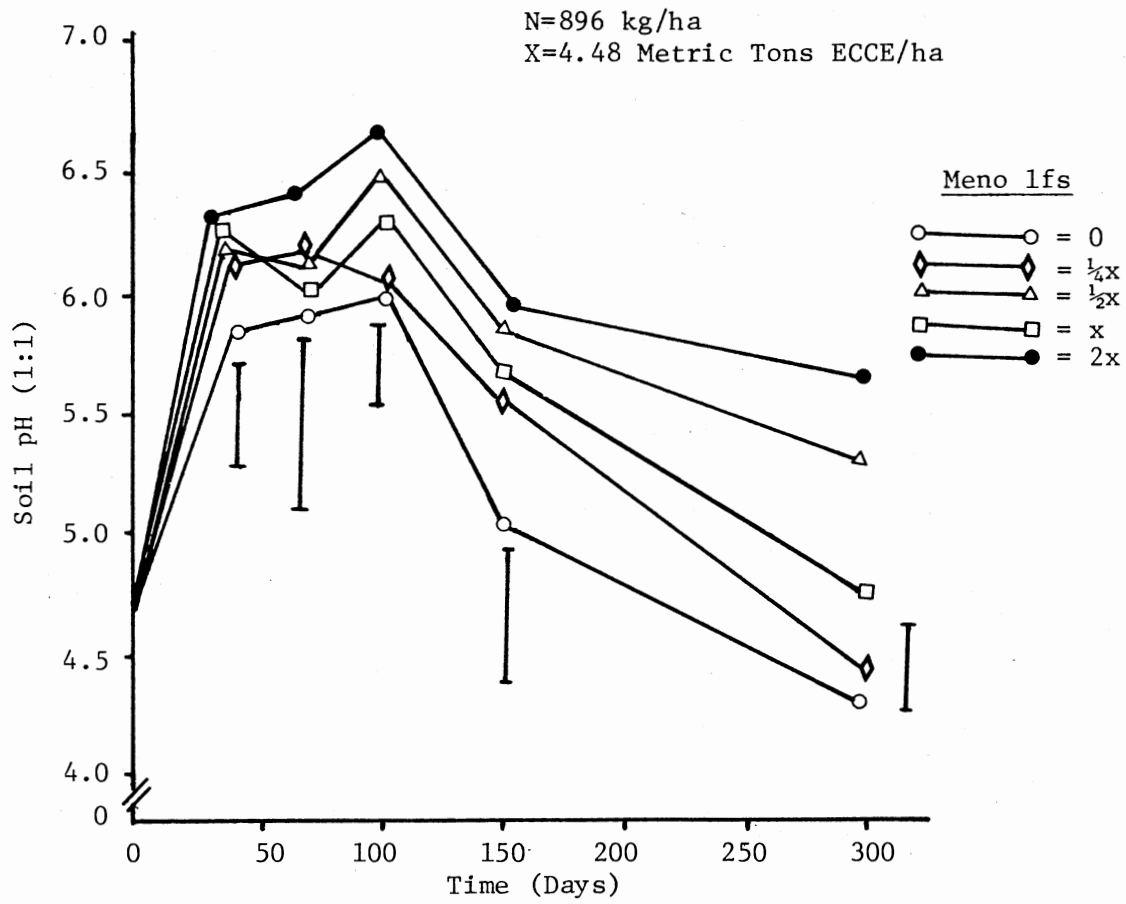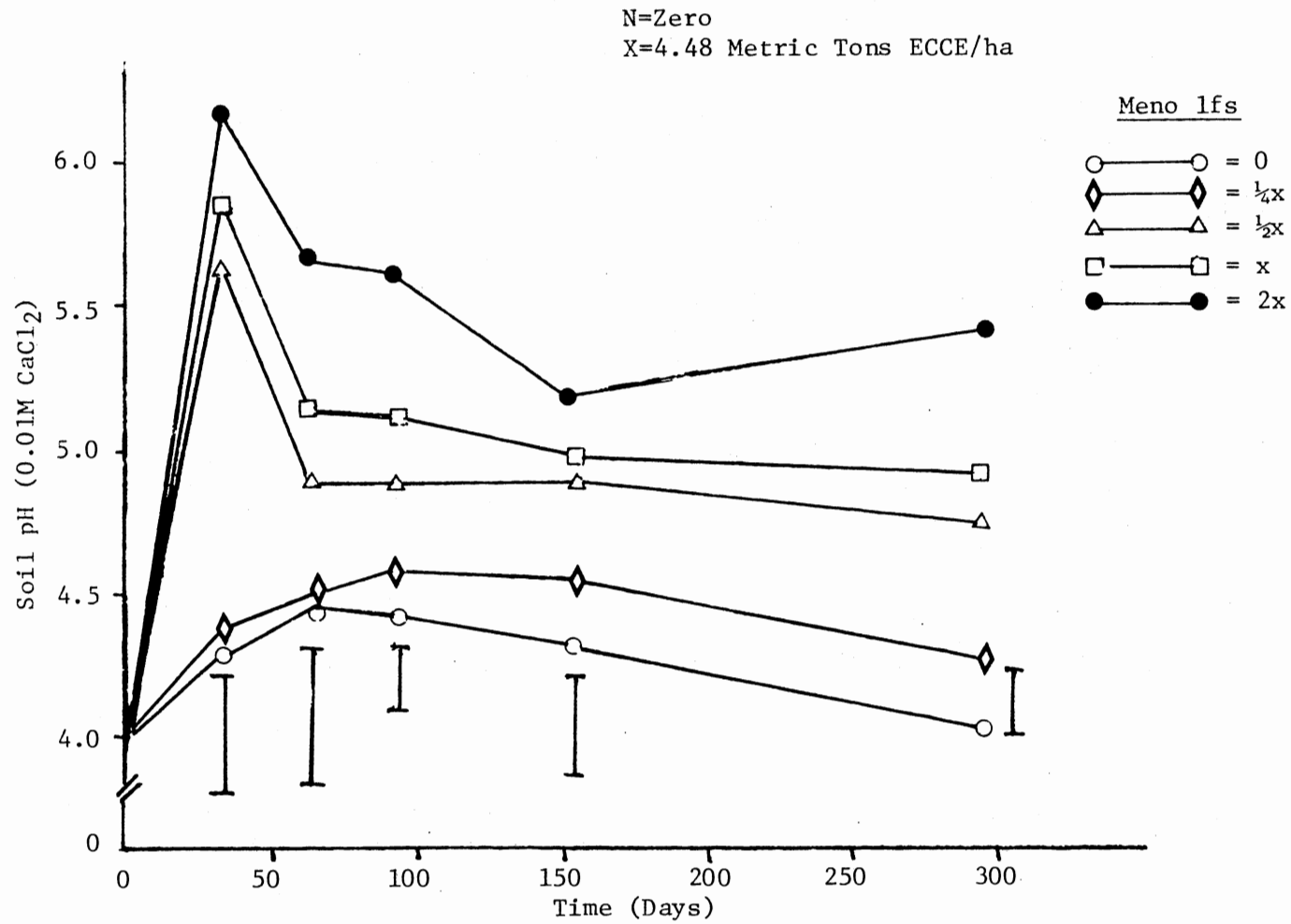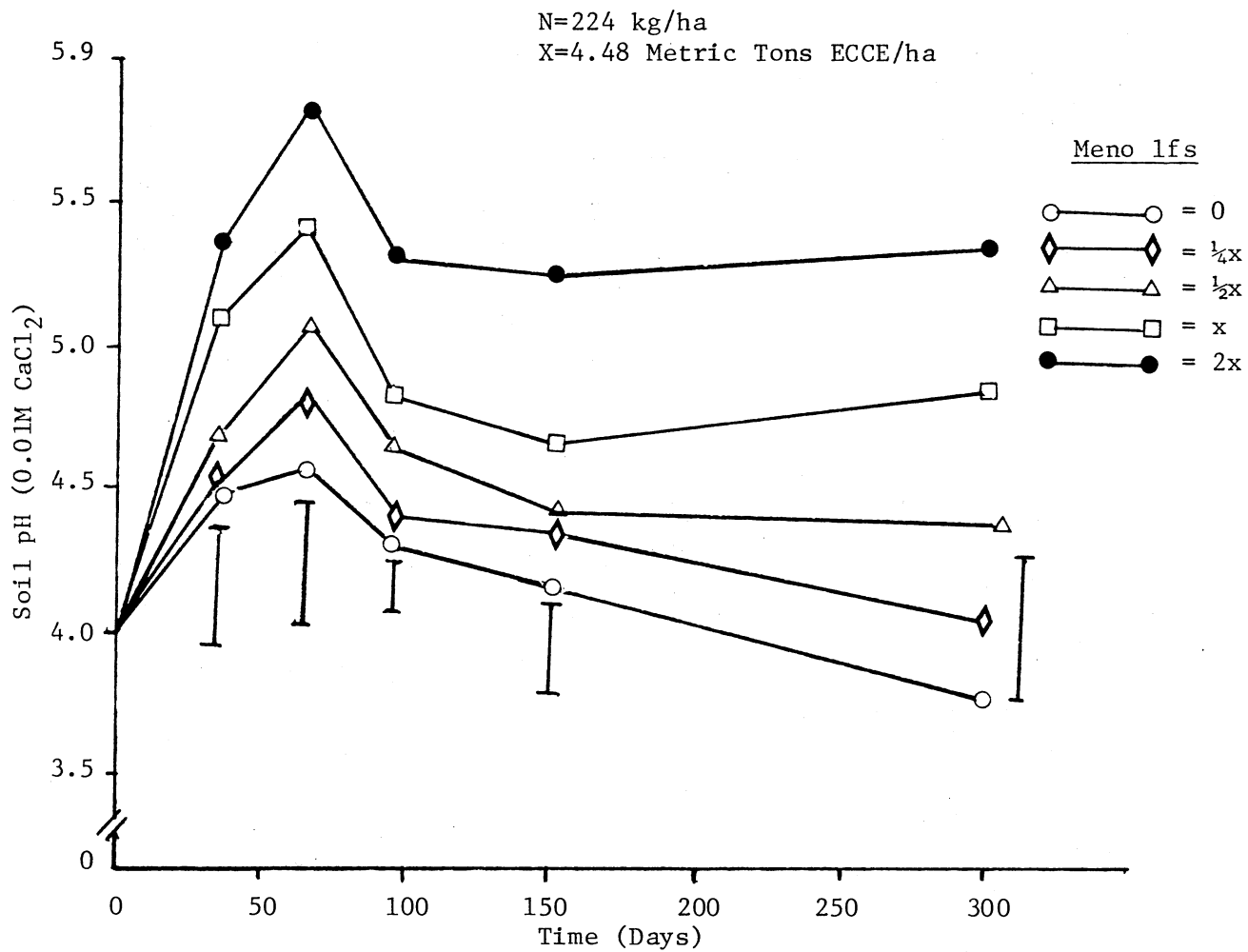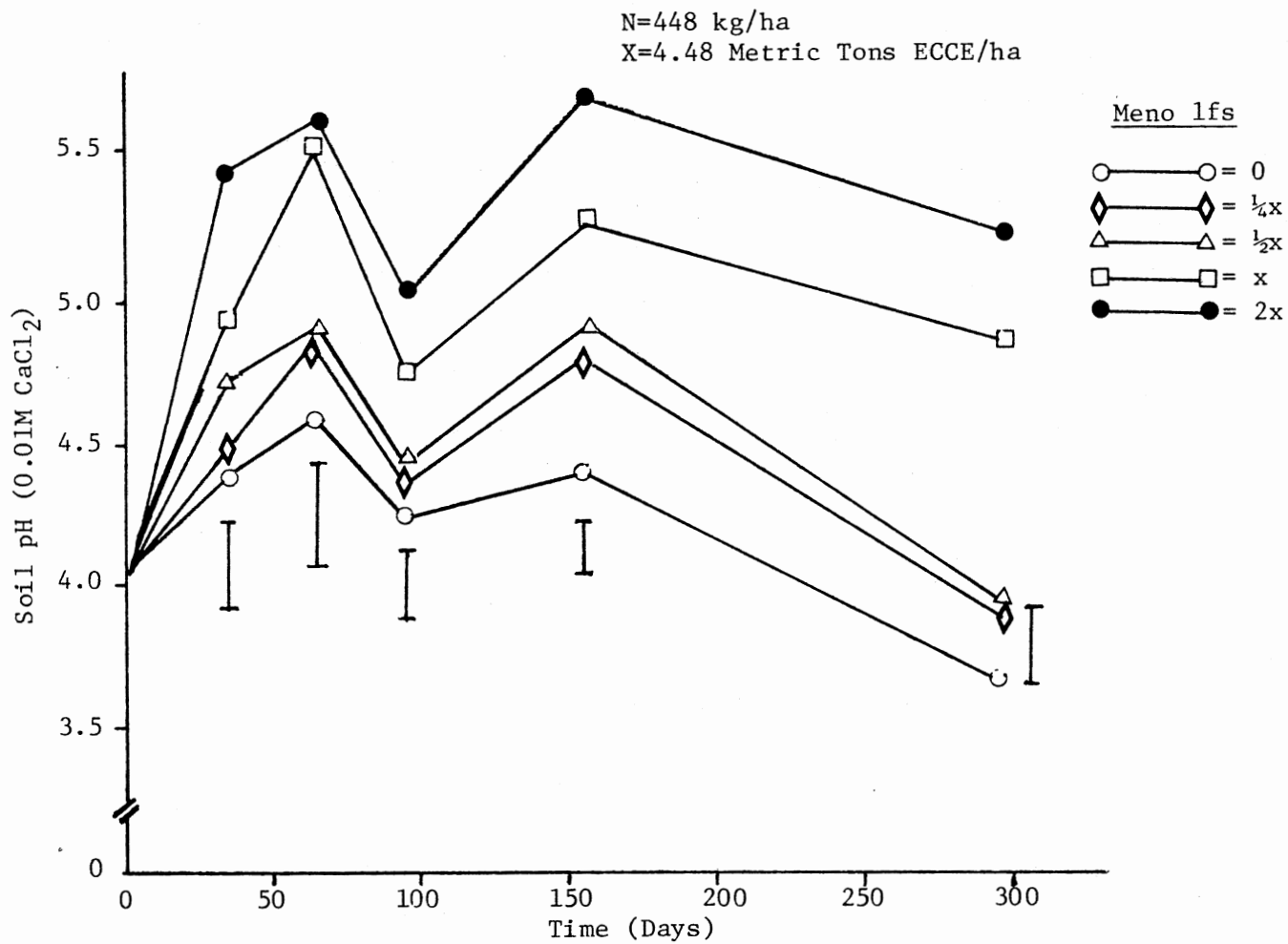Soil pH (0.01M CaCl₂)

Time (Days)

Figure 18.   Effects of Ag-Lime on pH (0.01M CaCl₂) of Meno
Loamy Fine Sand (N=448 kg/ha)
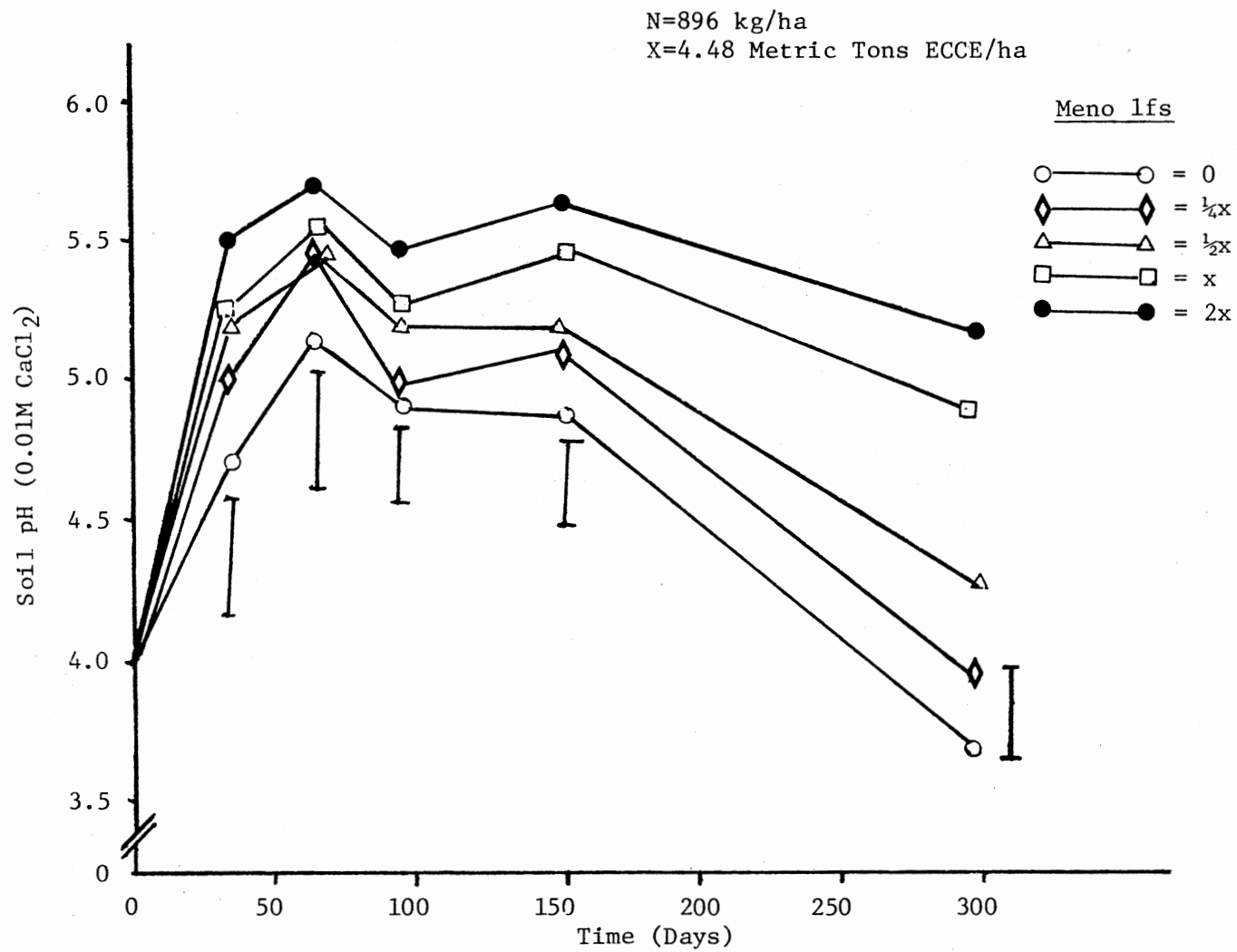
Figure 19. Effects of Ag-Lime on pH (0.01M $CaCl_2$) of Meno Loamy
Fine Sand (N=896 kg/ha)

## Extractable Aluminum and Manganese

The effect of ag-lime and N rates on Al content of Meno (Lahoma site) is presented in Table IX. Ag-lime had no effect on extractable Al within 35 days after treatment. It may be noteworthy that the lowest Al concentrations were measured at the highest N rate.

Ag-lime applications did affect measured Al concentrations on samples taken 153 days after treatment. In all ag-lime treatments except 896 kg N/ha significantly lower Al concentrations were measured with increasing rates of ag-lime. In spite of the fact that N rates tended to decrease soil pH, N rates decreased soluble Al concentrations at each ag-lime rate.

The effect of ag-lime and N on Mn concentrations is presented in Table X. At 35 days, ag-lime had no effect on Mn concentrations, but the application of 224 kg N/ha increased the Mn concentration. The lowest Mn concentrations were measured at the high N rates (448 and 896 kg/ha).

At 153 days, the Mn concentrations increased in the N=0 rate, but ag-lime rates had a significant effect on lowering the Mn concentrations in N=224 rate. Again, the lowest Mn concentrations were at the high N rates.

It will be interesting in the future studies on these plots to note the effects of N levels on soluble Al and Mn when the $NH_4$ ion has dissipated.

There was no yield on the Meno soil due to the failure to get a stand. The wheat was planted three times; the first planting failure resulted from too shallow of planting depth. The next two successive plantings failed to germinate due to severe cold weather.

TABLE IX

EFFECT OF LIME ON ALUMINUM CONTENT WITH VARYING RATES OF
NITROGEN WITH TIME AT A MENO LOAMY FINE SAND

| Lime Metric Tons ECCE/ha x=10.76 | Al(ug/g soil) at 35 Days N(kg/ha) | | | | Al(ug/g soil) at 153 Days N(kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 224 | 448 | 896 | 0 | 224 | 448 | 896 |
| 0 | 65.00 | 67.75 | 63.50 | 42.25 | 52.50 | 60.00 | 42.50 | 27.50 |
| 1/4x | 63.00 | 60.00 | 66.25 | 40.00 | 47.50 | 52.50 | 37.50 | 25.00 |
| 1/2x | 69.00 | 62.00 | 57.50 | 34.50 | 45.00 | 50.00 | 35.00 | 22.50 |
| x | 66.25 | 58.50 | 53.50 | 37.50 | 42.50 | 45.00 | 25.00 | 20.00 |
| 2x | 60.50 | 58.25 | 55.25 | 39.00 | 35.00 | 35.00 | 27.00 | 20.00 |
| LSD.05 | 13.79 | 17.33 | 12.11 | 14.54 | 13.52 | 12.15 | 12.02 | 12.28 |

TABLE X

EFFECT OF LIME ON MANGANESE CONTENT WITH VARYING RATES OF
NITROGEN WITH TIME ON A MENO LOAMY FINE SAND SOIL

| Lime<br>Metric Tons ECCE/ha<br>x=10.76 | Mn(ug/g soil) at 35 Days<br>N(kg/ha) | | | | Mn(ug/g soil) at 153 Days<br>N(kg/ha) | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 224 | 448 | 896 | 0 | 224 | 448 | 896 |
| 0 | 29.00 | 42.50 | 19.25 | 19.50 | 29.50 | 42.25 | 14.50 | 21.50 |
| 1/4x | 31.25 | 31.00 | 22.75 | 17.25 | 27.50 | 32.50 | 14.50 | 22.25 |
| 1/2x | 35.50 | 29.75 | 19.50 | 18.25 | 26.50 | 35.50 | 19.00 | 17.00 |
| x | 35.50 | 42.00 | 23.25 | 22.25 | 32.50 | 33.25 | 23.75 | 22.25 |
| 2x | 28.25 | 39.75 | 24.75 | 24.25 | 39.75 | 29.75 | 21.50 | 25.50 |
| LSD.05 | 10.24 | 24.48 | 11.69 | 10.14 | 8.35 | 11.11 | 12.72 | 7.27 |

CHAPTER V

SUMMARY AND CONCLUSIONS

Nitrogen and ag-lime rates were applied to two acid soils in North Central Oklahoma. Soil pH changes were measured after treatment and during the wheat growing season. In addition, extractable Al and Mn were determined from the surface soil and wheat grain and straw yields were taken from one location.

Soil pH values increased with depth for initial samples, and surface soil pH values increased as ag-lime rates increased. On the Pond Creek soil, ag-lime had a significant effect on lowering extractable Al and Mn concentrations. Ag-lime had little or no effect on reducing Al and Mn concentrations on the Meno soil. Grain yield on the Pond Creek soil was decreased by N application on zero lime plots. When the lime requirements were met, increases in yields were observed through the N=448 kg/ha. Straw yields did not follow the same trend as grain yield except ag-lime applications did result in increased yields. Small rates of ag-lime caused considerable improvement in total dry matter produced with x and 2x ag-lime applications.

In summary, measurements from these field plots during the first growing season after treatments were applied is not a long enough time period to completely assess the treatment effect. Much more meaningful information can be collected in subsequent years.

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TABLE XI

pH ANALYSIS OF VARIANCE OF 1:1 AND 0.01M $CaCl_2$
AT VARYING N RATES.-- CARRIER

| Analysis of Variance | | | | Mean Square | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1:1 | | | | 0.01M $CaCl_2$ | | |
| Source | DF | N=0 | 224 | 448 | 896 | N=0 | 224 | 448 | 896 |
| BLK | 3 | 0.1768 | 0.1433 | 0.0548 | 0.1674 | 0.1254 | 0.2115 | 0.0992 | 0.1780 |
| LIME | 4 | 5.0020 | 7.0183 | 6.2575 | 3.6619 | 4.8382 | 8.0345 | 7.7928 | 5.2016 |
| BLK*LIME | 12 | 0.1275 | 0.0743 | 0.0951 | 0.0686 | 0.1510 | 0.0631 | 0.1210 | 0.0607 |
| TIME | 4 | 0.2850 | 0.0957 | 0.6250 | 0.2602 | 0.1386 | 0.1939 | 0.1016 | 0.5021 |
| LIME*TIME | 16 | 0.0704 | 0.1090 | 0.1231 | 0.1154 | 0.1302 | 0.1287 | 0.1041 | 0.0486 |
| BLK*TIME | 12 | 0.0446 | 0.1100 | 0.0247 | 0.0226 | 0.0246 | 0.0321 | 0.0313 | 0.0342 |
| BLK*LIME*TIME | 48 | 0.0609 | 0.0180 | 0.0193 | 0.0170 | 0.0593 | 0.0357 | 0.0155 | 0.0346 |
| CORRECTED TOTAL | 99 | 0.2808 | 0.3753 | 0.3235 | 0.2015 | 0.2759 | 0.3885 | 0.3647 | 0.2720 |

TABLE XII

pH ANALYSIS OF VARIANCE OF 1:1 AND 0.01M CaCl$_2$
AT VARYING N RATES - LAHOMA

| Analysis of Variance | | | | | | Mean Square | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | | | 1:1 | | | | 0.01M CaCl$_2$ | | |
| Source | DF | N=0 | 224 | 448 | 896 | N=0 | 224 | 448 | 896 |
| BLK | 3 | 0.0419 | 0.5210 | 1.0258 | 3.5700 | 0.0874 | 0.1653 | 0.0375 | 0.9543 |
| LIME | 4 | 3.2049 | 3.8077 | 3.6276 | 1.7426 | 3.8740 | 4.3408 | 4.1466 | 2.1166 |
| BLK*LIME | 12 | 0.0573 | 0.1078 | 0.0705 | 0.0512 | 0.0382 | 0.0518 | 0.0355 | 0.0346 |
| TIME | 4 | 0.3492 | 2.4742 | 3.0500 | 6.5120 | 0.2326 | 1.2660 | 1.9506 | 3.3272 |
| LIME*TIME | 16 | 0.0349 | 0.0517 | 0.1613 | 0.1671 | 0.0482 | 0.0514 | 0.0975 | 0.1447 |
| BLK*TIME | 12 | 0.0793 | 0.0926 | 0.2267 | 0.5050 | 0.0490 | 0.0660 | 0.0685 | 0.0571 |
| BLK*LIME*TIME | 48 | 0.0482 | 0.0405 | 0.0229 | 0.0564 | 0.0302 | 0.0363 | 0.0173 | 0.0278 |
| CORRECTED TOTAL | 99 | 0.1904 | 0.3219 | 0.3741 | 0.5637 | 0.2016 | 0.2718 | 0.2842 | 0.2968 |

VITA

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Master of Science


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