

TILLAGE IMPLEMENT APPLICATIONS OF ANHYDROUS AMMONIA
AND LIQUID AMMONIUM POLYPHOSPHATE

by

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B.S., Kansas State University, 1967

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

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ACKNOWLEDGMENTS

Sincere appreciation is expressed to Dr. Larry Murphy, major professor, for his advice and counseling during the course of study. His assistance in designing the studies and preparing the manuscript was also greatly appreciated. Thanks is also extended to Dr. Roscoe Ellis, Jr. and Dr. William Powers who served as members of the supervisory committee.

Special appreciation is expressed to Farmland Industries, Inc. and to Phillips Petroleum Company for their financial support of the research project.

Appreciation is extended to the personnel of the KSU fertility laboratory for their assistance with the plot work and chemical analyses.

Special appreciation is expressed to the author's wife, Helen, for her sacrifices, encouragement, and understanding during the course of the study.

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INTRODUCTION

Today's farmer is continually being faced with the problem of rising production costs. His expenses could be reduced to some extent by combining fertilization and tillage operations. By combining the two operations, one trip over the field would at least be eliminated.

With the present fertilizer technology, anhydrous ammonia (NH_3) is the cheapest nitrogen carrier available for use in crop production. As a result, tillage implement adaptation for the application of anhydrous ammonia is becoming more common in the Plains States. The most common tillage implements used in Kansas for the incorporation of ammonia have been the undercutting blade and the chisel plow.

However, in addition to N, phosphorus must also be included in the fertility program to achieve maximum crop yields in the eastern half of Kansas. It would be beneficial if a P source could be incorporated at the same time using the tillage implements employed for the application of anhydrous ammonia. A liquid P source such as ammonium polyphosphate (APP) would be ideal because of its higher analysis and lower production costs (Huffman and Newman, 1970). If the simultaneous application of N and P were feasible it would be possible to apply an entire preplant fertilization program for wheat and row crops on high K soils through the use of tillage implements.

Another primary consideration in evaluating the simultaneous application of ammonia and APP is the effect P might have on soil nitrification. The agronomic significance of their dual application in the nitrifying process is not known.

A third factor in the evaluation of tillage implement applications of N and P is the effect of depth of placement of these materials in relation

to plant nutrient uptake. Surface applications of N and P which are incorporated only slightly into the soil could remain in an area of low available soil moisture and efficiency of absorption by plants could suffer from positional unavailability. The same nutrients placed at depths of 10 to 20 cm by the blade or chisel applicators would be less subject to moisture stress conditions.

In order to obtain an agronomic evaluation of tillage implement application of N and P, field studies were initiated to determine the following information: (1) The response of wheat and grain sorghum from the simultaneous application of anhydrous ammonia and liquid APP with an undercutting blade and with a chisel plow in comparison to a surface application of liquid urea-ammonium nitrate (UAN) and liquid APP; (2) The relative nutrient availability of N and P in relation to depth of placement from the three methods of application; and (3) The effect of anhydrous ammonia and liquid APP on the nitrification process.

LITERATURE REVIEW

Agronomic Considerations of Polyphosphates

The ammoniation of superphosphoric acid in the production of liquid and solid APP has resulted in their widespread use in the fertilizer industry. Higher analysis, higher water solubility, and lower costs of production, handling and transportation are the reasons attributed to the growth of APP (Huffman and Newman, 1970). The structure of polyphosphate molecules consist of condensed orthophosphate units linked together forming polymers of variable length. Normally, polyphosphate (poly-P) fertilizers contain about half of their P in the pyrophosphate (pyro-P) form and about half in the orthophosphate (ortho-P) form.

The effectiveness of poly-P as fertilizers depends upon the following characteristics; nutrient value, rate of hydrolysis, and chemical reactions with soil components.

Nutrient Value. Polyphosphates have been tested extensively in the field and greenhouse under a variety of soil conditions during the past ten years. Dobson, Wells, and Fisher (1970) compared ammonium orthophosphate (AOP) and APP as P sources for corn on an acid bottomland and an upland soil. Three years' field data indicated there was no perceptible difference between the two sources.

Ganiron et al. (1969) found that in a growth chamber experiment, mono-ammonium phosphate (MAP) was slightly more effective than APP in providing P for corn production on an acid soil (pH 5.7).

In a greenhouse study Stroehlein, Sabet, and Clementz (1968) compared APP and AOP with successive crops grown on four calcareous soils. Barley, the first crop, responded to P with AOP superior to APP. However, leaf P

content was greater when the P source was APP as compared to AOP. With tomatoes, the second crop, APP was significantly better than AOP.

Lathwell, Cope, and Webb (1960) reported that similar results were obtained with several crops in field trials on acid soils in Alabama, Georgia, Mississippi, New York, and North Carolina when liquid and solid sources of APP and AOP were compared.

In studying the response from surface applied fertilizers, Terman and Hunt (1964) found that APP was only slightly less effective than MAP at pH levels of 7.5 and 8.2. The reason for APP performing nearly as well as MAP under calcareous conditions was explained as a reaction of ammonium pyrophosphate with CaCO_3 or other forms of soil Ca to form $\text{Ca}(\text{NH}_4)_2\text{P}_2\text{O}_7 \cdot \text{H}_2\text{O}$, a reaction product found by Lehr, Englestad, and Brown (1964) to be a suitable source of N and P. However, in another field study Terman and Englestad (1966) reported that APP in both solid and liquid forms was usually equal or slightly superior to MAP for early growth response of cotton grown on an alkaline soil in Mississippi and for corn grown on a slightly acid soil in Iowa.

Adriano and Murphy (1970) found that with irrigated corn grown on slightly acid soil in Kansas the order of increasing P uptake among P carriers was rated $\text{MAP} = \text{APP} > \text{triple superphosphate (TSP)}$ based on the P concentrations at the 8-leaf sampling stage. In another study of poly-P in Kansas, (B. B. Webb, 1970. Field and growth chamber comparisons of ortho- and polyphosphates. Ph.D. Thesis. Kansas State University, Manhattan.) the abilities of APP and MAP to provide P for corn and grain sorghum under both irrigated and dryland conditions were apparently equal.

Hydrolysis. Gilliam and Sample (1968) listed seven factors known to affect the rate of hydrolysis of poly-P in decreasing order of importance: temper-

ature, pH, enzymes, presence of colloidal gels, complexing cations, phosphate concentration, and ionic environment in the solution. Most studies have confirmed that hydrolysis of poly-P in a soil system is a biological process.

Sutton, Gunary, and Larsen (1966) showed that the value of pyro-P as an immediate source of P for barley plants was largely dependent on its rate of hydrolysis to ortho-P, the preferred form of P for plant use. In a similar study, Sutton and Larsen (1964) showed that the half-life time for pyro-P hydrolysis varied from 4 to 100 days, but 78% of this variation could be explained in terms of biological activity and pH of the soil. Their studies revealed that ortho-P was more effective for plant utilization than poly-P when applied to acid soils of low biological activity, but no differences in effectiveness could be measured between the two sources on neutral soil with a high biological activity.

Blanchar and Hossner (1969a) studied the hydrolysis of ortho-, pyro-, tripoly-, and trimetaphosphate in 32 midwestern soils and concluded that the rate of hydrolysis for all materials was rapid enough in 14 days that it would not limit P availability to plants.

Miner and Kamprath (1971) studied the hydrolysis of liquid poly-P from a banded application. Hydrolysis was lowest in the band position where the concentration of condensed phosphate was highest. With increasing lateral distance from the band, a greater proportion of the condensed P was hydrolyzed. They postulated that the increased hydrolysis with increasing lateral distance from the band position could be due to the mechanisms by which the condensed P anions were held.

Laboratory investigations by Murphy et al. (1968) looked into the possibility of the intact poly-P molecule being taken up by corn plants. No poly-P

was detected by chromatographic techniques. However, some studies have shown that limited amounts of pyro-P can be taken up directly by the plant (Sutton and Larsen, 1964; Gilliam and Sample, 1968).

Englestad and Allen (1971b) found triammonium pyro-P to be less effective than MAP when both were recently added as sources of P for corn grown in cool soil (16C). No difference in effectiveness was noted between these sources when recently applied to warm soil (24C). They concluded, as did Sutton et al. (1966), that the soil temperature affected the biological process of hydrolysis.

Phosphatase is the enzyme that is involved in the hydrolysis of poly-P. Gilliam (1970) found that roots of P-deficient wheat, corn, and barley all rapidly hydrolyzed the pyro-P in nutrient solutions to ortho-P. A check of identical solutions containing no roots showed that less than 1% of the pyro-P was hydrolyzed during the same 24-hour period. Further studies revealed that this increased hydrolysis was caused by phosphatase present on external portions of the roots, and this activity was greater in P-deficient roots than in non-deficient roots.

Using Texas soils of varying chemical and mineralogical composition, Hossner and Melton (1970) observed that during the hydrolysis of pyro-P, a rather stable fraction which amounted to 10-20% of the applied pyro-P tended to persist in the soil. They felt that this fraction consisted of relatively non-hydrolyzable pyro-P compounds. Gilliam and Sample (1968) observed essentially the same behavior. However, Miner and Kamprath (1971) observed that the residual effectiveness of poly-P was similar to that of superphosphate.

When soils are flooded, as in the production of lowland rice, immediate changes in physical, chemical, and microbiological processes occur. Racz and Savant (1972) showed that the initial rate of pyro-P hydrolysis was

rapid and approximately the same for both flooded soil and soil maintained at field capacity. However, after about 3 days of incubation, flooded soil hydrolyzed pyro-P at a relatively greater rate than did soil maintained at field capacity. They concluded this difference to be due to an increase in pyro-P activity in the flooded soil. Hossner and Phillips (1971) also noted a greater rate of hydrolysis of pyro-P in flooded soils versus soil maintained at 1/3 atm moisture. They, however, suggested that low redox potentials in flooded soils increased hydrolysis by a lowering of the activation energy for pyro-P hydrolysis.

Reaction with Soil Minerals. The reaction of ortho-P with soil minerals is quite rapid, and water-soluble phosphates are converted to relatively insoluble compounds within a few hours when they are placed in the soil. Recent studies have shown that the chemical reactions of poly-P with clay minerals differ significantly from those of ortho-P and yield different reaction products.

Philen and Lehr (1967) found that the reactions of ammonium pyro- and tripolyphosphates were much less reactive with clay minerals and hydrous oxides of iron and aluminum than ortho-P. The only solid reaction products of the condensed phosphates were magnesium and calcium salts. No solid iron or aluminum compounds were formed because the iron and aluminum that was released by the minerals were sequestered by the condensed phosphates and remained in solution even after considerable hydrolysis of the condensed phosphate to ortho-P. The ability of poly-P to prevent the precipitation of ortho-P is an interesting property.

The marked difference between the reactions of poly-P and ortho-P with soil minerals prompted the idea that mobility of the poly-P might be a factor in their value as fertilizers (Huffman and Newman, 1970). However, it

has been shown that ortho-P and poly-P were immobilized by the soil minerals to about the same extent and differences between the two forms disappeared as hydrolysis and immobilization proceeded, (Hughes and Hashimoto, 1971; Hashimoto and Lehr, 1973). In some soils, the total movement of pyro-P was less than that of ortho-P (Gunary, 1966; E. C. Sample, 1967. Movement of phosphorus from ortho- and pyrophosphates in soils. Agron. Abst. p 84). Several researchers (Blanchar and Hossner, 1969b; Hashimoto et al., 1969; Sutton and Larsen, 1964), reported higher absorption capacities for pyro-P than for ortho-P.

Hashimoto, Hughes, and Philen (1969) found that iron oxide possesses certain catalytic activity in pyro-P hydrolysis in sterilized soils and subsoils where microbiological activity becomes less important. Similar reports by Juo and Maduakor (1973) showed that subsoils of tropical origin had slower rates of pyro-P hydrolysis when the total free iron oxide content was low.

Effect of N on P Uptake

Many studies have been conducted that show N particularly the ammonium-N form, has a stimulating effect on P uptake. Investigators generally relate the influence of N on P absorption to three factors: (1) morphological, (2) chemical, (3) physiological, or a combination of these three (Grunes, 1959).

Morphological. Increased root growth in the vicinity of banded N plus P, as compared to P alone, has been observed as one of the mechanisms responsible for increased uptake. Miller and Ohlrogge (1958) studied the P uptake on corn when ammonium-sulfate (AS) was banded with P in the soil. They felt that banding N with P increased the development of a larger root mass

which accounted for an increased absorption of P.

Duncan and Ohlrogge (1958) observed increased root proliferation in corn when AS and P were banded together, and the uptake of P was closely correlated with root development and volume of fertilized soil. The presence of banded N above or below the P band, but separated from it by enough soil to prevent mixture by diffusion, had little effect on root development.

In greenhouse experiments, Miller (1965) found that the addition of AS to a P band increased the absorption of P by a single corn root. However, his results showed that although increased root growth may result from the addition of N, it is not a prerequisite for increased P absorption. Chemical. Mamaril and Miller (1970) studied the effect of varying levels of ammonium-N on P uptake using a soil of pH 7.4. They found that P absorption increased with increasing rates of N and suggested that ammonium-N has a chemical effect on increasing the P availability of monocalcium phosphate (MCP). However, Blanchard and Caldwell (1966) examined the chemical effect of banding AS and MCP together, and found that ammonium-N did not change the availability of P in the soil.

The chemical relationship between N and P has also been attributed to be a cation-anion balance effect. Using nutrient solutions, Blair, Miller, and Mitchell (1970) recorded higher levels of phosphorus and sulfur in corn plants grown in ammonium-N treatments and higher calcium and magnesium in the nitrate-N treatments. They suggested a companion effect of the ammonium-N ion on P uptake.

The relative absorption of cations and anions has been shown to affect the pH of the soil-root interface. In a growth chamber study, Riley and Barber (1971) used soil that ranged in pH from 5.2 to 7.8 and found that fertilization of soybeans with ammonium-N decreased the pH of the rhizocyl-

inder (root plus strongly adhering soil) while fertilization with nitrate-N increased rhizocylinder pH. The ammonium-fertilized soybeans absorbed more P at all pH levels, and they concluded that the decreased pH of the rhizocylinder increased the P availability of the soil.

In a greenhouse study, Blair, Mamaril, and Miller (1971) found that the application of AS with MCP increased the P uptake of corn when compared to MCP alone on soils of pH 8.2, 7.4, and 5.5. No difference was measured on a soil of pH 4.2. They concluded that the increased P uptake was due to changes in the pH of the soil-root interface which resulted in a larger $\text{H}_2\text{PO}_4^-/\text{HPO}_4^{--}$ ratio at the root surface of the alkaline and neutral soils. The higher proportion of P in the H_2PO_4^- form increases P absorption because it is absorbed by plants to a greater extent than HPO_4^{--} .

Miller, Mamril, and Blair (1970) observed a P precipitate on the surface of roots grown in a MCP treatment, but not in the MCP + AS. The pH of the soil-root interface was 0.6 units lower in the MCP + AS than in the MCP treatment. They believed that the reduction in pH at the soil-root interface was due to H^+ exchanged from within the root for NH_4^+ ions in the soil. The higher ratio of the $\text{H}_2\text{PO}_4^-/\text{HPO}_4^{--}$ ions at the lower pH was thought to be responsible for the prevention of the precipitation and the increased absorption of P in the presence of ammonium-N.

Physiological. The cause of increased P absorption is increasingly attributed to an effect of N on the physiological processes that control the absorption of P. In a growth chamber study with barley, Grunes, Viets, and Shih (1958) suggested a mechanism whereby N causes an increased need for P absorption when they are banded together. Bennett, Pesek, and Hanway (1962) implied a similar physiological role.

Engelstand and Allen (1971a) studied the effect of form and proximity

of added N on P uptake. They found that ammonium-N had a stimulatory effect on P uptake and concluded that the effect of N is to enhance metabolic activity and in turn P uptake.

Thein and McFee (1970) hypothesized that the form of N is insignificant, but that a metabolite of N is responsible for the efficiency of P absorption and translocation. Using corn plants that were pretreated with N solutions, they demonstrated the need for N to be inside the root to stimulate P uptake and translocation rather than upon a companion effect from N outside the root.

In a similar study, Cole et al. (1963) reported that increased concentrations of N in corn plants established by N pretreatment increased the absorption of P during a 2-hour period. The presence of ammonium-N or nitrate-N in the solution during the 2-hour absorption period did not influence the P absorption rate. They theorized that a stimulation in the metabolic system of the plant resulted in a greater turnover of NADH and ATP coupled to P uptake reactions.

Leonce and Miller (1966) suggested that ammonium-N ion had a specific influence on the transfer of P across the root to the xylem. In their studies, ammonium-N plus P was shown to give increased P concentrations in corn tops when compared to nitrate-N plus P or P alone.

Olson and Dreier (1956) also suggested a physiological role of N stimulation on P uptake. However, they stated that such stimulation of P uptake would be of practical importance only where the crop is fertilized at low rates.

Anhydrous Ammonia as a N Carrier

Anhydrous ammonia is unique among N fertilizers in that it changes from

a liquid to a gas immediately after application. Therefore, it is important to consider the following factors: mechanism of retention, factors effecting retention, and effect on soil properties.

Mechanism of Retention. The mechanisms involved in the retention of ammonia have been proposed to be chemical or physical in nature. In acidic soils, ammonia reacts with hydrogen ions to form the ammonium ion that is chemically adsorbed by the clay minerals. Under alkaline conditions, ammonia is chemically adsorbed by soil organic matter to a greater extent due to its reaction with the carboxyl, phenol, aldehyde, ketone, and alcohol groups (Parr, 1969). Ammonia may also be physically adsorbed by clay minerals and probably by organic components thru a weak bonding known as van der Waals force (Mortland, 1955).

Ammonium ions can also be retained through the process of fixation with the organic matter and clay mineral content of the soil. Burge and Broadbent (1961) found that the ammonia fixation in organic soils was linearly correlated with percent carbon. Sohn and Peech (1958) concluded that soils with the greatest capacity to adsorb ammonia generally fixed the greatest amounts because the interlayer fixation of ammonium-N by clay minerals should increase with an increasing degree of saturation of the clay with ammonium ions. The availability of fixed ammonia to plants appears to be low.

Factors Effecting Retention. Retention and distribution of ammonia in soils are affected by many factors, but the main factors relate to soil moisture, soil texture, cation exchange capacity (CEC), and method of application.

Soil moisture content apparently affects the retention of ammonia, the distribution of ammonia, and also the mechanism of retention. Blue and Eno (1954) showed that the size of the initial zone of ammonia retention following field application decreased with increasing soil moisture content. A

drier soil evidently allows more freedom of movement from the initial retention zone.

Stanley and Smith (1956) stated that ammonia losses can occur on very wet soils because of the upward movement and evaporation of water. Likewise, Parr and Engibous (1967) disclosed that under conditions of excessive moisture, rapid and complete closure of the injection channel may not occur and direct loss of gaseous ammonia to the atmosphere is possible.

Parr and Papendick (1966) found that with increasing moisture content, soils have a greater initial capacity to retain ammonia because of the solvent action of water for ammonia. However, they observed more ammonia was ultimately retained by the air-dry and oven-dry soils than by the moist systems, which suggests a possible competitive interaction between NH_3 and water for retention sites.

James and Harward (1964) confirmed this mutual competition effect and found that water and NH_3 will compete with each other for adsorption sites on clay minerals when the moisture content is low. Brown and Bartholomew (1963) arrived at similar conclusions relative to water- NH_3 competition.

McDowell and Smith (1958) reported that soil texture had a pronounced effect on ammonia movement and retention following the application of anhydrous ammonia. Losses of ammonia were greatest from sands and least from finer-textured soils. Blue and Eno (1954) found that the Coastal Plain sandy soils lost appreciable ammonia upon application of anhydrous ammonia in the laboratory. Stanley and Smith (1956) also observed that the loss of ammonia was greater from sand than from silt loam and clay soils.

It is generally recognized that a soil with a high CEC is able to hold a larger quantity of ammonia as compared to a soil of low CEC, however, ammonia retention may not necessarily be highly correlated with CEC. Stanley

and Smith (1956) compared the loss of ammonia on sandy, silt loam, and clay soils that had CEC of 4.1, 14.5, and 32.0, respectively. The higher loss of ammonia was directly correlated with the lower CEC. Mortland (1955) studied the adsorption of ammonia on various adsorbants and found it directly related to CEC.

In relation to the methods of application, the distribution and loss of ammonia are affected by rates of application, spacing between points of release, and depth of application. Even though ammonia losses have been detected, all textures of soils can hold far more ammonia than crops require for maximum production (Parr and Engibous, 1967).

Swart, Murphy, and Swallow (1971) used an undercutting blade to study the retention and distribution patterns of anhydrous ammonia in representative Kansas soils. Ammonia retention was excellent when applied at a depth of 10 cm in silt loam and fine sandy loam soils. Fifteen-cm and 41-cm spacings between release points produced excellent distribution patterns, but 102-cm spacings frequently produced uneven and inadequate distributions. McDowell and Smith (1958) applied anhydrous ammonia to silt loam and sandy soils at various release point spacings, and losses were reduced by more than 60% when the 100-cm spacing was narrowed to 40 cm.

Effect on Soil Properties. Injecting anhydrous ammonia into the soil has an effect on the microbiological activity as well as the chemical and physical properties of the soil.

Parr and Engibous (1967) found that in most soils within several hours after the injection of anhydrous ammonia the pH in the center of the retention zone is usually somewhere between 9.5 and 10.0. Twenty-four hours after injection the pH dropped about one unit and then continued to drop more slowly. Eno and Blue (1957) found that anhydrous ammonia increased the pH

of Leon fine sand from 5.1 to 9.6 after ammoniation. Limed Leon fine sand had an initial pH of 7.6 and increased to as high as 9.8 with additions of NH_3 .

McDowell and Smith (1958) showed that the presence of high concentrations of ammonia in a localized area resulted in the partial breakdown of the soil organic matter. Parr and Engibous (1967) observed similar results.

Field experiments conducted by Gifford and Strickling (1958) showed there was a trend toward increased soil aggregate stability as a result of ammonia treatment at 23 locations in Maryland. The phenomenon was limited to the area of the release points and did not have a long-term effect.

Parr and Khasawneh (1968) observed that drying patterns existed in soil because of a more rapid rate of water evaporation around ammonia retention zones. Although these patterns tended to persist over a period of several months, their agronomic significance is not known.

Injection of NH_3 into the soil produces a sterilizing effect on the initial retention zone. Parr (1969) stated that the time elapsed before recovery of microbial activity was dependent on the amount of ammonia applied. With an initial concentration of 1000 ppm of ammonium-N, microbial recovery began after a desorption-incubation period of 25 hours. Initially, NH_3 caused a marked reduction in the saprophytic population. Bacteria and actinomycete counts increased during the desorption-incubation period, while numbers of fungi remained very low. Eno and Blue (1954) recorded a number of observations concerning the effect of anhydrous ammonia on the microbial population in sandy soils, but concluded that from a total population standpoint, none of the changes noted were likely to permanently disturb the ecological balance in the soil.

Nitrification

Nitrification is an oxidative biological process that takes place in two stages: ammonium (NH_4^+) \rightarrow nitrite (NO_2^-) \rightarrow nitrate (NO_3^-). The organisms responsible for the first and second conversions respectively, are the autotrophic bacteria, Nitrosomonas and Nitrobacter (Alexander, 1965). Several intermediate N compounds, other than nitrite, have been proposed, but Duisberg and Buehrer (1960) report that hydroxylamine and hyponitrous acid do not form in the course of nitrification. Normally, the conversion of nitrite to nitrate proceeds rapidly, and only traces of nitrite are found in the soil. Nitrification by heterotrophic soil microorganisms has been shown to exist in the laboratory, but their importance under field conditions is not known (Doxtader and Alexander, 1966).

The following areas will be reviewed relative to the process of nitrification: environmental factors, effects of NH_3 application, and patterns of nitrification.

Environmental Factors. Frederick (1956) observed a relationship between temperature and nitrification and found that the optimum temperature for nitrification lies between 27 C and 35 C. Anderson (1960) noted nitrification, though negligible, occurred in a sandy loam soil at 3 C; at 6 C it became active by the 3- to 6-week period; and at 12 C, 50 ppm as ammonium-N approached completion by the 12th week. Tyler, Broadbent, and Hill (1959) observed similar results in California soils and also suggested that the Nitrobacter group is more sensitive to low temperature than the Nitrosomonas group. Sabey et al. (1956) studied the temperature effect in some Iowa soils and found that nitrification proceeded during the entire fall season under field conditions and was not completely inhibited until the soil be-

came frozen. However, they point out that nitrification is slow under 10 C, and the possibility of oxidizing large amounts of ammonium-N is remote under 10 C.

There is evidence that nitrifiers become acclimated to the temperature regime of the area of soil origin, and that nitrifying organisms vary in their adaptability to low temperatures (Anderson, Boswell, and Harrison, 1971). Mahendrappa, Smith, and Christiansen (1966) studied the same effect in soils of the western US. They observed that in all soils from northern regions, nitrification was faster at 20 C and 25 C than at 35 C and 40 C. The reverse was true in the case of the southern soils which nitrified faster at 35 C.

Adequate soil aeration is required for the nitrifying bacteria. Amer and Bartholomew (1951) indicated that the optimum concentration of oxygen for nitrification in soil is about that contained in ordinary air.

Rates of nitrification usually are not appreciably affected by varying water contents in the range from wilting point to field capacity. In a calcareous soil, Justice and Smith (1962) found that 150 ppm of ammonium-N was 50% converted to nitrate-N in four weeks at moisture levels near the wilting point.

The nitrifying autotrophs are known to be sensitive to the hydrogen ion concentration of the soil. Morrill and Dawson (1962) found the most favorable pH for the growth of Nitrobacter in soils appears to be in the range of 6.2 to 7.0, while that for Nitrosomonas is above 7.6. Weber and Gainey (1962) indicated that nitrification proceeds until a pH of approximately 4.0 is reached. Braar and Giddens (1968) found low rates of nitrification in grassland soils (pH 4.8) and concluded that the acidic conditions resulted in a low population of nitrifiers. Additional pH effects will be reviewed

in the following sections.

Effects of Anhydrous Ammonia Application. Nommik and Nilsson (1963) have shown that immediately following the injection of anhydrous ammonia into the soil, a high concentration of free ammonia and ammonium-N exists in localized zones with a resulting rise in pH. These conditions are especially toxic to the Nitrobacter group (Aleem and Alexander, 1960).

The results of Stojanovic and Alexander (1958) show that nitrite can accumulate and persist in soils with a pH of 7.7 when the ammonium-N concentration is greater than 250 ppm. They determined that the toxicity was specific to Nitrobacter and was due to the alkaline pH and ammonium-N concentration, rather than the nitrite-N itself.

McIntosh and Frederick (1958) applied anhydrous ammonia under field conditions and found that nitrification initially proceeds more rapidly in the peripheral parts of the retention zone where the pH and ammonium-N concentrations are not high enough to inhibit the nitrifying organisms. With the formation of nitrate and the resultant decrease in pH, the zone of maximum nitrification rate moved toward the injection point.

A decrease in pH occurs during nitrification because hydrogen ions are produced in the oxidative process. McIntosh and Frederick (1958) found that the pH dropped from 9.5 to 5.5 after four weeks of nitrification. The initial soil pH was 6.8 prior to injecting 120 kg/ha of N as anhydrous ammonia.

Eno and Blue (1957) compared the nitrification rate of anhydrous ammonia, urea, and ammonium sulfate under different soil pH levels. They found that anhydrous ammonia and urea elevated the pH to a more optimum range for nitrification in acid soils, whereas ammonium sulfate provided a better environment for nitrification in neutral and alkaline soils.

There is no information available on the nitrification rate of anhydrous

ammonia as affected by added phosphorus. However, Aleem and Alexander (1960) studied the effect of phosphorus on the nutrition and physiology of the nitrifying autotrophs and found that the nutritional P requirement could easily be met under soil conditions. Therefore, any effect from P is likely to be related to the pH factor.

Patterns of Nitrification. Morrill and Dawson (1967) used percolation techniques to study nitrification in 116 soils of the US ranging in pH from 4.4 to 8.8. They found that the pH values appear to be the best single measurement of soil nitrification capabilities. Four different patterns of nitrification were related directly to soil reaction and are as follows: (1) NH_4^+ oxidized rapidly to NO_2^- which accumulated for extended periods of time before being oxidized to NO_3^- (pH 7.6); (2) NH_4^+ and NO_2^- are oxidized rapidly to NO_3^- (pH 6.5); (3) NH_4^+ oxidized slowly to NO_3^- without NO_2^- appearing, (pH 5.0); and (4) NH_4^+ oxidation not detectable by either NO_2^- or NO_3^- formation (pH 4.5).

Dancer, Peterson, and Chesters (1973) observed similar patterns using a single soil type with varying pH levels. They concluded that Nitrosomonas limits nitrification in acid soils while Nitrobacter is inhibited at the alkaline pH's.

Nutrient Availability in Relation to Placement

Newer tillage systems achieving reduced numbers of field operations have given renewed impetus for evaluating fertilizer placement. There is little information available regarding the efficiency of methods and equipment for applying fertilizers under the various tillage systems. However, nutrient uptake as related to soil moisture and root activity must be considered in evaluating the tillage systems.

Influence of Soil Moisture and Root Activity. Draycott, Hodgson, and Holli-day (1967) reviewed several years of work on placement of liquid fertilizers and the general conclusion was drawn that crop yields may be reduced in dry seasons because of nutrient unavailability in the surface layers of the soil. It is suggested that deep placement of plant nutrients into a zone of soil which remains moist over a longer time maintains greater nutrient availability than if placed in the drier topsoil.

The placement of phosphorus in soils is more critical than nitrogen because of its limited mobility (Heslep and Black, 1954). Robertson, Hutton, and Thompson (1958) studied the effect of depth of P placement on the response of corn to fertilization. They found that in dry years deeper placements gave significantly higher yields than shallow placement, whereas in wet years there was no difference. This is in agreement with Olsen, Wantanabe, and Danielson (1961) who stated that uptake of P was a linear function of the soil moisture content for a given soil.

The no-till method of planting makes it difficult to incorporate fertilizer into the surface. The slow diffusion of P in the soil raises a question about the availability of surface applied P. Under the no-till method of planting corn, Belcher and Ragland (1972) found that applying all of the P on the soil surface was equally effective to banding half of the P in the row and the other half on the soil surface. Singh et al. (1966) found that the P content in immature corn leaves was in some cases greater when the fertilizer P was applied on the surface under a no-till system than when P was incorporated to a depth of 12.5 cm. Advocates of the minimum till system feel that the greater amount of plant residues usually present on the surface will keep the upper part of the soil sufficiently moist to insure P availability for plants.

Eck and Fanning (1961) grew grain sorghum in the greenhouse to determine the effect of fertilizer placement in relation to the soil moisture supply on yield and nutrient uptake. They found that P fertilizer should be placed deep enough to insure its being in moist soil longer than the initial growth period if it is to be effective. They found placement of nitrogen fertilizer to be less critical.

Nitrogen, unlike P, is more mobile in the soil. Krause and Batsch (1968) conducted a field experiment to determine the movement of fall-applied ammonium-nitrate in sandy soils applied at the rate of 112 kg/ha N. By the use of lysimeters, they found that the leached nitrate-N reached a maximum concentration within three weeks of application. This illustrates the potential rapid leaching of nitrate-N added to sandy soils. Despite the coarse texture of the soil used by Krause and Batsch, ammonium-N was very stable against leaching because of its adsorption by the soil colloids.

Ray, McGregor, and Schmidt (1957) measured the diffusion of ammonium-N at field capacity after 72 hours and found that the lateral and vertical movement of ammonium-N was generally within 2- to 4-cm of the point of application.

Stewart and Eck (1958) studied the movement of surface-applied nitrate-N under various moisture levels and found that it moved into the soil at all moisture contents from field capacity to the permanent wilting percentage. They concluded that some utilization of surface-applied nitrate-N can be expected before any effective rain is received.

In summary, plants absorb nutrients only from those general areas in the soil in which roots are active. It is also well known that plants cannot absorb nutrients from a dry zone. Hence, root systems modified by shallow applications of fertilizer may be less effective during moisture stress periods.

MATERIALS AND METHODS

Wheat Studies

Tillage implement application of N and P was studied at five locations in the fall of 1971 using wheat as the first crop. Soil samples were taken at all sites prior to fertilizer applications (Table 1).

The variables of the study are listed in Table 2. Two N rates (34 and 67 kg/ha) and two P rates (0 and 15 kg/ha) were used in the study. The P carrier was liquid APP. This material consists of 10% N and 15% P (10-34-0). Two N carriers were used to meet the N requirement. For the blade and chisel applications, the N carrier was anhydrous ammonia (82% N). For the surface applications, a 32% urea-ammonium nitrate solution (UAN) was used as the N carrier, since NH_3 cannot be applied directly to the surface.

The liquid formulations for the various treatments were prepared in 19-liter plastic containers prior to application. Formulations were based upon the effective swath path of each applicator and attempts were made to keep the amount of liquid delivered fairly constant between the three methods of application (0.50 liters/9.29 square meters). For the blade and chisel treatments, all the P was supplied in the form of APP, and NH_3 was used to balance out the N requirement. For the surface treatments, all the P was supplied as APP and balancing N as UAN. Water was used to bring the 19-liter containers to volume to allow enough liquid for proper delivery through the applicator pumps.

Three different methods of application were used in applying the N and P (Table 2). Figure 1 shows the equipment that was employed. The under-cutting blade (V-blade) was 1.83 meters in width. Four release points were positioned beneath the blade 45 cm apart. Anhydrous ammonia was delivered

Table 1. Soil test results for the wheat and grain sorghum sites.

Location	Soil Series	Depth cm	pH	NO ₃ -N ppm	Avail. P kg/ha	Exch. K kg/ha
<u>Wheat:</u>						
Sandyland Exp. Field, St. John	Farnum-Pratt loamy fine sand	0-15	6.3	3.5	43	246
		15-60	6.4	4.5	27	220
Harper County	Pratt loamy sand	0-15	6.2	7.8	10	221
		15-60	6.2	5.4	9	177
Saline County	Idana silty clay	0-15	5.9	10.7	19	560
		15-60	6.3	17.7	12	460
Mitchell County	Hastings silt loam	0-15	7.8	51.1	26	560
		15-60	8.0	17.0	5	560
McPherson County	Butler silt loam	0-15	6.2	10.2	106	560
		15-60	6.8	3.7	40	404
<u>Grain Sorghum:</u>						
Newton Exp. Field	Goessel silty clay	0-15	5.6	9.7	83	629
		15-60	5.9	5.4	38	573
East Central Exp. Field, Ottawa	Woodson silty clay	0-15	5.9	10.3	87	329
		15-60	6.1	6.2	46	270
North Central Exp. Field, Belleville	Crete silty clay loam	0-15	5.6	13.5	62	762
		15-60	5.8	8.5	38	599
Cornbelt Exp. Field, Powhattan	Grundy silty clay loam	0-15	6.0	9.4	24	222
		15-60	6.6	3.5	15	311

Table 2. Treatments used for the 1971 wheat studies (*).

Nutrient Rate		Method of Application	Fertilizer Carrier
N	P		
--kg/ha--			
0	0	----	----
34	0	Blade	NH ₃
67	0	Blade	NH ₃
34	0	Chisel	NH ₃
67	0	Chisel	NH ₃
34	0	Surface	UAN
67	0	Surface	UAN
34	15	Blade	NH ₃ + APP
67	15	Blade	NH ₃ + APP
34	15	Chisel	NH ₃ + APP
67	15	Chisel	NH ₃ + APP
34	15	Surface	UAN + APP
67	15	Surface	UAN + APP

* 1972 grain sorghum studies utilized the same treatments except that the N rates were increased to 67 and 134 kg/ha N.

Fig. 1. Tillage implements employed for field applications of N and P.

(Above: Chisel plow applicator.)

(Below: Undercutting blade applicator equipped with a boom
for liquid surface treatments.)



to each release point individually. A ground-driven squeeze pump assembly regulated the liquid flow through an adjacent individual delivery line.

The chisel plow was 2.13 meters in width with seven release points positioned on 30 cm centers. Initially NH_3 flow was regulated by a needle valve assembly but this system was replaced by a positive displacement NH_3 pump. A ground-driven piston pump system was used to deliver the liquid solution. Ammonia and liquid delivery lines on the chisel were located on opposite sides of the shank to prevent freezing of the liquid line by vaporizing ammonia.

A boom was mounted on the back of the blade applicator to effectively apply the surface applications with the same piece of equipment. On the boom, five spray nozzles were located on 50 cm centers, and the spray path was approximately 2.44 meters. The liquid was delivered through the ground-driven squeeze pump assembly.

The plots for the wheat studies were arranged in a randomized complete block design with four replications. Plot dimensions were 4.27 by 15.24 meters. When the fertilizer material was applied, two passes of each applicator were made per plot (one on each side of the center line). Depth of placement of N and P was approximately 25 cm and 10 cm for the chisel and blade, respectively. The surface applications of liquid N and P were slightly incorporated into the soil surface by means of light discing. All applications were made at a travel speed of approximately 4.8 kilometers per hour.

The preplant fertilizer treatments were applied in September, and the local cooperators drilled the wheat. Crop information is listed in Table 3.

Leaf samples were collected from all wheat locations in November and April. The samples were collected by sampling diagonally across the length of the plot. Samples were rinsed in deionized water and oven-dried at 70C

Table 3. Crop information for the 1971-72 field studies.

Location	Fertilization Date	Seeding Date	Variety	Previous Crop
<u>Wheat:</u>				
Sandyland Exp. Field, St. John	Sept. 10	Sept. 21	Eagle	Wheat
Harper County	Sept. 6	Sept. 21	Triumph	Wheat
Saline County	Sept. 16	Oct. 4	Scout	Wheat
Mitchell County	Sept. 30	Oct. 6	Parker	Wheat
McPherson County	Sept. 21	Oct. 14	Parker	Wheat
<u>Grain Sorghum:</u>				
Newton Exp. Field	March 28	May 19	RS 702	Soybeans
East Central Exp. Field, Ottawa	March 27	June 18	DeKalb C42A	Wheat
North Central Exp. Field, Belleville	April 5	June 3	Pioneer 833	Corn
Cornbelt Exp. Field, Powhattan	March 29	June 6	Asgrow Dorado	Grain Sorghum

for a minimum of 72 hours. The dried tissue sample was ground in a Wiley mill using stainless steel knives and a 2 mm stainless steel screen. Samples were stored in sealed plastic containers.

Leaf samples were prepared for chemical analysis by the sulfuric acid digestion procedure of J. J. Hanway, Iowa State University. A 0.5 g sample of tissue, 10 ml of concentrated sulfuric acid, a small piece of copper wire, and a glass bead were placed in a 100 ml Pyrex volumetric flask and placed on a hot-plate. The flasks were heated slowly for about 4 hours until all frothing had ceased. The temperature was then increased until the sulfuric acid boiled. The flasks were swirled after the solution had cleared to wash down tissue particles from the sides of the flask. The solutions were allowed to boil for 12 hours and then removed from the hot-plate, cooled, and diluted to volume with deionized water. Polyethylene bottles were used to store the solutions. Assays for N, P, and K were then performed on the solutions.

Five ml of the digest solution were used for N determination by the micro-Kjeldahl steam distillation technique outlined by Bremner and Keeney (1965). Phosphorus was determined following a modification of the vando-molybophosphoric yellow color method of Jackson (1965). A 5 ml aliquot of the digest solution and 25 ml of vando-molybdate solution were used for the colorimetric procedure. Absorbance was read on a Beckman DB spectrophotometer at a wavelength of 390 mμ. A 5 ml aliquot of the digest solution, diluted 1:10 with deionized water, was used to determine K by flame photometry.

When tissue samples were collected from all locations in November and April, two sites (Harper County and Sandyland Experiment Field) were selected to obtain information on the correlation between the level of soil N and

P and plant uptake of N and P. In this part of the study, only two rates were compared (67 kg/ha N as NH_3 ; and 67 kg/ha N as NH_3 plus 15 kg/ha P as liquid APP) in evaluating the three methods of application.

At the time of sampling, two plants were cut off at ground level from each drill row across a distance of 2.13 meters that represented the applicator path. In the case of the April sampling, only one plant per drill row was taken at the Sandyland site. Soil samples were also collected to a depth of 30 cm from each drill row immediately below the location of the plant samples. Soil samples were also collected to the same depth between each drill row across the applicator path. Eight drill rows were included at the Sandyland site and ten drill rows at the Harper County location because of differences in drill row spacings.

Correlation study plant samples were processed and analyzed for N, P, and K using the same techniques previously described. Additional information was collected, however: (1) a dry weight of each two plant sample was obtained, and (2) plant samples were ground with a smaller Wiley mill using a 20-mesh screen. After the analyses for N, P, and K were completed, the concentration of the elements and the dry plant weight were used to obtain nutrient uptake per two plants.

Soil samples from the correlation study area were stored frozen until ready for analysis. Samples were dried at 70C for five days, ground, and stored in glass bottles. Using the steam distillation method, inorganic N (NH_4^+ -N and NO_3^- -N) was determined from a 4 gram sample. A 1 gram sample was used in the phospho-molybdate colorimetric determination of available P from a weak Bray extraction solution.

All locations were harvested with a small self-propelled combine. A 1.83 meter swath was cut from the center of each plot and grain weights

recorded. A small sample was collected in a plastic bag to determine moisture, test weight, and grain protein. Grain yields were adjusted to a constant 12.5% moisture basis. For protein analysis, grain samples were dried at 50 C, ground through a steel burr mill, and a 1 gram sample was used to determine the per cent N by the macro-Kjeldahl procedure described by Jackson (1965). Per cent N was converted to per cent grain protein (multiplication factor of 5.8). Statistical analysis was completed on the data using the least squares method. All results were reported at the 5% level of significance.

Grain Sorghum Studies

Four locations in 1972 were used to study the response of grain sorghum to tillage implement application of N and P. Soil samples were collected from the sites prior to fertilizer applications (Table 1). The plot design and treatments were similar to those of the wheat studies except that N rates were increased to 67 and 134 kg/ha (Table 2). Also a 28% N solution (UAN) was used for the surface application rather than a 32% N solution because of the lower salting-out temperature of the lower analysis solution. Plot width was changed to 4.57 by 15.24 meters to allow for six rows per plot with 75 cm spacing between rows. Fertilizer applications were applied pre-plant in early spring (Table 3). Experiment field personnel planted all locations.

Leaf samples were collected from all sites at two stages of growth. At the 8-leaf stage, the first fully extended leaf from the top of the plant was collected. At the North Central Field, the early sampling consisted of cutting off eight plants from each plot at ground level to determine nutrient uptake. The second leaf samples were taken at the boot stage of growth.

The uppermost, fully extended leaf was collected. All leaf samples were randomly selected from the two center rows of each plot.

Leaf samples were rinsed in deionized water and oven-dried at 70C for a minimum of 72 hours. The dried tissue sample was ground in a Wiley mill using stainless steel knives and a 2 mm stainless steel screen. Samples were stored in a sealed plastic containers. Samples were analyzed for N, P, and K in the same manner as previously described for the wheat studies.

The harvesting of the grain sorghum sites was hampered by wet weather. At the Newton Experiment Field and the East Central Field, the two center rows of each plot were harvested with small plot combines. At the Cornbelt and North Central Fields, the plots were hand harvested by taking a 6.10 meter section from the middle of the two center rows. The hand harvested heads were then threshed by a portable threshing unit. From both methods of harvesting, moisture samples were taken and the grain yields were adjusted to a 12.5% moisture basis. Grain protein was determined by the macro-Kjeldahl method.

Statistical analysis was completed on the data using the least squares method. All results were reported at the 5% level of significance.

Soil N-P distribution patterns for the three methods of application were studied at the North Central Field. The soil samples were collected in late June which corresponded to the early plant tissue sampling date. The sampling consisted of collecting soil cores across the width of the applicator path for the blade, chisel, and surface treatments where the N and P were applied together at the highest rate (134 kg/ha N and 15 kg/ha P). The area sampled was 2.13 meters in width and individual soil cores were taken at distances of 5.0 cm across this applicator path. The soil cores were divided into depths of 0-10, 10-20, and 20-30 cm. The samples

were stored frozen until the analyses could be started. Samples were then dried at 70C, ground, and stored in glass bottles. The steam distillation method was used in determining ammonium-N and nitrate-N. Available P was determined after extraction with the Bray No. 1 solution by the procedure mentioned earlier.

Nitrification Study

To examine the effects on nitrification of combining anhydrous ammonia and liquid ammonium polyphosphate, a study was conducted in the fall of 1972 at the Ashland Research Farm. Soil samples were collected at the site prior to fertilizer application (Table 4). An anhydrous ammonia applicator with rolling coulters was used to knife the two materials into the soil. This applicator was used, rather than the blade or chisel, because a closer proximity of the materials could be obtained. The materials were placed at a depth of approximately 15 cm. The ammonia was metered through a needle valve assembly and the liquid APP was delivered by a ground-driven positive displacement pump.

The following two treatments were used in this study which corresponded to similar preplant applications for wheat: (67 kg/ha N as NH_3 ; and 67 kg/ha N as NH_3 with the addition of 15 kg/ha P as liquid APP). Because of the sampling procedure, only one plot area (3.05 by 9.15 meters) was used for each treatment. At the time of application, one person followed directly behind the applicator path and marked the position of two release points. The release point positions were easily determined because of the mark left by the rolling coulters. The release points were 50 cm apart.

The sampling swath width across the path of the two release points was 1 meter and individual soil cores were taken at increments of 5.0 cm across

Table 4. Soil test results for the nitrification site.

Location	Soil Series	Depth cm	pH	O.M. %	NH_4^+ -N ppm	NO_3^- -N ppm	Avail. P kg/ha	Exch. K kg/ha
Ashland Research Farm	Muri silt loam	0-10	5.6	1.7	4.2	24.8	81	739
		10-20	5.8	1.7	1.9	15.3	59	554
		20-30	6.1	1.5	0.7	21.9	27	501

this distance. The soil cores were divided into depths of 0-10, 10-20, and 20-30 cm. Samples were collected in small plastic bags and sealed to prevent moisture loss. The following time schedule was used for sampling after the initial applications: 1 day, 3 days, 5 days, and then weekly for a period of 8 weeks (Table 5). All samples were stored frozen until the time of analysis.

An average weekly soil temperature (Table 5) was recorded during the 8 week period by placing a thermometer horizontally in the soil at a depth of 10 cm. Temperatures were read every other day at the same time of the day to compile the average weekly temperature.

In this study, it was desirable to measure the nitrite-N concentration in the soil. Therefore, a procedure was used in which the analysis was completed on a wet soil basis. A gravimetric moisture determination was made on all samples to determine the per cent dry weight. Approximately 20 grams of soil were weighed while frozen, dried at 60 C for 48 hours, and then reweighed to determine the per cent dry weight of each sample.

The dried portion of this sample was ground and then analyzed for pH. A 5 gram soil sample and 5 ml of deionized water were used to determine pH. Phosphorus was determined on the dried portion on the soil samples that were collected one month after the initial fertilizer applications. Available P was determined using the weak Bray extraction solution and colorimetric procedure mentioned earlier.

For the ammonium-N, nitrite-N, and nitrate-N analyses, a saturated calcium sulfate solution was used to extract the N ions from the wet soil. The procedure consisted of weighing approximately 10 grams of frozen soil into a 125 ml erlenmeyer flask and adding 50 ml of saturated CaSO_4 . A wrist action shaker was used to shake the solutions for 15 minutes. Samples were

Table 5. Sampling dates and soil temperature data for the nitrification study (*).

Sampling Date	Soil Temp. °C	Sampling Date	Av. Weekly Soil Temp. °C	Sampling Date	Av. Weekly Soil Temp. °C
Sept. 19	29	Oct. 2	26	Oct. 30	10
Sept. 21	28	Oct. 9	22	Nov. 6	9
Sept. 23	28	Oct. 16	18	Nov. 13	5
Sept. 25	24	Oct. 23	15		

* Fertilizer was applied September 18, 1972

then filtered through Whatman 42 filter paper and the filtrate collected in polyethylene bottles. The filtrate solutions were stored at approximately 3 C until the time of analysis.

Since nitrite-N is more unstable, this determination was completed before the ammonium-N and nitrate-N. Initially, a qualitative analysis was made on all samples by the use of a spot test. Four drops of filtrate solution were placed on a spot plate. To this was added one drop of 1% sulfanilamide (made up in 3N HCl) and one drop of 0.02% NEDD¹ reagent. If a purple color developed indicating the presence of nitrite-N, a quantitative determination was made. In this determination, 5 ml of extract solution was placed in a test tube with the addition of 10 ml of 1% sulfanilamide and 10 ml of 0.02% NEDD reagent. Solutions were mixed and allowed to stand for 30 minutes for color development. Absorbance was read on a Beckman DB spectrophotometer at a wavelength of 540 or 600 mu, depending on nitrite-N concentration.

For the ammonium-N and nitrate-N determinations, 5 ml of extract solution were used in the steam distillation procedure. With this method of analysis for nitrate-N, nitrite-N is also distilled off in the process. Therefore, the concentration of nitrite-N that was measured colorimetrically was subtracted from the micro-Kjeldahl concentration of nitrate-N to arrive at the final level of nitrate-N. For all calculations, the per cent moisture of each individual sample was taken into account for expressions on a dry weight basis.

¹N-1 naphthylethylenediamine dihydrochloro.

RESULTS AND DISCUSSION

Wheat Studies

Detailed data including leaf nutrient content, grain yield, grain protein, and test weight for the five studies investigated is presented in Appendix Tables I through V. Nutrient uptake from the highest rates of N and P is also included in Appendix Tables I and II. In the figures and tables presented, date 1 and date 2 refer to the November and April sampling, respectively. Soil test results for the sites studied are shown in Table 1 and crop information is presented in Table 3.

At the first sampling date, P concentrations in the leaves were significantly increased by P applications at three of the four locations (Harper, Saline, and Mitchell counties). The McPherson county location was not sampled in November because of insufficient growth. The methods of N-P applications also significantly influenced the P concentration in the plant tissue at the Saline and Harper county sites. Initial soil tests showed the two locations to be low in available P. The blade applications of N and P at the Saline county site were superior to the chisel and surface applications (Figure 2). Phosphorus concentrations in the leaf at the Harper county site (Figure 3) were significantly lower than chisel applications of N and P than from the other two methods. This same trend, although not statistically significant, was also noted at the other locations.

At the early sampling stage, P applied with the blade at a depth of 10 cm could have been more available due to placement. As mentioned previously, the P applied with the chisel at a depth of 25 cm generally produced a lower leaf P concentration than did the other methods. The trend toward lower P concentrations at the early stage of plant development from

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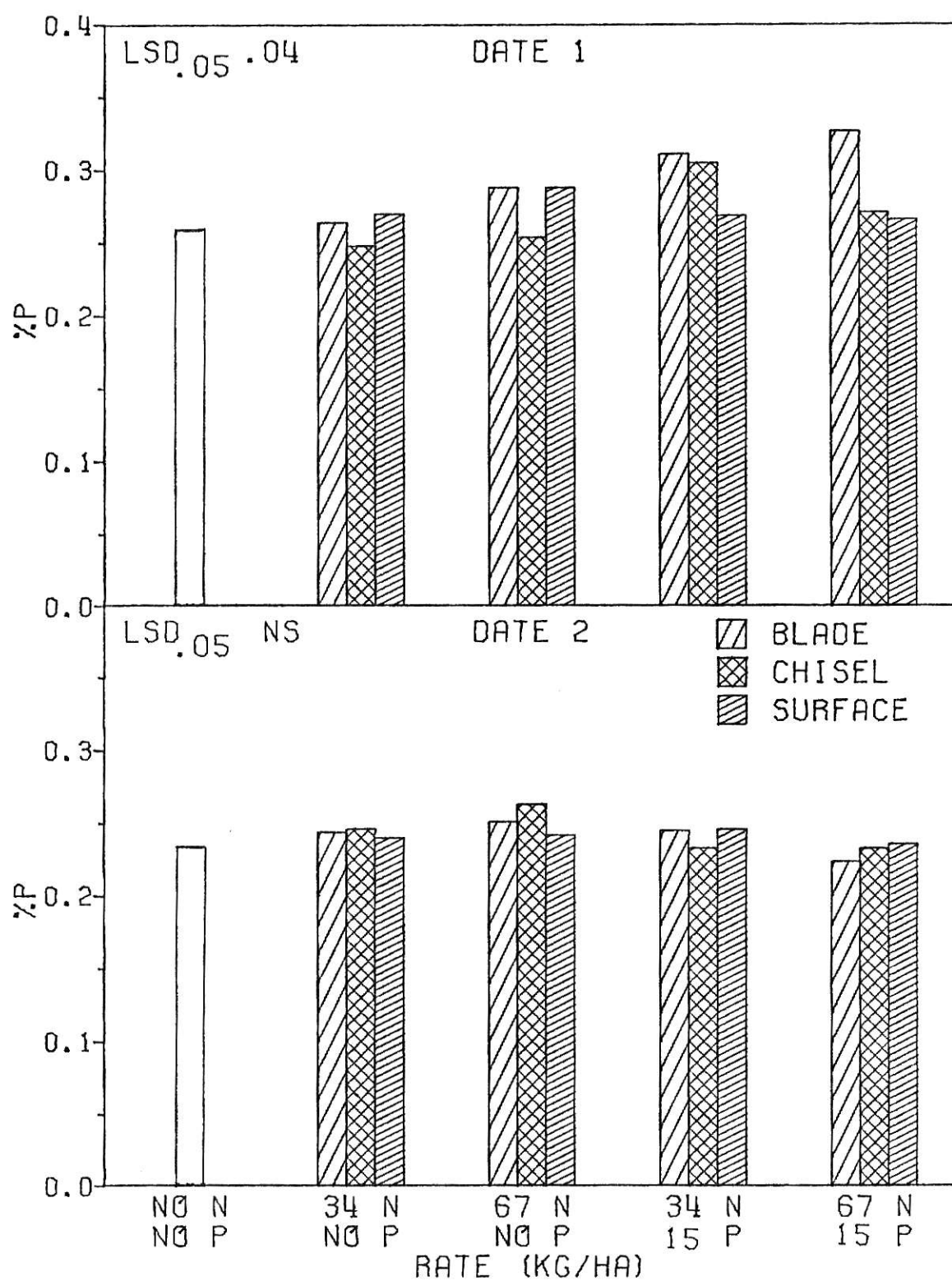


FIG. 2. P CONTENT OF WHEAT LEAVES AS AFFECTED BY METHODS OF N AND P APPLICATIONS - (SALINE COUNTY, 1971-72).

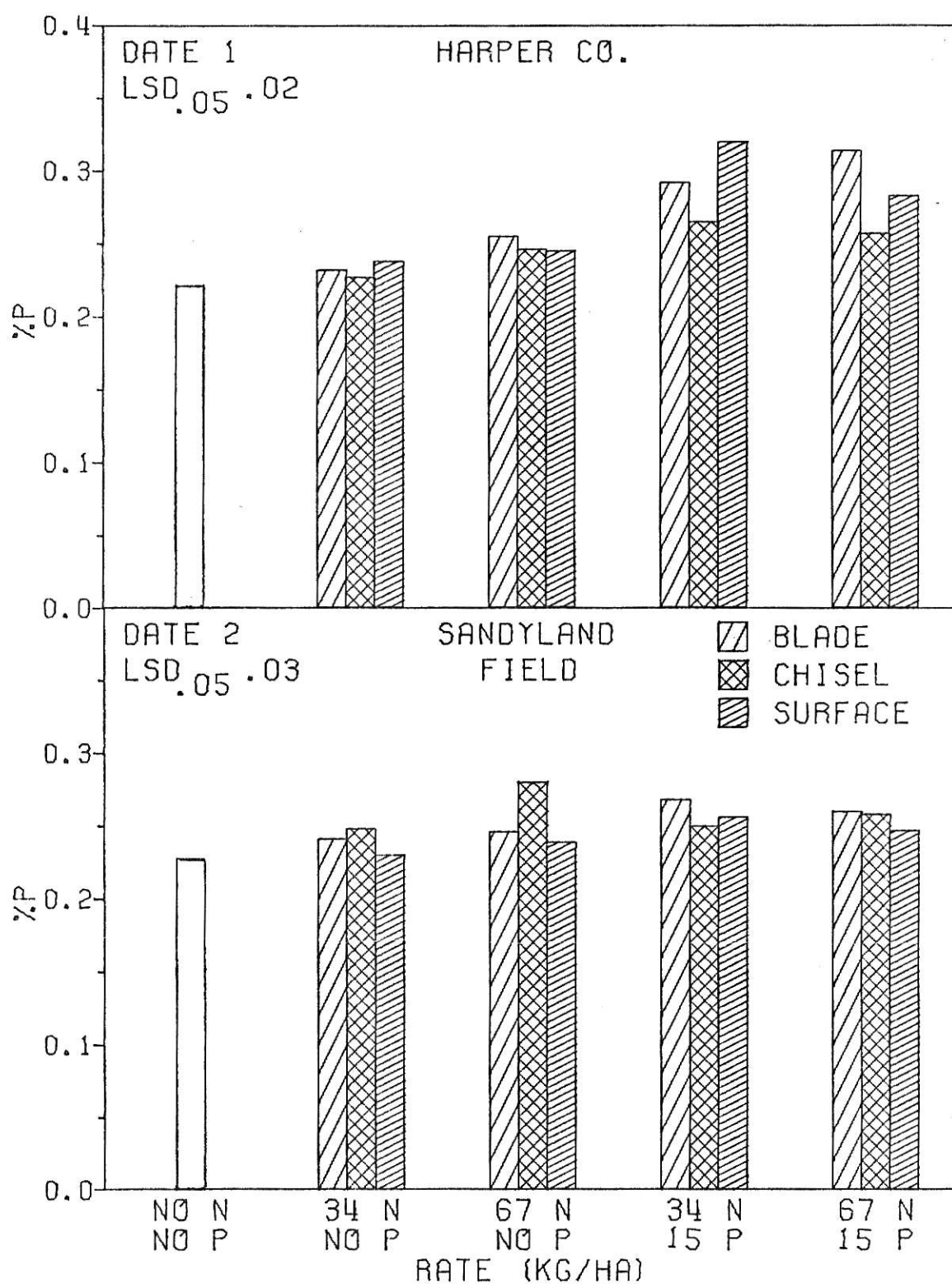


FIG.3. P CONTENT OF WHEAT LEAVES AS AFFECTED BY METHODS OF N AND P APPLICATIONS, 1971-72.

chisel applications could be due to the deeper placement of P. Developing wheat plants may have had more difficulty in contacting the P retention zone.

Although there were no differences in P concentrations between blade and surface applications of N and P at Harper county, P uptake was significantly higher from blade applications (Figure 4). Surface application of P produced a lower P uptake, with chisel applications producing somewhat higher levels. This was evident from visual comparisons of early wheat growth in Harper county (Figure 8). The surface applications of liquid P were only slightly incorporated into the soil surface. Since P is relatively immobile in the soil, this may explain the lower uptake of P from surface applications at the Harper county site where topsoil moisture was somewhat limiting.

With the April sampling, differences in P responses between the three methods of application were less significant than in November. At the Sandyland Field, tillage implement applications of N and P produced statistically higher leaf P contents than surface treatments, although differences were not large (Figure 3). Visual observations at the Saline county site (Figure 9) revealed that plant growth was perceptibly less in the case of surface N-P applications, with the chisel and blade applications producing about equal growth. However, leaf analyses at this site (date 2) did not indicate any differences in leaf P concentrations between the methods of N-P application (Figure 2).

Plant N concentrations were statistically unaffected by the rate of N or method of application in November and April samplings. However, there was a trend toward lower N concentrations from the surface application at the Sandyland Field and McPherson county sites (Figure 5). Even though N

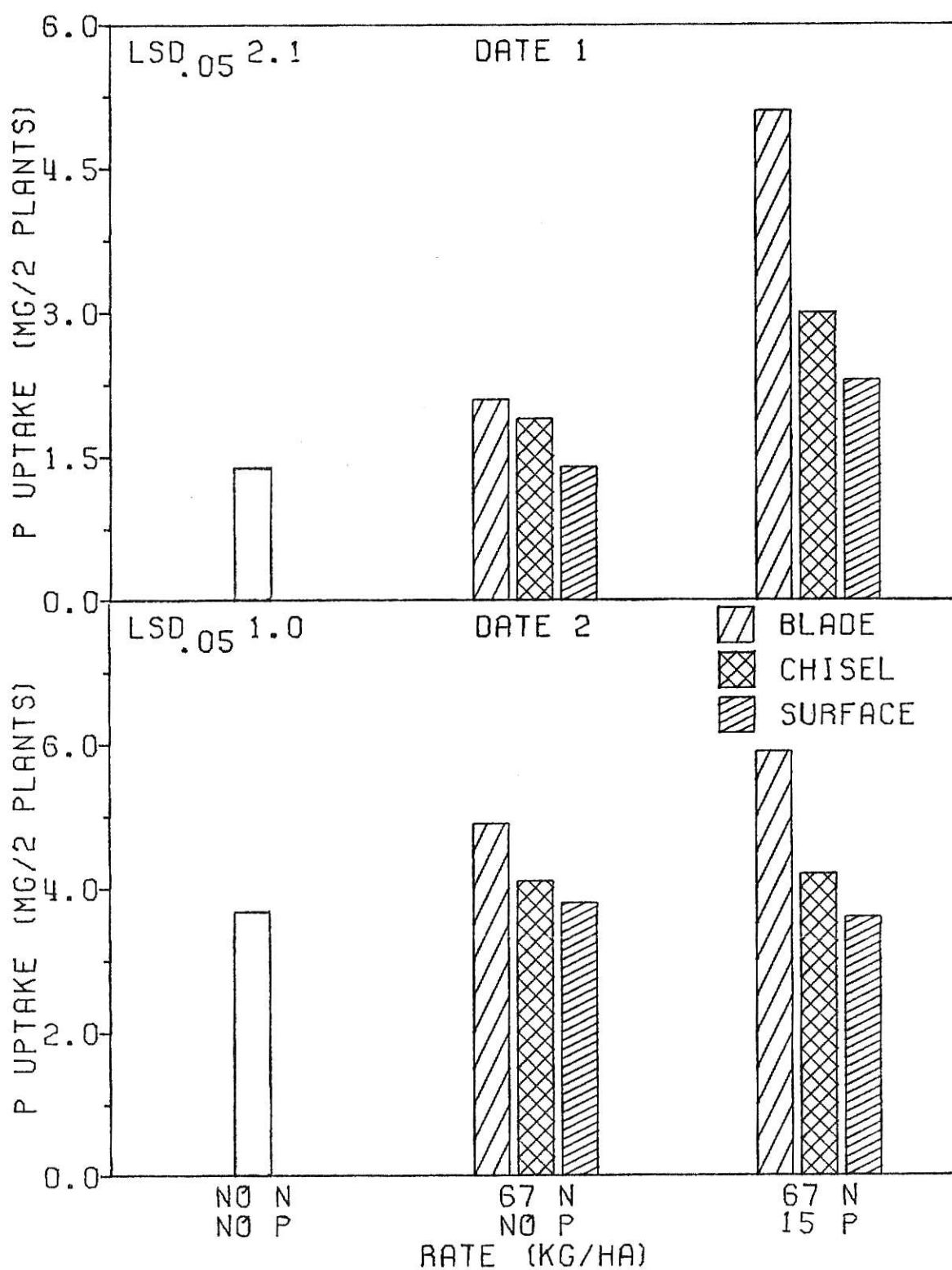


FIG.4. P UPTAKE OF WINTER WHEAT AS AFFECTED BY METHODS OF N AND P APPLICATIONS - (HARPER COUNTY, 1971-72).

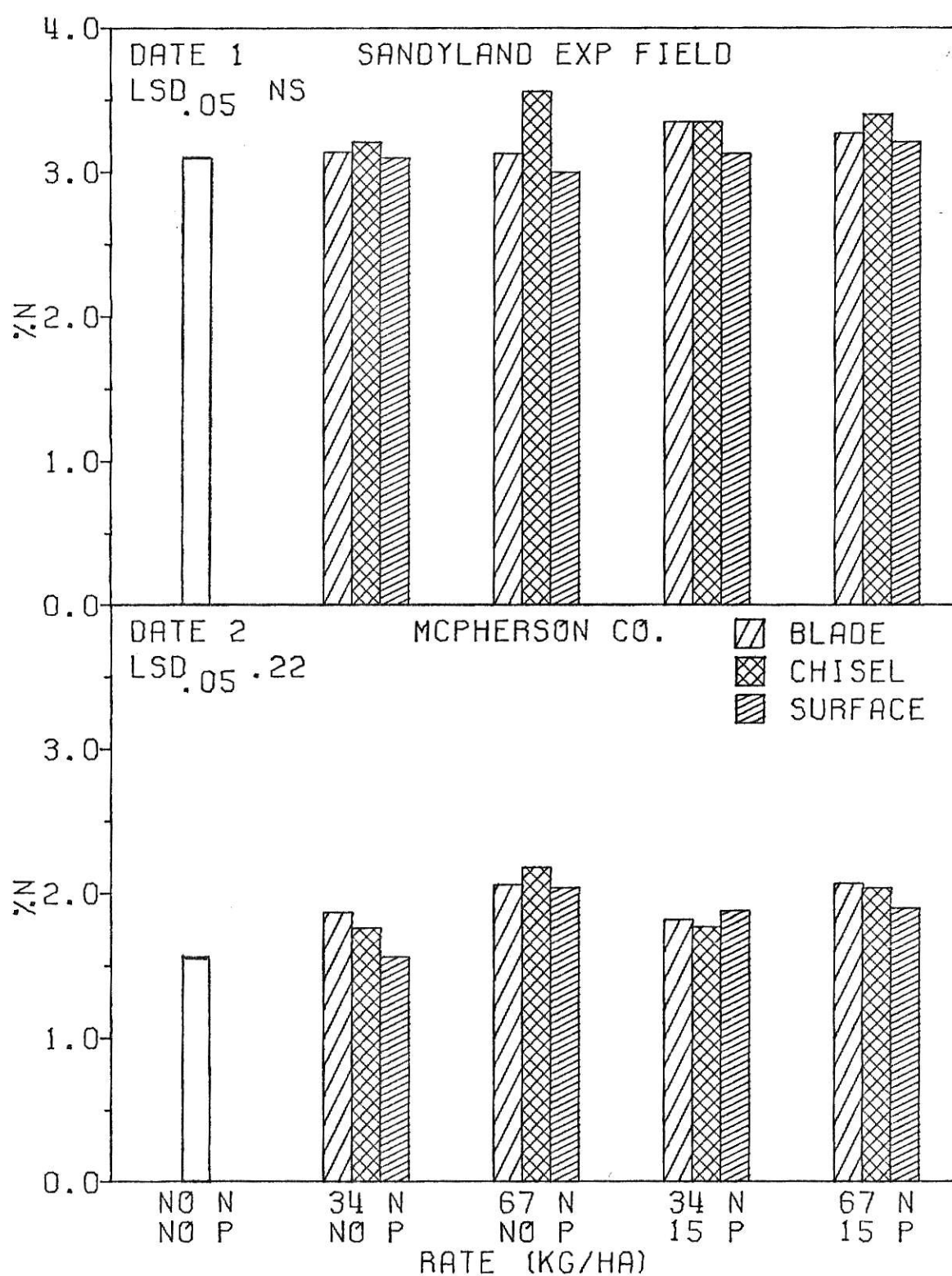


FIG.5. N CONTENT OF WHEAT LEAVES AS AFFECTED BY METHODS OF N AND P APPLICATIONS, 1971-72.

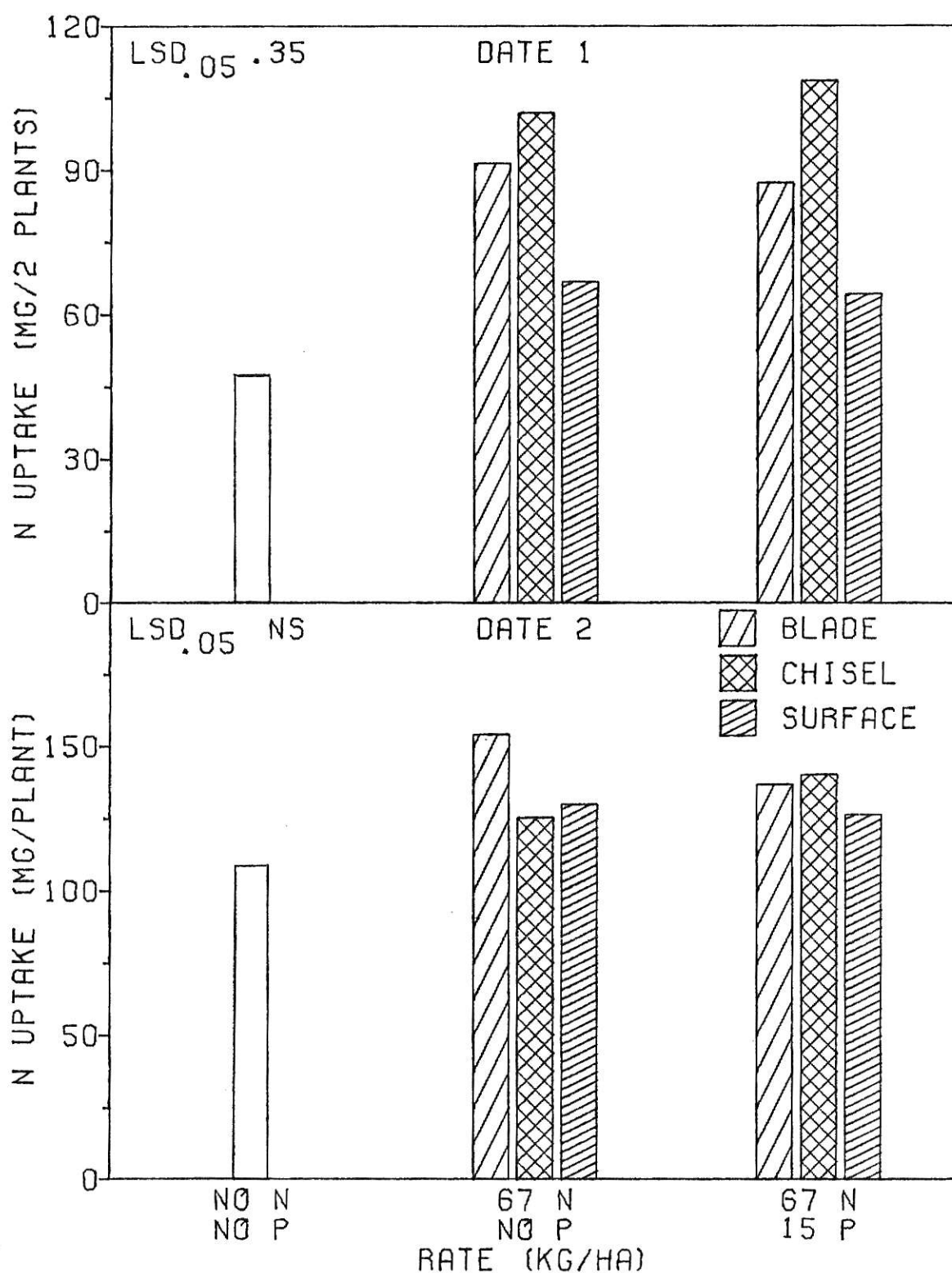


FIG.6. N UPTAKE OF WINTER WHEAT AS AFFECTED BY METHODS OF N AND P APPLICATIONS - (SANDYLAND EXP FIELD, 1971-72).

Fig. 7. Early season growth differences in wheat produced by placement of N and P (Sandyland Experiment Field, 1971).

(Above: Chisel application of 67 kg/ha N as NH_3 and 15 kg/ha P as liquid APP)

(Below: Liquid surface application of 67 kg/ha N as UAN and 15 kg/ha P as APP)



Fig. 8. Early season growth differences in wheat produced by placement of N and P (Harper County, 1971).

(Above: Blade application of 67 kg/ha N as NH_3 and 15 kg/ha as liquid APP)

(Below: Liquid surface application of 67 kg/ha N as UAN and 15 kg/ha P as APP)



Fig. 9. Late season growth responses in wheat from methods of N-P applications (Saline County, 1972).

(Above: Blade application of 67 kg/ha N as NH_3 and 15 kg/ha P as liquid APP on the left. Liquid surface application of 67 kg/ha N as UAN and 15 kg/ha P as APP on the right)

(Below: Blade N-P application on the left and chisel N-P application on the right at the rate of 67 kg/ha N as NH_3 and 15 kg/ha P as liquid APP)



concentrations were similar among the application methods, N uptake at the Sandyland Field in November did differ between methods (Figure 6). Tillage implement applications of N and P produced significantly higher N uptake than surface applications. A visual comparison of early wheat growth at the Sandyland Field between the chisel and surface applications of N and P clearly indicated this response (Figure 7). However, at this same location in April, N uptake was not significantly affected by method of N-P applications.

Even though N is more mobile in the soil, the N uptake results and visual observations in November at the Sandyland Field and Harper county locations suggest that surface applications of N were less efficient in supplying N to the plant than tillage applications where topsoil moisture was limiting.

As mentioned previously, the P concentrations in the leaf from chisel applications of N and P at the first sampling appeared to be lower than the other methods due to deeper placement. However, the N concentrations in the leaf did not show this trend. This could be because the anhydrous ammonia retention zone is larger in diameter than the P zone and developing plants would have less difficulty in contacting this area even though depth of application was 25 cm.

The K concentrations in the leaves at date 1 and date 2 from all locations were not affected by methods of N-P application. This would be the expected response since potassium was not included in the fertilizer applications.

The results of the correlation studies conducted in November and April at the Sandyland Field and Harper county site are shown in Tables 6 and 7. The objective of the study was to statistically correlate soil inorganic N

Table 6. Correlation coefficients relating inorganic soil N and available soil P to the plant uptake of N and P on winter wheat from three N-P application methods (Sandyland Exp. Field, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Correlation Coefficients (r)	
			Inorganic Soil N	Available Soil P
			vs Plant N Uptake	vs Plant P Uptake
<u>November Sampling:</u>				
67 0	Blade	NH ₃	0.339	0.166
67 0	Chisel	NH ₃	-0.257	-0.132
67 0	Surface	UAN	0.484*	0.474*
67 15	Blade	NH ₃ + APP	0.377*	0.235
67 15	Chisel	NH ₃ + APP	0.304	0.049
67 15	Surface	UAN + APP	-0.359*	0.599*
<u>April Sampling:</u>				
67 0	Blade	NH ₃	0.236	0.141
67 0	Chisel	NH ₃	0.152	-0.023
67 0	Surface	UAN	0.217	0.410*
67 15	Blade	NH ₃ + APP	0.140	0.198
67 15	Chisel	NH ₃ + APP	0.101	0.097
67 15	Surface	UAN + APP	0.224	0.378*

* Significant at the 5% level

Table 7. Correlation coefficients relating inorganic soil N and available soil P to the plant uptake of N and P on winter wheat from three N-P application methods (Harper County, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Correlation Coefficients (r)	
			Inorganic Soil N	Available Soil P
			vs Plant N Uptake	vs Plant P Uptake
<u>November Sampling:</u>				
67	0	NH ₃	0.423*	0.328*
67	0	NH ₃	0.452*	0.329*
67	0	UAN	0.126	0.196
67	15	NH ₃ + APP	0.276	0.318*
67	15	NH ₃ + APP	0.186	0.109
67	15	UAN + APP	0.326*	-0.118
<u>April Sampling:</u>				
67	0	NH ₃	0.268	0.238
67	0	NH ₃	0.381*	0.263
67	0	UAN	0.033	0.182
67	15	NH ₃ + APP	0.291	0.189
67	15	NH ₃ + APP	0.127	0.021
67	15	UAN + APP	-0.027	-0.221

* Significant at the 5% level

and available P to the plant uptake of N and P as affected by the three methods of N-P application. The results appeared to be inconsistent and it was difficult to draw any definite conclusions. At the Sandyland Field, the statistical correlations in general were higher for surface treatments and lower for chisel applications. However, the results obtained at this site may not be entirely valid due to problems in soil sampling. At the time of sampling, dry soil conditions made it difficult to keep the soil cores in the probe. It is conceivable that the soil cores did not represent the true N-P concentrations from the deeper depths. The correlations at the Harper county site were undoubtedly influenced by dry weather conditions and were also inconsistent. However, at this location, blade applications resulted in higher coefficients than surface treatments. At both sites, correlations in April were lower than November.

Significant grain yield responses due to differences between methods of N-P applications were recorded at the Sandyland Field and at the McPherson county location (Table 8). Blade applications produced consistently higher yields than chisel and surface applications at these two sites. No significant yield differences were noted between methods of application at the other locations. The Saline county location responded significantly to P applications, but there was no significant difference between methods of application.

Grain protein levels were increased due to N applications at three locations, but generally the increases were small (Table 8). The Sandyland Field was the only location where grain protein was affected by methods of application. The blade method produced significantly higher grain protein levels than chisel and surface applications.

Table 8. Comparisons of effects of methods of N and P application on yield and grain protein on winter wheat (Sandyland Exp. Field and McPherson County, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Sandyland Exp. Field		McPherson Co.	
			Yield kg/ha	Grain Protein %	Yield kg/ha	Grain Protein %
0 0	---	---	2486	10.6	2285	10.8
34 0	Blade	NH ₃	3158	11.2	2890	10.7
67 0	Blade	NH ₃	3360	12.5	3293	11.2
34 0	Chisel	NH ₃	2890	10.6	2822	10.6
67 0	Chisel	NH ₃	3326	10.8	3091	10.9
34 0	Surface	UAN	2822	10.8	2755	10.8
67 0	Surface	UAN	2755	11.4	2822	10.8
34 15	Blade	NH ₃ + APP	3360	11.2	3091	10.7
67 15	Blade	NH ₃ + APP	3091	12.1	3226	10.9
34 15	Chisel	NH ₃ + APP	2890	10.1	2486	10.4
67 15	Chisel	NH ₃ + APP	3158	10.3	3091	10.6
34 15	Surface	UAN + APP	3024	11.1	2755	10.6
67 15	Surface	UAN + APP	3024	11.0	3024	10.8
LSD .05	Treatment		202	0.5	336	ns
	N Rate		ns	0.4	134	-
	P Rate		ns	ns	ns	-
	Method of Application		134	0.5	202	-

There were no significant trends noted in grain test weight with the various N-P applications.

Grain Sorghum Studies

Detailed data including leaf nutrient concentrations, grain yield, and grain protein levels for the four sites investigated is presented in Appendix Tables VI through IX. Detailed results of the soil distribution pattern evaluations for the three methods of N-P applications are listed in Appendix Tables X through XII. In the figures and tables, date 1 refers to the 8-leaf stage of growth and date 2 refers to the boot stage of development. Soil test results for the sites studied are presented in Table 1 and crop information is presented in Table 3.

At the 8-leaf stage, the N concentration in leaf tissue was significantly affected by methods of N-P applications at the East Central and North Central Experiment Fields (Figures 10 and 11). At both sites, tillage implement N-P applications produced higher N concentrations than surface applications. No differences in N levels due to methods of application were observed at the Cornbelt and Newton Fields. Results of N uptake evaluations at the North Central Field did not reveal any significant difference between the methods of application.

At the boot stage of plant development, leaf analyses revealed that the N concentrations were significantly higher from the chisel N-P applications at three of the four sites (East Central, North Central, and Newton Fields). At the East Central and North Central Fields, leaf N concentrations resulting from surface N-P applications were also statistically lower than those from tillage applications (Figures 10 and 11). A later discussion on the soil distribution patterns of N and P from the different methods of applica-

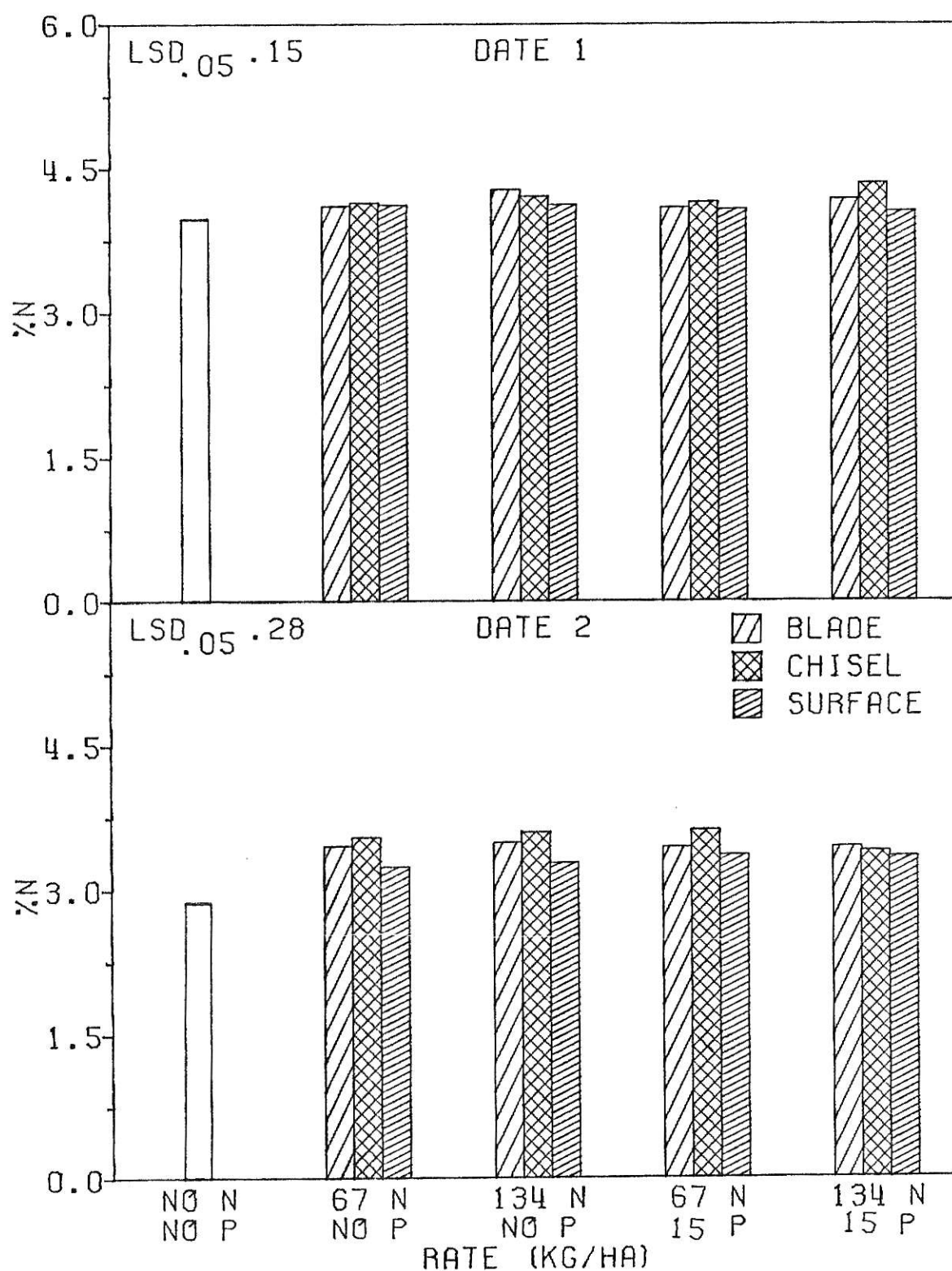


FIG.10. N CONTENT OF GRAIN SORGHUM LEAVES AS AFFECTED BY METHODS OF N-P APPLICATIONS - (EAST CENTRAL EXP FIELD, 1972).

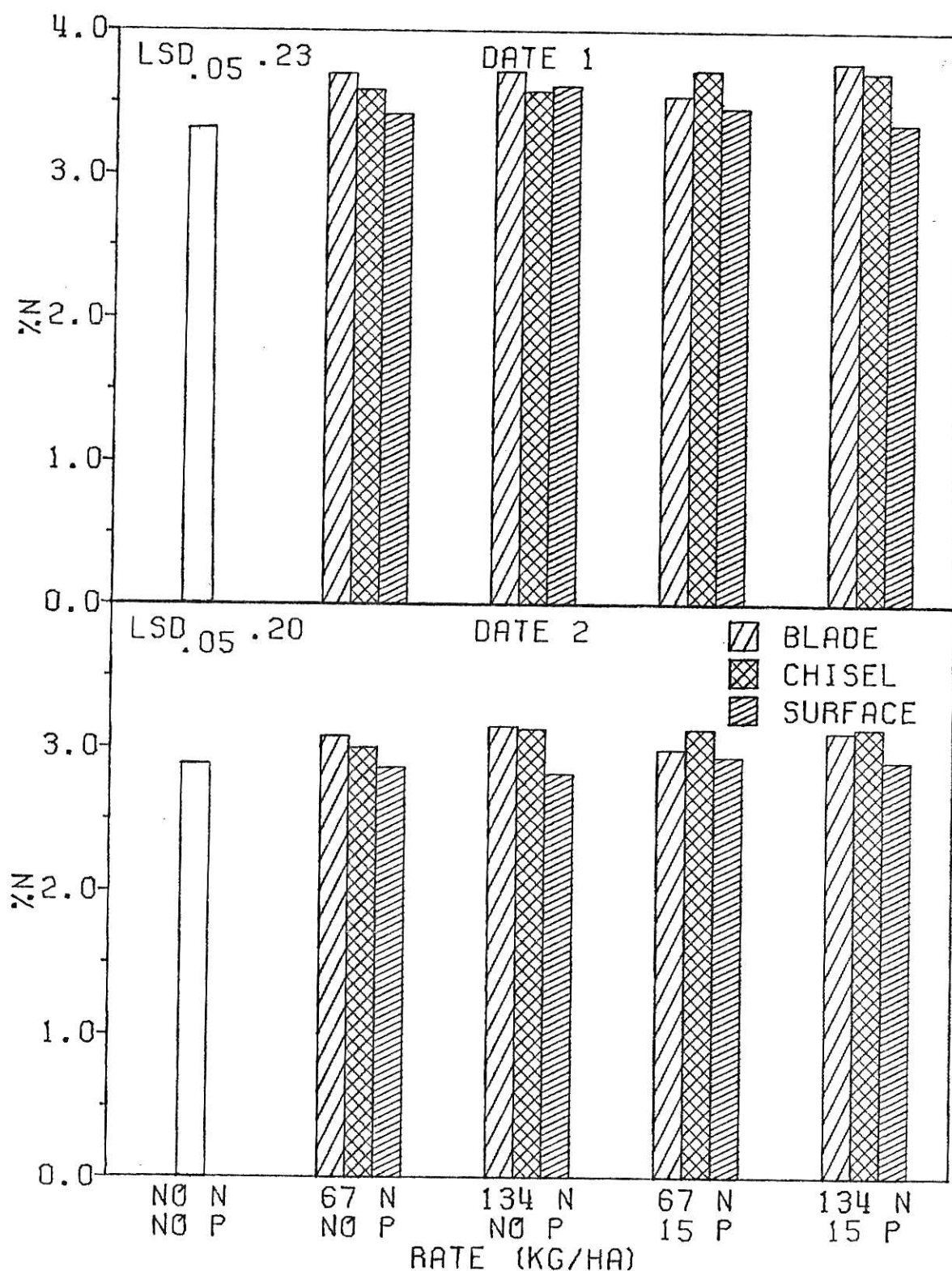


FIG.11. N CONTENT OF GRAIN SORGHUM LEAVES AS AFFECTED BY METHODS OF N-P APPLICATIONS - (NORTH CENTRAL EXP FIELD, 1972).

tion will point out the influence of fertilizer placement.

Leaf P concentration differences at all four locations from both samplings were not significant with respect to P rates or methods of application. Initial soil tests revealed that the available P was rather high at these sites, which might explain the poor P response.

The K content of the sorghum leaves, like that of the wheat tissue sampled, showed no general trends from the N-P applications.

Grain yields at all locations did not reveal significant differences among treatments from the N-P applications. Grain yield and grain protein data from the North Central and East Central Fields are shown in Table 9.

Despite the fact that no significant yield increases were recorded, grain protein levels were significantly affected by method of N-P applications. Surface N-P applications were relatively less effective at three of the four sites in inducing higher grain protein levels than applications with the undercutting blade and with the chisel. Chisel N-P applications produced the highest protein levels at all sites. Both blade and chisel methods produced more grain protein than surface applications at the North Central and East Central Fields (Table 9).

The N concentrations in the leaves at the boot stage of development related directly to the grain protein levels at all locations. The fact that chisel applications were superior in all cases suggests greater nutrient efficiency with the deeper placement.

Soil distribution patterns of inorganic N and available P at the North Central Field resulting from the three methods of application emphasize the significance of placement on efficiency of nutrient utilization (Figures 12 through 18). The soil samples were collected at the 8-leaf sampling date. Nitrate-N was the predominant form of inorganic soil N. However, soil

Table 9. Comparisons of effects of methods of N and P application on yield and grain protein levels of dryland grain sorghum (East Central and North Central Exp. Fields, 1972).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	East Central Field		North Central Field	
			Yield kg/ha	Grain Protein %	Yield kg/ha	Grain Protein %
0 0	---	---	5768	6.9	6772	10.6
67 0	Blade	NH ₃	6145	7.9	5894	11.3
134 0	Blade	NH ₃	6145	9.0	6145	11.5
67 0	Chisel	NH ₃	6395	8.6	7273	11.2
134 0	Chisel	NH ₃	6584	9.0	5831	11.7
67 0	Surface	UAN	5831	7.9	6584	10.1
134 0	Surface	UAN	6709	7.9	6207	10.9
67 15	Blade	NH ₃ + APP	6082	8.0	6834	10.7
134 15	Blade	NH ₃ + APP	6395	8.9	6333	11.5
67 15	Chisel	NH ₃ + APP	5706	9.0	6709	11.2
134 15	Chisel	NH ₃ + APP	5706	9.7	7211	11.3
67 15	Surface	UAN + APP	6395	7.9	7022	10.9
134 15	Surface	UAN + APP	7148	8.0	6772	11.1
LSD .05	Treatment		ns	0.7	ns	0.7
	N Rate		-	0.3	-	0.3
	P Rate		-	ns	-	ns
	Method of Application		-	0.4	-	0.3

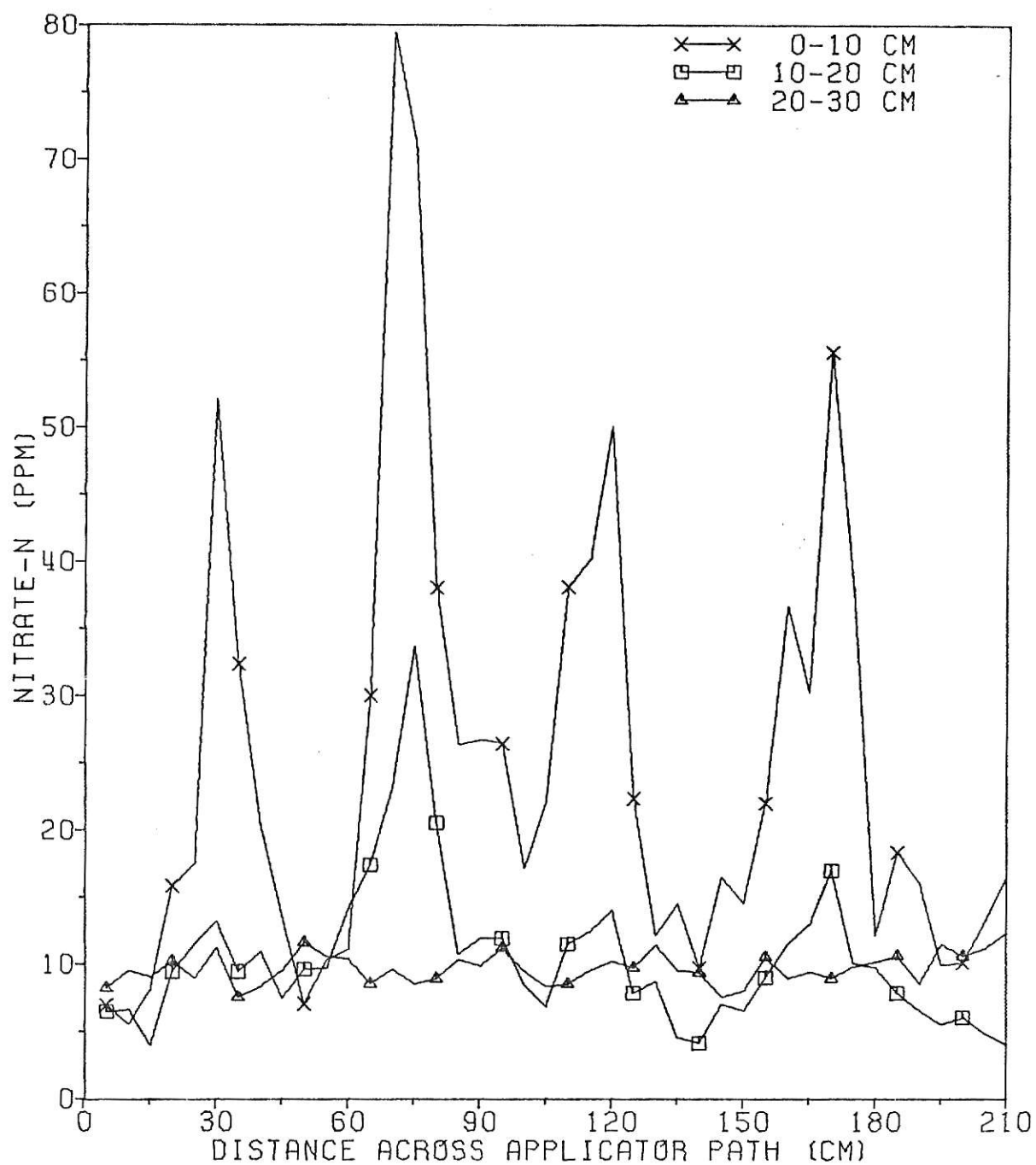


FIG.12. DISTRIBUTION OF NITRATE-N RESULTING FROM A BLADE APPLICATION OF 134 KG/HA N AS NH_3 AND 15 KG/HA P AS LIQUID APP. (NORTH CENTRAL EXP FIELD, 1972)

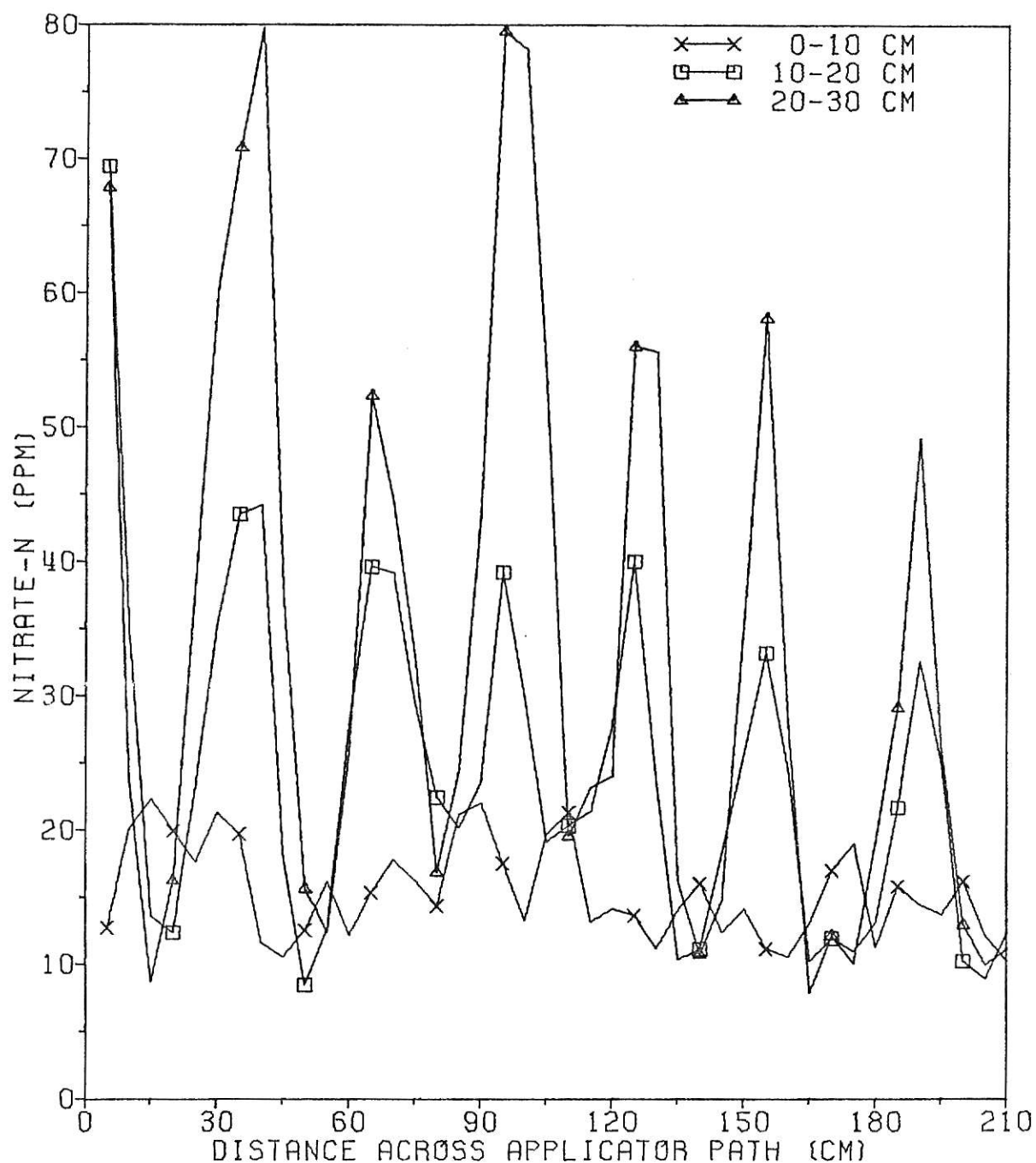


FIG.13. DISTRIBUTION OF NITRATE-N RESULTING FROM A CHISEL APPLICATION OF 134 KG/HA N AS NH_3 AND 15 KG/HA P AS LIQUID APP. (NORTH CENTRAL EXP FIELD, 1972)

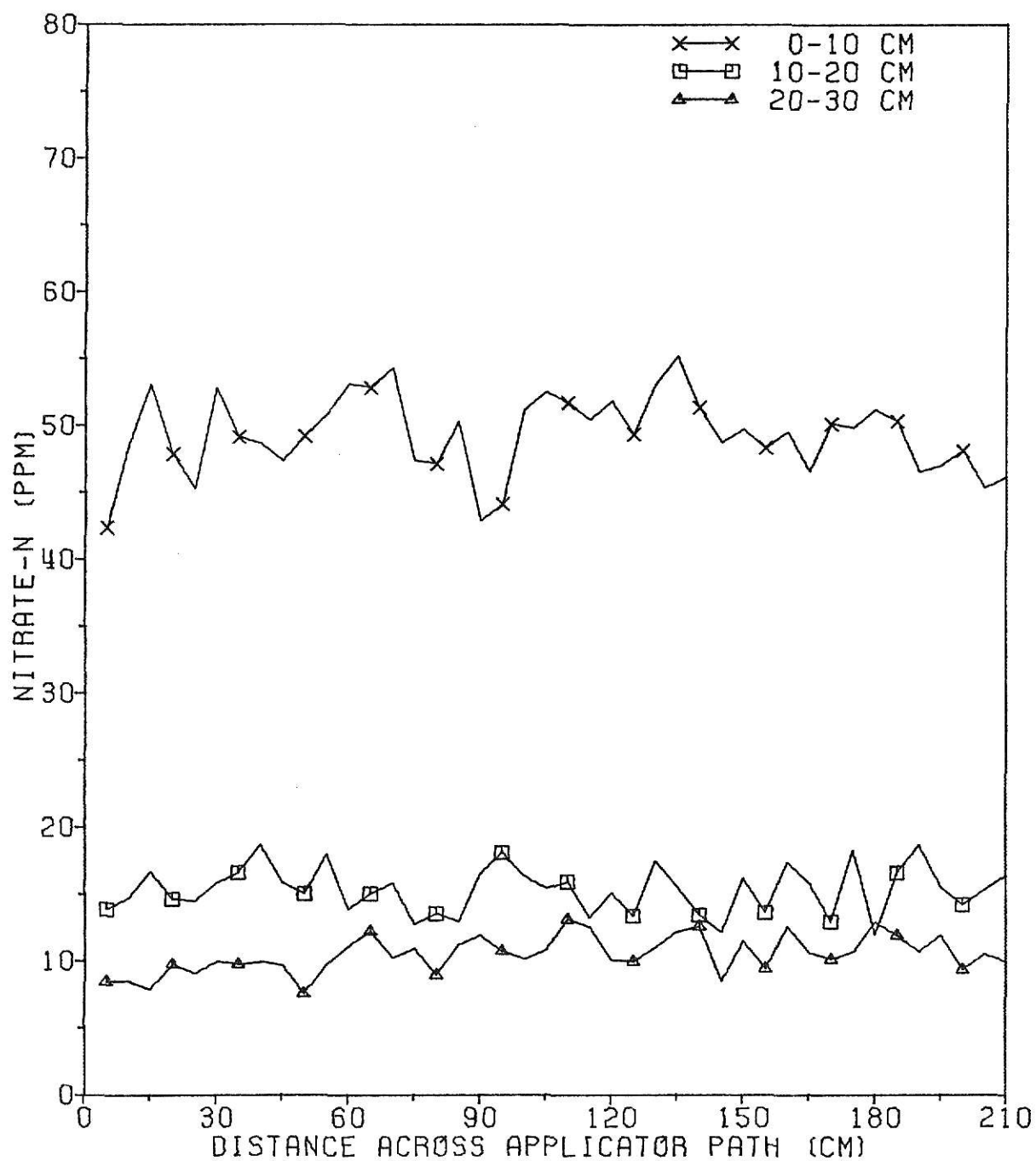


FIG.14. DISTRIBUTION OF NITRATE-N RESULTING FROM A LIQUID SURFACE APPLICATION OF 134 KG/HA N AS UAN AND 15 KG/HA P AS APP. (NORTH CENTRAL EXP FIELD, 1972)

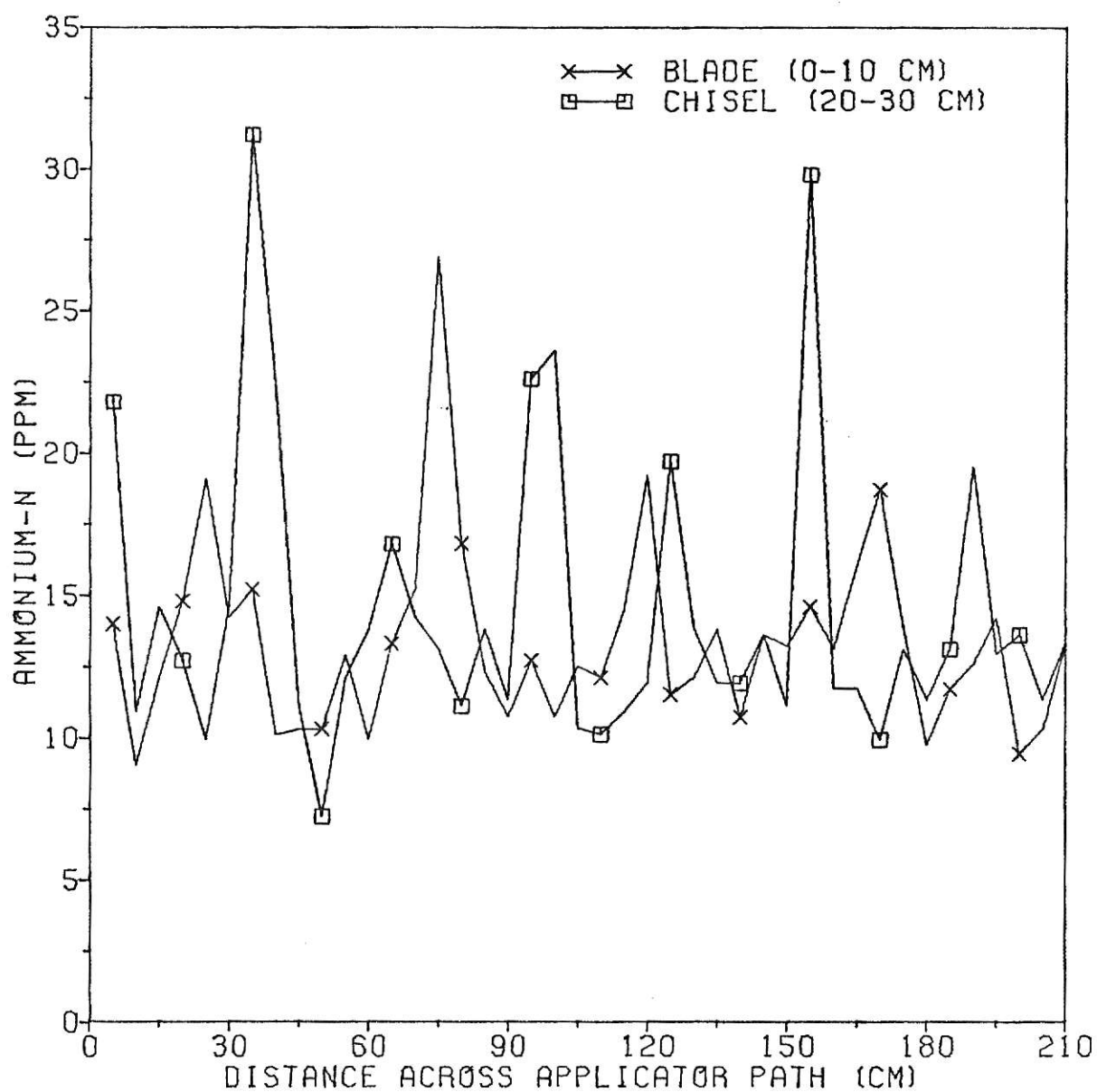


FIG.15. DISTRIBUTION OF AMMONIUM-N RESULTING FROM TILLAGE IMPLEMENT APPLICATIONS OF 134 KG/HA N AS NH_3 AND 15 KG/HA P AS LIQUID APP - (NORTH CENTRAL EXP FIELD, 1972).

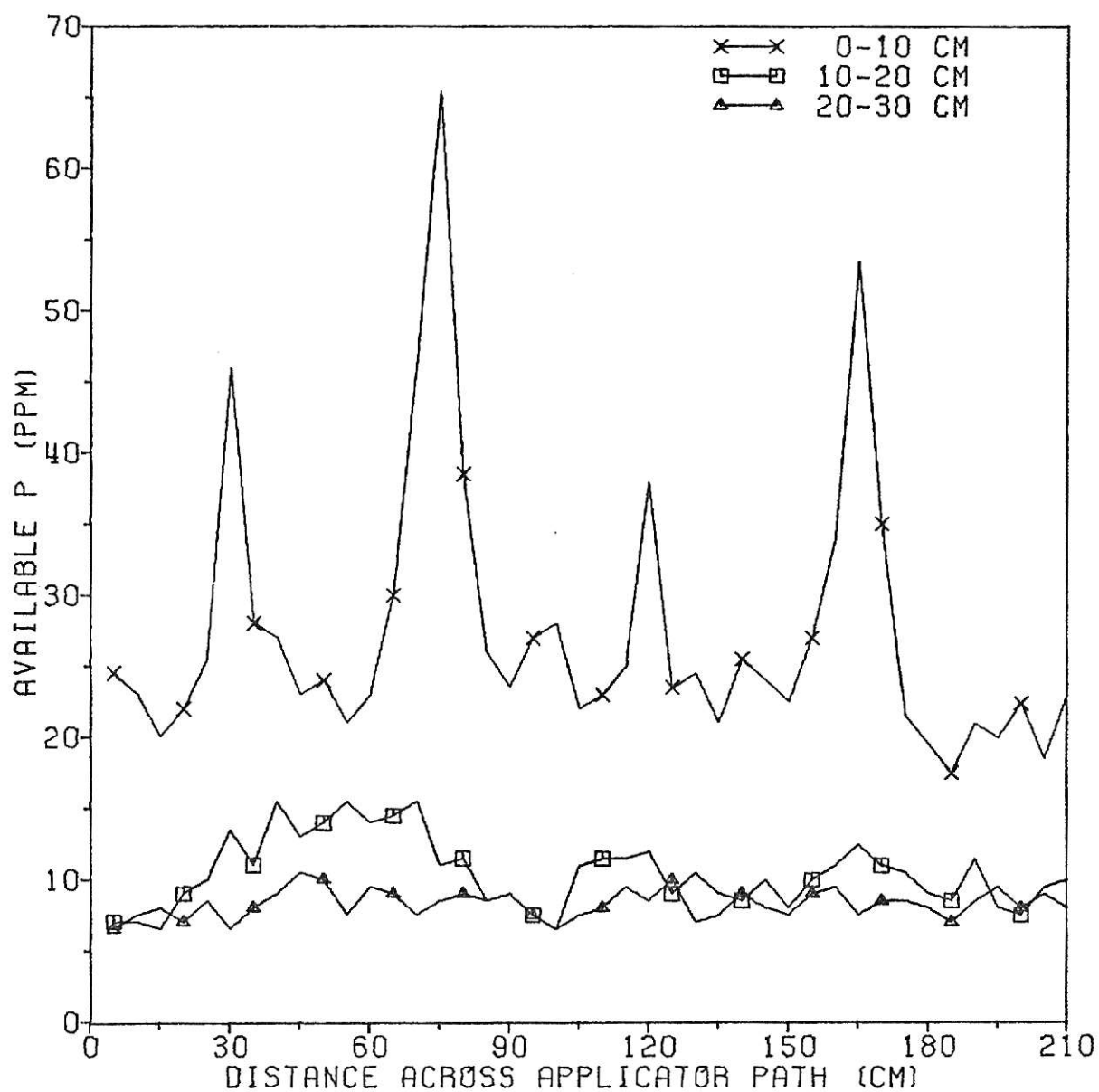


FIG.16. DISTRIBUTION OF AVAIL. P RESULTING FROM A BLADE APPLICATION OF 134 KG/HA N AS NH_3 AND 15 KG/HA P AS LIQUID APP. (NORTH CENTRAL EXP FIELD, 1972)

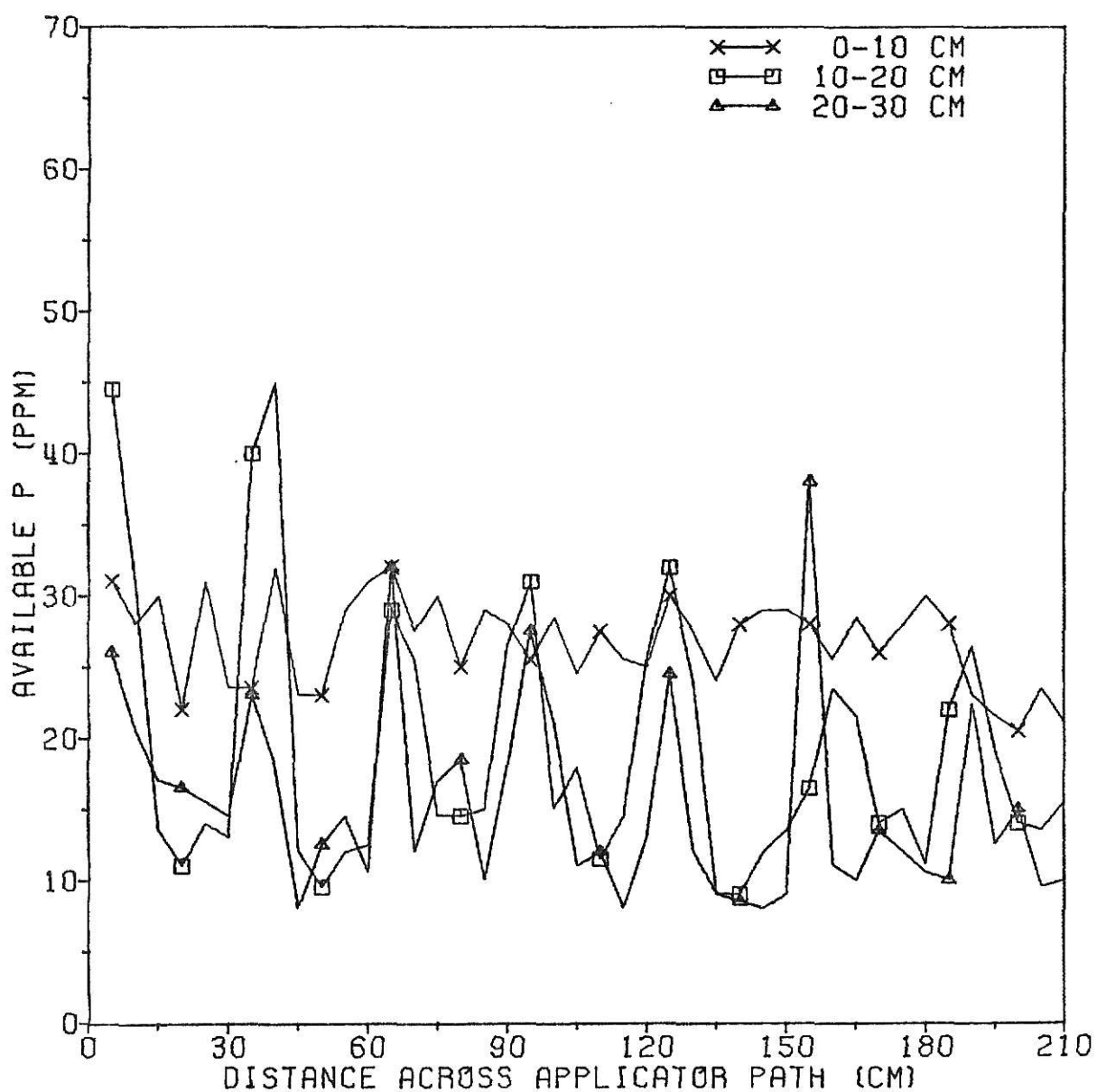


FIG.17. DISTRIBUTION OF AVAIL. P RESULTING FROM A CHISEL APPLICATION OF 134 KG/HA N AS NH_3 AND 15 KG/HA P AS LIQUID APP. (NORTH CENTRAL EXP FIELD, 1972)

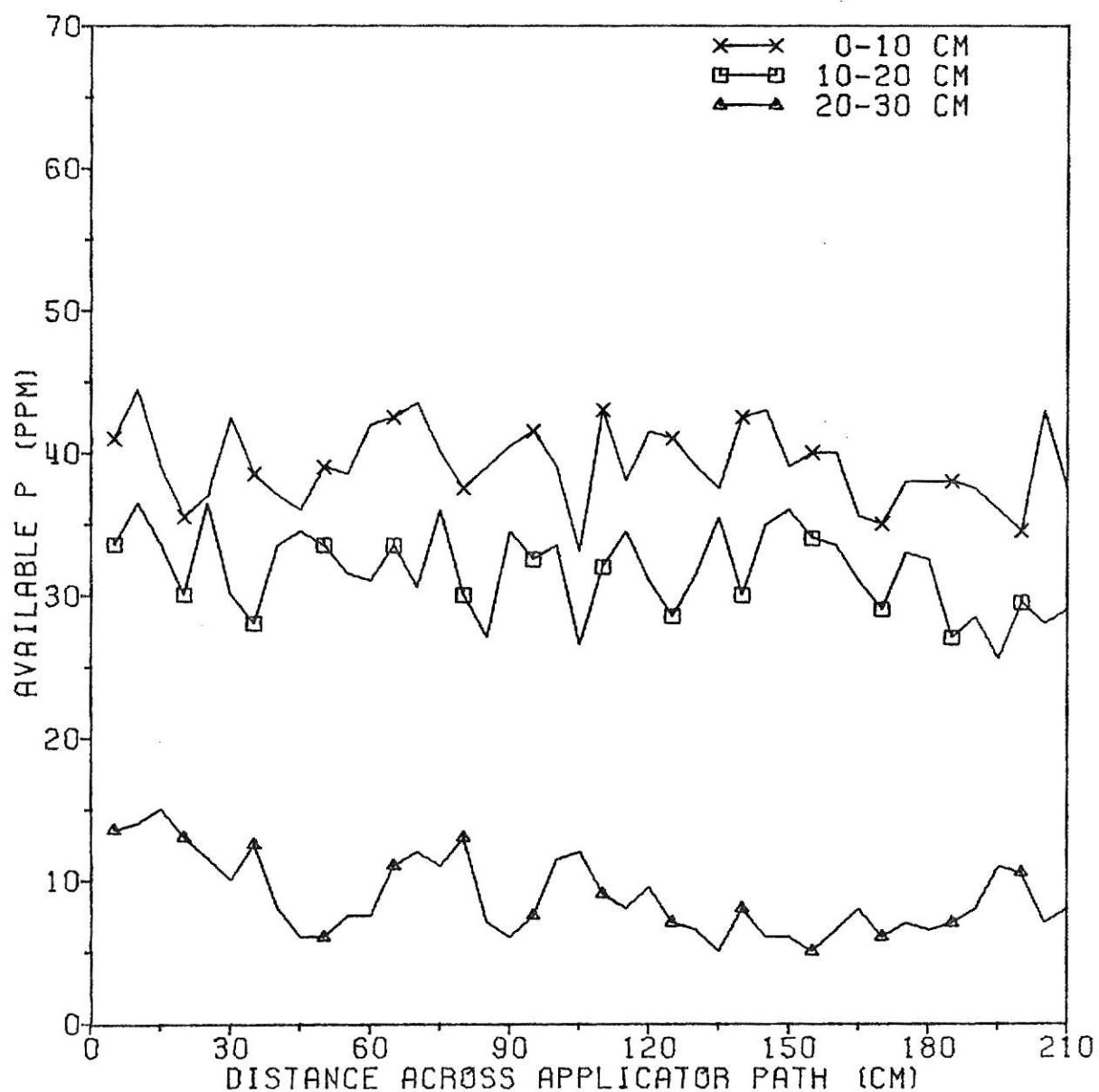


FIG.18. DISTRIBUTION OF AVAIL. P RESULTING FROM A LIQUID SURFACE APPLICATION OF 134 KG/HA N AS UAN AND 15 KG/HA P AS APP. (NORTH CENTRAL EXP FIELD, 1972)

analyses revealed that moderate amounts of ammonium-N had not been nitrified at the release point positions of the blade and chisel N-P applications even though the fertilizer was applied in early April. Evidently, the nitrification reaction had not been completed where the initial high ammonium-N concentrations existed around the release point positions.

Figure 12 shows that with the blade N-P application, the majority of the nitrate-N and available P (Figure 16) was present in the top 10 cm of the soil although moderate levels of nitrate-N also existed at the 10-20 cm depth. The positions of the four release points were quite apparent. Greater plant growth was observed at these positions in some of the wheat studies (Figure 8), although it was not noticeable with grain sorghum.

The distribution pattern from the chisel N-P application revealed that nitrate-N (Figure 13) and available P (Figure 17) were present at the deeper soil sampling depths of 10-20 and 20-30 cm. The deeper placement of N increased the N concentrations in the leaves and subsequently conversion to grain protein at all grain sorghum sites investigated in 1972.

The distribution of nitrate-N (Figure 14) and available P (Figure 18) from a surface N-P application revealed that the applied nutrients were confined to the top 10 cm of the soil. At the time of sampling, there was no evidence to indicate that the nitrate-N had leached below the top 10 cm depth. When topsoil moisture is limiting, the efficiency of utilization from surface applied nutrients could be restricted.

Nitrification Study

Detailed results from the nitrification of NH_3 and a simultaneous N-P application of NH_3 and liquid APP are presented in Appendix Table XIII for the eleven sampling dates. Soil test results for the site investigated are

presented in Table 4. Sampling dates and soil temperature data are presented in Table 5.

The nitrification results obtained from the simultaneous application of NH_3 and liquid APP were almost identical to the NH_3 treatment. As a result, the following discussion does not make any distinction between the two treatments.

Soil samples collected during the first week after N-P applications revealed very little nitrification during the period (Figures 19, 20, 25, and 26). The lag phase is reportedly due to an initial sterilizing effect on the nitrifying organisms from the anhydrous ammonia injection (Eno and Blue, 1954). During the initial lag phase, ammonium-N concentrations at the two release points ranged from 100 to 125 ppm. The NH_3 retention zone was about 10-15 cm in diameter. Soil pH values at a depth of 10 cm increased from 5.6 to 6.8 after the NH_3 application. Nitrite-N was not detected during the first week.

The nitrification of ammonium-N to nitrate-N occurred most rapidly 2 to 4 weeks after initial N-P applications (Figures 21, 22, 23, 27, 28, and 29). Ammonium-N decreased to less than 40 ppm at the release points while the nitrate-N increased to nearly 100 ppm. During this period, nitrite-N concentrations reached a maximum value of 5 ppm near the release points. Soil pH decreased from 6.8 to 5.4 due to the acidifying effect of the reaction. Nitrification continued at a slower rate after the 4th week, and nitrite-N was not detected after this period.

After the 6th week, the soil temperature at a depth of 10 cm was below 10 C and the nitrification process essentially stopped. Figures 24 and 30 from the 8-week sampling show the final level of ammonium-N to be less than 35 ppm while nitrate-N concentrations ranged from 125 to 150 ppm. Soil pH

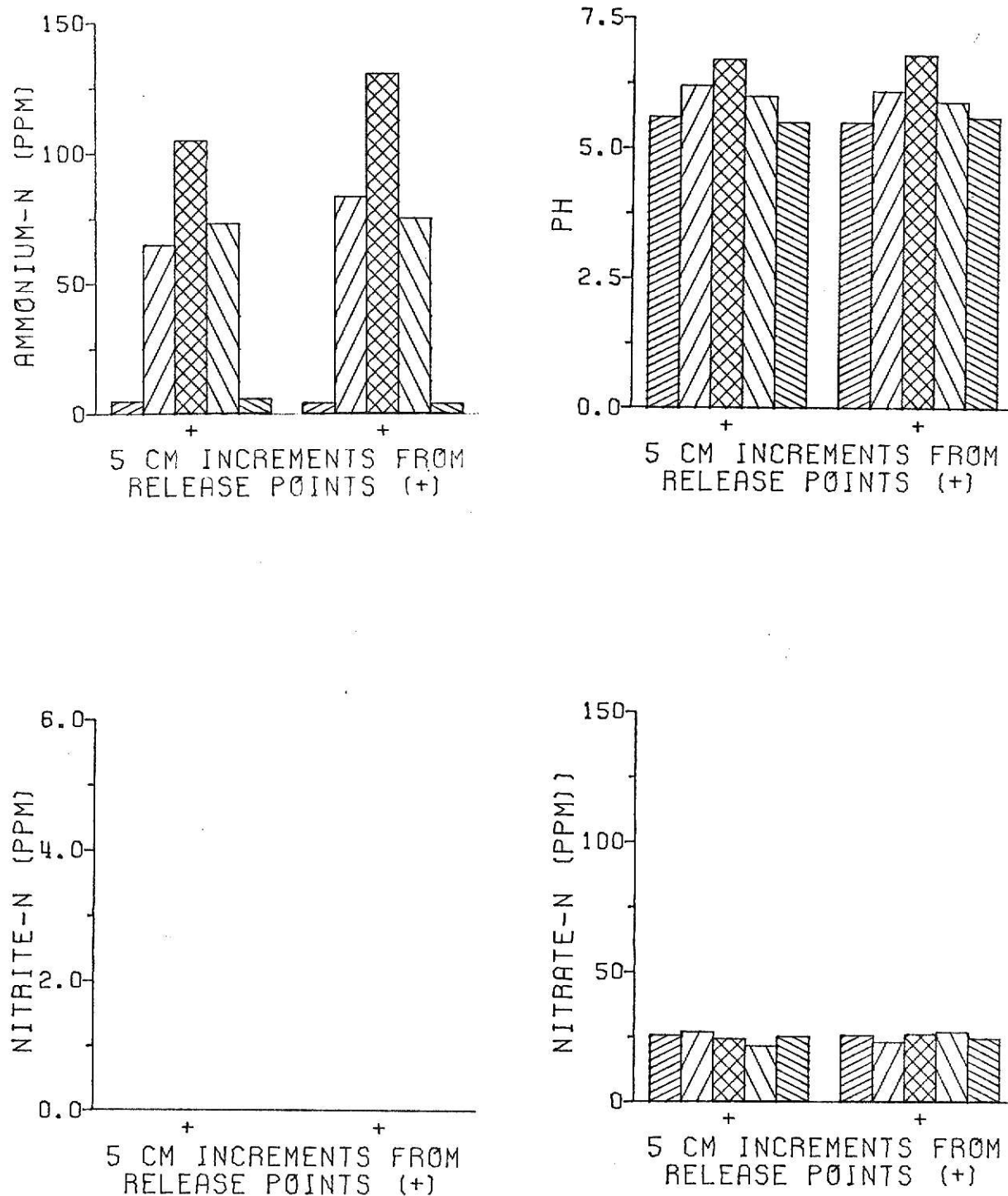


FIG.19. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA - 1 DAY AFTER APPLICATION. (DEPTH, 0-10 CM)

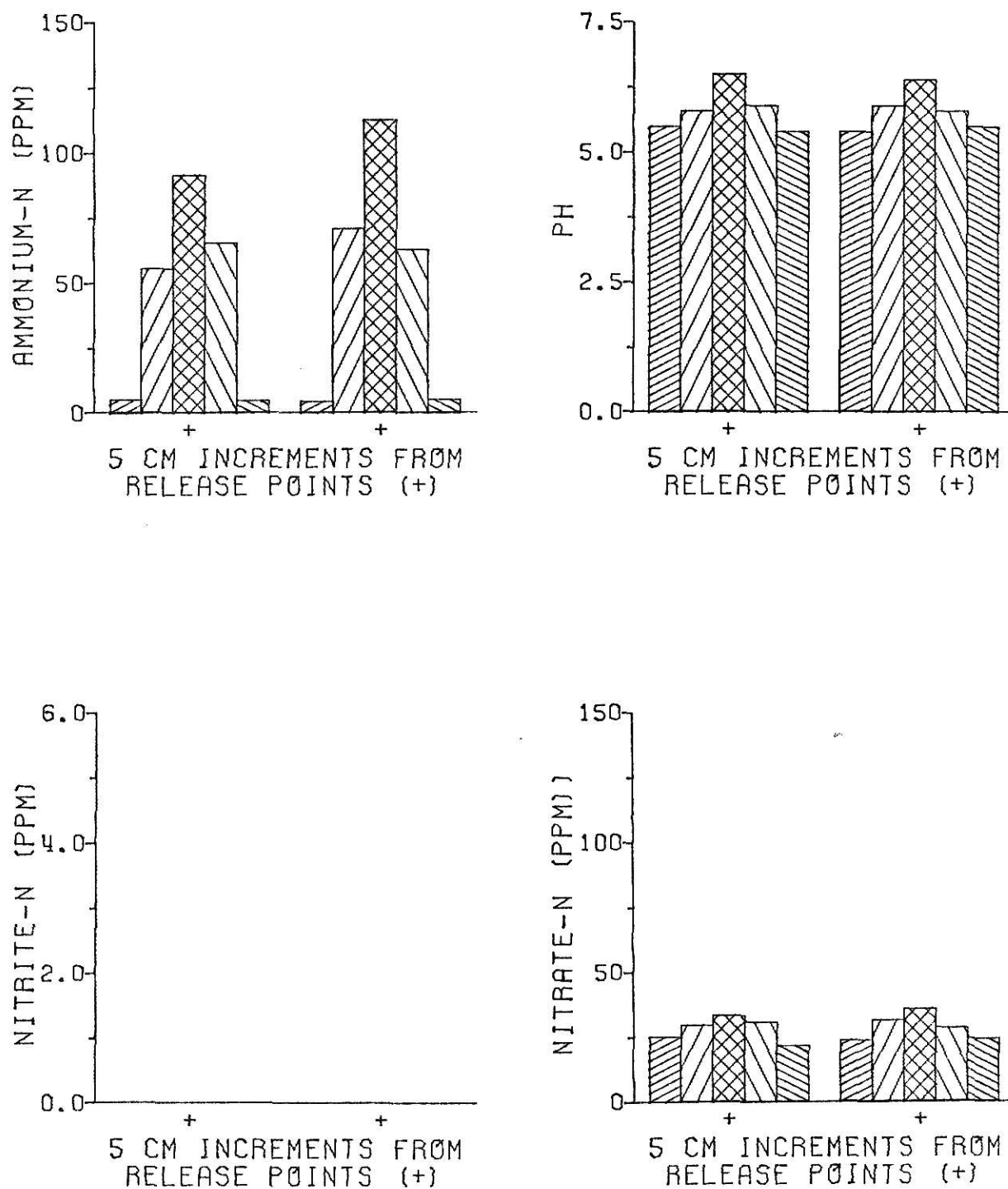


FIG.20. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA - 1 WEEK AFTER APPLICATION. (DEPTH, 0-10 CM)

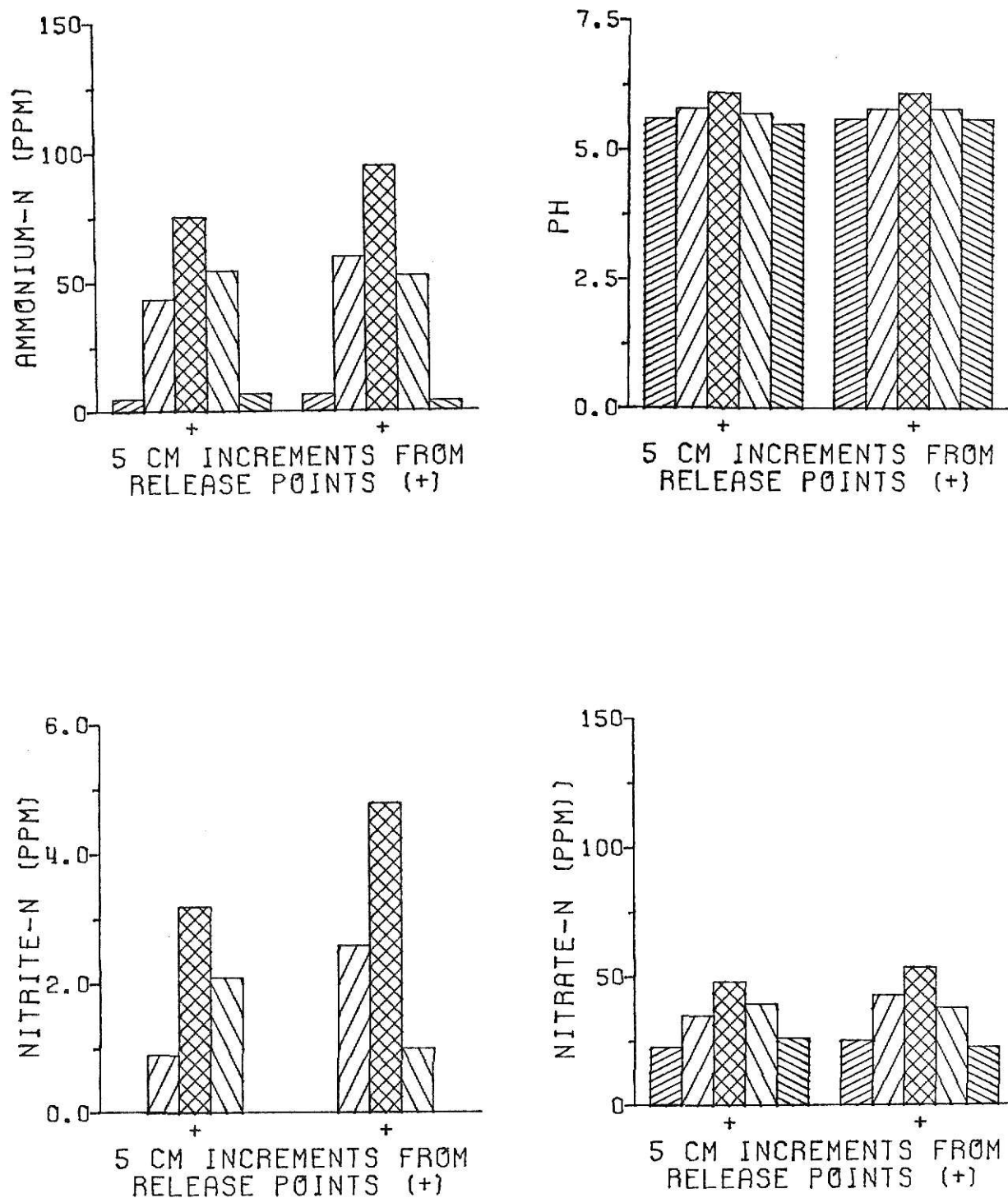


FIG.21. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA - 2 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

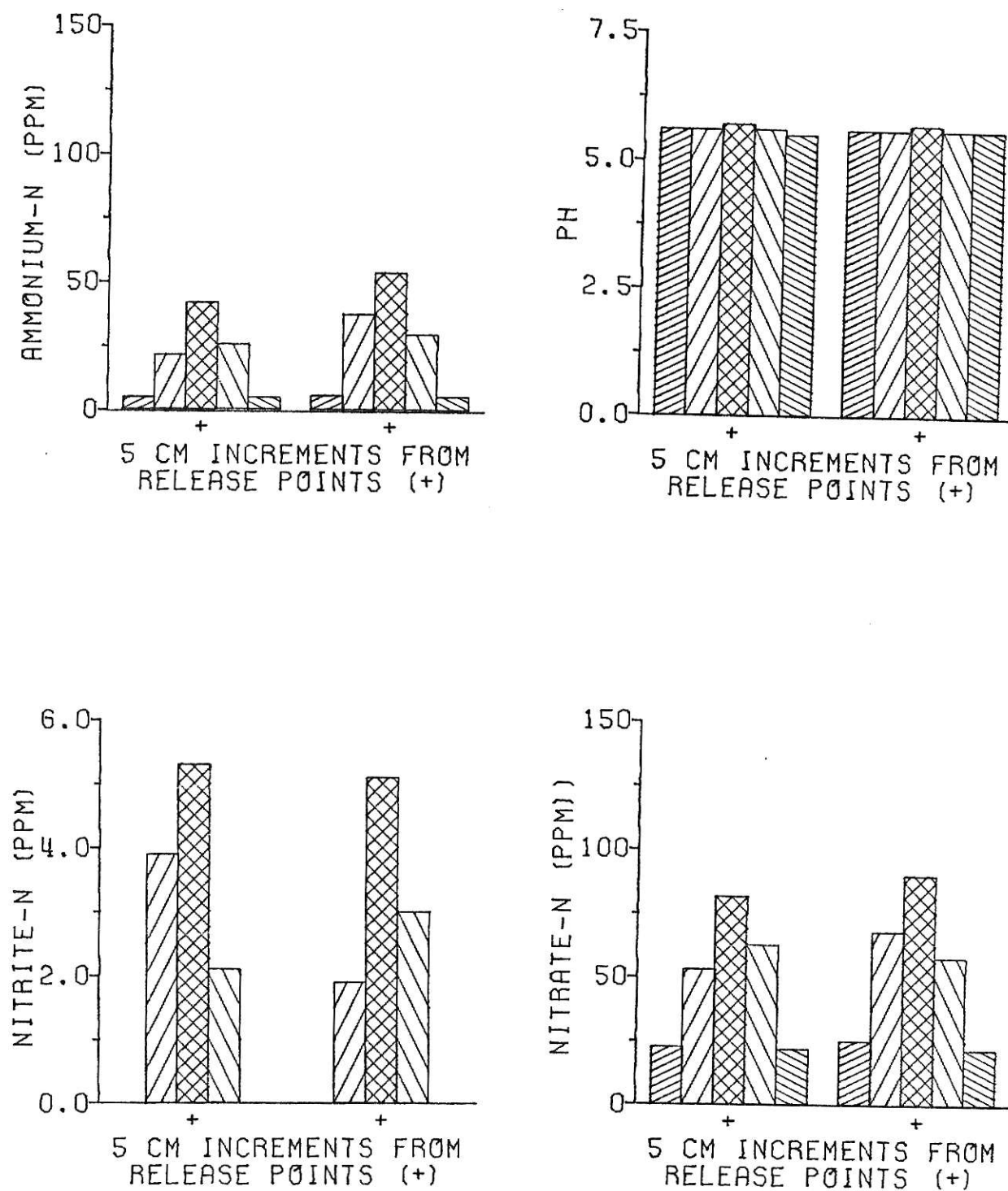


FIG.22. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA - 3 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

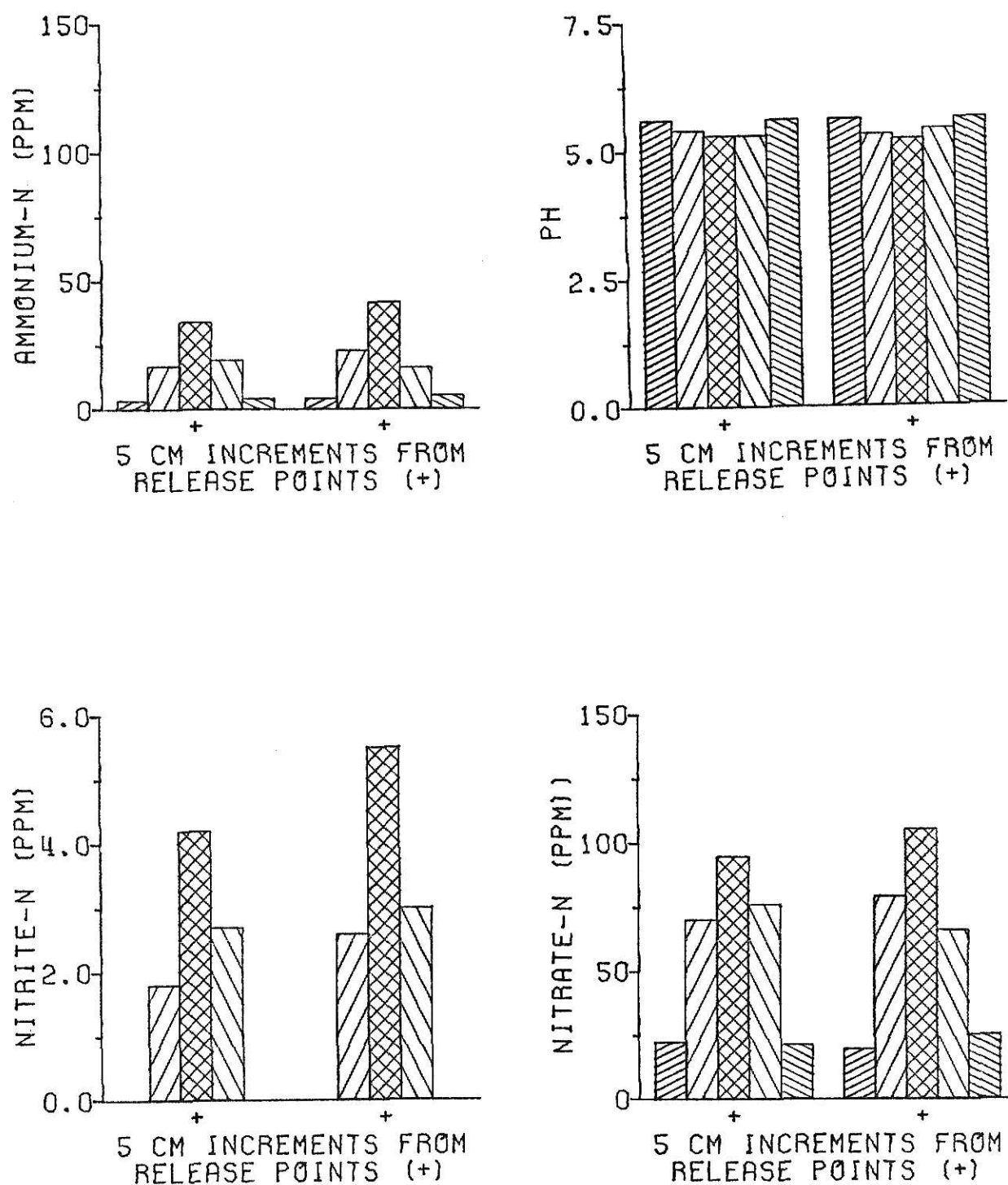


FIG.23. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA - 4 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

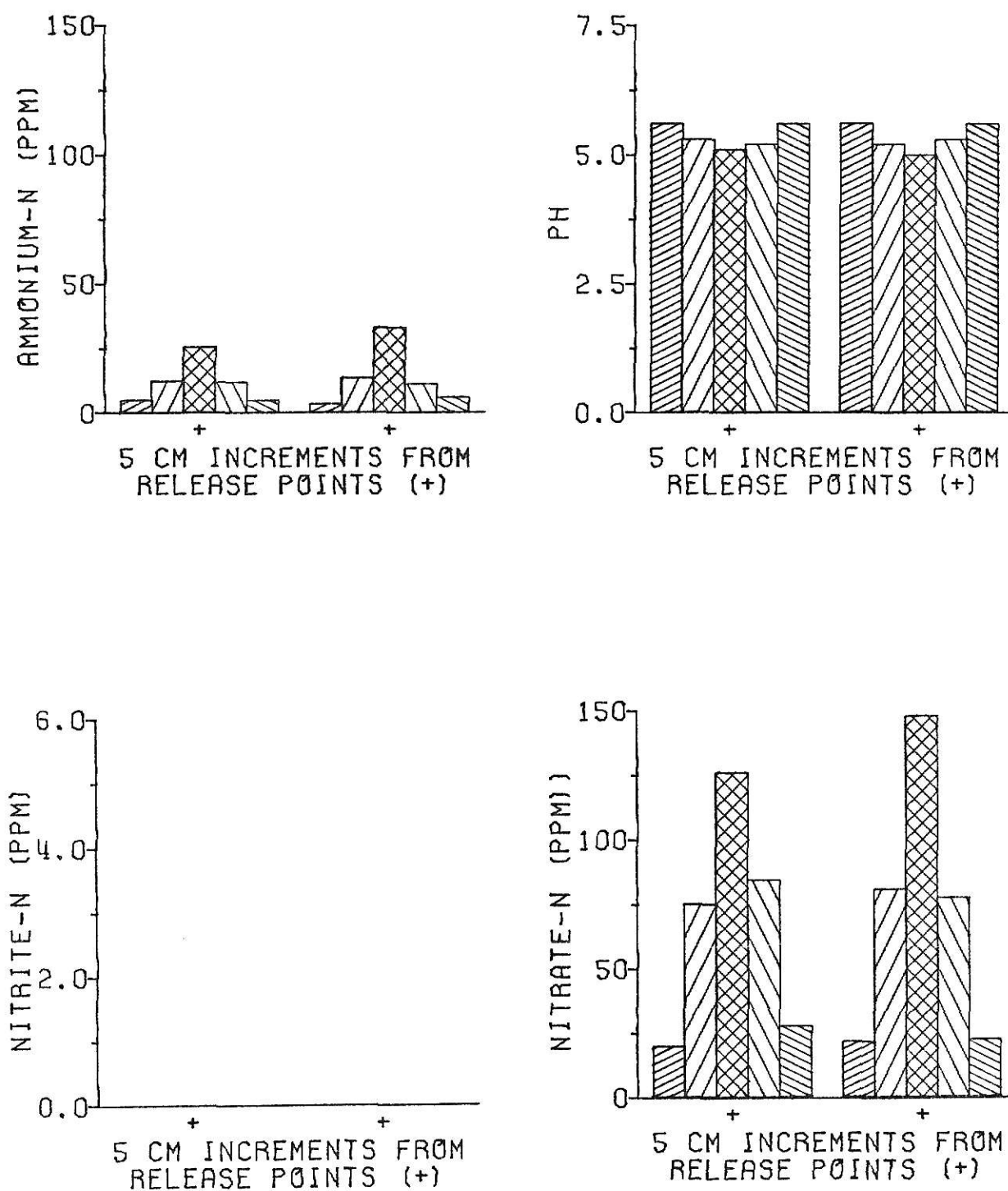


FIG.24. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA - 8 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

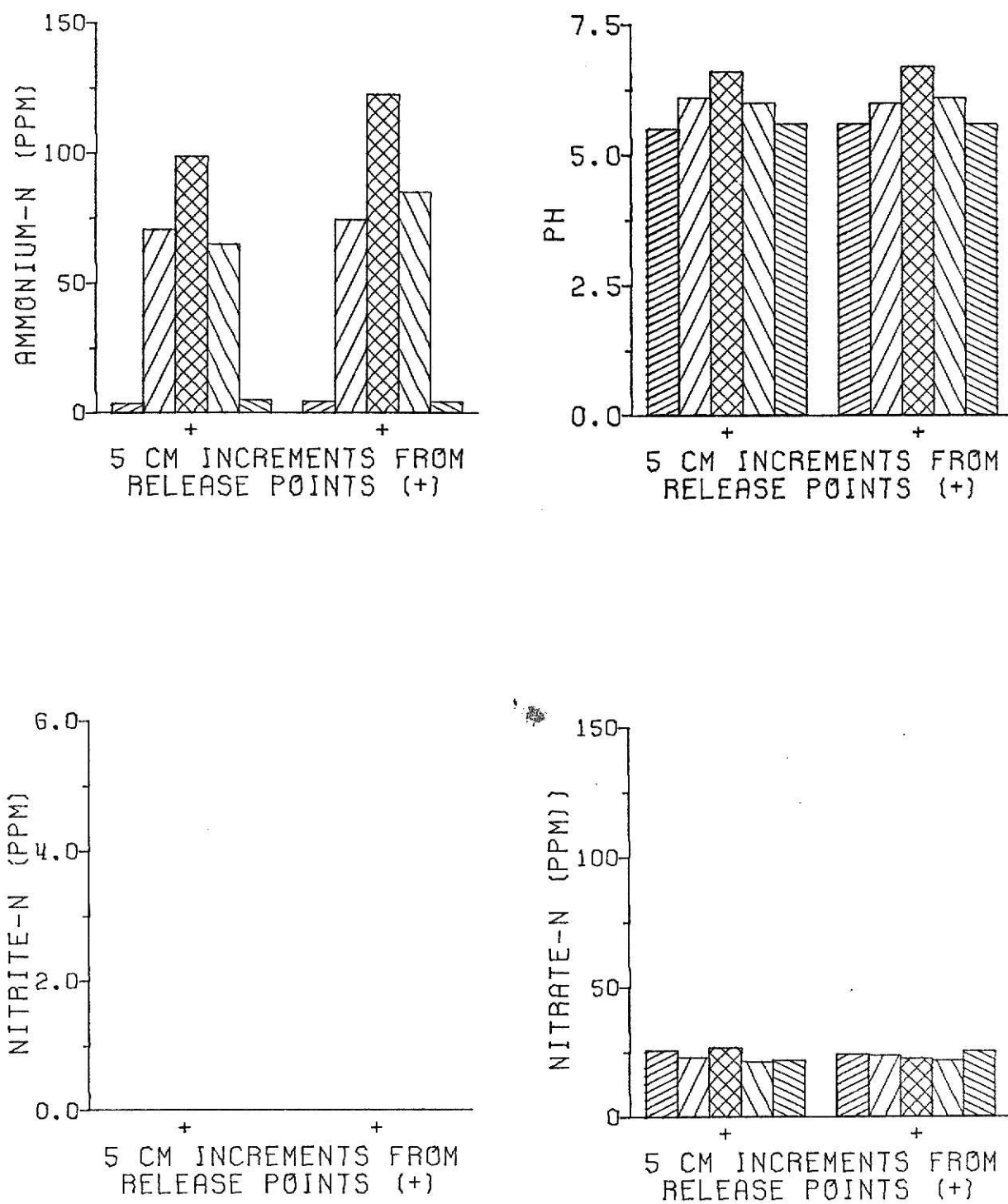


FIG.25. NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA .
IN COMBINATION WITH 15 KG/HA P AS LIQUID APP -
1 DAY AFTER APPLICATION. (DEPTH, 0-10 CM)

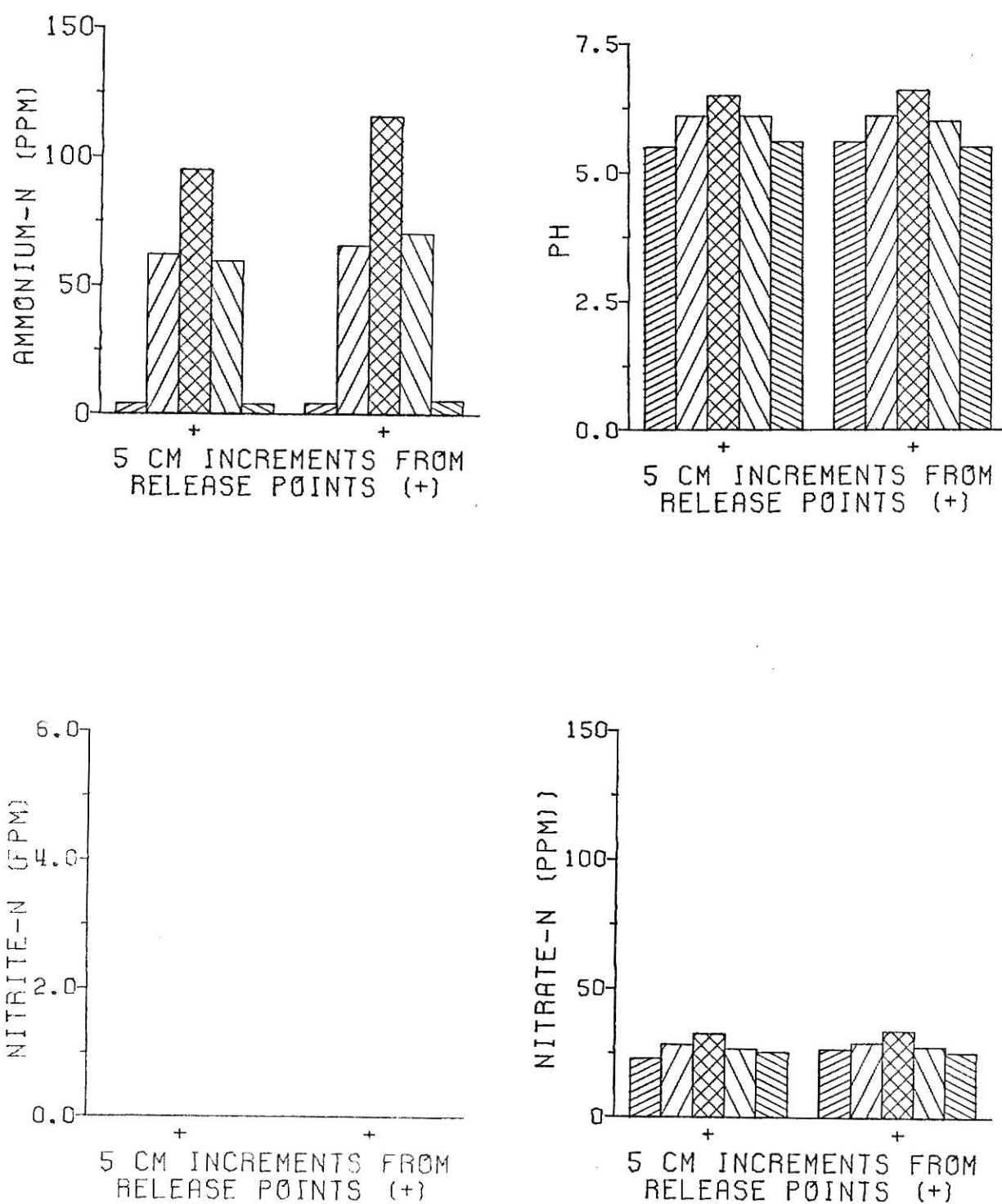


FIG.26 NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA IN COMBINATION WITH 15 KG/HA P AS LIQUID APP - 1 WEEK AFTER APPLICATION. (DEPTH, 0-10 CM)

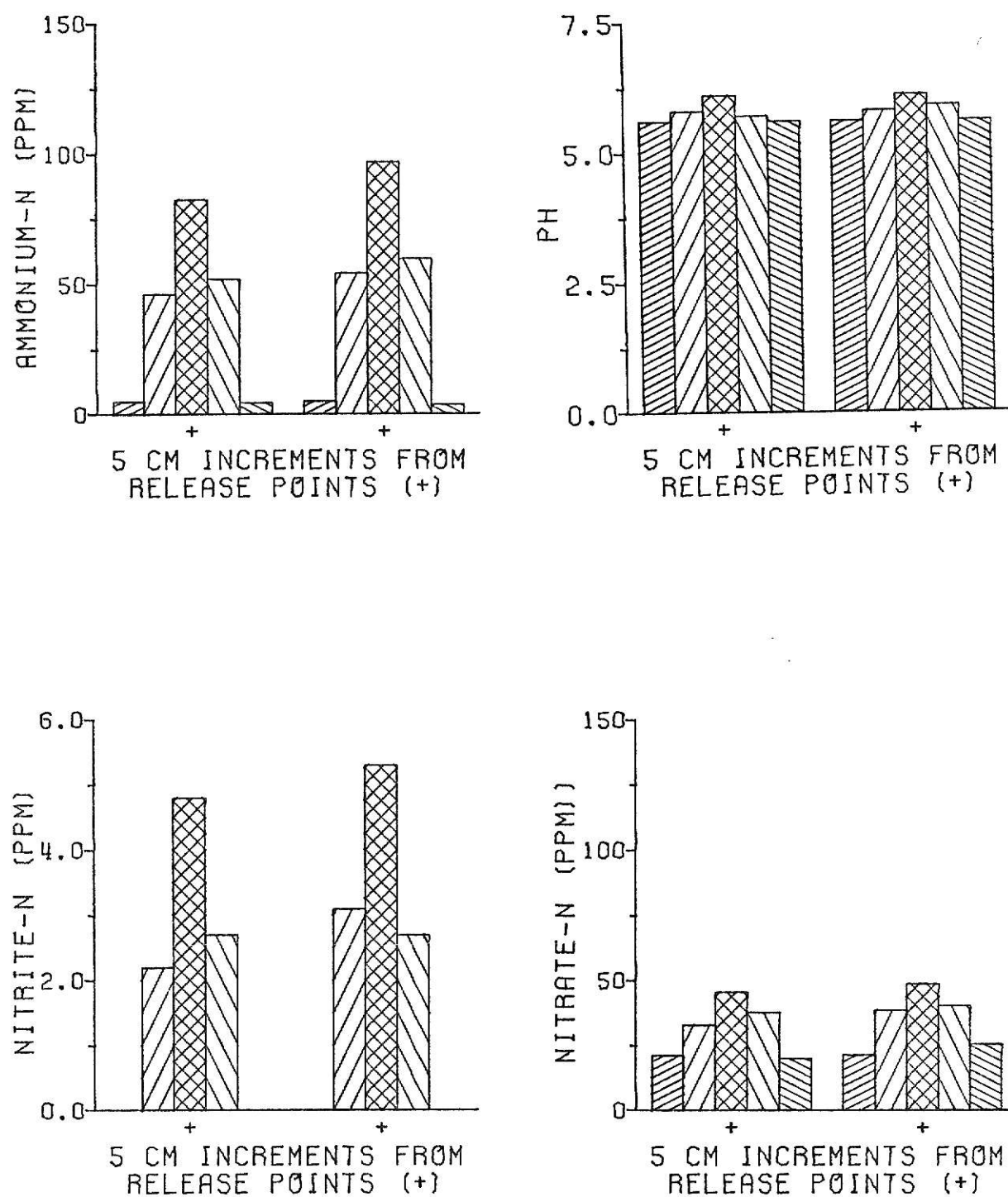


FIG.27 NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA IN COMBINATION WITH 15 KG/HA P AS LIQUID APP - 2 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

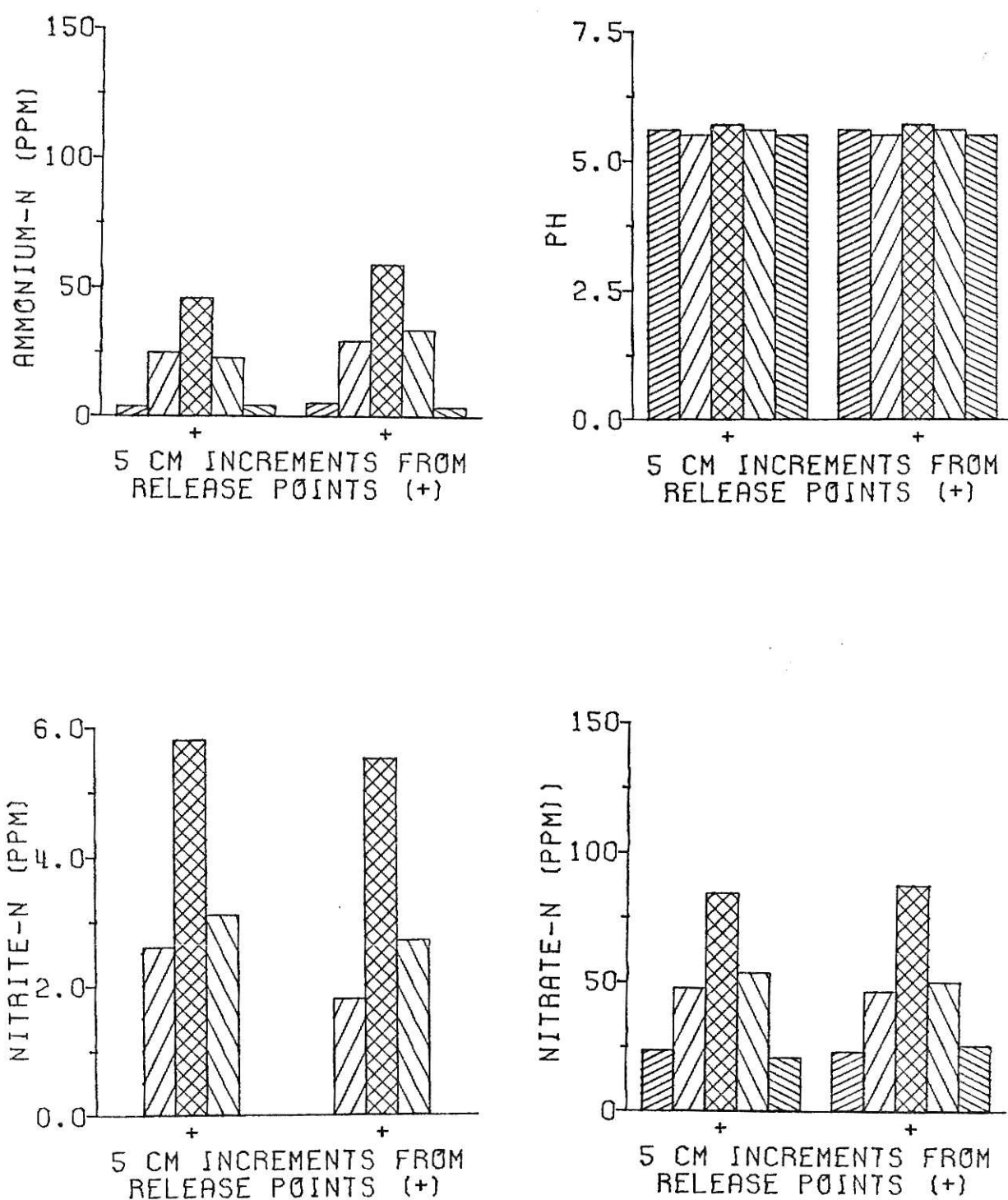


FIG.28 NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA IN COMBINATION WITH 15 KG/HA P AS LIQUID APP - 3 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

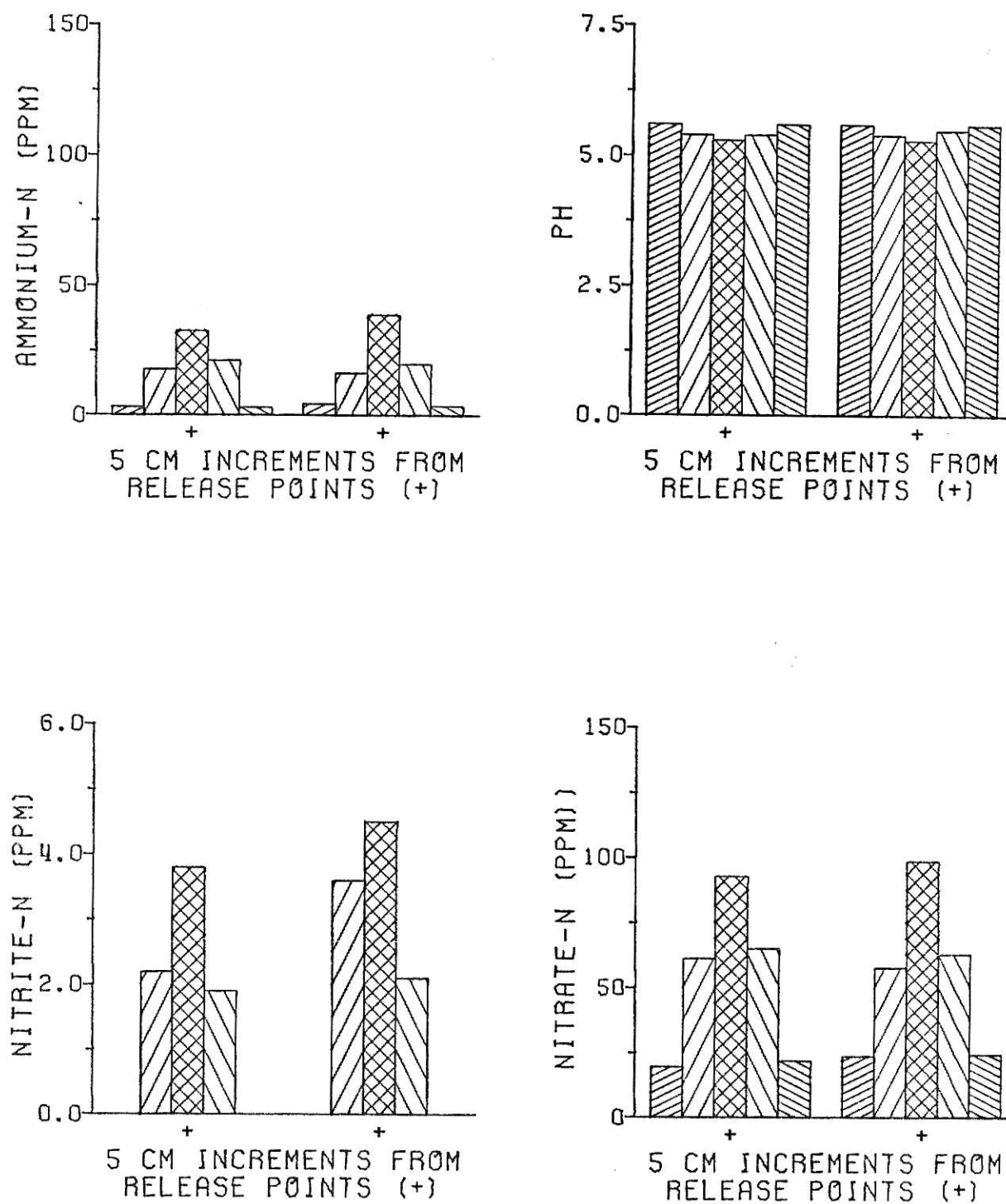


FIG.29 NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA IN COMBINATION WITH 15 KG/HA P AS LIQUID APP - 4 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

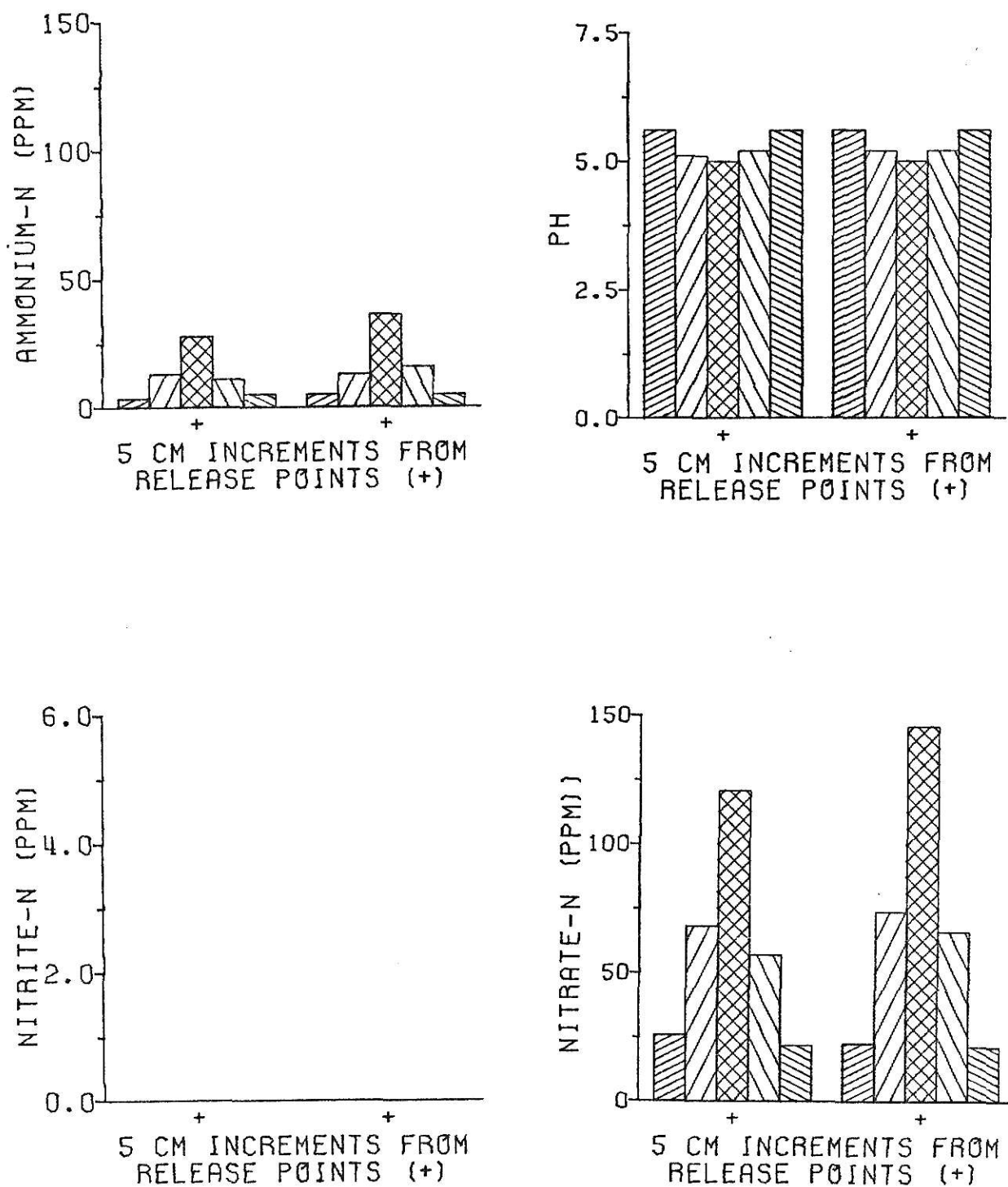


FIG.30 NITRIFICATION OF 67 KG/HA N AS ANHYDROUS AMMONIA IN COMBINATION WITH 15 KG/HA P AS LIQUID APP - 8 WEEKS AFTER APPLICATION. (DEPTH, 0-10 CM)

reached a minimum value of 5.0 near the center of the release points by the 8th week.

The concentration of available phosphorus 4 weeks after the simultaneous application of NH_3 and liquid APP was 255 and 285 ppm at the two release points (Appendix Table XIV). The P concentration did not appear to stimulate or inhibit the nitrification reaction under acid soil conditions (pH 5.6). Based upon the results, NH_3 and liquid APP can be placed in close proximity without any detrimental effect on nitrification.

Timewise, the nitrification study simulated preplant fertilizer applications for wheat. Although favorable moisture and temperature conditions led to 70% of the ammonium-N being converted to nitrate-N, there was no evidence of lateral or vertical movement of nitrate through the soil profile during the 8 week period. However, excessive moisture during the winter could possibly leach the nitrate below the root zone. Under such climatic conditions, preplant fertilizer applications for wheat would be somewhat less efficient in supplying N to the plant.

CONCLUSIONS

The results of the field investigations with winter wheat and dryland grain sorghum indicate that tillage implement applications of a complete N and P program is completely feasible. In fact, it may hold some advantages over surface applications under certain climatic conditions.

An important consideration in evaluating tillage implement applications of N and P is the effect of depth of placement of plant nutrients on efficiency of utilization. Under the climatic conditions of 1971-72, the deeper placement of nutrients from tillage implements was conducive to more efficient utilization than surface treatments which were only slightly incorporated into the soil. Surface applications of N and P evidently remained in an area of low available soil moisture and efficiency of absorption by plants was restricted due to positional unavailability. However, if adequate soil moisture was available near the soil surface, the differences in efficiency due to nutrient placement would probably be less significant between the three methods of application.

Comparative differences in leaf nutrient content and grain yield between the two tillage implement methods of application varied with the crop being studied. The undercutting blade appeared to give superior grain yield results on winter wheat, while the chisel plow was more efficient in N absorption in dryland grain sorghum studies. The distribution of N and P in the soil was good for both methods of application.

Chemical analyses of plant tissue showed that P uptake was good from the combined tillage application of N and P. Evidently, the hydrolysis of liquid AFP was not affected by the presence of anhydrous ammonia. In fact, the simultaneous application of N and P could be advantageous since researchers have shown that the ammonium ion has a synergistic effect on P absorption

by plants.

If anhydrous ammonia and liquid APP are to be applied in close proximity by tillage implements, the effects on nitrification should be of interest. Field results indicate that liquid APP did not stimulate or inhibit the nitrification of NH_3 . However, it was observed that 70% of the ammonium-N was converted to nitrate-N during an 8 week period that simulated preplant applications for wheat. If rainfall was excessive over the winter months, nitrate could conceivably be leached below the root zone. Under such conditions, a complete preplant application of N would not be recommended.

Modern farmers are continually assessing the economic considerations involved in fertilizer applications. If surface and tillage implement applications of plant nutrients are at least equal, there may be a cost advantage in tillage implement applications if they eliminate an operation. However, it is recognized that the combined application of NH_3 and liquid APP under such a program would involve the use of more nurse equipment and would pose a problem of adapting nurse facilities for both ammonia and liquids.

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VITA

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APPENDIX

Table I. Comparisons of methods of N and P application on leaf composition, nutrient uptake, yield, grain protein, and test weight (Sandyland Exp. Field, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield Kg/ha	Grain Prot. %	Test Wt. lb/bu
			Date-1			Date-2					
			N %	P %	K %	N %	P %	K %			
0	---	---	3.12	.392	2.57	1.46	.228	2.25	2486	10.6	59.7
34	Blade	NH ₃	3.14	.399	2.92	1.51	.241	2.30	3158	11.2	59.7
67	Blade	NH ₃	3.13	.416	2.97	1.66	.246	2.57	3360	12.5	59.8
34	Chisel	NH ₃	3.21	.396	2.84	1.41	.248	2.32	2890	10.6	59.7
67	Chisel	NH ₃	3.56	.453	3.10	1.50	.280	2.44	3326	10.8	59.7
34	Surface	UAN	3.10	.423	2.64	1.48	.230	2.30	2822	10.8	59.9
67	Surface	UAN	3.00	.401	2.79	1.45	.239	2.19	2755	11.4	60.2
34	Blade	NH ₃ + APP	3.35	.431	2.90	1.63	.268	2.52	3360	11.2	59.6
67	Blade	NH ₃ + APP	3.27	.455	2.86	1.52	.260	2.25	3091	12.1	60.2
34	Chisel	NH ₃ + APP	3.35	.403	2.96	1.42	.250	2.23	2890	10.1	59.2
67	Chisel	NH ₃ + APP	3.40	.421	3.08	1.49	.258	2.30	3158	10.3	60.0
34	Surface	UAN + APP	3.13	.434	2.73	1.54	.256	2.32	3024	11.1	60.0
67	Surface	UAN + APP	3.21	.423	2.70	1.58	.247	2.32	3024	11.0	60.0
ISD .05	Treatment		ns	.039	ns	ns	.027	ns	202	0.5	ns
	N Rate		-	ns	-	-	ns	-	ns	0.4	-
	P Rate		-	ns	-	-	ns	-	ns	ns	-
	Method of Application		-	ns	-	-	.013	-	134	0.5	-

Table I. (Continued).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Nutrient Uptake				
			Date-1		Date-2		
			N	P	N	P	K
			mg/2 plants				
0	---	---	48.3	7.2	45.0	108.7	18.8
67	Blade	NH ₃	91.4	10.9	80.3	154.3	24.4
67	Chisel	NH ₃	102.0	14.9	89.7	125.5	23.9
67	Surface	UAN	66.8	9.8	57.4	130.1	18.9
67	Blade	NH ₃ + APP	87.4	10.1	78.9	137.1	21.7
67	Chisel	NH ₃ + APP	108.7	14.9	97.5	140.6	25.3
67	Surface	UAN + APP	64.3	9.6	51.2	126.6	19.9
LSD .05	Treatment		34.8	4.0	36.4	ns	ns
	P Rate		ns	ns	ns	-	-
	Method of Application		24.6	2.8	ns	-	-

Table II. Comparisons of methods of N and P application on leaf composition, nutrient uptake, yield, grain protein, and test weight (Harper County, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition								Yield kg/ha	Grain Prot. %	Test Wt. lb/bu
			Date-1				Date-2						
			N %	P %	K %	N %	P %	K %					
0 0	---	---	2.98	.223	2.87	1.32	.187	1.59	1075	10.7	56.9		
34 0	Blade	NH ₃	2.97	.232	2.71	1.53	.161	1.52	1277	12.2	57.6		
67 0	Blade	NH ₃	3.32	.255	3.10	1.59	.153	1.57	1411	13.2	56.9		
34 0	Chisel	NH ₃	3.20	.227	2.81	1.45	.188	1.70	1344	11.8	57.2		
67 0	Chisel	NH ₃	3.48	.246	2.96	1.57	.159	1.66	1277	12.9	57.2		
34 0	Surface	UAN	3.34	.238	2.99	1.36	.164	1.66	1142	11.3	57.5		
67 0	Surface	UAN	3.08	.245	3.01	1.52	.164	1.57	1210	12.5	57.2		
34 15	Blade	NH ₃ + APP	2.99	.292	2.87	1.34	.189	1.65	1075	11.1	57.0		
67 15	Blade	NH ₃ + APP	3.14	.314	3.01	1.35	.204	1.62	1210	10.9	56.3		
34 15	Chisel	NH ₃ + APP	3.09	.265	3.13	1.37	.186	1.57	1344	10.8	57.9		
67 15	Chisel	NH ₃ + APP	2.86	.257	2.71	1.28	.176	1.48	1210	11.1	57.1		
34 15	Surface	UAN + APP	3.08	.320	3.15	1.35	.176	1.52	1142	11.2	57.0		
67 15	Surface	UAN + APP	3.11	.283	2.79	1.32	.171	1.48	1075	11.4	57.2		
ISD .05	Treatment		ns	.023	ns	0.18	.024	ns	ns	0.5	ns		
	N Rate		-	ns	-	ns	ns	-	-	0.4	-		
	P Rate		-	.012	-	0.07	.010	-	-	0.4	-		
	Method of Application		-	.014	-	ns	ns	-	-	ns	-		

Table II. (Continued).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Nutrient Uptake					
			Date-1 mg/2 plants			Date-2 mg/2 plants		
			N	P	K	N	P	K
0	---	---	14.5	1.4	19.9	35.0	3.7	37.6
67	Blade	NH ₃	28.9	2.1	25.8	51.9	4.9	51.0
67	Chisel	NH ₃	24.1	1.9	21.2	45.9	4.1	45.0
67	Surface	UAN	18.9	1.4	16.9	39.5	3.8	38.6
67	Blade	NH ₃ + APP	49.0	5.1	46.5	50.7	5.9	52.5
67	Chisel	NH ₃ + APP	30.6	3.0	28.4	35.1	4.2	39.2
67	Surface	UAN + APP	22.5	2.3	19.9	32.1	3.6	33.1
LSD .05	Treatment		24.1	2.1	22.6	11.0	1.0	10.6
	P Rate		13.9	1.2	13.1	6.3	0.6	ns
	Method of Application		17.1	1.5	16.0	7.8	0.7	7.5

Table III. Comparisons of methods of N and P application on leaf composition, yield, grain protein, and test weight on winter wheat (Saline County, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield kg/ha	Grain Prot. %	Test Wt. lb/bu
			Date-1			Date-2					
			N %	P %	K %	N %	P %	K %			
0	---	---	4.35	.261	2.66	2.51	.235	3.07	2890	12.8	61.5
34	Blade	NH ₃	4.31	.264	2.70	2.55	.244	3.13	2890	13.6	61.3
67	Blade	NH ₃	4.17	.288	3.56	2.82	.251	3.34	2755	14.0	61.3
34	Chisel	NH ₃	4.29	.248	2.57	2.61	.246	2.98	2352	13.4	60.8
67	Chisel	NH ₃	4.34	.254	2.62	2.83	.263	3.35	2486	13.6	60.3
34	Surface	UAN	4.38	.270	2.65	2.42	.240	3.05	2688	12.3	61.3
67	Surface	UAN	4.41	.288	2.85	2.55	.242	3.11	2621	13.9	61.0
34	Blade	NH ₃ + APP	4.46	.311	2.73	2.37	.245	2.94	3024	12.8	61.8
67	Blade	NH ₃ + APP	4.54	.327	2.59	2.25	.224	2.93	3158	13.1	62.0
34	Chisel	NH ₃ + APP	4.53	.305	2.67	2.26	.233	2.86	3158	12.8	62.1
67	Chisel	NH ₃ + APP	4.20	.271	2.65	2.41	.233	2.97	2957	13.1	61.6
34	Surface	UAN + APP	4.33	.269	2.84	2.43	.246	3.08	2755	12.1	61.4
67	Surface	UAN + APP	4.30	.266	2.73	2.54	.236	3.00	3091	13.3	61.1
LSD .05	Treatment		0.21	.036	ns	0.23	ns	0.28	403	1.0	0.7
	N Rate		ns	ns	-	0.10	-	ns	ns	0.4	ns
	P Rate		ns	.019	-	0.10	-	0.11	202	0.4	0.3
	Method of Application		ns	.023	-	ns	-	ns	ns	ns	ns

Table IV. Comparisons of methods of N and P application on leaf composition, yield, grain protein, and test weight on winter wheat (McPherson County, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield kg/ha	Grain Prot. %	Test Wt. lb/bu
			Date-1			Date-2					
			N %	P %	K %	N %	P %	K %			
0	---	---	Plant growth too small for sampling.						2285	10.8	60.4
34	Blade	NH ₃	1.87	.262	2.50	1.58	.290	2.45	2890	10.7	60.3
67	Blade	NH ₃	2.06	.268	2.91	2.06	.268	2.91	3293	11.2	59.5
34	Chisel	NH ₃	1.76	.288	2.82	1.76	.288	2.82	2822	10.6	58.9
67	Chisel	NH ₃	2.18	.271	3.23	2.18	.271	3.23	3091	10.9	58.7
34	Surface	UAN	1.56	.281	2.44	1.56	.281	2.44	2755	10.8	61.0
67	Surface	UAN	2.04	.275	2.91	2.04	.275	2.91	2822	10.8	59.7
34	Blade	NH ₃ + APP	1.82	.298	2.80	1.82	.298	2.80	3091	10.7	60.6
67	Blade	NH ₃ + APP	2.07	.296	3.01	2.07	.296	3.01	3226	10.9	59.8
34	Chisel	NH ₃ + APP	1.77	.286	2.57	1.77	.286	2.57	2486	10.4	59.8
67	Chisel	NH ₃ + APP	2.04	.273	3.15	2.04	.273	3.15	3091	10.6	59.1
34	Surface	UAN + APP	1.88	.276	2.68	1.88	.276	2.68	2755	10.6	59.6
67	Surface	UAN + APP	1.90	.289	2.76	1.90	.289	2.76	3024	10.8	60.6
LSD .05	Treatment		0.22	ns	0.17	0.22	ns	0.17	336	ns	0.8
	N Rate		0.09	-	0.13	0.09	-	0.13	134	-	ns
	P Rate		ns	-	ns	ns	-	ns	ns	-	ns
	Method of Application		ns	-	0.16	ns	-	0.16	202	-	0.8

Table V. Comparisons of methods of N and P application on leaf composition, yield, grain protein, and test weight on winter wheat (Mitchell County, 1971-72).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield kg/ha	Grain Prot. %	Test Wt. lb/bu
			Date-1			Date-2					
			N %	P %	K %	N %	P %	K %			
0	---	---	3.27	.347	2.25	3.88	.303	3.37	2150	12.8	59.6
34	Blade	NH ₃	3.02	.309	2.13	3.96	.321	3.43	2083	13.0	59.1
67	Blade	NH ₃	3.13	.328	2.19	3.85	.308	3.53	2083	12.9	59.2
34	Chisel	NH ₃	3.38	.322	2.11	3.98	.308	3.52	1882	12.8	58.8
67	Chisel	NH ₃	3.12	.339	2.11	3.87	.315	3.49	1949	12.8	58.8
34	Surface	UAN	3.09	.337	2.17	3.80	.308	3.51	2083	13.0	59.3
67	Surface	UAN	3.13	.324	2.19	3.86	.296	3.46	1949	13.0	59.2
34	Blade	NH ₃ + APP	3.26	.365	2.20	3.92	.318	3.46	2150	12.9	59.3
67	Blade	NH ₃ + APP	3.57	.385	2.32	3.91	.313	3.36	1949	12.8	59.1
34	Chisel	NH ₃ + APP	3.15	.348	2.07	4.02	.306	3.37	2016	13.1	58.7
67	Chisel	NH ₃ + APP	3.34	.354	2.43	4.00	.318	3.56	2016	12.8	58.9
34	Surface	UAN + APP	3.30	.351	2.25	3.84	.314	3.49	1949	12.8	58.8
67	Surface	UAN + APP	3.33	.379	2.48	4.04	.311	3.44	2083	12.9	59.4
ISD .05	Treatment		ns	.029	ns	ns	ns	ns	ns	ns	ns
	N Rate		-	ns	-	-	-	-	-	-	-
	P Rate		-	.015	-	-	-	-	-	-	-
	Method of Application		-	ns	-	-	-	-	-	-	-

Table VI. Comparisons of methods of N and P application on leaf composition, nutrient uptake, yield, and grain protein on dryland grain sorghum (North Central Exp. Field, 1972).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition					
			Date-1			Date-2		
			N %	P %	K %	N %	P %	K %
0 0	---	---	3.31	.358	4.21	2.89	.362	1.91
67 0	Blade	NH ₃	3.70	.383	4.35	3.08	.372	1.96
134 0	Blade	NH ₃	3.72	.371	4.44	3.15	.383	1.99
67 0	Chisel	NH ₃	3.59	.359	4.39	3.00	.382	1.91
134 0	Chisel	NH ₃	3.58	.356	4.76	3.13	.383	2.04
67 0	Surface	UAN	3.42	.359	4.59	2.86	.380	1.99
134 0	Surface	UAN	3.62	.372	4.27	2.82	.363	2.07
67 15	Blade	NH ₃ + APP	3.55	.358	4.35	2.99	.387	1.95
134 15	Blade	NH ₃ + APP	3.79	.373	4.56	3.11	.380	1.97
67 15	Chisel	NH ₃ + APP	3.73	.371	4.61	3.13	.384	1.92
134 15	Chisel	NH ₃ + APP	3.72	.368	4.61	3.14	.374	1.96
67 15	Surface	UAN + APP	3.47	.370	4.48	2.94	.379	2.03
134 15	Surface	UAN + APP	3.36	.382	4.33	2.91	.375	2.04
LSD .05	Treatment		0.23	ns	0.29	0.20	ns	ns
	N Rate		ns	-	ns	ns	-	-
	P Rate		ns	-	ns	ns	-	-
	Method of Application		0.11	-	0.15	0.09	-	-

Table VI. (Continued).

Nutrient Rates N kg/ha	P	Method of Application	Fertilizer Carrier	Nutrient Uptake		Yield kg/ha	Grain Protein %
				N	P mg/plant		
0	0	---	---	327	37.2	429	6772
67	0	Blade	NH ₃	307	33.2	373	5894
134	0	Blade	NH ₃	262	26.4	442	6145
67	0	Chisel	NH ₃	393	40.2	480	7273
134	0	Chisel	NH ₃	430	43.1	585	5831
67	0	Surface	UAN	365	40.7	515	6584
134	0	Surface	UAN	342	36.3	408	6207
67	15	Blade	NH ₃ + APP	326	31.5	380	6834
134	15	Blade	NH ₃ + APP	370	35.9	452	6333
67	15	Chisel	NH ₃ + APP	351	37.2	479	6709
134	15	Chisel	NH ₃ + APP	393	38.6	493	7211
67	15	Surface	UAN + APP	353	38.4	493	7022
134	15	Surface	UAN + APP	412	48.3	563	6772
LSD .05	Treatment			ns	ns	ns	ns
	N Rate			-	-	-	0.7
	P Rate			-	-	-	0.3
	Method of Application			-	-	-	ns
				-	-	-	0.3

Table VII. Comparisons of methods of N and P application on leaf composition, yield, and grain protein on dryland grain sorghum (East Central Exp. Field, 1972).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield kg/ha	Grain Protein %
			Date-1			Date-2				
			N %	P %	K %	N %	P %	K %		
0 0	----	----	3.99	.458	2.58	2.89	.402	2.42	5768	6.9
67 0	Blade	NH ₃	4.11	.452	2.39	3.46	.406	2.30	6145	7.9
134 0	Blade	NH ₃	4.28	.482	2.08	3.49	.415	2.27	6145	9.0
67 0	Chisel	NH ₃	4.14	.439	2.34	3.55	.401	2.20	6395	8.6
134 0	Chisel	NH ₃	4.21	.452	1.96	3.60	.391	2.07	6584	9.0
67 0	Surface	UAN	4.12	.458	2.31	3.24	.390	2.22	5831	7.9
134 0	Surface	UAN	4.12	.453	2.21	3.28	.393	2.30	6709	7.9
67 15	Blade	NH ₃ + APP	4.09	.451	2.35	3.44	.404	2.22	6082	8.0
134 15	Blade	NH ₃ + APP	4.18	.457	1.98	3.44	.419	2.27	6395	8.9
67 15	Chisel	NH ₃ + APP	4.15	.459	2.44	3.62	.418	2.18	5706	9.0
134 15	Chisel	NH ₃ + APP	4.34	.456	2.29	3.40	.389	2.37	5706	9.7
67 15	Surface	UAN + APP	4.07	.446	2.22	3.36	.437	2.24	6395	7.9
134 15	Surface	UAN + APP	4.05	.455	2.42	3.34	.452	2.28	7148	8.0
LSD .05	Treatment		0.15	ns	0.32	0.28	ns	ns	ns	0.7
	N Rate		0.06	-	0.13	ns	-	-	-	0.3
	P Rate		ns	-	ns	ns	-	-	-	ns
	Method of Application		0.08	-	ns	0.13	-	-	-	0.4

Table VIII. Comparisons of methods of N and P application on leaf composition, yield, and grain protein on dryland grain sorghum (Newton Exp. Field, 1972).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield kg/ha	Grain Protein %
			Date-1			Date-2				
			N %	P %	K %	N %	P %	K %		
0	---	---	4.32	.363	2.80	2.75	.312	1.97	4452	10.7
67	Blade	NH ₃	4.37	.362	2.86	2.64	.304	2.14	4201	12.0
134	Blade	NH ₃	4.48	.369	2.89	2.89	.328	2.12	4013	12.7
67	Chisel	NH ₃	4.46	.376	2.82	2.87	.322	2.04	4326	12.7
134	Chisel	NH ₃	4.50	.378	2.76	2.98	.341	2.13	4264	13.0
67	Surface	UAN	4.39	.356	2.68	2.78	.318	2.05	3574	12.0
134	Surface	UAN	4.38	.369	2.76	2.86	.325	2.03	4138	12.5
67	Blade	NH ₃ + APP	4.35	.338	2.75	2.75	.307	2.03	4013	12.3
134	Blade	NH ₃ + APP	4.36	.352	2.75	2.87	.323	2.11	4264	12.5
67	Chisel	NH ₃ + APP	4.48	.367	2.88	2.88	.316	2.05	3825	12.9
134	Chisel	NH ₃ + APP	4.55	.360	2.76	2.99	.337	2.07	4138	13.0
67	Surface	UAN + APP	4.40	.377	2.79	2.72	.323	2.04	4138	12.6
134	Surface	UAN + APP	4.38	.372	2.80	2.69	.308	2.09	4326	12.3
LSD .05	Treatment		ns	ns	ns	0.18	ns	ns	ns	0.7
	N Rate		-	-	-	0.07	-	-	-	ns
	P Rate		-	-	-	ns	-	-	-	ns
	Method of Application		-	-	-	0.09	-	-	-	0.4

Table IX. Comparisons of methods of N and P application on leaf composition, yield, and grain protein on dryland grain sorghum (Cornbelt Exp. Field, 1972).

Nutrient Rates N P kg/ha	Method of Application	Fertilizer Carrier	Leaf Composition						Yield kg/ha	Grain Protein %
			Date-1			Date-2				
			N %	P %	K %	N %	P %	K %		
0 0	---	---	4.00	.344	2.19	2.28	.271	1.87	7022	6.5
67 134	Blade Blade	NH ₃ NH ₃	4.08 4.12	.365 .365	2.24 2.28	2.61 2.82	.292 .320	1.95 1.96	7587 7022	7.2 8.0
67 134	Chisel Chisel	NH ₃ NH ₃	4.11 4.13	.369 .366	2.08 2.25	2.87 2.89	.313 .315	1.93 1.99	7273 7211	8.3 9.2
67 134	Surface Surface	UAN UAN	3.94 4.06	.345 .362	2.31 2.14	2.77 2.96	.307 .323	1.88 1.91	7587 7273	7.7 8.6
67 134	Blade Blade	NH ₃ + APP NH ₃ + APP	3.95 3.97	.349 .356	2.32 2.19	2.70 2.90	.305 .321	1.96 1.91	7587 6897	8.6 8.0
67 134	Chisel Chisel	NH ₃ + APP NH ₃ + APP	4.06 4.02	.379 .356	2.30 2.23	2.73 2.92	.312 .318	2.00 1.99	7273 7336	8.0 9.2
67 134	Surface Surface	UAN + APP UAN + APP	4.10 4.08	.368 .364	2.27 2.34	2.72 2.80	.310 .314	1.96 1.92	7712 7649	7.9 8.1
LSD .05	Treatment		ns	ns	ns	0.20	.022	ns	ns	0.6
	N Rate		-	-	-	0.08	.010	-	-	0.3
	P Rate		-	-	-	ns	ns	-	-	ns
	Method of Application		-	-	-	ns	ns	-	-	0.3

Table X. Distribution of soil N and P resulting from a blade application of 134 kg/ha N as NH_3 and 15 kg/ha P as liquid APP (North Central Experiment Field, 1972).

Sampling Width cm	Nitrate-N (ppm)			Ammonium-N (ppm)			Avail. P (ppm)		
	Depth (cm)			Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
5	6.9	6.4	8.2	14.0	10.3	8.1	24.5	7.0	6.5
10	5.5	6.6	9.5	9.0	8.2	8.8	23.0	7.0	7.5
15	8.1	3.9	9.0	12.1	9.7	8.9	20.0	6.5	8.0
20	15.8	9.4	10.2	14.8	10.9	8.2	22.0	9.0	7.0
25	17.5	11.5	8.9	19.1	10.1	9.2	25.5	10.0	8.5
30	52.1	13.2	11.2	14.2	11.9	8.6	46.0	13.5	6.5
35	32.3	9.4	7.5	15.2	10.3	9.3	28.0	11.0	8.0
40	20.3	10.9	8.3	10.1	11.7	9.9	27.0	15.5	9.0
45	13.4	7.4	9.5	10.3	8.0	9.1	23.0	13.0	10.5
50	7.0	9.6	11.6	10.3	13.1	9.3	24.0	14.0	10.0
55	10.3	9.7	10.5	12.9	12.1	8.0	21.0	15.5	7.5
60	11.1	14.2	10.3	9.9	11.3	11.3	23.0	14.0	9.5
65	30.0	17.4	8.5	13.3	8.4	10.7	30.0	14.5	9.0
70	79.5	23.2	9.6	15.2	13.7	8.7	46.5	15.5	7.5
75	71.2	33.7	8.5	26.9	11.1	8.3	65.5	11.0	8.5
80	38.0	20.5	8.9	16.8	10.3	9.6	38.5	11.5	9.0
85	26.3	10.7	10.3	12.3	11.1	9.9	26.0	8.5	8.5
90	26.7	11.9	9.8	10.7	11.3	10.3	23.5	9.0	9.0
95	26.4	11.9	11.2	12.7	11.3	8.7	27.0	7.5	7.5
100	17.1	8.4	9.4	10.7	8.8	8.0	28.0	6.5	6.5
105	22.1	6.8	8.3	12.5	8.0	8.8	22.0	11.0	7.5
110	38.1	11.5	8.5	12.1	8.6	8.5	23.0	11.5	8.0
115	40.2	12.4	9.5	14.5	10.9	9.7	25.0	11.5	9.0
120	50.1	14.0	10.2	19.2	8.8	8.4	38.0	12.0	8.5
125	22.3	7.8	9.7	11.5	9.2	8.1	23.5	9.0	10.0
130	12.1	8.7	11.4	12.1	10.1	7.5	24.5	10.5	7.0
135	14.5	4.5	9.5	13.8	10.7	9.7	21.0	9.0	7.5
140	9.7	4.1	9.3	10.7	10.3	8.1	25.5	8.5	9.0
145	16.5	7.0	7.5	13.6	9.7	8.7	24.0	10.0	8.0
150	14.5	6.5	8.0	13.2	9.7	8.3	22.5	8.0	7.5
155	22.0	9.0	10.5	14.6	9.4	9.0	27.0	10.0	9.0
160	36.7	11.5	8.9	13.1	14.8	8.8	34.0	11.0	9.5
165	30.2	13.0	9.4	16.0	8.8	10.1	53.5	12.5	7.5
170	55.6	17.0	8.9	18.7	12.3	9.2	35.0	11.0	8.5
175	38.0	10.0	9.8	13.8	12.9	11.8	21.5	10.5	8.5
180	12.1	9.7	10.2	9.7	10.7	8.8	19.5	9.0	8.0
185	18.3	7.8	10.6	11.7	10.1	10.4	17.5	8.5	7.0
190	16.0	6.5	8.5	12.6	12.3	9.7	21.0	11.5	8.5
195	9.9	5.5	11.5	14.2	13.1	7.0	20.0	8.0	9.5
200	10.1	6.0	10.6	9.4	11.1	11.3	22.4	7.5	8.0
205	13.2	4.8	11.2	10.3	7.2	9.7	18.5	9.5	9.0
210	16.5	4.0	12.3	13.2	9.7	10.4	23.0	10.0	8.0

Table XI. Distribution of soil N and P resulting from a chisel application of 134 kg/ha N as NH_3 and 15 kg/ha P as liquid APP (North Central Experiment Field, 1972).

Sampling Width cm	Nitrate-N (ppm)			Ammonium-N (ppm)			Avail. P (ppm)		
	Depth (cm)			Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
5	12.7	69.4	67.8	17.0	9.4	21.8	31.0	44.5	26.0
10	20.1	34.9	23.6	19.2	11.9	10.9	28.0	31.0	20.5
15	22.3	13.5	8.6	18.7	12.9	14.6	30.0	13.5	17.0
20	19.9	12.3	16.2	18.9	11.3	12.7	22.0	11.0	16.5
25	17.6	23.2	38.0	18.1	9.9	9.9	31.0	14.0	15.5
30	21.3	35.3	60.2	16.6	10.1	14.6	23.5	13.0	14.5
35	19.7	43.5	70.8	16.2	14.4	31.2	23.5	40.0	23.0
40	11.5	44.2	79.8	13.5	10.7	22.3	32.0	45.0	18.0
45	10.5	18.1	37.6	15.6	12.5	11.1	23.0	12.0	8.0
50	12.5	8.4	15.6	16.7	10.5	7.2	23.0	9.5	12.5
55	16.2	12.7	12.3	17.0	11.7	12.1	29.0	12.0	14.5
60	12.1	27.9	25.9	15.0	13.8	13.8	31.0	12.5	10.5
65	15.3	39.6	52.3	15.0	10.3	16.8	32.0	29.0	32.0
70	17.8	39.1	44.4	17.9	12.1	14.2	27.5	25.5	12.0
75	16.2	29.4	32.8	13.8	12.3	13.1	30.0	14.5	17.0
80	14.3	22.4	16.8	15.6	11.7	11.1	25.0	14.5	18.5
85	21.2	20.1	24.4	17.0	12.1	13.8	29.0	15.0	10.0
90	22.0	23.6	43.7	14.6	10.7	11.3	28.0	26.5	18.0
95	17.5	39.2	79.5	14.8	12.1	22.6	25.5	31.0	27.5
100	13.2	29.8	78.2	15.3	14.8	23.6	28.5	15.0	21.0
105	19.7	19.1	52.8	14.2	9.9	10.3	24.5	18.0	11.0
110	21.3	20.3	19.5	16.2	10.7	10.1	27.5	11.5	12.0
115	13.1	21.4	23.2	12.1	12.7	10.9	25.5	14.5	8.0
120	14.1	27.7	24.0	13.3	9.2	11.9	25.0	25.5	13.0
125	13.6	40.0	56.0	16.4	8.8	19.7	30.0	32.0	24.5
130	11.1	23.6	55.6	16.6	11.7	13.8	27.5	24.0	12.0
135	14.1	10.3	16.2	17.9	11.7	11.9	24.0	9.0	9.0
140	16.0	11.1	10.7	12.7	8.8	11.9	28.0	9.0	8.5
145	12.3	18.3	14.8	19.5	9.6	13.6	29.0	12.0	8.0
150	14.1	25.7	35.5	14.8	14.2	11.1	29.0	13.5	9.0
155	11.1	33.2	58.1	19.9	13.6	29.8	28.0	16.5	38.0
160	10.5	24.6	28.1	18.9	9.9	11.7	25.5	23.5	11.0
165	13.1	10.2	7.8	19.3	12.9	11.7	28.5	21.5	10.0
170	17.0	11.9	12.1	14.8	10.3	9.9	26.0	14.0	13.5
175	19.0	10.9	10.0	16.6	12.5	13.1	28.0	15.0	12.0
180	11.2	13.1	19.2	14.8	12.3	11.3	30.0	11.1	10.5
185	15.8	21.7	29.1	11.3	11.1	13.1	28.0	22.0	10.0
190	14.4	32.6	49.2	13.6	13.4	19.5	23.0	26.5	22.5
195	13.7	25.1	26.2	13.3	13.1	12.9	21.5	19.0	12.5
200	16.2	10.2	12.9	15.6	13.2	13.6	20.5	14.0	15.0
205	12.1	8.9	9.9	13.2	10.3	11.3	23.5	13.5	9.5
210	10.2	12.3	11.1	14.0	11.7	13.3	21.0	15.5	10.0

Table XII. Distribution of soil N and P resulting from a liquid surface application of 134 kg/ha N as UAN and 15 kg/ha P as APP (North Central Experiment Field, 1972).

Sampling Width cm	Nitrate-N (ppm)			Ammonium-N (ppm)			Avail. P (ppm)		
	Depth (cm)			Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
5	42.3	13.8	8.4	13.9	12.8	11.2	41.0	33.5	13.5
10	48.6	14.7	8.4	14.2	12.1	9.0	44.5	36.5	14.0
15	53.1	16.7	7.8	13.1	10.9	9.2	39.0	33.5	15.0
20	47.8	14.6	9.7	13.0	10.9	12.9	35.5	30.0	13.0
25	45.2	14.4	9.0	11.7	11.3	9.0	37.0	36.5	11.5
30	52.8	15.8	9.9	13.1	8.0	7.4	42.5	30.0	10.0
35	49.1	16.6	9.7	13.3	9.9	12.1	38.5	28.0	12.5
40	48.6	18.7	9.9	13.8	13.6	9.7	37.0	33.5	8.0
45	47.3	15.8	9.6	13.6	9.9	10.7	36.0	34.5	6.0
50	49.2	15.0	7.5	11.1	9.2	10.1	39.0	33.5	6.0
55	50.8	18.0	9.7	12.1	10.3	10.3	38.5	31.5	7.5
60	53.1	13.8	11.1	13.2	9.0	10.9	42.0	31.0	7.5
65	52.8	15.0	12.2	14.1	9.7	9.4	42.5	33.5	11.0
70	54.3	15.8	10.2	13.2	13.4	12.1	43.5	30.5	12.0
75	47.3	12.7	10.9	12.3	14.0	9.4	40.0	36.0	11.0
80	47.1	13.5	8.9	13.3	9.4	8.8	37.5	30.0	13.0
85	50.3	12.9	11.2	10.6	12.1	9.2	39.0	27.0	7.0
90	42.8	16.5	11.9	12.5	11.1	10.1	40.5	34.5	6.0
95	44.1	18.1	10.7	13.6	14.0	10.7	41.5	32.5	7.5
100	51.2	16.3	10.1	12.1	9.3	8.8	39.0	33.5	11.5
105	52.5	15.4	10.8	13.8	12.7	12.2	33.0	26.5	12.0
110	51.7	15.9	13.1	11.9	12.1	12.3	43.0	32.0	9.0
115	50.4	13.2	12.5	11.5	10.1	11.1	38.0	34.5	8.0
120	51.8	15.1	10.0	11.9	10.3	13.2	41.5	31.0	9.5
125	49.3	13.3	9.9	10.2	12.7	9.6	41.0	28.5	7.0
130	53.1	17.5	11.0	9.4	10.9	8.2	39.0	31.5	6.5
135	55.2	15.5	12.2	11.1	12.5	9.9	37.5	35.5	5.0
140	51.3	13.4	12.6	13.2	11.3	8.4	42.5	30.0	8.0
145	48.7	12.1	8.4	11.7	13.3	7.4	43.0	35.0	6.0
150	49.7	16.2	11.5	12.9	10.1	9.7	39.0	36.0	6.0
155	48.3	13.6	9.4	13.6	11.3	11.6	40.0	34.0	5.0
160	49.5	17.4	12.6	13.8	10.1	9.6	40.0	33.5	6.5
165	46.5	15.8	10.6	12.7	11.9	11.7	35.5	31.0	8.0
170	50.1	12.9	10.1	10.7	11.9	11.3	35.0	29.0	6.0
175	49.8	18.3	10.7	13.6	11.1	9.4	38.0	33.0	7.0
180	51.2	11.9	12.9	13.7	9.4	8.4	38.0	32.5	6.5
185	50.3	16.6	11.9	13.5	8.9	10.1	38.0	27.0	7.0
190	46.5	18.7	10.7	14.0	11.3	9.7	37.5	28.5	8.0
195	47.0	15.5	11.9	12.9	9.2	8.6	36.0	25.5	11.0
200	48.1	14.2	9.3	9.8	10.1	7.4	34.5	29.5	10.5
205	45.3	15.3	10.5	11.9	9.0	8.4	43.0	28.0	7.0
210	46.1	16.4	9.9	12.3	9.4	10.3	37.5	29.0	8.0

Table XIII. Nitrification of 67 kg/ha N (NH_3), as compared to 67 kg/ha N (NH_3) in combination with 15 kg/ha P (liquid APP) - 1 day after application. (Ashland Research Farm, 1972).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH_3 Application:												
15	5.8	2.1	1.9	-	-	-	23.6	17.8	24.6	5.7	6.0	6.0
10	4.9	2.0	1.5	-	-	-	25.8	15.6	15.8	5.6	5.9	6.0
5	64.9	20.6	1.4	-	-	-	27.1	12.7	17.8	6.2	6.1	6.1
0	105.0	44.8	1.2	-	-	-	24.3	19.4	19.8	6.7	6.2	5.9
5	73.2	22.8	1.0	-	-	-	21.6	17.8	20.8	6.0	5.8	6.0
10	5.7	1.9	1.1	-	-	-	25.3	15.4	21.8	5.5	5.8	6.1
15	4.0	2.8	0.5	-	-	-	26.6	14.6	23.2	5.6	5.9	6.0
15	4.8	1.9	0.7	-	-	-	26.3	15.0	23.6	5.5	5.7	6.1
10	4.0	2.3	1.5	-	-	-	25.8	13.8	17.4	5.5	5.8	6.2
5	83.5	29.8	1.6	-	-	-	23.2	15.9	18.5	6.1	6.1	6.1
0	130.6	48.6	1.0	-	-	-	26.2	16.2	19.2	6.8	6.3	6.1
5	75.1	25.2	1.0	-	-	-	27.0	17.8	23.6	5.9	6.0	6.0
10	3.8	2.9	2.1	-	-	-	24.6	18.2	22.5	5.6	5.8	6.0
15	5.1	2.0	1.6	-	-	-	25.2	15.4	24.1	5.5	5.8	6.1
NH_3 and Liquid APP Application:												
15	4.0	1.3	0.8	-	-	-	21.3	14.8	18.6	5.6	5.9	6.1
10	3.7	2.0	0.5	-	-	-	25.8	16.2	16.0	5.5	5.8	6.0
5	70.8	15.8	2.1	-	-	-	23.2	15.0	18.8	6.1	6.0	6.1
0	98.9	43.2	1.2	-	-	-	26.9	17.2	21.2	6.6	6.3	5.9
5	65.2	19.8	1.7	-	-	-	21.4	13.4	23.3	6.0	6.1	6.0
10	5.0	1.6	2.1	-	-	-	22.1	15.2	22.6	5.6	5.8	6.1
15	4.7	1.4	1.6	-	-	-	28.6	16.3	21.3	5.5	5.9	6.1
15	5.9	1.9	0.5	-	-	-	18.9	16.7	17.8	5.6	5.8	6.0
10	4.3	1.2	2.0	-	-	-	24.3	17.3	18.4	5.6	5.8	6.0
5	74.6	22.5	1.6	-	-	-	23.9	15.9	19.0	6.0	6.0	6.0
0	122.6	53.6	0.9	-	-	-	22.6	14.8	17.8	6.7	6.2	6.1
5	85.2	27.8	0.5	-	-	-	21.8	17.0	17.8	6.1	6.1	5.9
10	4.2	1.7	1.2	-	-	-	25.4	15.3	16.5	5.6	5.7	6.0
15	3.7	2.0	2.0	-	-	-	22.6	16.4	18.9	5.5	5.8	6.0

Table XIII. (Continued - 3 days after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	4.0	2.1	0.5	-	-	-	24.8	13.2	21.3	5.5	5.9	6.1
10	3.4	1.5	0.8	-	-	-	19.6	16.4	24.8	5.6	5.8	6.0
5	74.3	22.0	1.0	-	-	-	23.2	12.1	21.7	6.2	6.1	6.0
0	104.5	37.6	0.7	-	-	-	21.8	14.2	22.8	6.7	6.2	6.1
5	70.4	14.6	0.5	-	-	-	25.6	12.5	18.9	6.1	6.0	6.0
10	5.6	2.1	0.5	-	-	-	22.8	15.3	21.2	5.6	5.8	6.1
15	3.8	1.5	0.7	-	-	-	21.4	12.0	23.3	5.5	5.9	6.0
15	3.6	1.1	0.5	-	-	-	21.8	14.5	19.4	5.6	5.8	5.9
10	5.0	2.0	0.6	-	-	-	22.4	13.2	17.6	5.5	5.8	6.1
5	68.6	19.5	0.5	-	-	-	22.6	14.0	18.6	6.1	6.0	6.0
0	127.0	48.6	0.5	-	-	-	23.8	14.3	21.4	6.6	6.1	6.0
5	78.4	23.6	0.8	-	-	-	21.7	15.2	18.5	6.0	6.0	6.1
10	2.0	1.5	1.0	-	-	-	25.3	16.3	19.7	5.6	5.8	6.1
15	3.5	1.1	0.7	-	-	-	24.5	12.8	20.6	5.5	5.9	6.0
NH₃ and Liquid APP Application:												
15	4.8	2.8	0.8	-	-	-	24.2	16.1	16.0	5.6	5.7	6.0
10	5.1	2.6	1.2	-	-	-	23.0	13.4	17.4	5.5	5.8	6.1
5	68.3	23.2	1.4	-	-	-	27.0	17.9	19.4	6.1	6.0	5.9
0	111.4	47.8	1.8	-	-	-	25.1	18.4	18.5	6.6	6.2	5.8
5	76.2	25.7	1.0	-	-	-	21.0	16.2	21.4	6.1	5.9	6.0
10	4.5	1.7	0.9	-	-	-	25.3	15.8	19.4	5.5	5.8	6.1
15	3.2	2.1	0.5	-	-	-	26.1	15.0	17.8	5.6	5.9	6.0
15	1.0	1.9	0.7	-	-	-	25.1	12.8	17.8	5.6	5.8	6.1
10	2.8	1.5	0.5	-	-	-	26.2	11.9	18.6	5.5	5.8	6.0
5	86.4	26.3	1.8	-	-	-	28.9	17.8	22.3	6.1	6.0	6.0
0	125.7	46.0	1.5	-	-	-	22.1	14.6	19.5	6.8	6.2	6.1
5	71.2	29.4	1.1	-	-	-	27.0	12.2	19.8	6.0	6.1	6.0
10	5.5	2.0	1.2	-	-	-	25.6	13.1	21.4	5.6	5.8	6.1
15	5.0	1.5	0.5	-	-	-	26.4	12.8	23.2	5.7	5.7	5.9

Table XIII. (Continued - 5 days after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	2.8	2.1	1.0	-	-	-	23.7	14.6	20.8	5.5	5.9	6.1
10	5.4	1.1	0.7	-	-	-	22.0	12.1	24.6	5.6	5.8	6.0
5	73.6	19.3	0.8	-	-	-	25.8	13.8	21.8	6.1	6.0	6.1
0	102.8	41.6	1.1	-	-	-	26.3	12.8	19.7	6.6	6.1	6.0
5	68.4	21.6	0.9	-	-	-	24.2	16.3	20.7	6.0	6.0	6.1
10	3.9	1.8	0.7	-	-	-	23.8	17.8	24.3	5.6	5.8	6.1
15	4.0	1.5	0.6	-	-	-	19.6	15.1	22.6	5.5	5.8	6.1
15	6.1	1.8	1.7	-	-	-	25.1	14.6	24.8	5.6	5.8	6.2
10	3.5	2.3	0.5	-	-	-	23.8	13.7	23.2	5.5	5.8	6.1
5	72.8	23.7	0.7	-	-	-	24.2	15.2	21.6	6.2	6.0	6.0
0	124.0	54.3	0.5	-	-	-	25.3	16.3	20.7	6.7	6.2	6.0
5	81.6	25.2	1.3	-	-	-	22.8	14.2	23.5	6.1	6.1	6.1
10	5.0	2.3	0.9	-	-	-	25.1	17.0	24.6	5.6	5.9	6.1
15	3.8	1.9	0.7	-	-	-	25.0	15.3	25.9	5.5	5.8	6.0
NH₃ and Liquid APP Application:												
15	5.1	1.9	0.5	-	-	-	25.4	14.6	17.4	5.5	5.9	6.0
10	3.6	2.2	0.6	-	-	-	21.8	12.8	18.2	5.5	5.9	6.0
5	65.7	21.8	0.5	-	-	-	26.2	19.8	15.8	6.0	6.0	6.0
0	102.1	42.1	1.1	-	-	-	25.4	15.3	19.4	6.7	6.1	6.0
5	71.8	20.8	0.9	-	-	-	23.2	14.2	24.1	6.0	6.0	6.1
10	5.8	2.6	1.8	-	-	-	26.8	16.1	21.8	5.5	5.7	6.1
15	5.0	2.0	1.2	-	-	-	25.7	17.0	17.8	5.6	5.8	6.0
15	5.3	2.4	0.8	-	-	-	24.6	11.8	17.0	5.5	5.9	6.1
10	5.1	2.1	0.5	-	-	-	29.8	12.3	19.5	5.6	5.8	6.1
5	79.4	25.0	1.3	-	-	-	27.6	13.6	15.1	6.0	6.0	6.0
0	120.2	45.1	1.7	-	-	-	25.4	14.1	16.8	6.7	6.1	6.1
5	73.8	27.8	1.0	-	-	-	23.2	17.8	17.3	6.1	6.0	6.1
10	4.7	1.8	0.5	-	-	-	19.8	16.1	21.2	5.5	5.8	6.0
15	4.1	2.1	1.0	-	-	-	21.0	14.2	23.1	5.6	5.7	5.9

Table XIII. (Continued - 1 week after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	Depth (cm)	0-10	10-20	20-30	Depth (cm)	0-10	10-20	20-30	Depth (cm)	0-10	10-20	20-30
NH₃ Application:												
15	6.2	2.1	1.0	-	-	-	14.7	17.5	5.6	5.9	6.0	
10	5.1	1.7	1.1	-	-	-	15.0	16.0	5.5	5.8	6.1	
5	55.6	18.9	0.5	-	-	-	19.7	18.2	5.8	5.9	6.1	
0	91.5	37.4	0.7	-	-	-	23.2	19.0	6.5	6.0	6.1	
5	65.4	17.2	0.5	-	-	-	21.4	22.6	5.9	6.0	6.1	
10	4.7	2.8	0.5	-	-	-	16.8	24.1	5.4	5.8	6.0	
15	4.0	1.5	1.6	-	-	-	12.7	21.8	5.5	5.7	6.2	
15	2.3	1.3	0.8	-	-	-	17.8	12.5	5.5	5.8	6.2	
10	4.6	2.8	1.7	-	-	-	15.2	14.6	5.4	5.9	6.1	
5	71.0	19.5	1.1	-	-	-	19.8	10.2	5.9	6.0	6.0	
0	112.6	39.0	1.0	-	-	-	22.1	15.8	6.4	6.1	6.0	
5	63.0	21.0	0.8	-	-	-	20.1	19.4	5.8	5.9	6.1	
10	5.1	1.5	1.2	-	-	-	17.0	20.5	5.5	5.7	6.0	
15	5.7	1.8	0.7	-	-	-	11.9	21.2	5.6	5.8	6.1	
NH₃ and Liquid APP Application:												
15	4.8	1.1	0.6	-	-	-	15.4	23.8	5.6	5.9	6.0	
10	4.0	2.0	1.0	-	-	-	14.6	22.1	5.5	5.8	6.1	
5	62.1	17.8	0.5	-	-	-	18.4	19.9	6.1	6.0	6.1	
0	94.8	36.8	0.8	-	-	-	21.8	23.7	6.5	6.1	6.0	
5	59.3	18.3	1.2	-	-	-	17.8	24.6	6.1	6.0	6.0	
10	3.8	1.5	0.5	-	-	-	13.7	21.2	5.6	5.9	6.1	
15	5.2	2.1	0.6	-	-	-	15.8	19.7	5.6	5.8	6.0	
15	3.2	1.0	0.8	-	-	-	11.8	20.7	5.6	5.8	6.0	
10	4.1	1.7	0.5	-	-	-	12.6	23.6	5.6	5.9	6.1	
5	65.7	19.7	0.5	-	-	-	17.6	25.8	6.1	6.0	6.2	
0	115.8	44.2	0.8	-	-	-	20.8	24.6	6.6	6.1	6.0	
5	70.3	21.2	0.7	-	-	-	19.4	18.3	6.0	6.0	6.0	
10	5.3	1.8	0.5	-	-	-	14.0	23.6	5.5	5.8	5.9	
15	4.7	1.4	1.1	-	-	-	15.6	24.2	5.6	5.8	6.1	

Table XIII. (Continued - 2 weeks after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	4.3	2.1	0.5	-	-	-	23.8	12.6	17.8	5.5	5.9	6.0
10	5.0	1.9	0.7	-	-	-	22.6	13.8	19.5	5.6	5.8	5.9
5	43.5	16.0	1.0	0.9	0.5	-	35.0	24.0	20.5	5.8	5.9	6.1
0	75.1	29.8	1.1	3.2	0.2	-	48.1	30.6	17.8	6.1	5.9	6.2
5	54.6	14.5	0.9	2.1	-	-	39.6	25.1	12.5	5.7	5.9	6.1
10	6.8	2.3	1.2	-	-	-	26.2	16.2	18.9	5.5	5.8	6.0
15	4.2	1.2	1.7	-	-	-	22.7	14.6	17.8	5.6	5.9	6.0
15	3.8	2.0	0.5	-	-	-	27.4	14.2	16.9	5.4	5.9	6.1
10	6.5	1.7	1.2	-	-	-	25.3	13.8	15.7	5.6	5.8	6.1
5	59.8	14.6	1.0	2.6	-	-	42.8	26.2	16.4	5.8	5.9	6.0
0	94.8	31.3	1.3	4.8	0.9	-	53.6	31.5	18.3	6.1	5.8	6.0
5	52.4	17.8	0.5	1.0	0.1	-	37.8	25.8	17.0	5.8	5.9	6.0
10	3.8	1.9	0.7	-	-	-	22.5	15.7	14.2	5.6	5.9	6.1
15	2.9	1.8	1.2	-	-	-	21.4	14.1	13.0	5.5	5.8	6.1
NH₃ and Liquid APP Application:												
15	3.8	2.1	0.5	-	-	-	24.6	14.2	25.6	5.5	5.9	6.0
10	5.0	1.7	0.5	-	-	-	21.2	16.3	24.2	5.6	5.8	6.1
5	46.3	13.7	0.7	2.2	0.6	-	33.0	21.7	18.9	5.8	5.9	6.0
0	82.5	29.7	1.0	4.8	0.5	-	45.6	32.6	23.2	6.1	5.9	6.1
5	52.0	17.6	0.5	2.7	0.2	-	37.8	22.8	25.6	5.7	5.9	6.1
10	4.5	2.1	0.6	-	-	-	19.8	15.4	23.3	5.6	5.8	6.1
15	3.8	1.5	1.0	-	-	-	24.5	16.2	25.2	5.5	5.9	6.0
15	4.7	1.9	0.9	-	-	-	20.3	14.6	23.2	5.6	5.8	6.0
10	5.0	2.5	1.0	-	-	-	21.4	13.2	21.7	5.6	5.9	6.0
5	54.3	15.2	0.8	3.1	0.4	-	38.7	20.7	23.7	5.8	5.8	6.1
0	97.0	35.7	0.7	5.3	1.1	-	48.9	29.8	24.2	6.1	5.8	6.0
5	59.8	18.1	0.5	2.7	0.2	-	40.5	26.8	23.2	5.9	5.9	6.0
10	3.6	2.9	0.5	-	-	-	25.6	15.2	19.6	5.6	5.9	6.1
15	4.2	1.0	0.8	-	-	-	24.0	14.6	20.7	5.5	5.8	6.1

Table XIII. (Continued - 3 weeks after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	Depth (cm)			Depth (cm)			Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	3.5	4.8	1.1	-	-	-	19.7	15.2	21.8	5.5	5.8	6.0
10	4.8	3.6	0.8	-	-	-	22.6	17.6	16.5	5.6	5.7	6.0
5	21.4	9.4	1.7	3.9	0.4	-	53.1	27.3	18.9	5.6	5.8	6.0
0	41.8	17.8	1.3	5.3	0.2	-	81.5	39.4	20.2	5.7	5.7	6.1
5	25.7	7.6	0.8	2.1	1.0	-	62.7	31.8	24.1	5.6	5.8	6.0
10	4.7	5.8	2.1	-	-	-	21.8	18.1	17.5	5.5	5.8	6.1
15	3.2	3.2	1.9	-	-	-	23.6	11.2	24.3	5.6	5.7	5.9
15	3.7	4.7	1.2	-	-	-	27.8	14.7	18.9	5.6	5.8	6.0
10	5.4	5.0	1.6	-	-	-	25.2	15.6	17.0	5.6	5.8	6.2
5	37.5	11.7	2.0	1.9	0.8	-	68.2	34.8	19.4	5.6	5.7	6.1
0	53.8	22.1	0.7	5.1	1.3	-	90.1	42.6	18.6	5.7	5.8	6.1
5	29.6	9.4	0.5	3.0	0.4	-	57.8	29.1	19.2	5.6	5.7	6.0
10	5.1	4.5	0.6	-	-	-	21.8	16.4	21.3	5.6	5.8	6.1
15	3.5	5.0	0.5	-	-	-	20.9	15.8	23.6	5.5	5.7	6.0
NH₃ and Liquid APP Application:												
15	5.0	1.1	0.5	-	-	-	25.8	13.6	20.9	5.5	5.9	6.0
10	3.9	2.1	0.7	-	-	-	23.6	13.9	24.8	5.6	5.8	6.1
5	24.8	6.8	0.6	2.6	0.1	-	47.1	30.6	23.8	5.5	5.8	6.0
0	45.8	19.5	0.8	5.8	1.2	-	84.3	42.7	19.8	5.7	5.7	6.0
5	22.6	8.5	0.7	3.1	0.4	-	53.6	33.5	25.6	5.6	5.8	5.9
10	4.2	1.0	0.5	-	-	-	20.7	14.2	24.2	5.5	5.8	6.0
15	3.2	1.7	0.5	-	-	-	23.6	15.6	23.1	5.6	5.9	6.1
15	4.2	1.8	0.6	-	-	-	22.6	14.6	23.8	5.5	5.9	6.0
10	5.1	1.7	0.5	-	-	-	23.2	12.5	25.2	5.6	5.8	6.1
5	29.3	9.8	0.7	1.8	0.6	-	46.6	29.7	24.2	5.5	5.8	6.0
0	58.9	17.8	0.5	5.5	0.3	-	87.6	46.0	21.8	5.7	5.8	6.0
5	33.6	7.7	0.5	2.7	0.1	-	50.2	32.2	24.6	5.6	5.7	6.2
10	3.7	1.5	0.6	-	-	-	25.7	12.9	25.3	5.5	5.8	6.1
15	5.0	1.2	0.5	-	-	-	23.2	14.2	27.8	5.6	5.9	6.1

Table VIII. (Continued - 4 weeks after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH ₃ Application:												
15	5.2	2.1	0.5	-	-	-	25.7	14.0	18.9	5.5	5.7	6.0
10	3.5	1.9	0.5	-	-	-	22.3	15.2	16.5	5.6	5.8	6.1
5	16.8	7.0	1.0	1.8	0.2	-	70.1	31.8	21.4	5.4	5.7	6.0
0	34.0	12.2	0.7	4.2	0.4	-	94.8	46.0	22.0	5.3	5.6	6.0
5	19.1	5.3	0.8	2.7	0.1	-	76.1	30.7	17.8	5.3	5.8	6.1
10	4.2	2.1	0.5	-	-	-	21.2	18.2	21.0	5.6	5.8	6.0
15	3.9	1.2	1.0	-	-	-	17.8	13.4	24.7	5.5	5.9	6.0
15	3.5	2.0	0.8	-	-	-	18.2	14.5	21.0	5.6	5.7	5.9
10	4.2	2.1	0.5	-	-	-	19.5	12.8	17.4	5.6	5.8	6.2
5	23.0	8.1	1.0	2.6	0.7	-	79.4	35.1	18.2	5.3	5.7	6.1
0	41.5	14.8	0.7	5.5	0.3	-	105.7	54.1	12.5	5.2	5.6	6.0
5	16.0	6.2	0.6	3.0	0.1	-	66.1	32.1	17.4	5.4	5.7	6.1
10	5.2	2.8	0.5	-	-	-	25.1	17.6	19.0	5.6	5.8	6.1
15	4.0	2.5	1.0	-	-	-	22.6	12.0	21.3	5.6	5.8	6.0
NH ₃ and Liquid APP Application:												
15	4.2	1.3	0.5	-	-	-	24.9	14.0	19.8	5.5	5.7	6.0
10	3.3	1.2	1.2	-	-	-	19.6	15.0	17.4	5.6	5.8	6.1
5	17.8	4.8	0.5	2.2	0.1	-	61.2	33.7	23.8	5.4	5.7	6.1
0	32.6	10.6	0.6	3.8	0.4	-	92.8	45.8	18.6	5.3	5.6	6.0
5	21.3	5.2	0.5	1.9	-	-	65.0	29.7	25.3	5.4	5.7	6.1
10	2.9	1.0	0.5	-	-	-	21.8	12.9	20.8	5.6	5.8	6.1
15	4.0	0.9	0.6	-	-	-	25.7	15.8	16.4	5.5	5.7	6.0
15	4.8	1.8	0.5	-	-	-	22.8	16.0	23.1	5.5	5.8	6.1
10	4.5	2.0	0.5	-	-	-	23.7	12.9	17.8	5.6	5.8	6.1
5	16.4	6.1	0.9	3.6	0.3	-	57.8	32.6	20.9	5.4	5.7	6.2
0	38.9	12.7	0.7	4.5	0.8	-	98.8	49.5	18.9	5.3	5.6	6.1
5	19.9	5.6	0.5	2.1	-	-	62.8	36.8	20.1	5.5	5.8	6.0
10	3.6	2.3	0.6	-	-	-	24.2	13.7	24.0	5.6	5.9	5.9
15	3.2	1.9	0.5	-	-	-	29.5	15.7	23.2	5.5	5.8	6.1

Table XIII. (Continued - 5 weeks after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	3.8	3.7	0.5	-	-	-	25.2	14.0	19.5	5.5	5.7	6.0
10	4.2	2.5	0.6	-	-	-	26.3	11.8	23.5	5.6	5.8	6.0
5	13.5	4.2	1.0	-	-	-	74.8	34.0	17.8	5.3	5.7	6.1
0	27.8	5.0	0.8	-	-	-	113.6	51.3	19.5	5.2	5.6	6.1
5	15.7	3.8	0.5	-	-	-	78.0	37.7	21.4	5.2	5.7	6.2
10	3.7	2.3	0.6	-	-	-	29.0	21.0	20.2	5.5	5.8	6.1
15	4.1	1.9	1.0	-	-	-	21.0	15.6	17.6	5.6	5.9	6.0
15	4.9	2.0	1.7	-	-	-	19.7	14.2	17.6	5.6	5.9	6.1
10	4.6	2.6	1.1	-	-	-	25.0	13.7	18.5	5.5	5.8	6.0
5	19.6	2.9	0.6	-	-	-	84.0	31.6	19.2	5.3	5.7	6.1
0	34.8	6.3	0.5	-	-	-	128.6	49.8	17.8	5.1	5.5	6.0
5	13.1	4.7	0.7	-	-	-	73.0	38.0	21.4	5.2	5.6	6.0
10	3.8	2.5	1.0	-	-	-	24.6	15.0	19.8	5.6	5.8	6.0
15	4.0	2.3	0.8	-	-	-	22.1	13.2	22.0	5.5	5.9	6.1
NH₃ and Liquid APP Application:												
15	4.2	2.0	0.6	-	-	-	20.8	11.5	19.9	5.5	5.7	6.0
10	4.0	1.5	0.7	-	-	-	26.0	15.6	23.2	5.6	5.8	6.1
5	14.8	3.6	0.6	-	-	-	62.3	35.6	20.6	5.3	5.7	6.0
0	26.8	4.2	0.5	-	-	-	108.9	49.7	21.9	5.2	5.6	6.1
5	17.6	3.9	0.5	-	-	-	65.4	31.8	23.8	5.3	5.6	6.0
10	3.8	1.8	0.6	-	-	-	21.3	18.4	21.9	5.6	5.8	6.1
15	4.5	2.0	0.5	-	-	-	25.0	12.9	24.2	5.6	5.7	6.1
15	5.3	1.4	0.5	-	-	-	26.3	14.8	25.4	5.5	5.9	6.0
10	6.1	1.3	0.6	-	-	-	19.8	15.0	19.8	5.6	5.8	6.1
5	15.3	3.2	0.5	-	-	-	67.4	34.6	20.0	5.2	5.6	6.1
0	32.7	5.8	0.5	-	-	-	123.6	53.8	19.8	5.1	5.5	6.0
5	19.0	2.8	0.6	-	-	-	71.8	39.1	20.1	5.3	5.6	6.1
10	5.9	1.1	0.5	-	-	-	21.8	13.2	22.3	5.6	5.9	6.1
15	5.0	2.0	0.6	-	-	-	23.8	14.1	21.7	5.6	5.8	6.0

Table XIII. (Continued - 6 weeks after application).

Distance from Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	2.1	3.1	0.6	-	-	-	25.1	17.8	21.9	5.5	5.8	6.0
10	4.0	3.4	1.0	-	-	-	23.6	16.5	19.8	5.6	5.8	6.2
5	11.4	2.1	0.9	-	-	-	70.7	38.4	21.2	5.3	5.7	6.1
0	23.7	1.9	0.5	-	-	-	124.3	55.7	23.8	5.1	5.6	6.0
5	13.2	2.0	0.5	-	-	-	85.0	41.0	17.6	5.2	5.6	6.1
10	3.6	1.8	0.7	-	-	-	21.5	18.9	21.4	5.6	5.9	6.0
15	4.1	1.7	1.2	-	-	-	19.8	15.8	16.8	5.5	5.8	5.9
15	5.0	2.7	0.8	-	-	-	20.9	15.2	22.6	5.5	5.7	6.1
10	5.4	2.8	0.5	-	-	-	25.6	16.1	23.8	5.6	5.9	6.1
5	14.2	1.7	0.5	-	-	-	79.8	32.6	21.9	5.3	5.7	6.0
0	31.0	1.6	0.5	-	-	-	141.2	53.0	20.5	5.0	5.6	6.1
5	11.2	2.0	0.8	-	-	-	76.0	37.4	18.6	5.2	5.7	6.2
10	4.6	2.1	1.0	-	-	-	21.8	18.2	19.4	5.6	5.8	6.0
15	5.3	2.5	1.0	-	-	-	23.4	16.5	21.3	5.5	5.8	6.1
NH₃ and Liquid AFP Application:												
15	3.8	1.9	0.6	-	-	-	20.2	14.3	20.2	5.6	5.8	6.0
10	4.5	2.0	0.5	-	-	-	23.0	12.9	17.8	5.5	5.9	6.1
5	13.5	1.8	1.0	-	-	-	59.8	41.8	20.9	5.3	5.6	6.0
0	24.6	2.3	0.9	-	-	-	117.6	53.2	19.8	5.1	5.5	6.1
5	11.2	2.7	0.5	-	-	-	64.3	35.6	23.2	5.2	5.6	6.6
10	5.6	1.7	0.7	-	-	-	21.8	12.0	18.6	5.6	5.8	6.1
15	4.0	1.8	0.5	-	-	-	24.8	16.0	21.8	5.5	5.8	6.2
15	3.8	1.8	0.9	-	-	-	24.2	15.0	18.9	5.5	5.8	6.0
10	2.0	1.7	1.1	-	-	-	21.8	14.7	24.6	5.6	5.9	6.1
5	13.7	2.6	0.7	-	-	-	64.2	30.6	21.0	5.2	5.7	6.1
0	32.8	1.5	0.5	-	-	-	137.0	50.9	19.8	5.0	5.6	6.0
5	16.4	1.4	0.6	-	-	-	73.8	34.8	20.3	5.2	5.6	6.1
10	3.4	1.9	0.5	-	-	-	19.8	13.5	21.8	5.6	5.9	6.1
15	3.8	1.8	0.5	-	-	-	20.7	14.2	22.0	5.5	5.8	6.1

Table XIII. (Continued - 7 weeks after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	Depth (cm)	0-10	10-20	20-30	Depth (cm)	0-10	10-20	20-30	Depth (cm)	0-10	10-20	20-30
NH₃ Application:												
15	3.7	3.8	0.5	-	-	-	24.0	15.6	23.0	5.5	5.9	6.1
10	4.1	1.9	0.5	-	-	-	25.8	14.8	17.0	5.4	5.8	6.1
5	9.7	2.1	0.6	-	-	-	76.8	37.0	20.4	5.2	5.6	6.0
0	28.9	3.2	0.8	-	-	-	119.0	52.0	21.8	5.0	5.5	6.0
5	16.0	2.1	1.0	-	-	-	83.9	42.0	23.6	5.3	5.7	6.2
10	3.2	1.9	1.3	-	-	-	26.0	19.6	25.0	5.6	5.8	6.1
15	4.0	1.8	1.0	-	-	-	22.1	14.8	21.8	5.5	5.7	6.0
15	3.0	1.9	0.5	-	-	-	27.4	13.8	16.0	5.6	5.8	6.0
10	5.0	2.1	0.5	-	-	-	22.6	14.8	19.0	5.5	5.8	6.0
5	10.8	2.8	1.0	-	-	-	73.0	34.6	18.5	5.2	5.7	6.1
0	35.7	2.7	0.7	-	-	-	146.5	49.0	21.0	5.1	5.6	6.1
5	14.7	2.6	0.6	-	-	-	84.2	39.8	19.7	5.2	5.6	6.0
10	5.3	1.9	1.0	-	-	-	28.0	13.7	21.8	5.6	5.9	5.9
15	4.7	1.2	0.7	-	-	-	25.0	14.2	23.6	5.5	5.8	6.2
NH₃ and Liquid APP Application:												
15	5.0	2.1	0.5	-	-	-	24.0	14.3	23.6	5.5	5.8	6.1
10	4.6	1.9	0.5	-	-	-	23.2	12.9	20.5	5.6	5.9	6.1
5	11.3	2.0	0.6	-	-	-	66.3	38.2	21.8	5.3	5.7	6.0
0	26.5	1.7	0.5	-	-	-	124.5	48.9	19.7	5.1	5.6	6.0
5	13.2	1.8	0.7	-	-	-	59.7	37.1	20.2	5.2	5.6	6.1
10	3.8	1.7	0.8	-	-	-	27.0	15.7	21.8	5.6	5.9	6.1
15	4.2	1.8	1.0	-	-	-	26.0	16.2	23.6	5.5	5.8	6.1
15	5.8	1.5	0.6	-	-	-	24.8	14.2	19.7	5.6	5.8	6.0
10	5.9	2.1	0.5	-	-	-	23.2	11.9	21.8	5.5	5.9	6.2
5	11.0	2.8	0.7	-	-	-	68.0	39.0	21.6	5.3	5.6	6.1
0	34.9	3.2	0.6	-	-	-	141.7	54.6	22.0	5.0	5.5	6.0
5	14.6	1.0	0.5	-	-	-	70.0	35.6	18.9	5.2	5.7	6.1
10	3.8	2.3	0.5	-	-	-	21.7	14.6	21.3	5.6	5.9	6.0
15	3.0	1.9	0.5	-	-	-	20.6	15.0	22.0	5.5	5.8	5.9

Table XIII. (Continued - 8 weeks after application).

Distance From Release Points cm	Ammonium-N (ppm)			Nitrite-N (ppm)			Nitrate-N (ppm)			pH		
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
NH₃ Application:												
15	3.7	1.9	0.7	-	-	-	23.0	13.7	23.8	5.5	5.9	6.0
10	5.0	2.2	0.6	-	-	-	19.8	12.0	19.8	5.6	5.7	6.1
5	12.3	2.4	0.5	-	-	-	75.1	36.1	21.6	5.3	5.7	6.0
0	25.7	1.8	0.5	-	-	-	126.1	55.2	18.9	5.1	5.5	6.1
5	11.9	1.2	1.1	-	-	-	84.5	42.9	17.8	5.2	5.8	6.0
10	4.8	1.0	1.0	-	-	-	27.8	14.8	19.4	5.6	5.9	6.1
15	3.7	2.3	1.2	-	-	-	20.5	17.9	21.5	5.6	5.8	6.0
15	5.0	3.0	0.6	-	-	-	25.8	15.1	22.5	5.5	5.8	5.9
10	3.5	2.6	0.5	-	-	-	21.7	16.0	21.4	5.6	5.9	6.1
5	13.6	1.2	0.6	-	-	-	81.0	39.5	18.9	5.2	5.5	6.0
0	33.2	3.0	0.8	-	-	-	148.1	59.6	21.0	5.0	5.4	6.1
5	11.1	4.0	1.1	-	-	-	77.6	42.8	19.0	5.3	5.6	6.0
10	6.0	2.5	1.0	-	-	-	22.5	13.8	21.4	5.6	5.8	6.1
15	3.9	1.9	1.1	-	-	-	21.6	14.0	18.9	5.5	5.8	6.0
NH₃ and Liquid APP Application:												
15	4.0	1.8	0.5	-	-	-	23.7	15.8	19.7	5.5	5.8	6.0
10	3.6	2.1	0.5	-	-	-	25.8	14.8	21.8	5.6	5.9	6.1
5	13.2	1.5	0.8	-	-	-	68.3	41.0	22.0	5.1	5.6	6.0
0	27.8	1.8	0.6	-	-	-	121.0	53.5	23.6	5.0	5.5	6.1
5	10.9	1.9	0.5	-	-	-	57.0	38.5	19.4	5.2	5.6	6.0
10	5.0	2.1	0.5	-	-	-	21.8	12.9	17.8	5.6	5.9	6.2
15	6.0	0.9	0.6	-	-	-	23.2	15.6	21.8	5.5	5.8	6.1
15	4.7	0.9	0.5	-	-	-	19.9	14.6	19.7	5.6	5.8	6.0
10	5.0	2.6	0.5	-	-	-	22.6	12.9	23.7	5.6	5.9	6.1
5	13.0	2.5	0.9	-	-	-	74.0	37.0	26.0	5.2	5.6	5.9
0	36.3	1.8	0.8	-	-	-	146.3	52.8	21.0	5.0	5.5	6.0
5	15.8	1.4	0.5	-	-	-	66.2	40.3	20.7	5.2	5.7	6.0
10	4.8	2.1	0.6	-	-	-	21.3	16.8	19.6	5.6	5.9	6.0
15	5.3	1.9	0.5	-	-	-	25.8	12.9	23.8	5.5	5.8	6.1

Table XIV. Distribution of available P resulting from the simultaneous application of NH_3 and liquid APP, as compared to NH_3 alone, during the nitrification study - 4 weeks after application (Ashland Research Farm, 1972).

Distance From Release Points cm	Avail. P (ppm) ^a			Avail. P (ppm) ^b		
	Depth (cm)			Depth (cm)		
	0-10	10-20	20-30	0-10	10-20	20-30
15	73.5	54.0	21.5	75.0	50.0	21.0
10	71.5	56.0	22.0	75.0	54.0	23.0
5	76.5	53.5	22.5	76.0	59.0	24.0
0	75.0	54.0	26.5	225.0	78.0	28.0
5	74.5	54.5	25.5	75.5	50.0	23.0
10	71.5	59.0	22.0	80.0	53.5	25.5
15	72.0	51.0	23.0	77.5	51.0	26.0
15	72.5	56.0	24.5	75.0	54.0	26.5
10	76.5	55.5	26.0	67.5	50.0	22.5
5	78.0	56.5	23.5	73.5	53.5	25.0
0	75.0	55.0	22.5	285.0	88.0	23.5
5	72.0	51.0	28.0	73.5	54.0	21.5
10	75.0	54.0	21.5	67.5	59.0	20.5
15	71.0	47.5	24.0	74.0	52.0	28.0

^a Treatment was 67 kg/ha N as NH_3

^b Treatment was 67 kg/ha N as NH_3 and 15 kg/ha P as liquid APP

TILLAGE IMPLEMENT APPLICATIONS OF ANHYDROUS AMMONIA
AND LIQUID AMMONIUM POLYPHOSPHATE

by

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B.S., Kansas State University, 1967

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1973

Field studies were conducted in 1971-72 to evaluate the effectiveness of N and P applied preplant for wheat (Triticum aestivum L.) and grain sorghum (Sorghum bicolor) by means of an undercutting blade and a chisel plow. Tillage implement applications of anhydrous ammonia (NH_3) and liquid ammonium polyphosphate (APP) were compared with surface applications of urea-ammonium nitrate (UAN) and APP solution combinations.

Grain yields were significantly affected by methods of N-P applications at two of the five wheat sites. In both cases, the blade applications produced the highest yields with the surface applications producing the lowest yields. Grain protein levels were significantly higher from increased N rates, but method of application had little effect.

Method of N-P application also significantly influenced the P concentration in the leaf tissue at two of the four wheat sites sampled in November. Blade applications were superior at both locations. April leaf tissue analyses revealed that tillage N-P applications were comparatively equal to surface applications in supplying P to the plant.

Plant N concentrations in wheat leaf tissue were statistically unaffected by the rate of N or method of application. However, there was a trend toward lower N concentrations from surface applications at two of the locations.

Correlation studies conducted at two sites were inconsistent in attempting to relate soil N and P concentrations to the uptake of N and P from the three methods of application. Problems in soil sampling and dry weather undoubtedly affected the results. However, N and P uptake at the same sites were significantly higher from the tillage implement N-P applications.

Grain sorghum yields at four dryland locations were not significantly affected by N-P applications. However, at all locations, the method of N-P application significantly affected the grain protein levels. Chisel appli-

cations produced the highest protein levels at all locations. Surface applications were significantly lower in grain protein levels than comparable tillage implement applications at two of the sites.

Nitrogen concentrations in the grain sorghum leaf at the boot stage of development related directly to the grain protein levels at all locations. The fact that chisel N-P applications were superior in all cases suggests greater nutrient uptake efficiency with the deeper placement. The relative position and distribution of N and P in the soil from the three methods of N-P applications was confirmed at one of the grain sorghum sites by soil analyses.

A nitrification study conducted during the fall season evaluated the effects of placing NH_3 and liquid APP in close proximity. Field results indicate that liquid APP did not stimulate or inhibit the nitrification of NH_3 .

Based upon the results obtained from field investigations, tillage implement applications of a complete N-P program for both grain sorghum and wheat seem to be completely feasible. In fact, these practices may hold some advantages over surface applications under certain climatic conditions.