NITRIFICATION INHIBITION (N-SERVE) EFFECTS ON WINTER WHEAT (*TRITICUM AESTIVIUM* L.) YIELD AND DISEASE SUSCEPTIBILITY (*CEPHALOSPORIUM* STRIPE)

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INTRODUCTION

Scientists have long recognized the importance of nitrogen in plant growth and development. It is recognized as being the single most limiting nutrient in crop production in the U.S. These facts are readily understood when it is considered that nitrogen is a major constituent in some of the most important compounds in a plant. It is an integral part of chlorophyll, nucleic acids, proteins, amino acids and other plant components. Although 80% of the atmosphere is composed of nitrogen, it is deficient in soils because only certain microorganisms are able to assimilate molecular nitrogen into forms that are available for plant use.

Plants absorb their nitrogen mainly in the inorganic form as ammonium (NH_4^+) and nitrate (NO_3^-) ions. The quantity of these two ions in the soil depends largely on the amounts supplied as commercial fertilizers and the amounts released from the reserves of organic soil nitrogen. The amount of inorganic nitrogen available for plant use depends on a balance that exists among different factors affecting nitrogen in the soil, including; mineralization, immobilization and losses from the soil itself (Tisdale and Nelson, 1975). Through these processes nitrogen compounds are continually undergoing change; organic and inorganic, some available for plant use and others not.

Scientists have tried for years to alter the processes that affect soil nitrogen. Alteration of the changes in soil nitrogen form may result in more efficient use of the nitrogen available to the plant. Finding a chemical that satisfactorily supresses the nitrification of the ammonium ion and slows the production of leachable nitrate has been the goal of much research in the past. Under certain conditions, retaining the nitrogen in the ammonium form could result in certain agronomic advantages. During the last two decades, several chemicals that inhibit nitrification have been developed. Use information concerning such compounds under different conditions and different crops is now needed.

LITERATURE REVIEW

Nitrification, a process of major importance in soil fertility, is the biological oxidation of ammonium to nitrate. This conversion proceeds in the presence of two obligate autotrophic bacteria, Nitrosomonas and Nitrobacter. There are two well defined steps in this conversion. The first step is the oxidation of ammonium to nitrite (NO_2^-) by the bacteria Nitrosomonas and proceeds in the following manner:

$$2NH_4^+ + 3O_2 \longrightarrow 2NO_2^- + H_2O + 4H^+$$

The second step further oxidizes the nitrite to nitrate through the activity of the bacteria Nitrobacter in the following step:

$$2NO_2^- + O_2 \longrightarrow 2NO_3^-$$

Both reactions require molecular oxygen, a favorable pH, water and a suitable temperature.

Generally the rate limiting step in the conversion of ammonium to nitrate is the oxidation of ammonium to nitrite. The conversion of nitrite to nitrate proceeds fairly rapidly. Consequently, there is rarely a substantial accumulation of potentially toxic nitrite in the soil.

Even though most plants preferentially absorb nitrate, there are several reasons why nitrification may be disadvantageous for crop production. Since the nitrate ion is negatively charged, it is not adsorbed by the colloidal fraction of the soil and is subject to movement in the soil by water. Upward movement by water may result in the accumulation of nitrates in the upper part of the soil profile during periods of high evaporation, resulting in positional unavailability of the nitrogen and possibly nitrate toxicity to animals consuming vegetative portions of plants accumulating nitrates. Nitrates may also be leached through the soil profile and out of the plants root zone. Eventually, leached nitrate may enter ground water.

Another possible fate of oxidized nitrogen is denitrification of nitrate into nitrogen gas (N_2) or hyponitrite (N_2O_2) which are lost to the atmosphere. This process may proceed either chemically or biologically under anaerobic conditions when the soil is saturated with water. Nitrification of ammonium may also lower the pH of the soil through the release of protons.

Possible Effects of Nitrification Inhibitors

Utilization of nitrification inhibitors may alter the rates of these reactions. Estimates of losses of applied nitrogen vary but may exceed 50 percent of total amount applied (Broadbent and Clark, 1965). If these losses can be minimized, the initial application rate of nitrogen could be reduced, and ultimately profits from field crops would increase. A few years ago, fertilizer nitrogen was relatively cheap and farmers could simply add a little more nitrogen to compensate for the losses. Today, the farmer is caught in a cost-price squeeze and must use proper management to return a profit. In addition, prospects of an energy shortage, coupled with the fertilizer industry's heavy reliance on increasingly expensive energy, portends possibilities of short supplies and higher costs. Cleve Goring, Dow Chemical Company, estimates that if farmers across the U.S. could recover an additional 5 percent of the nitrogen applied annually, a savings of 10 billion cubic feet of natural gas per year could

could result (Lehnert, 1976).

There is, however, much confusion on the relative effectiveness of nitrate and ammonium as nitrogen sources for plants. There is some concern that the use of nitrification inhibitors would place the plant on an exclusively ammonium diet. Spratt (1974) reported that plants respond best to a mixture of ammonium and nitrate nutrition. However, most plants absorb ammonium as well as nitrate. Excess nitrate is stored in the plant as nitrate, while excess ammonium is stored as glutamine and asparagine, common amides, which are not toxic and are easily converted to proteins.

Naftel (1931) reported that corn, (*Zea mays*), cotton (*Gossypium hirsutum* L.) and wheat (*Triticum aestivium* L.) prefer ammonium nitrogen up to the age of 28 days, but after 35 days the reverse is true. These studies also report an increased phosphorus uptake when ammonium replaced nitrate as the nitrogen source. Sulfur, on the other hand, was shown in these studies to decrease in the plant tissue with a nitrate source of nitrogen. Blair et al. (1970) conducted a similar study, but reported that sulfur uptake was increased with an ammonium treatment.

Blair et al. (1970) compared nitrate and ammonium as nitrogen sources for corn in the absence of yield differences and studied the effect of these sources on the uptake of other ions. They reported a higher uptake of nitrogen from the nitrate source, calcium nitrate, than from ammonium hydroxide. However, twenty five percent of the increased nitrogen was stored in the inorganic nitrate ion form in the leaf tissue of the plant.

Naturally this would not increase the actual protein content in the leaf tissue or the grain. They also found a higher phosphorus concentration in leaf tissue from the ammonium treatment which agrees with the findings of other workers.

It is generally agreed that phosphorus banded with ammoniacal fertilizers increases the efficiency and uptake of phosphorus. When this effect was first noticed, it was believed to be the result of increased root proliferation in the area of the bands. Because of a better rooting system, more nutrients were believed to be absorbed. This may explain part of the increased phosphorus uptake but not all of it.

Leonce and Miller (1966) hypothesized that the ammonium ion has a specific effect on phosphate ions ($H_2PO_4^-$, $HPO_4^=$) to transport them across the root symplast into the xylem. This explaination does not seem to explain all the increased phosphorus uptake either and other trains of thought have evolved.

One possibility for both increased phosphorus and sulfur ($SO_4^=$) uptake associated with ammonium nutrition was suggested by Kirkby (1968) and Kirkby and Mengel (1967). This view is based on an anion-cation balance that exists in plants. When plants are grown in a solution containing ammonium, the pH of the solution declines and the phosphorus and sulfur concentrations in the plant increase. The lowering of the solution pH is a result of the expulsion of protons from the plant in order to equalize the anion-cation balance in the plant. Sulfur and phosphorus anions are also absorbed into the plant to bring the system back into balance. When nitrate ions are supplied as the nitrogen source, OH^- and/or HCO_3^- ions are released into the soil solution and calcium, magnesium and potassium cations are brought into the plant to balance the negative charge of the nitrate ion. An indication of this phenomenon is an increase in the pH of the solution caused by the release of the OH^- and HCO_3^- ions.

Another possibility for increased phosphorus absorption by plants subjected to ammonium nitrogen is related to the pH of the soil solution in the rhizosphere and the solubility of different phosphorus compounds in the soil. This theory was postulated by Miller et al. (1970). Using monocalcium phosphate (MCP, $Ca(H_2PO_4)_2 \cdot H_2O$) as the phosphorus source, they showed that a high pH caused phosphorus to precipitate on the roots as dicalcium phosphate (DCP, $CaHPO_4 \cdot 2H_2O$). At a pH of 7.3 the ratio of $H_2PO_4^-$: $HPO_4^=$ ions was 0.8, while lowering the pH to 6.7 increased the ratio to 3.2. The lowering of the pH resulted in the reformation of dicalcium phosphate on the roots to monocalcium phosphate. This reformation provides more $H_2PO_4^-$ ions which are absorbed 10 times faster than $HPO_4^=$ ions (Hagen and Hopkins, 1955).

Effects of Nitrification Inhibitors on Crop Diseases

Another possible benefit from nitrification inhibitors use in crop production is in the area of disease resistance. Nitrogen form has been intensively studied in relation to host nutrition and disease severity for many years. Huber and Watson (1974) state that it is generally the form of nitrogen supplied to the plant, ammonium or nitrate, that affects disease severity and not the amount of nitrogen supplied. There are many interactions involved in determining if disease severity increases, decreases or is unchanged by a specific form of nitrogen. Factors such as temperature, soil pH, time of fertilizer application, plant preference for a certain nitrogen form and crop rotations interact with nitrogen form to influence the severity of crop diseases.

Huber and Watson (1974) compiled a list of common plant diseases and the general effect nitrogen form has on their severity. A few diseases that may be lessened in severity by the plants utilization of ammonium nitrogen are; Diplodia stalk rot of corn, Ophiobolus take-all root rot of wheat and Puccina stripe and stem rust of wheat. Diseases in which the severity is increased by ammonium nitrogen are; Fusarium root rot of wheat, Fusarium stalk rot of corn and Cercosporella eye spot of wheat.

Cephalosporium Stripe

Cephalosporium stripe is a fungal disease with the causal agent being Cephalosporium gramineum. Cereal crops seem to be most affected, with wheat, barley (Hordeum brachyantherum Neuski), oats (Avena sativa L.), rye (Secale cereale L.) and several grasses serving as hosts for Cephalosporium gramineum. Cephalosporium stripe was first reported in Japan in 1931 and has since been detected in many parts of the world (Mathre and Johnston, 1975). It was reported in New York in 1957, Montana in 1959, Illinois in 1960, Michigan in 1966 and was first detected in Kansas in 1972 (Willis and Shively, 1974). The first reported incidence of the disease in Kansas was in Elk county. It has since been reported in the eastern two-thirds of Kansas.

Cephalosporium gramineum is short lived on clean ground but may be present for long periods of time in crop residue. It is usually found in continuous cropped, non-rotated cereal crop areas. Wiese and Ravenscroft (1975) found that the number of *Cephalosporium granineum* propagules per gram of soil decreased in number from 100,000 found in October to February, to less than 5,000 per gram of soil in the May through July period.

Cultural practices that appear to provide a favorable environment for *Cephalosporium gramineum* are large amounts of residue from a previously infected crop in the top three inches of the soil, high soil temperatures following planting, early planting dates, high moisture conditions, low soil pH and overfertilization. Knifed phosphorus applications seem to be most important in *Cephalosporium* stripe infections because of the proliferous root growth near the bands. The symptoms of the disease are not apparent during early spring, suggesting that the infection is a result of spring heaving of the soil. During the spring, freezing and thawing of the soil results in root breakage by which the plants may be infected. Most of the conditions condusive to *Cephalosporium* stripe infection result from proliferous root development during the fall growing period which increases the chances of root injury during the winter (Pool and Sharp, 1969).

The visible symptoms of *Cephalosporium* stripe are long yellowish stripes on the leaves extending to the leaf sheath and a discoloration of the region below the first node of the plant. As the plant matures, the stripes disappear as the entire leaf dies. The discoloration of the stem may resemble freeze injury. The infected plants become stunted with bleached, sometimes sterile heads and shriveled kernels (Willis, 1976).

Cephalosporium stripe infects the vascular system of the plant. After infecting the plant, the xylem becomes plugged with conidial masses which obstructs water movement through the plant. By products of the fungal cells may play a role in the progress of the disease. Spalding et al. (1961) presented evidence of polysaccharides and pectin plugs forming and restricting the vascular flow through the plant.

Losses from Cephalosporium stripe infection of winter wheat may be as high as 70% (Richardson and Rennie, 1970). The loss results from undersized, shriveled kernels and sterile heads. Some cultural factors which seem to aid in the control of the disease are stubble burning, rotation to a non-cereal crop, deep plowing immediately after harvest, late planting dates, lower fall applied fertilizer rates and liming the soil to a near neutral pH.

Nitrification Inhibitors

Many chemicals have been tested as nitrification inhibitors over the years. Research has suggested certain traits necessary for a good nitrification inhibitor. Hauck (1972) discussed these characteristics in detail. The inhibitor should be specific in that it should only inhibit Nitrosomonas growth or activity. Inhibition of Nitrobacter should not occur because such inhibition could cause an undesirable accumulation of nitrite. The inhibitor and its eventual metabolite should be nontoxic to other microflora, animals and plants.

The inhibitor should be persistent and remain active for a sufficiently long period of time, usually several months. For most uses this would hopefully be from the time of fall application until spring. After application, the inhibitor should be mobile in that it it moves with the fertilizer from the initial point of application. Also, the inhibitor should be economically feasible to use as a fertilizer additive.

In light of recent research in regard to nitrification inhibitors, there are several other characteristics which may be desirable. The inhibitor should be compatible with conventional fertilizer application equipment. If farmers are expected to use an inhibitor, it must not be cost prohibitive as far as equipment alterations are concerned. The inhibitor must not weaken, corrode or otherwise render fertilizer equipment unsafe. Also, inhibitors should be applicable to all types of ammoniacal fertilizers, i.e., solids, liquids and anhydrous ammonia.

Bundy and Bremner (1973) tested 24 compounds for their effectiveness as nitrification inhibitors on three soil types ranging from clay loam to sandy clay loam. Each compound was applied at a concentration of 10 ppm to the soil, along with 200 ppm nitrogen as ammonium. The soils were incubated at 30 C for 14 days and analyzed for ammonium, nitrite and nitrate. The average effectiveness of the 14 most potent of the 24 compounds decreased in the following order: 2-chloro-6-(trichloromethyl) pyridine (N-Serve), 4-amino-1,2,4-triazole (ATC), sodium or potassium azide, 2,4-diamino-6-trichloromethyl-5-triazine (CL 1580), dicandiamide, 3-chloro-acetanilide, 1-amino-2-thiourea, 2,5-dichloroaniline, phenyl- mercuric acetate, 3-mercapto-1,2,4-triazole, 2-amino-4-chloro-6-methyl pyrimidine (AM), sulfathiazole (ST), and sodium diethyldithiocarbamate.

This is only a partial list of the many compounds that have been or are being tested as nitrification inhibitors. Some of the other compounds include pyridine derivatives, resin polymer coatings, soil fumigants, neem oil, carbon disulfide, isothiocyanates, guanylthiourea and others. Probably the people doing the most work along this line are the Japanese. At least 10 companies hold patents on chemicals developed specifically for use as nitrification inhibitors in Japan.

In comparisons of various nitrification inhibitors, it must be remembered that biological activity, soil type, temperature, moisture conditions and other environmental factors affect the action of compounds in different ways and to a varying degree. It is the intent of this review to describe several inhibitors, the results obtained with them and to not judge their worth as nitrification inhibitors for particular conditions.

Potassium Azide (KN_3)

The effectiveness of potassium azide (KN_3) and the azide ion (N_3^-) as nitrification inhibitors has been demonstrated. Potassium azide is a nonselective, inorganic biocide which has been shown to be active as a fungicide, herbicide and bactericide. In light of this, information concerning its biological activity in soils as well as its potential as an effective nitrification inhibitor is limited.

At a level of 10 ppm on a dry basis, and after 2, 4 and 8 weeks of incubation, it was found that potassium azide was approximately 90, 85 and 50 percent as effective as nitrapyrin in inhibiting the process of nitrification. Nitrapyrin was more effective at longer incubation periods because of its greater residual activity when applied with anhydrous ammonia. It was found that potassium azide is potentially less phytotoxic in this particular type of application (Parr et al. 1971).

Papendick et al. (1971) evaluated the effectiveness of potassium azide as a nitrification inhibitor for field applied anhydrous ammonia on a Naff silt loam soil in the winter wheat area of eastern Washington. Two months after application, the amounts of nitrate-nitrogen recovered from the retention zone, as a percent of the total extractable nitrogen, were 67, 48 and 36 percent for anhydrous ammonia, anhydrous ammonia plus 2 percent potassium azide and anhydrous ammonia plus 6 percent potassium azide, respectively. They concluded that potassium azide was an effective nitrification inhibitor for use with anhydrous ammonia at the levels of potassium azide studied.

Cochran et al. (1973) evaluated potassium azide and nitrapyrin as nitrification inhibitors for anhydrous ammonia applied on irrigated and dryland silt loam soils in eastern Washington. Both compounds were effective under dryland conditions but potassium azide was completely ineffective following irrigation. This was presumably due to the leaching of the chemical through the soil profile. Nitrapyrin by contrast, was retained in the profile and remained effective. Hughes and Welch (1970) reported potassium azide remained effective at 10 to 30°C but became less effective at higher temperatures.

2-amino-4-chloro-6-methyl pyrimidine (AM)

2-amino-4-chloro-6-methyl pyrimidine (AM) was developed in Japan by Toyo Koatsu Industries Inc. Chemical decomposition occurs under field conditions and can be formulated with most fertilizers except acidic materials such as superphosphate. AM is specific in respect to nitrification activity and is low in toxicity to other organisms. Toxic concentrations are reported to be in the 10-30 ppm range for most crops. The recommended rates average 1.5 to 3.0 for most conditions. The half-life of AM in several soils varied from 15-60 days, as reported by researchers in Japan. AM is adsorbed by soil organic matter rather than by the colloidal fractions of the soil (Hauck, 1972).

There are factors which may reduce AM effectiveness under field conditions. Some nitrification occurs in the presence of AM and produces a local acidic condition which may hasten AM decomposition. While selective in the inhibition of *Nitrosomonas* growth, it is not as selective as nitrapyrin and reinfestation of nitrifying bacteria may occur relatively fast. Papendick et al. (1968) reported that AM was not as effective a nitrification inhibitor as nitrapyrin when applied at equal concentrations. However, in 1968, 15,400 metric tons of compound fertilizers (NPK) were ammended with 0.3 percent AM (Hauck, 1972).

Carbon Disulfide (CS_2)

Carbon disulfide has been studied as a potential nitrification inhibitor. Ashworth et al. (1975) reported carbon disulfide as being very cheap and a very potent nitrification inhibitor in closed systems. Using a rate of 260 kg N/ha with the addition of 2.7 kg nitrapyrin and 15 kg carbon disulfide, the amount of nitrate produced was measured for 60 days following injection. Anhydrous ammonia and aqua ammonia were the ammonium carriers. For the first 50 days, no nitrate nitrogen was produced in the bands containing the carbon disulfide while the nitrapyrin treatments had intermediate amounts of nitrate present. It was also reported that carbon disulfide diffused through the soil at a faster rate than nitrapyrin.

2-chloro-6-(trichloromethyl) pyridine (N-Serve)

Possibly the most promising of all the prospective nitrification inhibitor compounds tested to date is 2-chloro-6-(trichloromethyl) pyridine (N-Serve) or nitrapyrin. Developed in the early 1950's by the Dow Chemical Company, it is now marketed under the trade name N-Serve and was formerly known as Dowco 160. Work was being conducted with chlorinated pyridines when it was discovered that some of these compounds were active toward the inhibition of Nitrosomonas bacteria activity. Eventually the compounds nitrapyrin, as well as a herbicide now known as Tordon, were developed.

The active ingredient of N-Serve, 2-chloro-6-(trichloromethyl) pyridine, is a white crystalline powder having a molecular weight of 230.9 and a melting point of 63°C. Two types of N-Serve are available. N-Serve 24 is soluble in anhydrous ammonia with the carrier of the active ingredient being xylene. N-Serve 24E is soluble in water and is used in formulating solutions such as urea-ammonium nitrate or other water based ammoniacal fertilizers. Both types contain 294 grams of active ingredient per liter of N-Serve.

As early as 1962, Sweezy and Turner (1962) reported yield increases with the addition of N-Serve to ammonium and urea fertilizers. Using varying rates of from 0.125 to 2.0 percent of the applied nitrogen, they realized increased growth and yields in cotton, sweet corn and sugar beets (**Beta vulgaris**). The reason for the increase was attributed to a reduction of leaching. Huber et al. (1969) working with winter wheat in northern Idaho studied the effects of N-Serve on ammonium and nitrate concentrations in the soil as well as yields. N-Serve significantly increased the amount of ammonium in the soil profile in the spring following fall fertilization with ammonium sulfate. Yields were also increased by the addition of N-Serve.

Sabey (1968) reported that N-Serve suppressed nitrification during early spring when fertilizers were applied in November. Boswell and Anderson (1974) conducted a similar study using polyethylene bags and found that N-Serve delayed the nitrification process for at least a four month period when used with ammonium nitrate.

Working with a sandy loam soil, Page (1975) found that the rate of decay for ammonium was approximately 1 percent per day at 0 C and had a Q_{10} of 2.1. However, if N-Serve was added to the soil, the rate of nitrification was halved. Along this same line, Redeman et al. (1964) found that the half-life of N-Serve varied from 4 to 22 days. He also found that high organic matter content, heavy soil texture and a high pH lowered the half-life of N-Serve under field conditions.

Using an Urrbrae soil in Australia, Lewis and Stefanson

(1975) found that pasture soils required a N-Serve concentration equal to 5.0 percent of the applied nitrogen to inhibit the nitrification process. In a frequently cropped soil, a 0.2 percent concentration was effective. This may partially be explained by a higher organic matter content and a lower carbon to nitrogen ratio in the cropped soil. Some organic matter is necessary to adsorb the N-Serve, while an excessive amount of organic matter may bind it too tightly and render it useless in inhibiting the nitrification process.

While it has been shown that N-Serve is an effective, mobile and sufficiently persistant nitrification inhibitor, it has also been demonstrated to be non-toxic to plants, microbial life and animals. The toxicity of the chemical is reported to be low, with acute lethal dosages of 1.2, 0.7 and 1.09 grams per kilogram of body weight for rats, mice and rabbits (Turner and Goring, 1966). Laskowski et al. (1975) found that N-Serve has no effect on fungi or bacteria at a 1-10 ppm concentration and produced only small reductions in colony numbers at 100-1000 ppm.

Numerous field tests conducted with N-Serve have demonstrated that rates of several pounds per acre were non-toxic to organisms other than Nitrosomonas, including seedlings of higher plants. N-Serve degrades to 6-chloropicolinic acid, its principle metabolite, which seems to have even less phytotoxic effect than N-Serve with the possible exceptions of effects on cotton, soybeans (Glycine max L.), alfalfa (Medicago sativa L.) and sugar beets (Geronimo et al., 1973).

Grunes (1959) cited several investigators who have reported greater phosphorus absorption when the nitrogen was in the ammonium rather than the nitrate form. Nielson et al. (1967) reported that the plant uptake of phosphorus was greater with the addition of N-Serve than without. With a 57.6 ppm phosphorus treatment, added as monocalcium phosphate, the plant tissue contained 0.48 percent phosphorus with N-Serve and 0.30 percent in the tissue without N-Serve. However the percent nitrogen in the tissue decreased from 2.5 percent to 2.0 percent with the incorporation of N-Serve.

The mode of action of N-Serve is not completely understood. Campbell and Aleem (1965) presented evidence that the action of N-Serve affects that component of cytochrome oxidase, found in Nitrosomonas, which is involved in ammonium oxidation. By the same token, the nitrite activating enzyme "nitrite-cytochrome c reductase" was scarcely affected by recommended rates of N-Serve with the possibility of a slight stimulation of the enzyme activity. It is suggested that N-Serve exhibits a chelating action upon the copper (Cu^{++}) component of the cytochrome oxidase enzyme effective in ammonium oxidation. This effect can be shown, by the reversion of the inhibition effect, by adding sufficient copper to the system. Another effect may involve the inhibition of the chemosynthetic reactions dependent upon ammonium oxidation coupled with phosphorylation.

Research to date indicates that N-Serve may also be an effective tool in regard to plant disease control. Scott et al. (1975) reported on work conducted on a silt loam soil in Sullivan county, Indiana in regard to the effect of N-Serve on take-all root rot in wheat and stalk rot in corn. At 134 kg N/ha, there was a 26 percent reduction of stalk rot in corn with the addition of N-Serve and at 224 kg N/ha plus N-Serve there was a reduction of 8 percent in the number of "white heads", an indication of take-all root rot in wheat.

N-Serve Safety Factors

There may be an equipment hazard associated with the use of N-Serve. Anhydrous ammonia is corrosive to aluminum and aluminum alloys in the liquid phase. Recent work has shown that the addition of any additive besides water will increase the rate of corrosion. The effects of addition of N-Serve to anhydrous ammonia may be more severe if the valves and fittings are made of aluminum or aluminum alloys. This reaction may cause these parts to fail to function properly. This corrosion occurs only in the liquid phase and not in the vapor phase, because N-Serve has a much lower vapor pressure than anhydrous ammonia.

The most severely affected component of application equipment is the liquid level gauge since it is partially submerged in liquid anhydrous ammonia. Equipment should be thoroughly inspected for corrosion, pitting and other indications of possible equipment failure. Anhydrous ammonia solutions containing N-Serve should never be stored longer than 3 weeks. When replacing equipment for N-Serve use, pieces such as gauges and floats should be replaced with either stainless or mild steel components. Teflon gaskets should be used on all fittings and couplings that will come in contact with the N-Serve solutions (Anonymous, 1976).

Objectives

N-Serve has been demonstrated to be safe, effective, specific, mobile and non-toxic as a nitrification inhibitor under certain conditions. It is also reasonably economical to use when applied at the recommended rates of 0.56 to 1.12 kg A.I. per hectare. The cost will be approximately $ .80 to $ 1.60 per hectare when these rates are followed.

However, in light of the research indicating the effectiveness of N-Serve, more information is needed on the feasibility of using N-Serve with anhydrous ammonia and urea-ammonium nitrate solution (UAN) in the winter wheat area of the Plains States. Despite indications of increased efficiency of ammonium fertilizers with the addition of N-Serve in northern Idaho and eastern Washington, studies were needed in Kansas to ascertain the value of including N-Serve as a management tool in winter wheat production.

Objectives of these studies were:

1) To compare the efficiency of ammoniacal fertilizers for winter wheat with and without the addition of N-Serve.

2) To measure effects of N-Serve on grain yield of winter wheat under dryland conditions.

3) To determine the effect of N-Serve on the grain protein content of winter wheat when grown with and without N-Serve.

4) To investigate effects of N-Serve on nutrient uptake by winter wheat plants.

5) To study the severity of Cephalosporium stripe

(*Cephalosporium gramineum* L.) infection of winter wheat as affected by N-Serve, varietal differences and other cultural practices.

6) To investigate effects of N-Serve on a nitrogen-phosphorus interaction, in the soil, in winter wheat production.

MATERIALS AND METHODS

Field Studies

Several types of studies were conducted at a total of eleven sites for the 1976 and 1977 wheat crops. The sites were located in Harper, Sedgwick, Stafford, McPherson (2), Labette, Harvey, Riley, Dickinson, Ellsworth and Reno counties in Kansas. N-Serve studies were located in six of the counties, nitrogen-phosphorus methods of application studies were located in five counties and *Cephalosporium* stripe infection studies were located in two counties. Soil analyses for each location was run by the Soil Testing Laboratory at Kansas State University. Soil test data and general information of the soils are described in Table 1.

N-Serve Field Studies

Several types of N-Serve studies were conducted during the 1976 and 1977 crop years. The first type of study was conducted in Harper, Stafford and Riley counties in 1976, and Stafford, Harvey and Labette counties in 1977. A randomized complete block design with four replications was utilized to compare nitrogen rate, nitrogen source and time of nitrogen application. Nitrogen rates were 34, 67 and 101 kg N/ha. The nitrogen carriers were anhydrous ammonia (82-0-0), anhydrous ammonia plus N-Serve and urea (45-0-0). The anhydrous ammonia with and without N-Serve was applied pre-plant in the fall while the urea was applied as a topdress in late winter. N-Serve 24 was applied at a rate of 0.56 kg active ingredient (A.I.) per 101 kg of

Table 1. GENERAL SOIL DESCRIPTION AND SOIL TYPE

Location	County	Soil Type	Soil Depth (cm)	Organic Matter	pH	PPM P	PPM K	PPM N
Ashland Agronomy Farm	Riley	Muir sil	0-15	1.4	6.2	15.5	165	5.0
		Pachic Haplustoll	15-60	1.1	6.7	8.0	160	3.0
Sandyland Exper. Field	Stafford	Naron lfs	0-15	0.7	6.2	22.0	99	3.6
		Udic Argiustoll	15-60	0.4	6.3	12.0	82	6.0
Galen Horn Farm	McPherson	Goessel sicl	0-15	1.7	5.8	41.5	265	14.7
		Udic Pellustert	15-60	1.3	6.5	6.5	237	9.6
Dennis Baker Farm	Harper	Bethany sil	0-15	1.3	6.0	3.0	151	5.0
		Pachic Paleustoll	15-60	1.0	6.6	0.0	111	1.8
Heston Exper. Field	Harvey	Goessel sicl	0-15	2.0	6.1	17.5	250	11.0
		Udic Pellustert	15-60	1.2	6.9	3.5	250	3.1
Parsons Exper. field	Labette	Parsons sil	0-15	2.2	5.5	4.0	69	5.2
		Mollic Albaqualf	15-60	1.6	5.2	1.5	50	3.6
Del Knackstedt Farm	McPherson	Butler sil	0-15	1.9	5.9	24.0	270	4.9
		Abruptic Argiaquoll	15-60	1.3	7.0	2.5	265	1.2
South Central Exper. Field	Reno	Grant sil	0-15	1.2	6.0	13.0	237	7.0
		Udic Argiustoll	15-60	0.9	6.9	8.0	262	4.0
Leroy Huseman Farm	Ellsworth	Hastings sil	0-15	1.5	6.0	5.5	260	17.7
		Udic Argiustoll	15-60	0.9	6.3	2.5	225	4.8
Jared Hoover Farm	Dickinson	Hastings sil	0-15	2.0	6.1	10.5	250	2.8
		Udic Argiustoll	15-60	1.8	6.5	4.0	250	1.8
Henry Schmitz Jr. Farm	Sedgwick	Kay sil	0-15	2.2	5.7	56.0	300	7.0
		(not classified)	15-60	1.7	6.2	15.0	202	4.9

Table 1. (continued) GENERAL SOIL DESCRIPTION AND SOIL TYPE

Location	County	Soil Type	Soil Depth (cm)	Organic Matter	pH	PPM P	PPM K	PPM N
Greenhouse study	Wallace	Richfield sil Aridic Argiustoll	0-15	0.5	8.0	2.0	355	1.0
Greenhouse study	Riley	Tivoli sand Typic Ustipsamments	0-15	0.1	8.2	7.0	48	0.1
Greenhouse study	Shawnee	Sarpey ls Typic Udipsamments	0-15	0.6	7.2	18.0	136	1.6

actual nitrogen applied (Table 2 and Table 3).

Plot dimensions were 9.1 meters (m) long by 3.0 m wide. A 9.1 m alley separated the four replications. Pre-plant fertilizer applications were applied during the middle of August while topdressings were applied during the first week of February.

The plots were seeded to Eagle variety winter wheat at the Harper and Stafford county sites while the Riley county site was seeded to Centurk at a rate of 67 kg/ha. The wheat was sown in early October, using a 1.5 m Ontario drill at all locations. The plots were mechanically harvested during the first of July during both years.

Anhydrous ammonia with and without N-Serve was applied by fitting a John Blue nitrolator to a 2.3 m wide shank applicator. Five knife injectors spaced 0.46 m apart were mounted to the applicator. N-Serve was applied by dissolving 103 ml of the nitrification inhibitor in 13.4 kg of liquid anhydrous ammonia. A 19 liter tank complete with all hardware and furnished by the Phillips Petroleum Company, was used to mix and dispense the N-Serve and anhydrous ammonia (Fig. 1). The urea was applied as a conventional treatment on the soil surface by using a 2.4 m Barber metered-flow dry fertilizer applicator (Fig. 2). The center 2.4 m of each plot was fertilized in each type of application.

Leaf tissue samples were collected monthly from March through May at the Stafford and Riley county sites in 1976. Extremely dry weather at the Harper county location prevented the spring growth needed for leaf tissue sampling. In 1977, only two samplings were collected at the Stafford and Labette county

Table 2. TREATMENTS FOR THE N-SERVE - ANHYDROUS AMMONIA - UREA STUDIES. (1976 and 1977)

N-Rate kg/ha	Nitrogen Carrier	Time of Application
0	---	-----
34	NH_3	Pre-plant
67	NH_3	Pre-plant
101	NH_3	Pre-plant
34	NH_3+N-Serve	Pre-plant
67	NH_3+N-Serve	Pre-plant
101	NH_3+N-Serve	Pre-plant
34	Urea	Topdress
67	Urea	Topdress
101	Urea	Topdress

Table 3. TREATMENTS FOR THE N-SERVE -ANHYDROUS AMMONIA - UAN SOLUTION STUDY. (1977)

N-Rate kg/ha	Nitrogen Carrier	Time of Application
0	---	-----
34	NH_3	Pre-plant
67	NH_3	Pre-plant
101	NH_3	Pre-plant
34	NH_3+N-Serve	Pre-plant
67	NH_3+N-Serve	Pre-plant
101	NH_3+N-Serve	Pre-plant
34	UAN Solution	Topdress
67	UAN Solution	Topdress
101	UAN Solution	Topdress

Fig. 1. Rolling coulter anhydrous ammonia applicator used for spring anhydrous ammonia applications and 19 liter ammonia tank used for N-Serve applications.

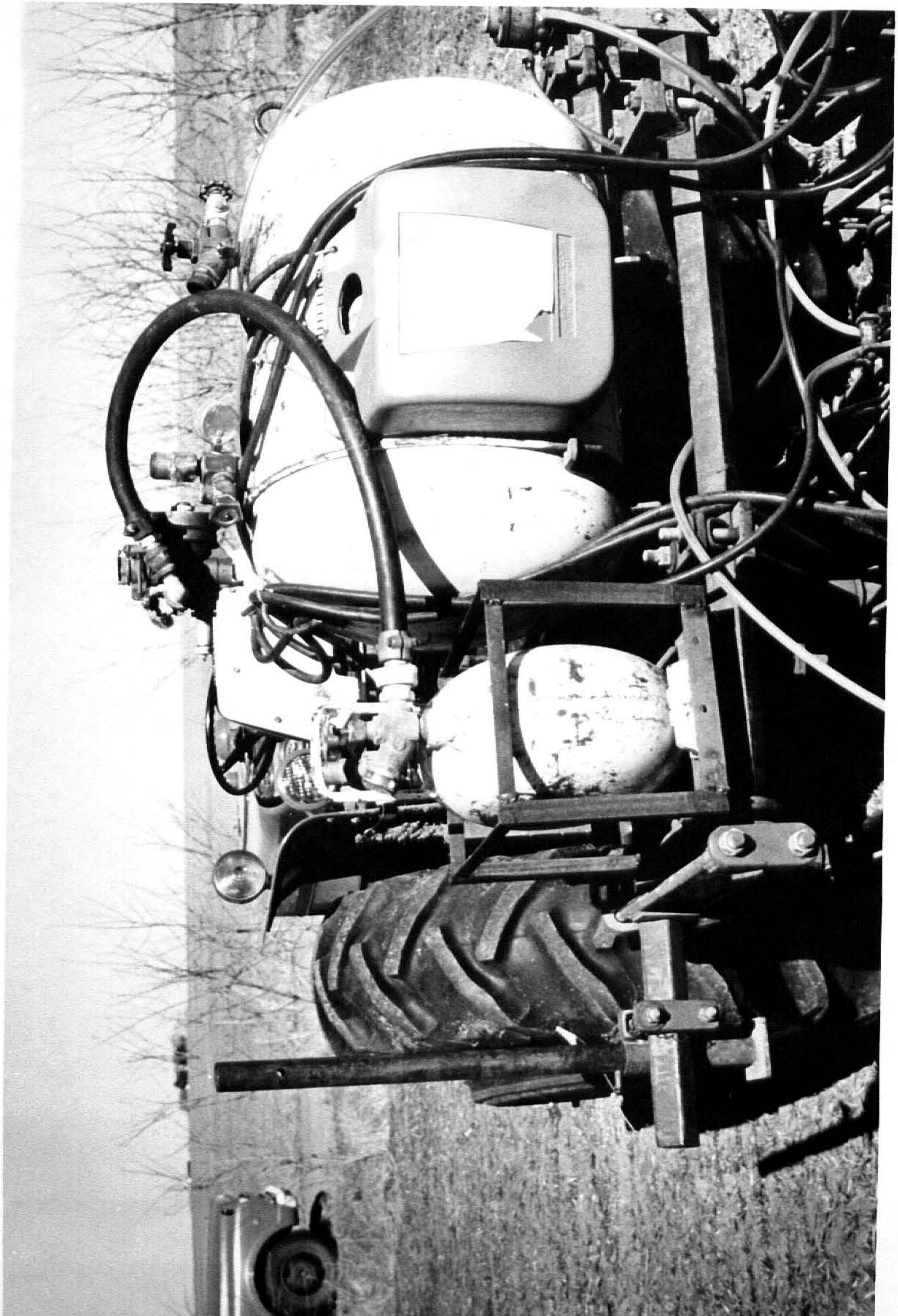
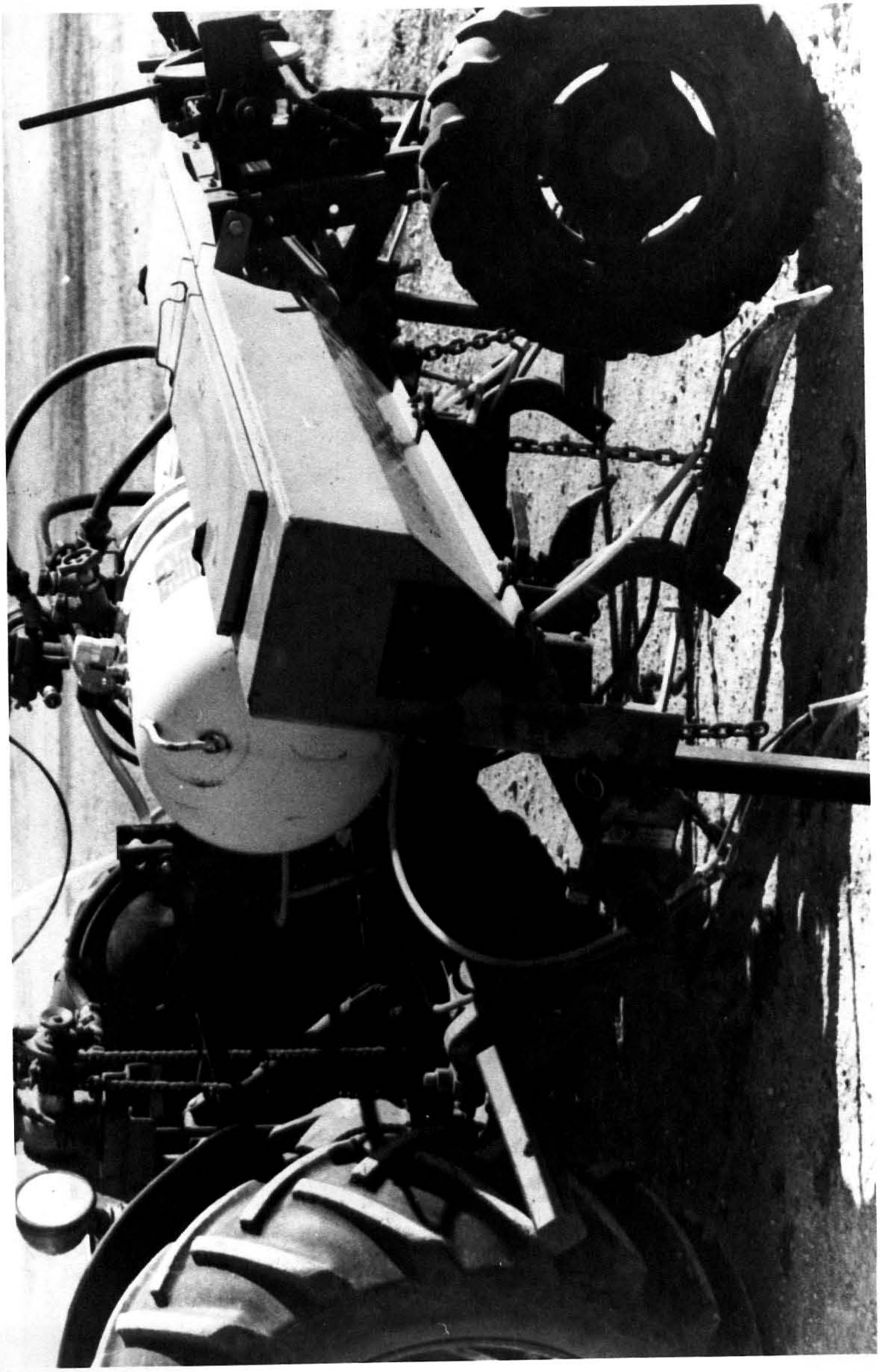


Fig. 2. Combination dry fertilizer applicator, anhydrous ammonia shank applicator and UAN solution applicator mounted on Massey Ferguson 135 tractor.



sites due to the early maturity of the wheat crop. Dry weather prevented collection of leaf tissue samples at the Harvey county location in 1977.

Plots were mechanically harvested using a Massey Ferguson 35 combine which was altered by Kansas State University Agronomy Farm personnel. A strip 1.8 m wide was harvested from the center of each plot. The grain harvested from each plot was weighed on the combine. After the weight was recorded, a sample of the grain was placed in a plastic bag to be used for moisture determination and chemical analysis. The procedure for the preparation and analysis of leaf tissue and grain samples will be discussed in a later section.

A second type of N-Serve study was conducted at the McPherson (#1) county site in 1976. A randomized complete block design with three replications was used to compare nitrogen rate, nitrogen source, varietal differences and time of nitrogen application. Nitrogen rates of 50 and 101 kg N/ha were achieved by applying calcium nitrate (15.5-0-0), anhydrous ammonia and anhydrous ammonia plus N-Serve. The fertilizers were applied in the fall as pre-plant treatments or in late winter as topdress applications (Table 4). Spring anhydrous ammonia, with and without N-Serve, was applied by using a rolling coulter ammonia applicator which resulted in minimal damage to the wheat stand (Fig. 1).

Two winter wheat varieties, Eagle and Sturdy, were sown on September 23 at a rate of 67 kg/ha. Individual plots measured 9.1 m long and 3.0 m wide. Leaf tissue samples were collected on May 5. Also on May 5, ratings on the severity of Ceph-

Table 4. TREATMENTS FOR THE 1976 N-SERVE - CEPHALOSPORIUM STRIPE STUDY.

N-Rate kg/ha	Nitrogen Carrier	Variety	Time of Application
0	----	Sturdy	-----
0	----	Eagle	-----
50	$Ca(NO_3)_2$	Sturdy	Pre-plant
101	$Ca(NO_3)_2$	Sturdy	Pre-plant
50	NH_3	Sturdy	Pre-plant
101	NH_3	Sturdy	Pre-plant
50	NH_3+N-Serve	Sturdy	Pre-plant
101	NH_3+N-Serve	Sturdy	Pre-plant
50	$Ca(NO_3)_2$	Sturdy	Spring
101	$Ca(NO_3)_2$	Sturdy	Spring
50	NH_3	Sturdy	Spring
101	NH_3	Sturdy	Spring
50	NH_3+N-Serve	Sturdy	Spring
101	NH_3+N-Serve	Sturdy	Spring
50	$Ca(NO_3)_2$	Eagle	Pre-plant
101	$Ca(NO_3)_2$	Eagle	Pre-plant
50	NH_3	Eagle	Pre-plant
101	NH_3	Eagle	Pre-plant
50	NH_3+N-Serve	Eagle	Pre-plant
101	NH_3+N-Serve	Eagle	Pre-plant
50	$Ca(NO_3)_2$	Eagle	Spring
101	$Ca(NO_3)_2$	Eagle	Spring
50	NH_3	Eagle	Spring
101	NH_3	Eagle	Spring
50	NH_3+N-Serve	Eagle	Spring
101	NH_3+N-Serve	Eagle	Spring

alosporium stripe infection were made. The procedure for making these ratings is discussed in a later section. The plots were mechanically harvested and grain samples saved for protein analysis.

For the 1977 wheat crop, a study was initiated at the McPherson (#2) county site. This study compared nitrogen rate, nitrogen source and time of nitrogen application in a randomized complete block design with three replications. Nitrogen rates were 34, 67 and 101 kg N/ha applied as anhydrous ammonia, anhydrous ammonia plus N-Serve and urea-ammonium nitrate solution (UAN solution, 28-0-0). Anhydrous ammonia and anhydrous ammonia plus N-Serve were applied pre-plant while UAN solution was applied as a topdressing in late winter (Table 3). The UAN solution was applied through the use of a John Blue positive displacement solution pump mounted on the tractor. The Massey Ferguson tractor was equipped with a ground speed dependent power take off which eliminated variation in fertilizer coverage because of varying ground speeds. The solution was applied through five nozzles mounted on the tool bar and connected to the pump.

Plot dimensions were 3.0 m wide and 20.1 m long with a 4.6 m alley separating the three replications. Leaf tissue samples were collected on April 4 and again on May 5 and prepared for chemical analysis. The grain was mechanically harvested during mid-July and samples saved for later analysis.

At the McPherson (#1) county site, a randomized complete block design with three replications was conducted in 1977. Nitrogen rate, nitrogen source and varietal differences were evaluated in regard to the effectiveness of N-Serve. The nitrogen rates examined were 34, 67 and 101 kg N/ha. The nitrogen sources were anhydrous ammonia and UAN solution (Table 5). N-Serve was mixed at a rate of 0.56 kg A.I. per 101 kg of actual nitrogen applied per hectare. For the UAN solution, N-Serve 24E was mixed at a rate of 6.73 ml of N-Serve per liter of UAN solution. Two hundred sixty-three, 527 and 790 ml of this solution was applied per plot for the 34, 67 and 101 kg N/ha treatments. The UAN formulations were applied by knifing the solution to a depth of five inches, a depth comparable to the anhydrous ammonia applications. The shanks of the applicator were fitted with a tube that paralleled the anhydrous ammonia tubes. These tubes were then connected to a John Blue solution pump.

Two winter wheat varieties, Eagle and Sturdy, were planted in the 3.0 by 9.1 m plots. Leaf tissue samples were collected on April 4 and May 5. Due to extremely wet weather during the spring, harvesting of the study was not possible. Excess weed growth also resulted in no Cephalosporium stripe severity ratings being taken.

Cephalosporium Stripe Field Studies

Cephalosporium stripe control studies were conducted at two locations during 1976 and 1977. Two studies conducted at the McPherson (#1) county location were incorporated in the N-Serve studies previously discussed.

Another type of study was located at the McPherson (#1) and Sedgwick county sites during 1976. A factorial, randomized complete block design with three replications was utilized at both locations. These studies compared seven varieties of win-

Table 5. TREATMENTS FOR THE 1977 N-SERVE - <u>CEPHALOSPORIUM</u> STRIPE STUDY.

N-Rate kg/ha	Nitrogen Carrier	N-Serve	Time of Application
0	---	No	---------
0	---	Yes	Pre-plant
34	NH_3	No	Pre-plant
67	NH_3	No	Pre-plant
101	NH_3	No	Pre-plant
34	NH_3	Yes	Pre-plant
67	NH_3	Yes	Pre-plant
101	NH_3	Yes	Pre-plant
34	UAN	No	Pre-plant
67	UAN	No	Pre-plant
101	UAN	No	Pre-plant
34	UAN	Yes	Pre-plant
67	UAN	Yes	Pre-plant
101	UAN	Yes	Pre-plant

ter wheat and four nitrogen rates with the incidence and severity of Cephalosporium stripe infection (Table 6). Seven varieties including Sage, Sturdy, Centurk, Tam 101, Cloud, Eagle and Gage were planted at a rate of 67 kg/ha during the latter part of September. The nitrogen rates were 0, 34, 67 and 101 kg N/ha applied as topdress urea in late winter. 60 kg/ha of diammonium phosphate (18-20-0) was starter banded with the seed at drilling time.

An identical study was conducted at a Sedgwick county site but included burning of the previous wheat crop stubble. The stubble was burned immediatly after harvesting the 1974-1975 wheat crop. The burned and unburned stubble studies were adjacent to each other with a 49 m alley separating the two studies. The studies were then treated in the same manner.

On May 5, visual ratings on the severity of Cephalosporium stripe infection were made. With help from William G. Willis, Extension Plant Pathologist from Kansas State University, a scale of from 1 to 10 was utilized. A reading of 0 indicated no visual evidence of Cephalosporium stripe infection, while a reading of 10 indicated that every plant in the plot had visual signs of Cephalosporium stripe infection. The plots were mechanically harvested during mid-July. A sample of the grain was saved for chemical analysis.

McPherson (#1) and Sedgwick counties were the sites of Cephalosporium stripe disease studies again in 1977. Nitrogen rates, winter wheat varieties, planting dates and the burning of the previous crop's residue were compared to the incidence and severity of Cephalosporium stripe infection. The stubble

Table 6. TREATMENTS FOR THE 1976 *CEPHALOSPORIUM* STRIPE WINTER WHEAT STUDIES.

N-Rate kg/ha	Time of Application	Variety
0	Spring	Sage
0	Spring	Sturdy
0	Spring	Centurk
0	Spring	Tam 101
0	Spring	Cloud
0	Spring	Eagle
0	Spring	Gage
34	Spring	Sage
34	Spring	Sturdy
34	Spring	Centurk
34	Spring	Tam 101
34	Spring	Cloud
34	Spring	Eagle
34	Spring	Gage
67	Spring	Sage
67	Spring	Sturdy
67	Spring	Centurk
67	Spring	Tam 101
67	Spring	Cloud
67	Spring	Eagle
67	Spring	Gage
101	Spring	Sage
101	Spring	Sturdy
101	Spring	Centurk
101	Spring	Tam 101
101	Spring	Cloud
101	Spring	Eagle
101	Spring	Gage

was burned immediately following the harvesting of the 1975-76 wheat crop. A factorial, randomized complete block design with three replications was used at each site (Table 7).

The nitrogen rates were 0, 34, 67 and 101 kg N/ha applied as topdress urea in late winter. 60 kg/ha of diammonium phosphate was applied as a banded starter at drilling time. Sturdy, Eagle and Gage were planted on September 20 and October 10. No Cephalosporium stripe severity ratings were taken, due to wet weather and various other diseases present in the studies. The studies in Sedgwick county were mechanically harvested in July.

Nitrogen-Phosphorus Methods of Application Studies

A study comparing methods of nitrogen and phosphorus application for winter wheat was conducted in Harper county in 1975 and 1976. Methods of phosphorus application were knifed, surface applied and drilled. The drilled treatments were applied while seeding and the fertilizer was applied in direct seed contact. Nitrogen was applied as anhydrous ammonia when the nitrogen was knifed or as UAN solution (32-0-0) when applied as a surface treatment. The phosphorus carrier was ammonium polyphosphate (APP, 11-16-0) and was applied simultaneously with the anhydrous ammonia, surface applied by broadcasting over the soil surface or drilled with the seed. Phosphorous was applied at 12 and 24 kg P/ha while the nitrogen rate was 84 kg N/ha. All surface applied applications were immediately incorporated into the soil by disking (Table 8).

Plot dimensions were 9.1 m long and 3.0 m wide with a 6.1 m alley separating the four replications. Leaf tissue samples were

Table 7. TREATMENTS FOR THE 1977 <u>CEPHALOSPORIUM</u> STRIPE WINTER WHEAT STUDIES.

N-Rate kg/ha	Time of Application	Variety	Date of Planting
0	Spring	Sturdy	Sept. 20
0	Spring	Sturdy	Oct. 10
0	Spring	Eagle	Sept. 20
0	Spring	Eagle	Oct. 10
0	Spring	Gage	Sept. 20
0	Spring	Gage	Oct. 10
34	Spring	Sturdy	Sept. 20
34	Spring	Sturdy	Oct. 10
34	Spring	Eagle	Sept. 20
34	Spring	Eagle	Oct. 10
34	Spring	Gage	Sept. 20
34	Spring	Gage	Oct. 10
67	Spring	Sturdy	Sept. 20
67	Spring	Sturdy	Oct. 10
67	Spring	Eagle	Sept. 20
67	Spring	Eagle	Oct. 10
67	Spring	Gage	Sept. 20
67	Spring	Gage	Oct. 10
101	Spring	Sturdy	Sept. 20
101	Spring	Sturdy	Oct. 10
101	Spring	Eagle	Sept. 20
101	Spring	Eagle	Oct. 10
101	Spring	Gage	Sept. 20
101	Spring	Gage	Oct. 10

Table 8. TREATMENTS FOR THE 1975 AND 1976 METHODS OF N AND P APPLICATION FOR WINTER WHEAT.

N-Rate kg/ha	P-Rate kg/ha	Application N Method	P Method
0	0	---	---
84	0	Knife	---
84	0	Surface	---
84	12	Knife	Knife
84	12	Surface	Surface
84	12	Knife	Drilled
84	12	Surface	Drilled
84	24	Knife	Knife
84	24	Surface	Surface
84	24	Knife	Drilled
84	24	Surface	Drilled

Table 9. TREATMENTS FOR THE 1977 METHODS OF N AND P APPLICATION FOR WINTER WHEAT.

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N Method	P Method
0	0	---	-----	-----
84	0	NH_3	Knife	-----
84	0	UAN	Knife	-----
84	0	UAN	Broadcast	-----
84	0	UAN	Dribble	-----
84	20	NH_3	Knife	Knife
84	20	UAN	Knife	Knife
84	20	NH_3	Knife	Broadcast
84	20	UAN	Knife	Broadcast
84	20	UAN	Broadcast	Broadcast
84	20	UAN	Dribble	Dribble
84	20	NH_3	Knife	Band
84	20	UAN	Knife	Band
84	20	UAN	Broadcast	Band
84	20	UAN	Dribble	Band
84	20	NH_3+N-Serve	Knife	Knife

taken on April 1 in 1975, but were not taken in 1976 due to extremely dry weather. The plots were mechanically harvested both years during mid-July. Grain samples were saved from the 1976 harvesting to be analyzed for phosphorus and grain protein.

In 1977, similar methods of nitrogen and phosphorus application studies were located in Dickinson, Labette, Ellsworth and Reno counties on winter wheat. A randomized block design with four replications was used to compare phosphorus rate, methods of phosphorus application, nitrogen source and methods of nitrogen application. The methods of phosphorus and nitrogen application were knife, broadcast and dribble. The nitrogen sources were UAN solution and anhydrous ammonia. In addition, one plot received N-Serve in combination with anhydrous ammonia (Table 9). N-Serve was added at a rate of 0.56 kg A.I./ha. Dribble applications of UAN solution was applied by removing the nozzles from the boom sprayer and allowing the solution to "dribble" from the nozzle openings on 0.46 m centers.

The phosphorus source was ammonium polyphosphate (APP, 11-16-0). Phosphorus was applied at a rate of 20 kg P/ha, while nitrogen was applied at a rate of 84 kg N/ha. All fertilizers were applied pre-plant the previous August.

Plot dimensions were 3.0 m wide by 9.1 m long with a 3.1 m alley separating the replications. Leaf tissue samples were collected April 1 and prepared for chemical analysis. The plots were mechanically harvested during the first part of July and a sample of the grain saved for protein analysis and phosphorus determination.

Greenhouse and Growth Chamber Studies

Greenhouse (3) and growth chamber (1) studies were conducted to determine the effectiveness of N-Serve's inhibition effect on nitrification, N-Serve effects on dry matter production and N-Serve effects on nitrogen, phosphorus, potassium and sulfur availability and uptake when injected into the nitrogen retention zone. The first study was initiated on April 24, 1976. Using a completely randomized design with three replications, anhydrous ammonia, anhydrous ammonia with N-Serve, phosphorus and sulfur additions to the soil were compared. Anhydrous ammonia with and without the addition of N-Serve was applied at rates of 30, 60 and 90 parts per million (ppm) to the soil. When phosphorus and sulfur were added as fertilizer treatments, they were applied at raes of 40 and 20 ppm respectively (Table 10). APP was used as the phosphorus source while ammonium thiosulfate (ATS, 12-0-0-26) was used as the sulfur carrier.

Two kilo grams of soil were placed in plastic containers measuring 15 cm in diameter and 19 cm high. A complete description and analysis can be found in Table 1. The soil was dried and sieved through a 0.65 cm mesh screen to remove all debris and oversized soil particles before weighing and being placed in the containers. One hundred-fifty ml of distilled-deionized water was added to each pot of soil and allowed to equilibrate for two days to insure uniform wetting of the soil.

ATS,APP and urea were injected into each pot with a 10 ml graduated syringe fitted with a needle 8 cm long. The injection of these fertilizers simulated knifing of the nutrients into the same retention zone as would be found in dual knife applic-

Table 10. TREATMENTS FOR THE 1976 GREENHOUSE AND GROWTH CHAMBER STUDIES.

N-Rate ppm	Nitrogen Carrier	P-Rate ppm	S-Rate ppm
0	---	0	0
30	NH_3	0	0
30	NH_3	40	0
30	NH_3	40	20
60	NH_3	0	0
60	NH_3	40	0
60	NH_3	40	20
90	NH_3	0	0
90	NH_3	40	0
90	NH_3	40	20
30	NH_3+N-Serve	0	0
30	NH_3+N-Serve	40	0
30	NH_3+N-Serve	40	20
60	NH_3+N-Serve	0	0
60	NH_3+N-Serve	40	0
60	NH_3+N-Serve	40	20
90	NH_3+N-Serve	0	0
90	NH_3+N-Serve	40	0
90	NH_3+N-Serve	40	20

ations in the field. The needle was inserted into the center of the pot 8 cm deep. The ATS was applied at a rate of 0.11 ml per pot by diluting 2.2 ml of ATS to 100 ml with distilled-deionized water and injecting 5 ml of the diluted solution into each pot. This resulted in 9 ppm nitrogen and 20 ppm sulfur being applied to each pot. The APP was applied at a rate of 0.16 ml of APP per pot by diluting 3.26 ml of APP to 100 ml and injecting 5 ml of the diluted solution into each pot. This application resulted in 40 ppm phosphorus and 12 ppm nitrogen being applied to each pot.

Urea was used to balance the nitrogen applied by the ATS and APP. For the treatments receiving only anhydrous ammonia, 0.90 grams of urea was added to each pot. 1.8 grams of urea was dissolved in 100 ml of distilled-deionized water and 5 ml of this solution was injected into these pots. For the treatments receiving anhydrous ammonia and APP, 0.04 grams of urea was added to each pot by dissolving 0.78 grams of urea in 100 ml of distilled-deionized water and injecting 5 ml of this solution into these pots. The pots receiving anhydrous ammonia, ATS and APP received no additional nitrogen as urea. The amount of water added to each pot was balanced by injecting 5 ml of water into the pots receiving APP and anhydrous ammonia. Ten ml of water was injected into the pots receiving only anhydrous ammonia.

The anhydrous ammonia was added to the pots by using a pot injector, originally designed by the Phillips Petroleum Company, to which modifications were made. The anhydrous ammonia cylinder was designed to hold 240 ml of liquid anhydrous ammonia after an 80% fill valve was added. A liquid fill valve was added to fill the tank from any conventional anhydrous ammonia tank. The amount of anhydrous ammonia released from the cylinder in one injection was regulated by using a "N-Jector" applicator made by Direct Nitrogen Ltd., Wallington, Surrey (Fig. 3). A metering chamber, sealed with nylon seals, was adjusted to dispense an accurate and reproducible amount of anhydrous ammonia.

The injector was calibrated by collecting the anhydrous ammonia released in each injection in 30 ml of distilled-deionized water to which 5 ml of boric acid indicator solution was added. The ammonia-water-boric acid solution was then titrated with 1 N sulfuric acid to determine the amount of anhydrous ammonia in solution (Table 11).

For nitrogen rates of 30, 60 and 90 ppm nitrogen, a total of 71.0, 151.6 and 227.4 mg of anhydrous ammonia was injected to a depth of 8 cm. The actual rates of nitrogen applied were then 58.5, 124.9 and 187.4 mg or 29.2, 62.4 and 93.7 ppm nitrogen per pot. N-Serve was applied at a constant rate equalling 0.56 kg A.I. per 101 kg of nitrogen. At this rate, 0.325, 0.691 and 1.04 mg A.I., or 0.16, 0.36 and 0.52 ppm A.I., was applied to each pot for the 30, 60 and 90 ppm nitrogen treatments respectively. The anhydrous ammonia pot injector was filled with anhydrous ammonia from the 19 liter tank used in field studies.

One week after applying the fertilizer treatments, 1 seed per 3.2 cm^2 of Eagle wheat was planted in each pot for a total of 55 seeds planted per pot. At this rate, approximately 50 seedlings emerged in each pot. The pots were watered periodically and after three weeks growth in the greenhouse the plants were harvested. The plants were cut off approximately 6 cm from

Fig. 3. Anhydrous ammonia "N-Jector" pot applicator used for ammonia and ammonia with N-Serve applications in greenhouse and growth chamber studies. Note adjusting sleeve in bottom picture.

Table 11. CALIBRATIONS FOR THE ANHYDROUS AMMONIA POT APPLICATOR.

Valve Setting	mgm NH_3	mgm Nitrogen	ppm N (2 kg of soil)
-0.5	71.0	58.5	29.2
0	82.0	67.5	33.8
0.5	93.9	77.3	38.6
1.0	107.1	88.2	44.1
1.5	126.2	103.9	52.0
2.0	136.9	112.7	56.4
2.5	150.9	124.3	62.2
3.0	165.3	136.1	68.0
3.5	181.0	149.1	74.6
4.0	195.1	160.7	80.4
4.5	210.4	173.3	86.6
5.0	226.5	186.5	93.2

the soil surface. Three weeks later a second harvest was made. Each harvest cutting was dried at 60°C, dry weights recorded and the samples prepared for chemical analysis.

A second study similar to the first was initiated on September 14, 1976. This study was conducted in a growth chamber with day temperatures of 27°C for 13 hours and night temperatures of 16°C for 9 hours. Two hours each day were allocated to a transition time of cooling or heating to the desired temperature. Design, treatments and methods were identical to the preceeding study. The only difference was that a sandy soil was used. A complete description and analysis of the soil can be found in Table 1.

Soil samples were taken at the end of the study by taking a single 2.54 cm probe through the center of the anhydrous ammonia, ATS and APP retention zone. These samples were placed immediately in a sealed plastic bag and immersed in liquid nitrogen to freeze the samples and stop all microbial action in the soil. The samples were then stored in a freezer at 0 to -15°C until the samples could be prepared for chemical analysis.

The same sandy soil was used in a wheat growth and rate of nitrification study started on February 15, 1977. The first part of the study consisted of comparing effects of anhydrous ammonia with and without N-Serve, phosphorus and methods of phosphorus application on nutrient uptake and dry matter production of winter wheat (Table 12). The second part of the study compared the amount of nitrate and ammonium ions found in the soil during the growth period with the amounts present after one week. A separate set of pots receiving identical treatments as the

Table 12. TREATMENTS FOR THE SPRING 1977 N-SERVE - PHOSPHORUS GREENHOUSE STUDY.

N-Rate ppm	Nitrogen Carrier	P-Rate ppm	Phosphorus Method	Urea Rate ppm N
0	---	0	-----	12
0	---	40	Broadcast	0
0	---	40	Knife	0
90	NH_3	0	-----	12
90	NH_3	40	Broadcast	0
90	NH_3	40	Knife	0
90	NH_3+N-Serve	0	-----	12
90	NH_3+N-Serve	40	Broadcast	0
90	NH_3+N-Serve	40	Knife	0

pots for the first part of the study, but not planted to wheat, were used in the nitrate and ammonium ion determination part of the study.

The nitrogen rate was 90 ppm nitrogen as anhydrous ammonia and 12 ppm nitrogen from either APP or a urea solution. Phosphorus was applied at a rate of 40 ppm. N-Serve was applied at a rate of 1.04 mg A.I. per pot dissolved in the anhydrous ammonia. This was comparable to 0.56 kg A.I./ha. Phosphorus was applied as an injection in the same soil zone as the anhydrous ammonia or broadcast over the soil surface and incorporated.

The APP (11-16-0) was formulated by diluting 2.3 ml of APP to 300 ml with distilled-deionized water. Twenty ml of this solution was either injected into the ammonia retention zone or mixed with the soil by pipeting the solution into the soil while transfering the soil from one container to another. The 20 ml of solution supplied 0.15 ml of APP or 80 mg of phosphorus to each pot. In addition to the 80 mg of phosphorus, 24 mg of nitrogen was supplied by the APP.

The urea solution was formulated by dissolving 1.03 grams of urea in 100 ml of distilled-deionized water and injecting 5 ml of the solution into the soil. This resulted in 51.5 mg of urea or 24 mg of nitrogen being applied to each pot.

For the pots used for the plant growth and nutrient uptake part of the study, wheat crowns were dug at the Ashland Agronomy Farm and planted one week after fertilization. Four crowns of Eagle wheat were transplanted into each pot and watered periodically as needed. Leaf tissue was harvested three weeks after planting. The tissue samples were dried at 60°C for five days and dry weights recorded. The samples were then prepared for chemical analysis.

Soil samples were taken from the pots not planted to wheat 10, 20, 40 and 65 days after initial fertilization. A 2.54 cm diameter soil probe was taken from the center of the anhydrous ammonia retention zone. The samples were then immediately analyzed for nitrate and ammonium ions. A sample was saved from each pot for moisture determination.

Two phosphorus sources, two methods of phosphorus application and anhydrous ammonia were involved in the evaluation of the effectiveness of N-Serve in inhibiting the nitrification process in a third greenhouse experiment (Table 13). The phosphorus sources were APP and 85% orthophosphoric acid (0-27-0) applied at a rate of 40 ppm to two kg of a sandy loam soil (Table 1). The orthophosphoric acid was formulated by diluting 0.38 ml of the acid to 100 ml with distilled-deionized water. Twenty ml of the acid solution was applied either as an injection into the anhydrous ammonia retention zone or by mixing with the two kg of soil. This rate applied 0.13 grams or 0.08 ml of the acid to each pot. APP was applied to each pot in 20 ml of water in the same manner. Urea was either mixed or injected into the soil by the same methods. Urea was applied only to the pots receiving no APP. The total nitrogen rate was then 102 ppm, with 90 ppm being supplied by the anhydrous ammonia and 12 ppm supplied by either APP or urea. N-Serve was applied at a rate equal to 0.56 kg A.I./ha.

The study was started on June 1, 1977 with the fertilizers being applied one week later. Soil samples were taken 21, 35, 44,

Table 13. TREATMENTS FOR THE SUMMER 1977 N-SERVE - PHOSPHORUS GREENHOUSE STUDY.

N-Rate ppm	Nitrogen Carrier	P-Rate ppm	Phosphorus Carrier	Phosphorus Method	Urea Rate ppm
90	NH_3	0	---	-----	12
90	NH_3	40	APP	Broadcast	0
90	NH_3	40	APP	Knife	0
90	NH_3	40	H_3PO_4	Broadcast	12
90	NH_3	40	H_3PO_4	Knife	12
90	NH_3+N-Serve	0	---	-----	12
90	NH_3+N-Serve	40	APP	Broadcast	0
90	NH_3+N-Serve	40	APP	Knife	0
90	NH_3+N-Serve	40	H_3PO_4	Broadcast	12
90	NH_3+N-Serve	40	H_3PO_4	Knife	12

56 and 63 days after fertilization. Soil probes were taken from the center of the retention zone and immersed in liquid nitrogen to freeze the samples and stop all microbial activity in the soil. The samples were then stored in a freezer at 0 to -15°C until analysis for nitrate and ammonium ions could be completed. A sample from each pot was saved for moisture determination.

Laboratory Techniques for Leaf Tissue Analysis

All leaf tissue samples were dried at 60°C for five days. The dried samples were then ground through a Wiley mill to pass through a 1 mm stainless steel screen. Small greenhouse samples were ground through a Micro-Wiley mill to pass through a 0.75 mm stainless steel screen. Both mills were equipped with stainless steel knives. The entire mill was cleaned with compressed air between each sample. Approximately 10 grams of the ground sample was stored in a plastic container for later analysis.

The samples were redried for 24 hours at 65°C immediately prior to the actual analysis. Nitrogen, phosphorus and potassium analysis followed a sulfuric acid digest (Linder and Harley, 1942). A 0.25 gram sample was weighed into a digestion tube and 2 ml of concentrated acid was added. The samples were placed under a hood in an aluminum digestion block and 1 ml of 30% H_2O_2 added. The samples were then heated to a temperature of 375°C until the fumes condensed about halfway up the digestion tube. The samples were heated for approximately 45 minutes. The samples were then cooled for 10 minutes and an additional 1 ml of H_2O_2 was added and the samples heated again. This procedure was repeated until the solution remained clear. The digestion tubes were then removed from the heat, diluted to 50 ml with distilled deionized water and stored in polyethylene bottles. These solutions were then used for nitrogen, phosphorus and potassium analysis.

Nitrogen was determined colorimetrically on a spectrophotometer at 660nm. A 1 ml aliquot of the digested plant material was first diluted to 10 ml with distilled-deionized water and mixed well. A second dilution of 0.5 ml of the sample solution was diluted to 6.0 ml and mixed well. A solution of sodium dichloroisocyanurate and 0.6 N sodium hydroxide was prepared. Twenty four grams of reagent grade sodium hydroxide was dissolved in 900 ml of distilled-deionized water. The solution was cooled and 5 grams of sodium dichloroisocyanurate was added. This solution, called solution A, was then diluted to 1 liter.

Another solution, solution B, composed of 8.5% sodium salicylate and 0.03% sodium nitroprusside was prepared. Eighty five grams of sodium salicylate was dissolved in 600 ml of distilled-deionized water and 0.3 grams of sodium nitroprusside added. This solution was then diluted to 1 liter.

A 2 ml aliquot of solution A was added to the diluted sample and then 2 ml of solution B added. The color was allowed to develop for two hours and read on the spectrophotometer. A set of standards containing 0, 50, 100, 150, 200 and 250 ppm nitrogen as ammonium were prepared from a 1000 ppm stock nitrogen solution of ammonium sulfate. The color was developed by the same procedure described above and a standard curve determined. The spectrophotometer was set at an absorbance of 0 for the 0 ppm standard, and read 0.3 for 150 ppm, 0.4 for the 200 ppm and

0.5 for the 250 ppm nitrogen standard. The percent nitrogen in the samples was determined from this curve.

Phosphorus was determined by using an ammonium moybdate - ammonium vanadate solution. The solution was prepared by dissolving 162 grams of ammonium molybdate in 2 liters of distilled-deionized water. Nine grams of ammonium vanadate was dissolved in 2 liters of boiling distilled-deionized water, cooled and mixed with the ammonium molybdate solution. This solution was then mixed with 675 ml of nitric acid and diluted to 18 liters.

Using a 1:10 Re-Pipet, a 1 ml sample of the sulfuric acid digest was added to 5 ml of the vanadomolybdate solution. The color was then allowed to develop for 30 minutes and read on a Spectrophotometer 88 at 330 nm. A standard curve was prepared by preparing standards of 6, 12, 24, 36 and 48 ppm phosphorus from a stock solution containing 600 ppm phosphorus from potassium dihydrogen phosphate and 4 ml of concentrated sulfuric acid. A 1 ml aliquot of these standards was added to 5 ml of the vanadomolybdate solution. The color was allowed to develop for 30 minutes and read on the spectrophotometer. The final standards had concentrations of 1, 2, 4, 6 and 8 ppm phosphorus. The formula, $C=\overline{K}$ (OD) was used by determining an average K value and reading absorbance on the spectrophotometer.

Potassium was determined by diluting the sulfuric acid digest 1:10 with distilled-deionized water. Potassium was determined by flame photometry. A standard curve was determined by using standard solutions of 0, 5, 10, 20 and 30 ppm potassium prepared from a stock solution of potassium chloride.

Laboratory Techniques for Grain Analysis

Grain samples were prepared for analysis after determining moisture. The plot weight of the grain was then adjusted to 12.5 percent moisture. Grain yield was then calculated as kilograms of grain per hectare by multiplying the plot weight by an appropriate factor for the plot size.

Grain samples were ground through a Udy rotary-abrasion mill and approximately 10 grams of sample was stored in sealed, plastic containers. Nitrogen was then determined by the same procedure described for leaf tissue analysis. Crude protein was calculated by multiplying the percent total nitrogen in the grain by a factor of 5.85. For bushels of grain per acre, 60 pounds of grain per bushel was used as the conversion factor.

Laboratory Techniques for Soil Analysis

Soil samples were analyzed for exchangeable ammonium and nitrate ion concentrations by using the micro-Kjeldahl method. Samples were prepared for analysis by first thawing the samples at room temperature. Each sample was then crumpled into fine particles while still in the plastic bag. A 5 gram sample was placed in a micro-Kjeldahl distillation flask and 10 ml of 2 N potassium chloride was added. The flasks were then attached to the distillation unit and 0.1 gram of heavy magnessium oxide added. Twenty five ml of the distillate was collected in a 50 ml Erlynmeyer flask containing 5 ml of boric acid indicator solution. The sample was then titrated with 0.01991 N sulfuric acid.

Nitrate was determined by adding 0.2 grams of Devarda's alloy, milled to pass through a 100 mesh screen, to the distillation flasks after ammonium distillation. Twenty five ml of the distillate was collected in 5 ml of boric acid indicator solution. The distilled ammonium was determined by titrating with 0.01991 N sulfuric acid. Blanks containing 10 ml of potassium chloride were analyzed periodically in the manner described. The calculations for the amount of nitrate and ammonium ions present in the soil employed the following formula:

$$\text{ppm N} = \frac{(\text{ml of sample acid - blank ml})\ (0.01991)\ (14000)}{\text{Dry weight of soil in grams}}$$

Statistical Analysis

The data collected was analyzed by the General Analysis of Variance (GANOVA) system revised by Kris Arheart of Kansas State University in 1972. This system was developed for the Universities IBM 370 computer. Analysis of variance and least significant difference (LSD) tests were tested at the 5% level of significance.

RESULTS AND DISCUSSION

N-Serve

Most of the research conducted with N-Serve in the past has been in moderately humid areas with more than adequate rainfall. Much of this research involved solid fertilizer materials such as ammonium nitrate, ammonium sulfate and urea. The results of the studies reported here were obtained by using anhydrous ammonia as the nitrogen source in an area of limiting rainfall.

Effect of N-Serve and Nitrogen Rate on Wheat Yield and Protein

Generally there were no visual responses to N-Serve during either year (Fig. 4). There was a visual response due to nitrogen rate at most of the locations during both years. Normally a taller, more vigorous plant resulted from higher nitrogen rates (Fig. 5).

N-Serve did not significantly affect grain yields at any location during 1976 (Fig. 6). Tables 14-16 include yield and protein data from the four locations of N-Serve studies in 1976. There were no significant differences between anhydrous ammonia, anhydrous ammonia with N-Serve or urea when compared to yield at the Riley, Stafford or Harper county locations. Anhydrous ammonia provided a significant yield increase over calcium nitrate at the McPherson (#1) county location. N-Serve had no effect on yield at this location. A study of *Cephalosporium* stripe study was conducted in conjunction with this study and is reported in a later section.

Figure 7 indicates the protein levels of the grain at each

Fig. 4. Visual comparison of responses of winter wheat to anhydrous ammonia, anhydrous ammonia with N-Serve and urea. 67 kg N/ha (60 lbs N/A) and 101 kg N/ha (90 lbs N/A), Labette Co., 1977.


N SERVE
60
NH3NS
60
UREA


N SERVE
90
NH3
90
NH3 NS
PARSONS, KS
MAY 6, 1977

Fig. 5. Visual responses of winter wheat to nitrogen fertilization rates. Top, Control vs. 67 kg N/ha (60 lbs N/A) as anhydrous ammonia, Labette Co., 1977; Bottom, Control vs. 101 kg N/ha (90 lbs N/A) as urea, Stafford Co., 1977.


N SERVE
0
60
NH3


N SERVE
0
90
UREA
ST JOHN, KS
MAY 5, 1977

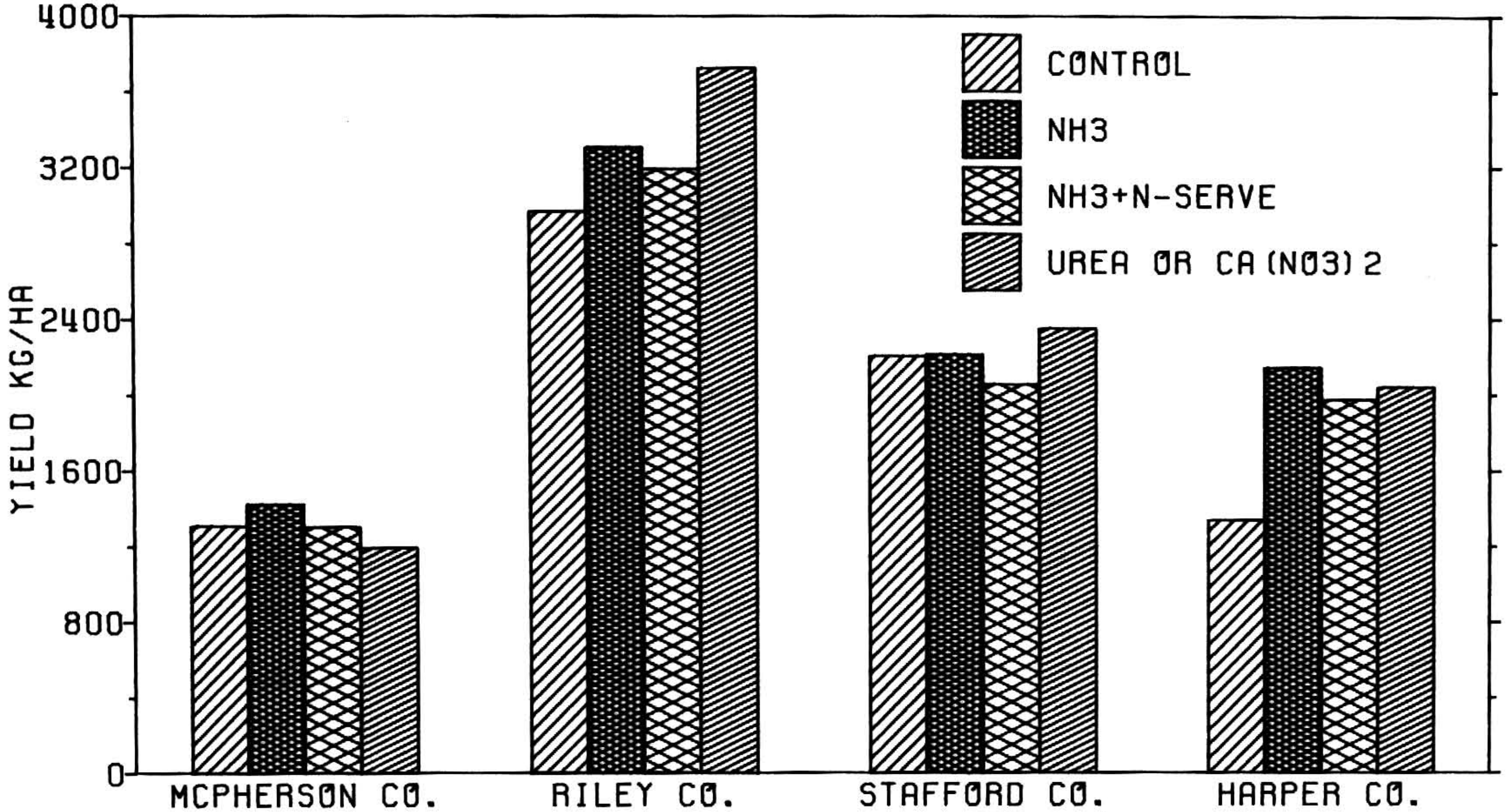


FIG. 6 EFFECT OF N-SERVE ON 1976 WHEAT YIELDS.

Table 14. EFFECTS OF N-SERVE AND N-RATE ON THE GRAIN YIELD OF WINTER WHEAT. (Riley and Stafford Co. 1976)

N-Rate kg/ha	Nitrogen Carrier	Riley Co. bu/A	Riley Co. kg/ha	Riley Co. % Protein	Stafford Co. bu/A	Stafford Co. kg/ha	Stafford Co. % Protein
0	---	44.2	2970	10.3	32.8	2204	13.2
34	NH_3	49.4	3320	10.2	38.6	2594	11.9
67	NH_3	50.1	3367	10.3	29.4	1976	13.5
101	NH_3	48.1	3232	10.8	30.7	2063	14.0
34	NH_3+N-Serve	51.1	3434	9.9	36.7	2466	12.4
67	NH_3+N-Serve	44.8	3011	10.2	33.3	2238	13.2
101	NH_3+N-Serve	46.7	3138	10.9	21.8	1465	13.3
34	Urea	52.6	3535	10.1	39.4	2648	11.7
67	Urea	57.2	3844	10.1	36.9	2480	12.2
101	Urea	53.3	3582	10.5	28.6	1922	13.7
Treatment $LSD_{(.05)}$		NS	NS	0.6	10.1	679	1.2
Mean Values:							
N-Rate	34	51.0	3427	10.1	38.2	2567	12.0
	67	50.7	3407	10.2	33.2	2231	12.9
	101	50.4	3387	10.7	27.0	1814	13.6
	$LSD_{(.05)}$	NS	NS	0.4	5.8	390	0.7
N-Carrier	NH_3	49.2	3306	10.4	32.9	2211	13.1
	NH_3+N-Serve	47.5	3192	10.3	30.6	2056	13.0
	Urea	55.4	3723	10.2	35.0	2352	12.5
	$LSD_{(.05)}$	NS	NS	NS	NS	NS	NS

Table 15. EFFECTS OF N-SERVE AND N-RATE ON THE GRAIN YIELD OF WINTER WHEAT. (Harper Co. 1976)

N-Rate kg/ha	Nitrogen Carrier	Yield bu/A	Yield kg/ha	% Protein
0	---	19.9	1337	11.3
34	NH_3	26.8	1801	11.2
67	NH_3	29.6	1989	12.0
101	NH_3	39.2	2634	13.2
34	NH_3+N-Serve	23.5	1579	11.1
67	NH_3+N-Serve	30.7	2063	12.3
101	NH_3+N-Serve	34.1	2292	12.8
34	Urea	28.7	1929	11.7
67	Urea	28.1	1888	11.7
101	Urea	34.2	2298	13.0
	Treatment $LSD_{(.05)}$	9.6	645	1.0
Mean Values:				
N-Rate	34	26.3	1767	11.3
	67	29.5	1982	12.0
	101	35.8	2406	13.0
	$LSD_{(.05)}$	5.5	370	0.6
N-Carrier	NH_3	31.9	2144	12.2
	NH_3+N-Serve	29.4	1976	12.1
	Urea	30.4	2043	12.1
	$LSD_{(.05)}$	NS	NS	NS

Table 16. EFFECTS OF N-SERVE AND N-RATE ON THE YIELD AND PROTEIN OF WINTER WHEAT. (McPherson Co. 1976).

Variety	Time of Application	Nitrogen Carrier	N-Rate kg/ha	Yield bu/A	Yield kg/ha	% Protein	Cephalosporium Rating
Sturdy	---	---	0	8.1	544	12.8	4.0
Eagle	---	---	0	25.8	1734	10.6	5.0
Sturdy	Pre-plant	$Ca(NO_3)_2$	50	7.9	531	13.4	3.3
Sturdy	Pre-plant	$Ca(NO_3)_2$	101	6.7	450	13.0	5.3
Sturdy	Pre-plant	NH_3	50	10.1	679	12.3	6.3
Sturdy	Pre-plant	NH_3	101	13.9	934	12.7	6.0
Sturdy	Pre-plant	NH_3+N-Serve	50	10.2	685	13.8	6.0
Sturdy	Pre-plant	NH_3+N-Serve	101	9.6	645	13.4	6.0
Sturdy	Spring	$Ca(NO_3)_2$	50	10.3	692	13.2	7.3
Sturdy	Spring	$Ca(NO_3)_2$	101	12.6	847	12.9	6.3
Sturdy	Spring	NH_3	50	15.1	1015	13.8	7.0
Sturdy	Spring	NH_3	101	12.9	867	13.9	6.7
Sturdy	Spring	NH_3+N-Serve	50	10.9	732	13.8	6.0
Sturdy	Spring	NH_3+N-Serve	101	11.5	773	13.5	2.3
Eagle	Pre-plant	$Ca(NO_3)_2$	50	20.0	1344	11.1	3.7
Eagle	Pre-plant	$Ca(NO_3)_2$	101	25.2	1693	11.5	3.0
Eagle	Pre-plant	NH_3	50	25.6	1720	12.1	4.0
Eagle	Pre-plant	NH_3	101	29.2	1962	11.4	4.0
Eagle	Pre-plant	NH_3+N-Serve	50	29.0	1949	11.8	4.0
Eagle	Pre-plant	NH_3+N-Serve	101	32.6	2191	12.0	3.3
Eagle	Spring	$Ca(NO_3)_2$	50	28.4	1908	11.2	5.0
Eagle	Spring	$Ca(NO_3)_2$	101	31.2	2097	12.3	6.3
Eagle	Spring	NH_3	50	24.0	1613	11.0	4.0
Eagle	Spring	NH_3	101	39.0	2621	12.5	4.0
Eagle	Spring	NH_3+N-Serve	50	24.5	1646	11.8	3.0
Eagle	Spring	NH_3+N-Serve	101	26.9	1805	12.4	4.3

Table 16. (continued).

	Yield bu/A	Yield kg/ha	% Protein	Cephalosporium Rating
Mean Values:				
N-Rate				
50	18.0	1210	12.4	5.0
101	21.0	1411	12.6	4.8
$LSD_{(.05)}$	2.5	168	NS	NS
N-Carrier				
NH_3	21.2	1425	12.5	5.2
$Ca(NO_3)_2$	17.8	1196	12.3	5.0
NH_3+N-Serve	19.4	1304	12.8	4.4
$LSD_{(.05)}$	3.1	208	0.4	0.4
Time of Application				
Spring	20.6	1384	12.7	5.2
Pre-plant	18.3	1230	12.4	4.6
$LSD_{(.05)}$	NS	NS	NS	0.3
Variety				
Sturdy	11.0	739	11.8	5.7
Eagle	28.0	1882	13.3	4.1
$LSD_{(.05)}$	2.5	168	0.3	0.3

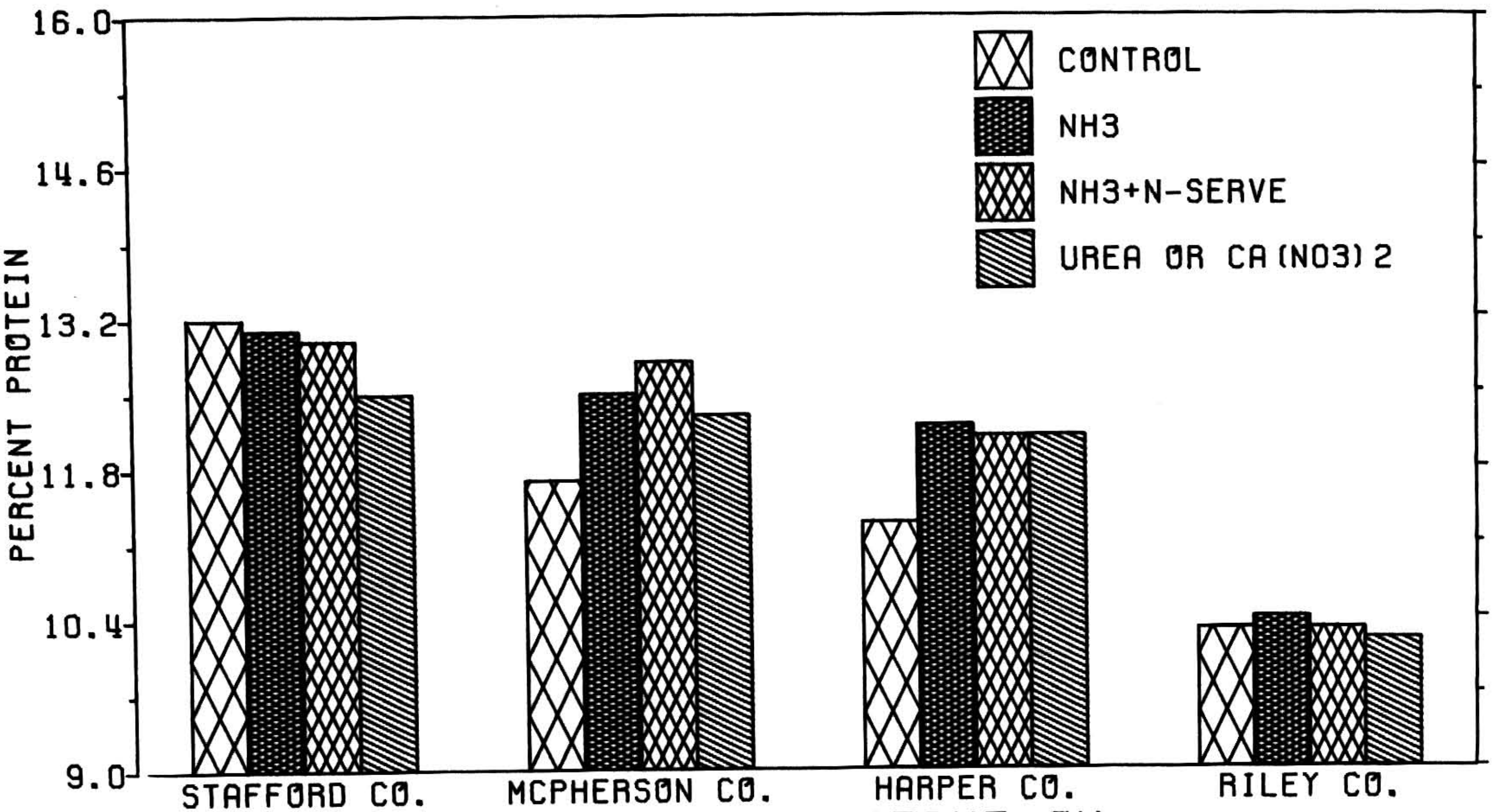


FIG. 7 EFFECT OF N-SERVE ON 1976 WHEAT PROTEIN

location for 1976. N-Serve exhibited a significant effect on protein at the McPherson (#1) county site. Anhydrous ammonia with N-Serve produced significantly higher protein concentrations than calcium nitrate. At each of the other locations there were no significant differences due to nitrogen carriers.

Nitrogen rate produced varying effects on grain yield. The Harper county data included a significant response to nitrogen rate when the rate was increased from 34 to 101 kg N/ha. There was also a significant increase in yield at the McPherson (#1) county location when the nitrogen rate was increased from 50 to 101 kg N/ha. Figure 8 shows an opposite response to nitrogen rate at the Stafford county location. Yields were significantly depressed when the nitrogen rate was increased from 34 to 101 kg N/ha.

Nitrogen rate effects on the protein content of the grain were non-significant at the McPherson (#1) county location. At the Riley county site, the 101 kg N/ha rate produced significantly higher protein than the 34 or 67 kg N/ha rates. The 101 and 67 kg N/ha rates each produced significantly more protein than the 34 kg N/ha rate at the Stafford county location. At the Harper county site, 101 kg N/ha produced a significant increase in grain protein in comparison to the 34 and 67 kg N/ha rates. The 67 kg N/ha treatment was significantly higher in grain protein than the low rate. Figure 9 shows the effect of nitrogen rate and nitrogen carrier on grain protein at the Stafford county location. The 67 and 101 kg N/ha rates were significantly higher in protein than the 34 kg N/ha rate.

The 1977 yield data are presented in Fig. 10. Tables 17-19

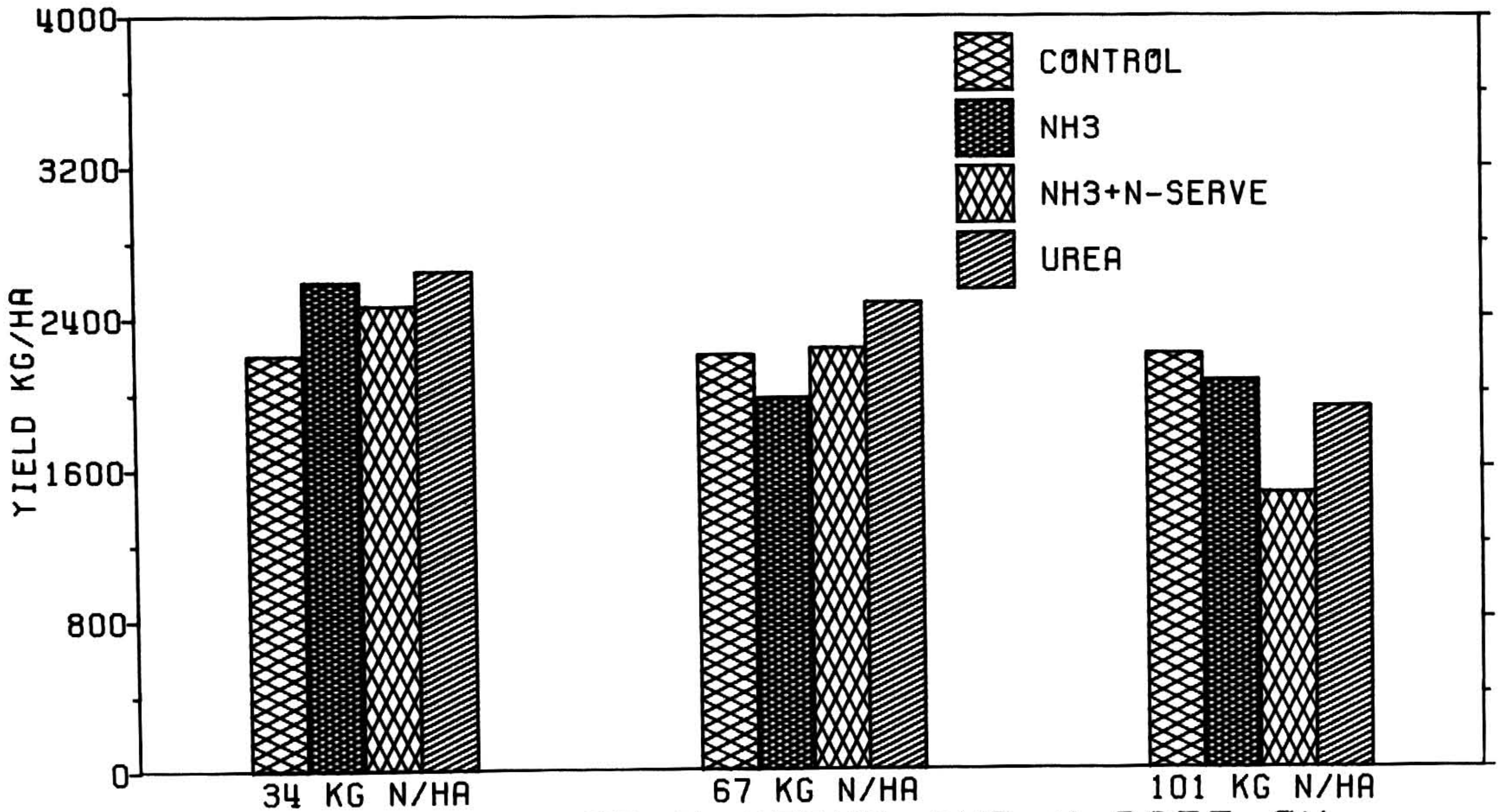


FIG. 8 EFFECTS OF N-SERVE AND N-RATE ON WHEAT YIELDS. STAFFORD CO. 1976

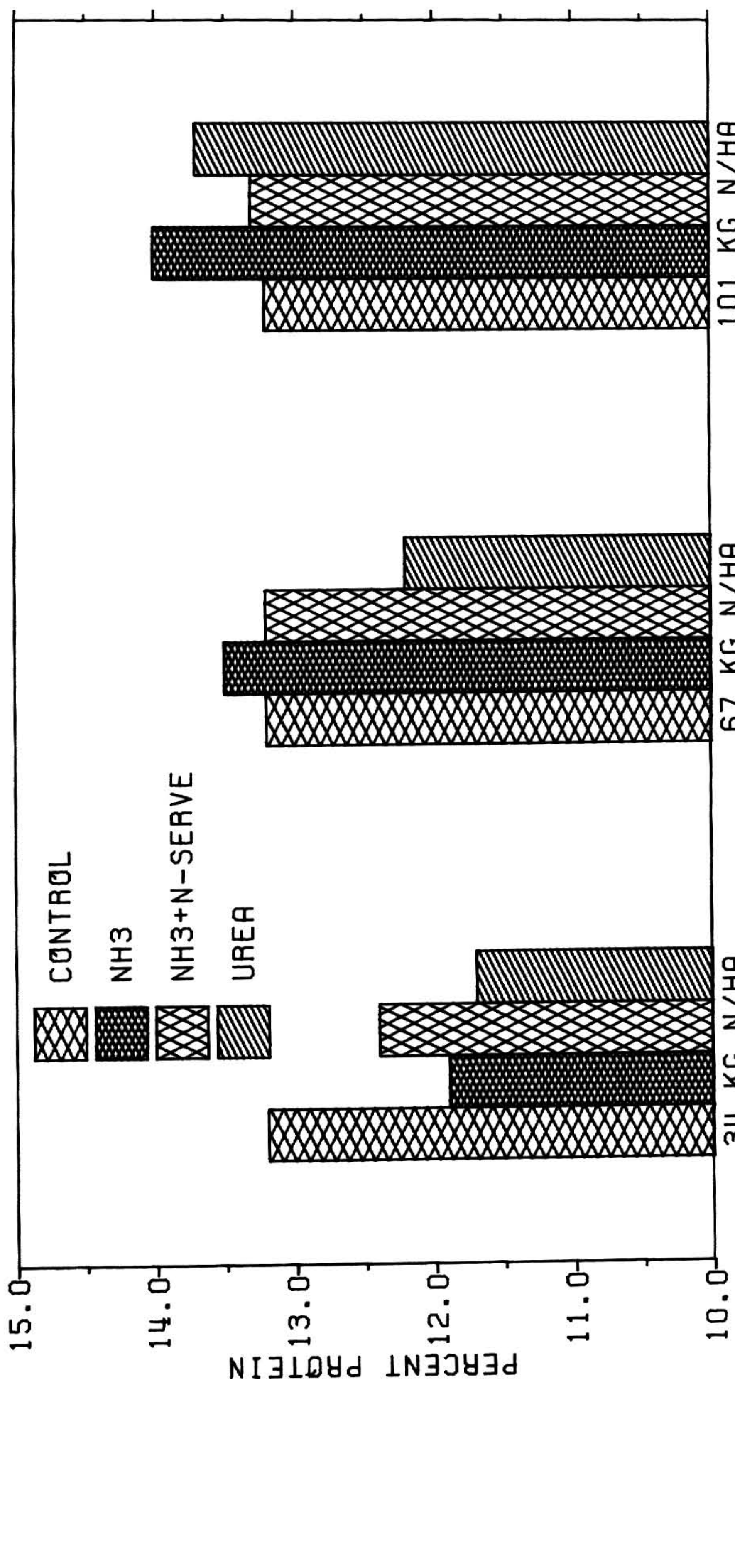


FIG. 9 EFFECTS ØF N-SERVE AND N-RATE ØN WHEAT PRØTEIN. STAFFØRD CØ. 1976

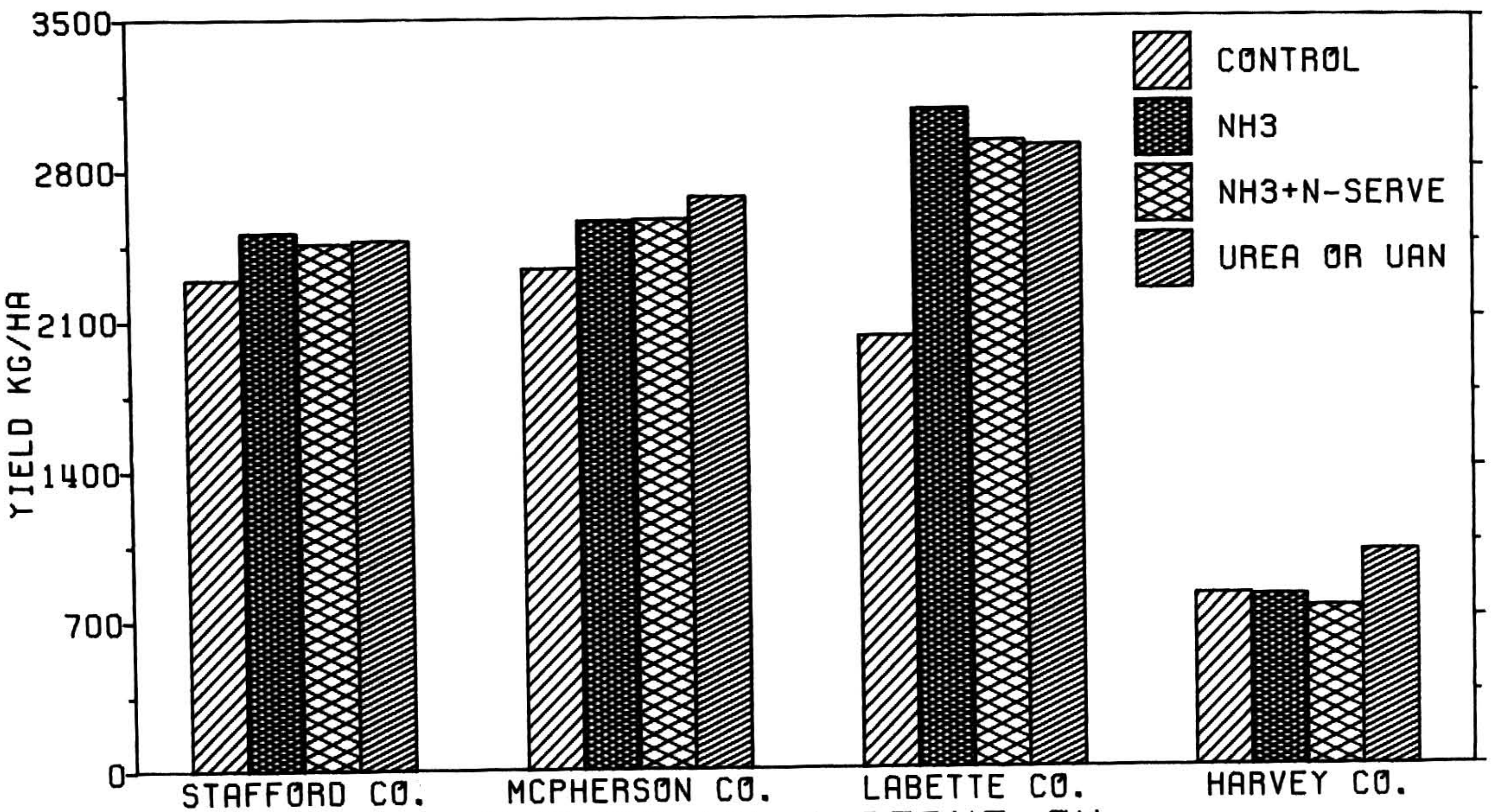


FIG. 10 EFFECT OF N-SERVE ON 1977 WHEAT YIELDS

Table 17. EFFECTS OF N-SERVE AND N-RATE ON THE YIELD AND PROTEIN OF WINTER WHEAT. (Stafford and Labette Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	Stafford Co. bu/A	Stafford Co. kg/ha	Stafford Co. % Protein	Labette Co. bu/A	Labette Co. kg/ha	Labette Co. % Protein
0	---	34.1	2292	12.0	30.0	2016	9.0
34	NH_3	38.1	2560	13.4	41.4	2782	10.1
67	NH_3	37.9	2547	14.2	43.2	2903	11.0
101	NH_3	36.3	2439	15.1	47.7	3205	13.1
34	NH_3+N-Serve	36.6	2460	12.6	40.5	2722	11.1
67	NH_3+N-Serve	36.2	2433	14.5	46.7	3138	12.4
101	NH_3+N-Serve	36.9	2480	14.6	43.4	2916	13.0
34	Urea	37.2	2500	13.8	40.2	2701	10.3
67	Urea	37.0	2486	13.6	45.5	3058	11.7
101	Urea	36.2	2433	14.3	43.8	2943	13.3
Treatment	$LSD_{(.05)}$	NS	NS	0.9	2.1	141	1.4
Mean Values:							
N-Rate	34	37.3	2507	13.3	40.7	2735	10.5
	67	37.0	2486	14.1	45.1	3031	11.7
	101	36.4	2446	14.7	45.0	3024	13.1
	$LSD_{(.05)}$	NS	NS	0.5	1.2	81	0.8
N-Carrier							
	NH_3	37.4	2513	14.2	44.1	2964	11.4
	NH_3+N-Serve	36.6	2460	13.9	43.5	2923	11.7
	Urea	36.8	2473	13.9	43.2	2903	12.2
	$LSD_{(.05)}$	NS	NS	NS	NS	NS	NS

Table 18. EFFECTS OF N-SERVE AND N-RATE ON THE YIELD AND PROTEIN OF WINTER WHEAT. (Harvey Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	Yield bu/A	Yield kg/ha	% Protein
0	---	12.0	806	15.1
34	NH_3	13.5	907	14.3
67	NH_3	11.3	759	14.8
101	NH_3	10.9	732	15.3
34	NH_3+N-Serve	10.1	679	14.5
67	NH_3+N-Serve	10.2	685	15.1
101	NH_3+N-Serve	13.0	874	15.3
34	Urea	10.3	692	14.9
67	Urea	15.4	1035	15.3
101	Urea	19.2	1290	14.7
	Treatment $LSD_{(.05)}$	2.8	188	1.1
Mean Values:				
N-Rate	34	11.3	759	14.6
	67	12.3	827	15.1
	101	14.4	968	15.1
	$LSD_{(.05)}$	1.6	108	NS
N-Carrier	NH_3	11.9	800	14.8
	NH_3+N-Serve	11.1	746	15.0
	Urea	15.0	1008	15.0
	$LSD_{(.05)}$	1.6	108	NS

Table 19. EFFECTS OF N-SERVE AND N-RATE ON THE YIELD AND PROTEIN OF WINTER WHEAT. (McPherson Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	Yield bu/A	Yield kg/ha	% Protein
0	---	34.8	2339	12.6
34	NH_3	37.8	2540	12.9
67	NH_3	38.3	2574	12.0
101	NH_3	38.2	2567	13.5
34	NH_3+N-Serve	36.8	2473	13.7
67	NH_3+N-Serve	38.2	2567	12.6
101	NH_3+N-Serve	39.5	2564	12.9
34	UAN	40.4	2715	12.8
67	UAN	40.3	2708	12.7
101	UAN	38.3	2574	13.0
	Treatment $LSD_{(.05)}$	4.0	269	1.3
Mean Values:				
N-Rate	34	38.3	2574	13.1
	67	38.9	2614	12.4
	101	38.7	2601	13.1
	$LSD_{(.05)}$	NS	NS	NS
	NH_3	38.1	2560	12.8
	NH_3+N-Serve	38.2	2567	13.1
	UAN	39.7	2668	12.9
	$LSD_{(.05)}$	NS	NS	NS

include the yield and protein data for the 1977 wheat crop as well as analysis of variance. As was the case in 1976, there were no significant N-Serve effects. At the Harvey county location, urea was significantly better as a nitrogen source than either anhydrous ammonia or anhydrous ammonia with N-Serve, but yields were generally very poor due to drought. Nitrogen carriers produced non-significant yield differences at the McPherson (#2), Stafford and Labette county sites.

Grain protein data obtained for nitrogen carrier comparisons at each of the four locations in 1977 are reported in Fig. 11. There were no significant responses to nitrogen source, including N-Serve effects, at any location.

Nitrogen rates produced significant responses in grain yields at the Labette and Harvey county locations in 1977. The 67 and 101 kg N/ha rates yielded significantly higher than the 34 kg N/ha rate at the Labette county location. At the Harvey county location, increased nitrogen as topdress urea in late winter resulted in significant increases in yield. Pre-plant nitrogen, including anhydrous ammonia plus N-Serve, had no effect. Nitrogen rate exerted no significant effect on yield at the McPherson (#2) or Stafford county locations.

Nitrogen rate produced a significant increase in grain protein at two of the four 1977 locations. The 101 kg N/ha rate was significantly superior in protein production to either the 34 or 67 kg N/ha rates in Stafford county. Similarly, The 67 kg N/ha rate resulted in a significant increase in protein production when compared to the 34 kg N/ha rate. Protein was also significantly increased with each increase in nitrogen rate at

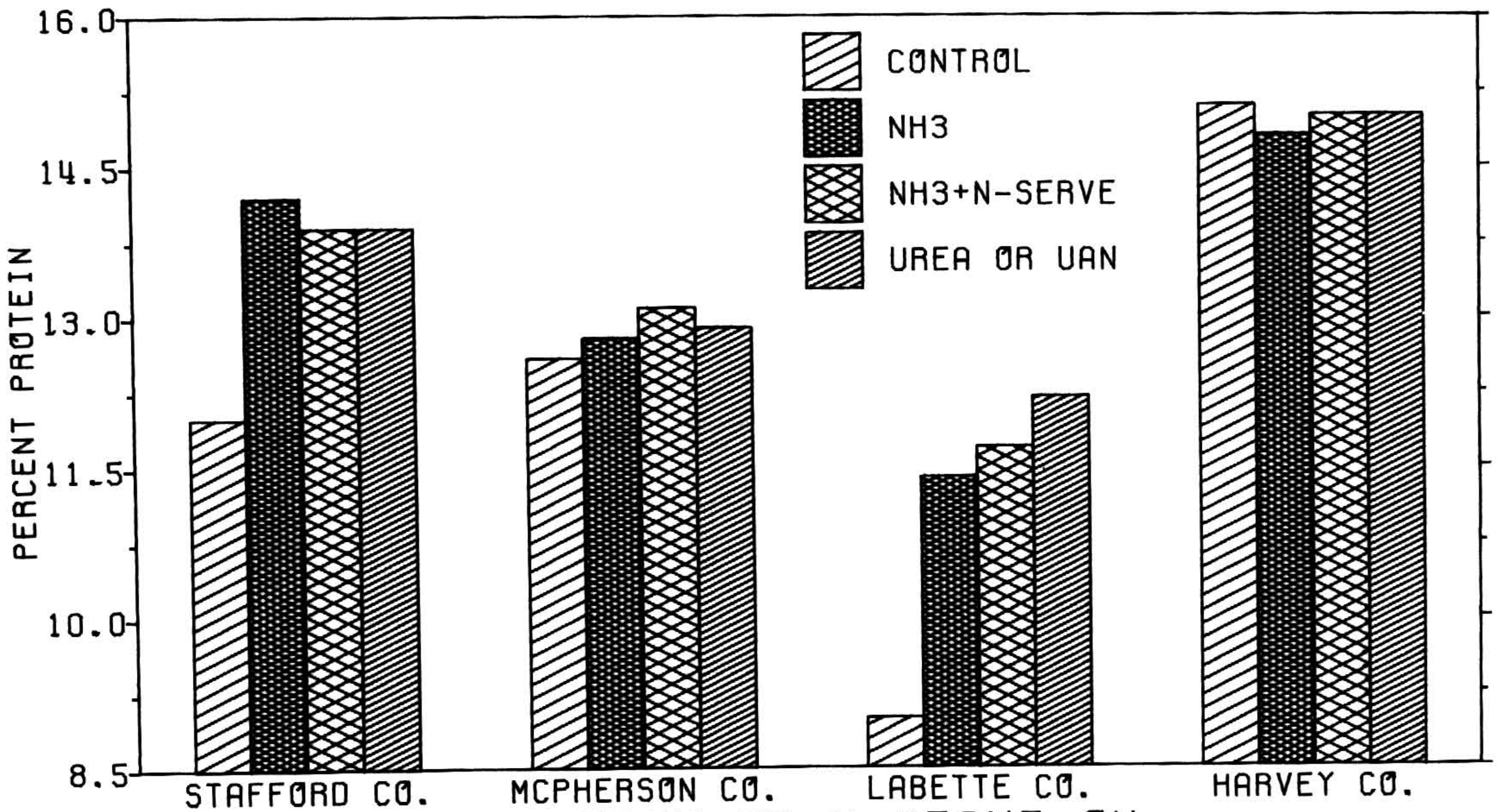


FIG. 11 EFFECT OF N-SERVE ON 1977 WHEAT PROTEIN

the Labette county location. There was no significant response in protein levels due to nitrogen rates at the Harvey or McPherson (#2) county locations.

In summary, N-Serve applied in anhydrous ammonia provided no increase in yields and little effect on grain protein levels in 1976 and 1977 in Kansas, particulary when compared to anhydrous ammonia alone. This was due to the fact that conditions conducive to nitrogen loss by denitrification or leaching did not occur during the two years of this study. Anhydrous ammonia, anhydrous ammonia with N-Serve and urea are equal in their abilities to provide nitrogen to wheat plants under these conditions. Calcium nitrate applied in the fall was not as effective as the other nitrogen carriers in terms of yield or protein production on a fine textured soil. Increased protein levels in grain were realized as readily by increased rates of nitrogen as from the inclusion of a nitrification inhibitor.

Effect of N-Serve and N-Rate on Nutrient Uptake in Winter Wheat

Wheat tissue samples were collected on three dates in 1976. Effects of nitrogen source and nitrogen rates on nutrient uptake for 1976 are presented in Tables 20-22. Due to dry weather conditions, no leaf tissue samples were collected at the Harper county location. Only one tissue sampling was conducted at the McPherson (#1) county site.

Urea produced significantly higher concentrations of nitrogen in the plant tissue at the first sampling date than did anhydrous ammonia with and without N-Serve at the Riley county site. Nitrogen source had no significant effect on phosphorus

Table 20. EFFECTS OF N-SERVE AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (Riley CO., 1976)

N-Rate kg/ha	Nitrogen Carrier	April 1			May 9			June 3		
		%N	%P	%K	%N	%P	%K	%N	%P	%K
0	---	2.26	.294	2.03	2.06	.311	1.44	0.52	.188	0.78
34	NH_3	2.13	.277	1.98	2.03	.286	1.44	0.53	.159	0.81
67	NH_3	2.40	.300	2.22	2.55	.308	1.48	0.58	.160	0.85
101	NH_3	2.57	.325	2.29	2.37	.289	1.36	0.54	.150	0.91
34	NH_3+N-Serve	2.08	.287	1.89	1.99	.313	1.31	0.48	.172	0.80
67	NH_3+N-Serve	2.09	.312	1.84	1.93	.280	1.37	0.47	.165	0.76
101	NH_3+N-Serve	2.81	.326	2.36	2.39	.283	1.46	0.66	.160	1.05
34	Urea	2.34	.291	1.98	2.15	.299	1.36	0.57	.177	0.83
67	Urea	2.67	.306	2.13	2.37	.297	1.33	0.55	.161	0.83
101	Urea	2.84	.299	2.20	2.56	.302	1.48	0.63	.156	0.94
Treatment	$LSD_{(.05)}$	0.32	.042	0.26	0.23	NS	NS	0.13	.024	0.11
Mean Values:										
N-Rate	34	2.33	.285	1.95	2.06	.299	1.37	0.53	.169	0.81
	67	2.39	.306	2.06	2.28	.295	1.39	0.53	.162	0.81
	101	2.74	.317	2.06	2.44	.291	1.43	0.61	.155	0.97
	$LSD_{(.05)}$	0.19	.024	0.15	0.13	NS	NS	0.07	NS	0.06
N-Carrier	NH_3	2.37	.301	2.17	2.32	.294	1.43	0.55	.156	0.86
	NH_3+N-Serve	2.33	.308	2.03	2.10	.292	1.38	0.53	.166	0.87
	Urea	2.62	.299	2.10	2.36	.299	1.39	0.58	.165	0.86
	$LSD_{(.05)}$	0.19	NS	NS	0.13	NS	NS	NS	NS	NS

Table 21. EFFECTS OF N-SERVE AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (Stafford Co., 1976)

N-Rate kg/ha	Nitrogen Carrier	April 1 %N	April 1 %P	April 1 %K	May 9 %N	May 9 %P	May 9 %K	June 3 %N	June 3 %P	June 3 %K
0	---	3.03	.331	2.64	2.74	.318	1.69	0.68	.140	0.94
34	NH_3	3.11	.326	2.80	3.01	.320	1.71	0.85	.124	0.97
67	NH_3	3.31	.310	2.73	3.13	.332	1.65	0.83	.136	0.97
101	NH_3	3.40	.304	2.66	3.52	.313	1.71	1.03	.128	0.96
34	NH_3+N-Serve	3.05	.351	2.75	3.41	.335	1.73	0.93	.158	1.13
67	NH_3+N-Serve	3.31	.315	2.59	3.07	.319	1.77	0.90	.155	1.05
101	NH_3+N-Serve	3.76	.346	2.96	3.65	.327	1.69	1.19	.129	1.11
34	Urea	3.19	.324	2.87	2.92	.324	1.67	0.69	.129	0.86
67	Urea	3.35	.370	2.80	2.89	.328	1.69	0.76	.146	0.92
101	Urea	3.54	.364	3.01	3.20	.330	1.65	0.97	.148	1.07
Treatment	$LSD_{(.05)}$	0.53	.062	0.45	0.64	NS	NS	0.17	.032	0.15
Mean Values:										
N-Rate	34	3.12	.333	2.81	3.03	.327	1.70	0.83	.137	0.97
	67	3.32	.331	2.71	3.11	.326	1.70	0.83	.146	1.10
	101	3.57	.338	2.88	3.46	.323	1.68	1.06	.135	0.95
	$LSD_{(.05)}$	0.31	NS	NS	0.37	NS	NS	0.10	NS	0.08
N-Carrier	NH_3	3.27	.313	2.73	3.22	.322	1.69	0.91	.130	1.06
	NH_3+N-Serve	3.37	.337	2.77	3.38	.327	1.73	1.01	.147	0.93
	Urea	3.36	.352	2.89	3.00	.327	1.67	0.81	.141	1.02
	$LSD_{(.05)}$	NS	.036	NS	0.37	NS	NS	0.10	NS	0.08

Table 22. EFFECTS OF N-SERVE AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (McPherson Co., 1976)

N-Rate kg/ha	Nitrogen Carrier	Variety	Time of Application	May 5 %N	May 5 %P	May 5 %K
0	---	Sturdy	---	2.39	.305	1.63
0	---	Eagle	---	1.85	.303	1.26
50	$Ca(NO_3)_2$	Sturdy	Pre-plant	2.11	.344	1.37
101	$Ca(NO_3)_2$	Sturdy	Pre-plant	1.98	.338	1.94
50	NH_3	Sturdy	Pre-plant	2.24	.332	1.85
101	NH_3	Sturdy	Pre-plant	2.05	.322	1.59
50	NH_3+N-Serve	Sturdy	Pre-plant	2.09	.294	1.67
101	NH_3+N-Serve	Sturdy	Pre-plant	2.36	.319	1.53
50	$Ca(NO_3)_2$	Sturdy	Spring	2.11	.298	1.62
101	$Ca(NO_3)_2$	Sturdy	Spring	2.19	.324	1.68
50	NH_3	Sturdy	Spring	2.27	.286	1.76
101	NH_3	Sturdy	Spring	2.02	.324	1.53
50	NH_3+N-Serve	Sturdy	Spring	1.96	.323	1.70
101	NH_3+N-Serve	Sturdy	Spring	2.18	.340	1.62
50	$Ca(NO_3)_2$	Eagle	Pre-plant	1.94	.317	1.20
101	$Ca(NO_3)_2$	Eagle	Pre-plant	2.21	.284	1.57
50	NH_3	Eagle	Pre-plant	2.16	.326	1.70
101	NH_3	Eagle	Pre-plant	2.42	.314	1.42
50	NH_3+N-Serve	Eagle	Pre-plant	2.27	.308	1.33
101	NH_3+N-Serve	Eagle	Pre-plant	2.35	.302	1.42
50	$Ca(NO_3)_2$	Eagle	Spring	2.24	.319	1.33
101	$Ca(NO_3)_2$	Eagle	Spring	2.54	.305	1.41
50	NH_3	Eagle	Spring	2.08	.308	1.39
101	NH_3	Eagle	Spring	2.31	.325	1.66
50	NH_3+N-Serve	Eagle	Spring	2.45	.298	1.33
101	NH_3+N-Serve	Eagle	Spring	2.01	.320	1.65
		Treatment	$LSD_{(.05)}$	0.49	.049	0.35

Mean Values:

			%N	%P	%K
N-Rate	50		2.16	.313	1.52
	101		2.22	.318	1.58
		$LSD_{(.05)}$	NS	NS	NS
Nitrogen Carrier	$Ca(NO_3)_2$		2.16	.316	1.52
	NH_3+N-Serve		2.21	.313	1.53
	NH_3		2.19	.317	1.61
		$LSD_{(.05)}$	NS	NS	NS
Time of Application	Pre-plant		2.20	.317	1.55
	Spring		2.18	.314	1.56
		$LSD_{(.05)}$	NS	NS	NS
Variety	Sturdy		2.13	.320	1.66
	Eagle		2.25	.310	1.45
		$LSD_{(.05)}$	NS	NS	0.10

or potassium concentrations. At the Stafford county location, nitrogen source had no significant effect on either nitrogen or potassium concentrations. Urea produced significantly higher phosphorus concentrations in the plant tissue than did anhydrous ammonia at the first sampling date (Fig. 12).

Urea and anhydrous ammonia resulted in significantly higher nitrogen concentrations in the leaf tissue than anhydrous ammonia plus N-Serve at the second sampling date at Riley county. No significant effects on phosphorus or potassium concentrations were noted for this sampling date. In Stafford county, the reverse was true, anhydrous ammonia plus N-Serve produced a significant nitrogen concentration increase when compared to urea. Effects of nitrogen source on phosphorus and potassium concentrations for the second sampling date at Stafford county were non-significant (Fig. 13 and Fig. 14).

There were no significant differences in the comparisons of nitrogen source effects on nutrient concentrations at the Riley county location for the third sampling date in 1976. At the Stafford county location, anhydrous ammonia with N-Serve was significantly superior to anhydrous ammonia or urea in comparisons of nitrogen leaf concentrations in plant tissue at the third sampling date. Anhydrous ammonia produced significantly higher nitrogen levels in the leaf tissue than urea. Potassium concentrations (date 3) in Riley county were significantly lower in plots receiving anhydrous ammonia with N-Serve than for anhydrous ammonia or urea. There was no significant effect on phosphorus concentrations due to nitrogen carrier at the Riley county location.

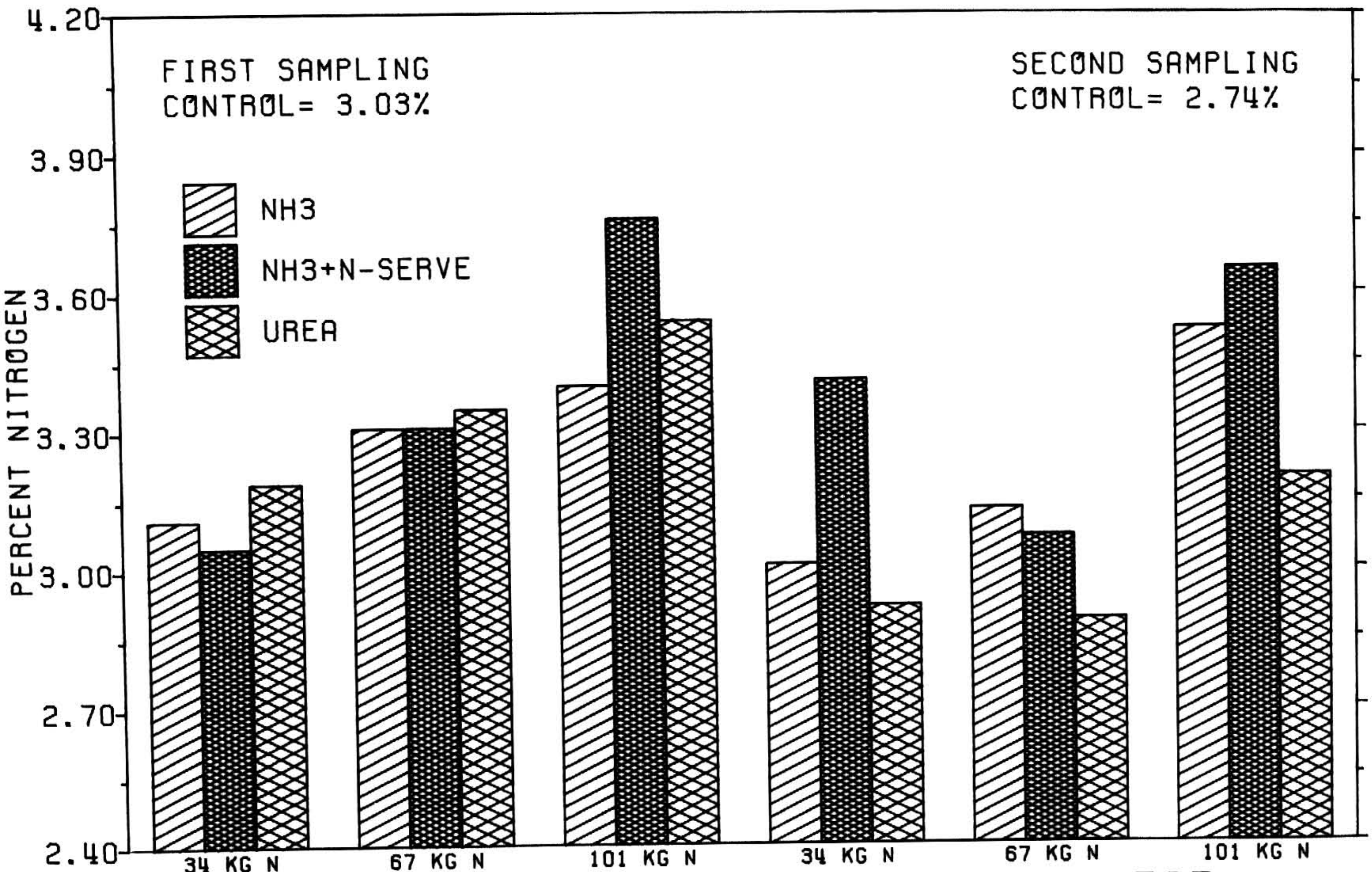


FIG. 12 NITROGEN CONCENTRATION OF WHEAT TISSUE. STAFFORD CO. 1976

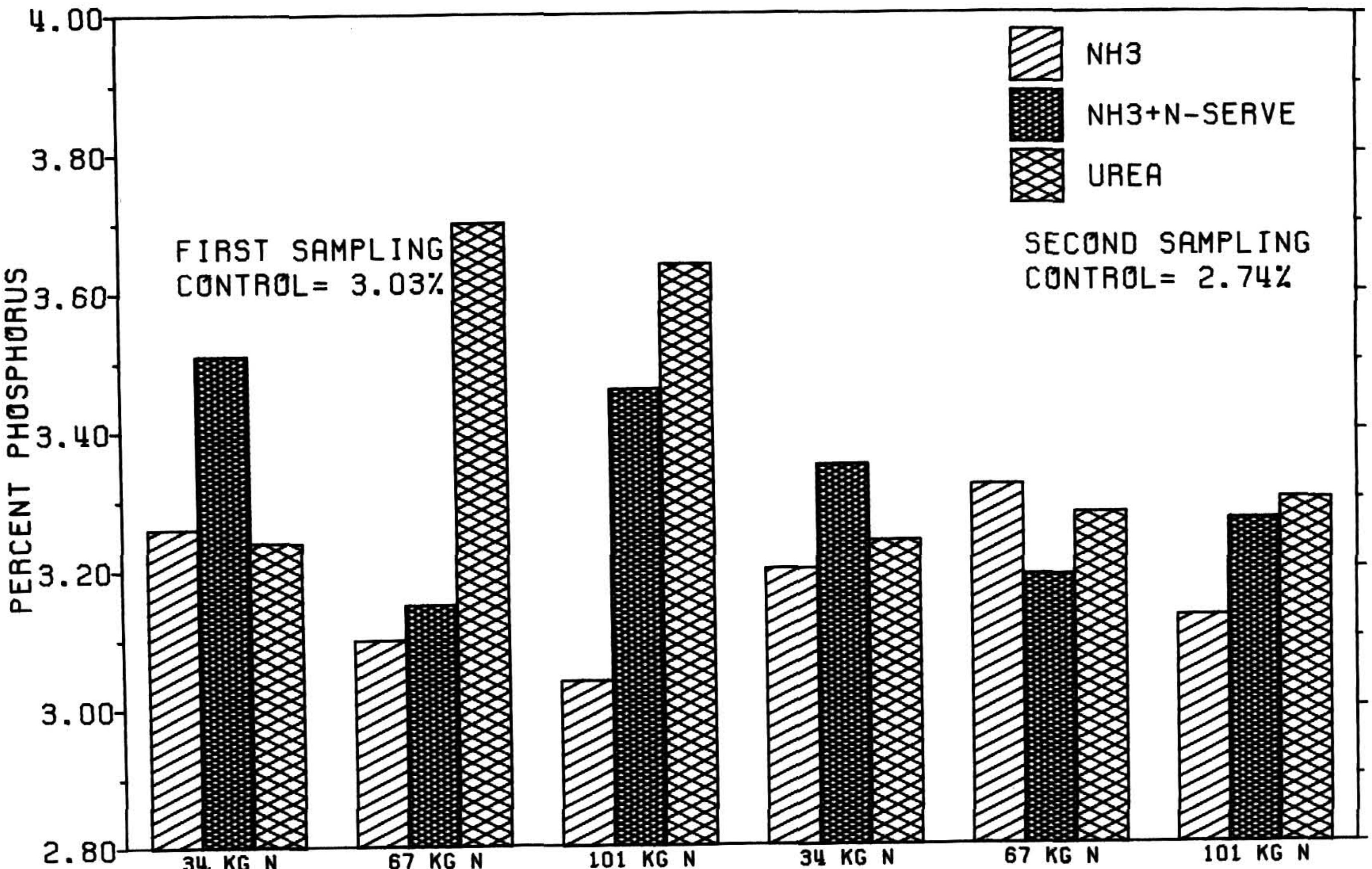


FIG. 13 PHOSPHORUS CONCENTRATION OF WHEAT TISSUE. STAFFORD CO. 1976

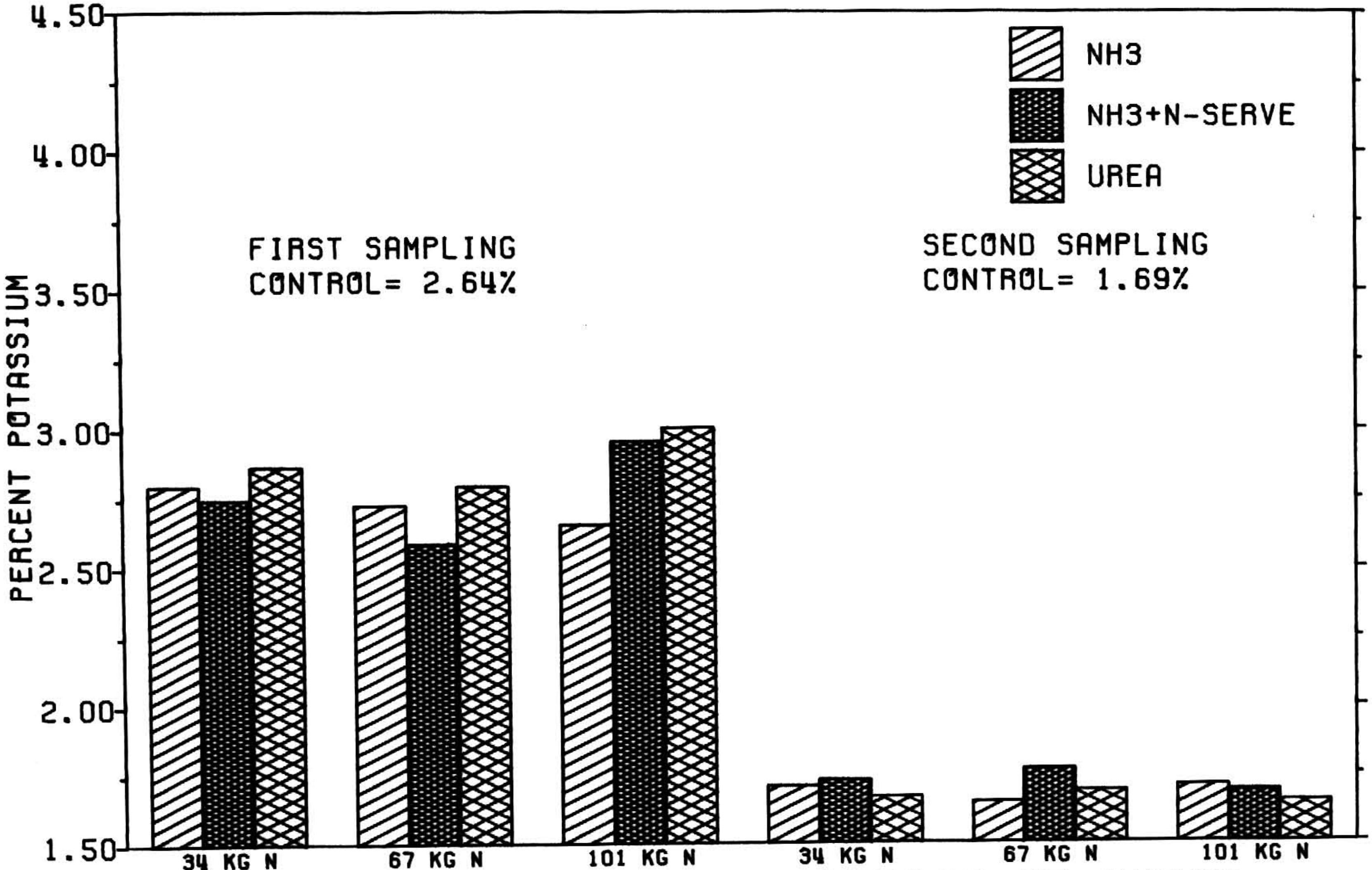


FIG. 14 POTASSIUM CONCENTRATION OF WHEAT TISSUE. STAFFORD CO. 1976

The McPherson (#1) county location produced only non-significant differences in nitrogen, phosphorus and potassium concentrations due to nitrogen carrier effects (Table 22). The leaf tissue sampling date at this location was comparable to the second sampling date at the other locations (Riley and Stafford).

Nitrogen concentrations were generally more responsive to rate of applied nitrogen than nitrogen source in 1976. At the Riley county location, 101 kg N/ha resulted in higher nitrogen concentrations for the first sampling date than either of the lower rates. Phosphorus concentrations followed a similar trend with 101 kg N/ha producing significantly higher leaf concentrations than the 34 kg N/ha rate. Potassium concentrations were similarly increased with an application rate of 101 kg N/ha as compared to the 34 and 67 kg N/ha rates. At the Stafford county location, the 101 kgN/ha rate was significantly higher than 34 kg N/ha in comparisons of leaf tissue nitrogen concentrations for the first sampling date. Phosphorus concentrations were not affected by nitrogen rate at the Stafford county location, but potassium varied at the first sampling date.

For the second sampling date at Riley county, 101 kg N/ha produced significantly highest nitrogen concentration levels, and 67 kg N/ha produced significantly higher leaf nitrogen concentrations than 34 kg N/ha. Phosphorus was unaffected by nitrogen rates at the Riley county location. Similar results were noted in Stafford county. There were no significant effects of nitrogen rate on phosphorus and potassium levels at date 2 in Riley or Stafford counties, despite increased nitrogen concentrations.

The third sampling date at Riley county provided data similar to those of the first two sampling dates. The 101 kg N/ha rate produced significantly higher nitrogen and potassium concentrations than either of the lower rates. Phosphorus concentrations in the leaf tissue were unaffected by nitrogen rates. At Stafford county, the 101 kg N/ha application rate resulted in higher nitrogen concentrations, while the 67 kg N/ha rate produced significantly higher potassium levels than the low or high nitrogen rates. Phosphorus concentrations were unaffected by nitrogen application rates. All responses of nutrient concentrations to nitrogen application rates were non-significant at the McPherson (#1) county location.

The same sort of results were obtained from the 1977 leaf tissue analyses. Due to early maturity of the wheat crop, only two samplings were collected. Sparse plant growth at the Harvey county location prevented leaf tissue sampling at this site.

Anhydrous ammonia with and without N-Serve and UAN solution with and without N-Serve were used as nitrogen carriers at the McPherson (#1) county location. Data collected from this study is presented in Table 23. N-Serve produced no significant response in nitrogen, phosphorus and potassium concentrations in the leaf tissue. However, UAN solution had significantly less effect than anhydrous ammonia on nitrogen and phosphorus concentrations at the first sampling date. The second sampling date data indicated anhydrous ammonia superiority to UAN solution in regard to nitrogen and potassium concentrations in leaf tissue. There were no significant differences in leaf tissue phosphorus concentrations induced by nitrogen carriers at the second samp-

Table 23. EFFECTS OF N-SERVE, N-CARRIER AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (McPherson Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	April 5 %N	April 5 %P	April 5 %K	May 5 %N	May 5 %P	May 5 %K
0	---	2.86	.406	3.24	2.01	.347	1.69
0	N-Serve	2.71	.396	3.36	2.09	.345	1.86
34	NH_3	3.46	.393	3.53	2.45	.350	2.29
67	NH_3	4.13	.390	3.47	2.48	.341	2.25
101	NH_3	4.31	.414	3.46	2.89	.324	2.63
34	NH_3+N-Serve	3.32	.406	3.47	2.35	.341	2.21
67	NH_3+N-Serve	4.21	.413	3.58	2.64	.332	2.37
101	NH_3+N-Serve	4.48	.438	3.84	2.71	.372	2.65
34	UAN	3.01	.369	3.59	2.37	.363	2.10
67	UAN	3.30	.395	3.55	2.34	.350	2.12
101	UAN	4.24	.396	3.57	2.75	.330	2.38
34	UAN+N-Serve	2.93	.378	3.50	2.00	.357	1.78
67	UAN+N-Serve	3.39	.387	3.26	2.24	.352	1.84
101	UAN+N-Serve	4.19	.397	3.65	2.49	.331	2.37
Treatment $LSD_{(.05)}$		0.39	.041	0.23	0.43	.044	0.57
Mean Values:							
N-Rate	34	3.18	.387	3.52	2.27	.353	2.09
	67	3.76	.396	3.47	2.43	.344	2.15
	101	4.30	.411	3.63	2.71	.339	2.50
	$LSD_{(.05)}$	0.19	NS	0.12	0.21	NS	0.29
N-Carrier	NH_3	3.98	.409	3.56	2.59	.343	2.40
	UAN	3.51	.387	3.52	2.35	.347	2.10
	$LSD_{(.05)}$	0.16	.017	NS	0.18	NS	0.23
N-Serve	Yes	3.75	.403	3.55	2.40	.347	2.20
	No	3.74	.393	3.53	2.53	.343	2.30
	$LSD_{(.05)}$	NS	NS	NS	NS	NS	NS

ling date.

A nitrogen rate of 101 kg N/ha resulted in significantly higher date 1 nitrogen concentrations than the lower rates of 34 and 67 kg N/ha (Table 23). The 67 kg N/ha rate was also superior to the 34 kg N/ha rate in this regard. One hundred-one kg N/ha also resulted in higher potassium levels than the 34 kg N/ha rate. Phosphorus concentrations were unaffected by nitrogen application rates for the first sampling date. The same type of results were obtained from the second sampling date. The high nitrogen rate again resulted in significantly higher nitrogen concentrations than did the two lower rates. Potassium levels were significantly higher for each successive nitrogen rate. Phosphorus concentrations were unaffected by nitrogen rate.

The other N-Serve studies conducted in 1977 were similar to the studies conducted in Riley and Stafford counties in 1976. The only exception was that UAN solution was used as a nitrogen source instead of urea at the McPherson (#2) county location. The data collected from these leaf tissue samplings are presented in Tables 24-26.

Anhydrous ammonia with N-Serve and UAN solution both produced higher phosphorus concentrations in the leaf tissue than did anhydrous ammonia for the first sampling date at the McPherson (#2) county site. These carriers also resulted in higher potassium levels in the leaf tissue than did anhydrous ammonia. At the Stafford county site, urea produced a higher concentration of potassium in the leaf tissue than anhydrous ammonia with and without N-Serve. There were no significant effects of

Table 24. EFFECTS OF N-SERVE AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (Stafford Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	April 5			May 5		
		%N	%P	%K	%N	%P	%K
0	---	2.93	.276	2.90	1.96	.264	1.46
34	NH_3	3.17	.265	2.81	2.11	.282	1.42
67	NH_3	3.50	.258	2.69	2.35	.270	1.51
101	NH_3	3.76	.283	3.06	2.47	.276	1.68
34	NH_3+N-Serve	3.13	.278	2.84	2.07	.268	1.51
67	NH_3+N-Serve	3.55	.244	2.80	2.31	.265	1.50
101	NH_3+N-Serve	3.49	.256	2.83	2.40	.261	1.67
34	Urea	3.37	.264	2.94	2.53	.283	1.60
67	Urea	3.53	.259	2.95	2.34	.272	1.52
101	Urea	3.74	.283	3.06	2.47	.276	1.68
	Treatment $LSD_{(.05)}$	0.33	.038	0.22	0.23	.016	0.21
Mean Values:							
N-Rate	34	3.22	.269	2.87	2.24	.277	1.51
	67	3.53	.254	2.81	2.33	.269	1.51
	101	3.68	.268	2.95	2.43	.270	1.62
	$LSD_{(.05)}$	0.19	NS	NS	0.13	NS	NS
N-Carrier	NH_3	3.50	.263	2.82	2.29	.275	1.48
	NH_3+N-Serve	3.39	.259	2.82	2.26	.265	1.56
	Urea	3.54	.269	2.98	2.45	.277	1.60
	$LSD_{(.05)}$	NS	NS	0.13	0.13	.009	NS

Table 25. EFFECTS OF N-SERVE AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (Labette Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	April 5 %N	April 5 %P	April 5 %K	May 5 %N	May 5 %P	May 5 %K
0	---	2.95	.255	3.18	1.80	.355	0.86
34	NH_3	3.85	.260	3.16	2.02	.333	1.04
67	NH_3	3.96	.255	3.19	2.20	.304	1.08
101	NH_3	4.01	.259	3.03	2.18	.334	1.07
34	NH_3+N-Serve	3.62	.256	2.94	2.10	.339	0.98
67	NH_3+N-Serve	3.97	.255	3.12	2.13	.317	1.06
101	NH_3+N-Serve	3.49	.261	2.67	2.27	.317	1.13
34	Urea	3.88	.264	3.16	1.93	.329	0.97
67	Urea	3.95	.256	3.15	2.10	.341	1.08
101	Urea	4.18	.257	3.17	2.11	.317	1.12
Treatment	$LSD_{(.05)}$	0.64	.021	0.48	0.15	.041	0.16
Mean Values:							
N-Rate	34	3.78	.260	3.09	2.02	.334	1.00
	67	3.96	.255	3.15	2.14	.321	1.08
	101	3.89	.259	2.96	2.19	.323	1.11
	$LSD_{(.05)}$	NS	NS	NS	0.09	NS	NS
N-Carrier	NH_3	3.94	.258	3.13	2.13	.324	1.07
	NH_3+N-Serve	3.69	.257	2.91	2.17	.324	1.06
	Urea	4.00	.259	3.16	2.04	.329	1.06
	$LSD_{(.05)}$	NS	NS	NS	0.09	NS	NS

Table 26. EFFECTS OF N-SERVE AND N-RATE ON THE COMPOSITION OF WINTER WHEAT. (McPherson Co., 1977)

N-Rate kg/ha	Nitrogen Carrier	April 5			May 5		
		%N	%P	%K	%N	%P	%K
0	---	4.62	.336	3.75	3.38	.311	2.71
34	NH_3	4.83	.311	3.69	3.95	.312	2.95
67	NH_3	4.71	.334	3.90	3.73	.309	2.75
101	NH_3	4.50	.315	3.24	4.73	.336	3.69
34	NH_3+N-Serve	4.72	.322	3.90	3.78	.314	2.86
67	NH_3+N-Serve	5.11	.341	4.00	4.37	.299	2.99
101	NH_3+N-Serve	5.01	.367	4.15	4.18	.318	3.04
34	UAN	4.87	.344	4.13	3.98	.303	2.99
67	UAN	4.96	.325	4.18	4.16	.299	3.11
101	UAN	5.21	.344	4.36	4.52	.326	3.50
Treatment	$LSD_{(.05)}$	0.51	.028	0.39	0.54	.026	0.49
Mean Values:							
N-Rate	34	4.80	.326	3.91	3.90	.310	2.93
	67	4.93	.333	4.03	4.09	.302	2.95
	101	4.91	.342	3.91	4.48	.327	3.41
	$LSD_{(.05)}$	NS	NS	NS	0.31	.015	0.28
N-Carrier	NH_3	4.68	.320	3.61	4.14	.319	3.13
	NH_3+N-Serve	4.95	.343	4.02	4.11	.311	2.97
	UAN	4.01	.338	4.22	4.22	.309	3.20
	$LSD_{(.05)}$	NS	.016	0.23	NS	NS	NS

nitrogen carriers at the Stafford county site for the first sampling date when compared to nitrogen and phosphorus levels in the plant material. Nitrogen carriers produced no significant differences in leaf tissue composition for the first sampling date in Labette county.

Urea produced significantly higher leaf tissue nitrogen concentrations on the second date of sampling in Stafford county when compared to anhydrous ammonia with and without N-Serve. Anhydrous ammonia and urea both produced significantly higher phosphorus concentrations in the plant tissue than did ammonia with N-Serve (Date 2). There were no significant differences in the potassium levels of the leaf tissue from the plots treated with the three nitrogen carriers. Ammonia with and without the addition of N-Serve significantly increased the nitrogen concentrations in tissue from the second sampling at Labette county. Nitrogen carriers induced no significant differences in the phosphorus or potassium levels in the leaf tissue.

Nitrogen carrier effects on nutrient concentrations in the second date tissue material were non-significant at the McPherson (#2) county location. Nitrogen rates also had no significant effect on leaf tissue composition at the McPherson (#2) and Labette county locations in the first tissue sampling material.

At the Stafford county location, significantly higher concentrations of leaf tissue nitrogen at the first sampling date resulted from each increment of applied nitrogen. Nitrogen rate had no effect on phosphorus or potassium levels of the leaf tissue from the first sampling date.

Second sampling date data indicated significant effects of nitrogen rate on concentrations of all three nutrients at the McPherson (#2) county site. One hundred and one kg N/ha produced higher nitrogen, phosphorus and potassium concentrations in the leaf tissue than both lower nitrogen application rates. At the Stafford county location, 101 kg N/ha resulted in higher mean concentrations of nitrogen in the plant material than the 34 kg N/ha rate. No significant effects of nitrogen rate on the phosphorus or potassium levels occured. In Labette county, the higher nitrogen rates resulted in significant increases in leaf tissue nitrogen when compared to 34 kg N/ha of applied nitrogen. Phosphorus and potassium concentrations were unaffected by nitrogen rates.

In summary, nitrogen carriers either with or without the addition of N-Serve had essentially the same effects on the nutrient content of wheat leaf tissue and no consistent advantage was noted for any material. A possibility exists that anion concentrations, such as phosphate and sulfate, might be increased with the inclusion of N-Serve into ammoniacal fertilizers. This might result by prolonging the life of the cationic ammonium in the soil. This was not demonstrated in this series of studies, however. The possibility still exists that better results might occur in higher pH and low phosphorus soils. Nitrogen rate generally affected the plant tissue composition by increasing the nutrient uptake when higher nitrogen application rates were used.

Effects of Nitrogen and Phosphorus Methods of Application on Winter Wheat

The results of studies conducted in 1975 and 1976 comparing methods of nitrogen and phosphorus application for winter wheat in Harper county are presented on Tables 27 and 28. The type of experimental design used allows valid comparisons between individual treatments and not application methods. However, certain trends cannot be overlooked when comparing the different nitrogen and phosphorus application techniques.

During both years, striking visual differences existed between plots receiving a dual knife application of nitrogen and phosphorus and those plots fertilized by conventional methods of knifing of nitrogen and broadcasting of phosphorus. Figure 15 shows the difference in vegetative growth between a dual knife application of 84 kg N/ha as anhydrous ammonia and 24 kg P/ha as APP and other methods of phosphorus and nitrogen applications which seperate the fertilizers.

The data presented in Tables 27 and 28 indicates a 336 and 51 kg/ha yield advantage for a dual knife application versus a surface applied application of nitrogen and phosphorus in 1975 and 1976 respectively. There was also an increase in yield when knifed applications of nitrogen were used compared to surface nitrogen applications. This was particulary true in 1976 when dry weather prevailed at this time and location. This would seem to indicate some effect of positional availability of the nutrient source. However, other comparisons can be made that can partially negate the advantages of positional availability. When dual knifed applications are compared to knifed anhydrous

Table 27. COMPARISONS OF METHODS OF N AND P APPLICATION FOR WINTER WHEAT. (Harper Co., 1975)

N-Rate kg/ha	P-Rate kg/ha	Application N-Method	Application P-Method	Yield bu/A	Yield kg/ha	Tissue (April 1) %N	Tissue (April 1) %P
0	0	-----	-----	22	1478	2.62	.18
84	0	Knife	-----	34	2285	3.83	.18
84	0	Surface	-----	32	2150	2.65	.17
84	12	Knife	Knife	46	3091	3.39	.26
84	12	Surface	Surface	40	2688	2.92	.18
84	12	Knife	Drill	38	2554	3.14	.18
84	12	Surface	Drill	33	2218	2.52	.19
84	24	Knife	Knife	44	2957	2.89	.29
84	24	Surface	Surface	41	2755	2.56	.23
84	24	Knife	Drill	39	2621	2.80	.21
84	24	Surface	Drill	34	2285	2.41	.21
		Treatment	$LSD_{(.05)}$	8	538	0.59	.03

Mean Values:

		Yield bu/A	Yield kg/ha	%N	%P
N Method	Knife	40	2688	3.21	.22
	Surface	36	2419	2.61	.20
P Method	Knife	45	3024	3.14	.28
	Surface	40	2688	2.74	.20
	Drill	38	2554	2.72	.20
N-P Method	Knife N-P	45	3024	3.14	.28
	Surface N-P	40	2688	2.74	.20

Table 28. COMPARISONS OF METHODS OF N AND P APPLICATION FOR WINTER WHEAT. (Harper Co., 1976)

N-Rate kg/ha	P-Rate kg/ha	Application N-Method	Application P-Method	Yield bu/A	Yield kg/ha	Grain % Protein	Grain %P
0	0	-----	-----	14.7	988	10.9	.352
84	0	Knife	-----	24.1	1620	13.1	.279
84	0	Surface	-----	19.4	1304	11.7	.292
84	12	Knife	Knife	32.4	2177	12.4	.284
84	12	Surface	Surface	25.8	1734	11.0	.346
84	12	Knife	Drill	34.3	2305	12.2	.312
84	12	Surface	Drill	25.7	1727	11.0	.326
84	24	Knife	Knife	34.9	2345	12.0	.329
84	24	Surface	Surface	26.1	1754	10.8	.318
84	24	Knife	Drill	41.9	2816	11.6	.315
84	24	Surface	Drill	28.3	1902	10.5	.367
		Treatment	$LSD_{(.05)}$	5.7	383	0.7	.064
Mean Values:							
		N Method	Knife	33.5	2251	12.3	.304
			Surface	25.1	1687	11.0	.330
		P Method	Knife	33.6	2258	12.2	.306
			Surface	26.0	1747	11.3	.332
			Drill	32.5	2184	11.3	.330
		N-P Method	Knife N-P	33.6	2258	12.2	.306
			Surface N-P	26.0	1747	11.3	.332

Fig. 15. Visual responses of winter wheat to methods of nitrogen and phosphorus application. 84 kg N/ha (75 lbs N/A) and 24 kg P/ha (50 lbs P_2O_5/A), Harper Co., 1976. Note superior growth in lower picture due to dual knifed applications of ammoniacal liquid ammonium polyphosphate (APP) and anhydrous ammonia.


METHODS N-P
APPLICATION
N P2O5
75 50
SURFACE SURFACE
KSU HARPER COUNTY


METHODS N-P
APPLICATION
N P2O5
75 50
KNIFE DRILL
KSU HARPER COUNTY


METHODS N-P
APPLICATION
N P2O5
75 50
KNIFE KNIFE

ammonia and drilled phosphorus, the differences were still 437 kg/ha in 1975.

Nitrogen and phosphorus concentrations in the leaf tissue in 1975 and the protein content of the grain in 1976 followed the same pattern. Higher nutrient concentrations and protein levels were found in the dual, knifed applications when compared to other application methods. However, higher phosphorus levels were found in the grain with the surface applications in 1976.

The results of these studies seemed to indicate that a possible interaction occurs between the ammonium ion and phosphate ion when applied in a small single retention zone in the soil. The work conducted in 1975 and 1976 led to further investigations examining the effect of dual knife applications of anhydrous ammonia and phosphorus, and the possibility of an ammonium-phosphate interaction. The data collected from Reno, Ellsworth, Labette and Dickinson counties in 1977 is presented on Tables 29-34. No leaf tissue samples were taken at the Labette county location due to droughty conditions and yield data is not available from Dickinson county due to hail damage.

The 1977 results were not as clear cut as those in 1975 or 1976. Figure 16 shows the striking visual differences that were evident on April 15, 1977 between methods of nitrogen and phosphorus applications. Phosphorus responses at all locations were visible throughout the growth period, but were most apparent during early spring. Differences between knifed-knifed, knifed-broadcast and knifed-banded applications of nitrogen and phosphorus were easily distinguished at all locations.

Knifed nitrogen as anhydrous ammonia or UAN solution were

Table 29. EFFECTS OF METHODS OF N AND P APPLICATION ON WINTER WHEAT YIELD AND GRAIN COMPOSITION. (Reno Co., 1977)

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N-Method	Application P-Method	Yield bu/A	Yield kg/ha	Grain % Protein	Grain %P
0	0	---	-----	-----	21.1	1418	14.7	.266
84	0	NH_3	Knife	-----	22.2	1492	14.8	.238
84	0	UAN	Knife	-----	25.3	1700	15.0	.278
84	0	UAN	Broadcast	-----	20.7	1391	14.4	.266
84	0	UAN	Dribble	-----	23.2	1559	14.3	.294
84	20	NH_3	Knife	Knife	39.3	2641	14.8	.307
84	20	UAN	Knife	Knife	43.0	2890	14.6	.322
84	20	NH_3	Knife	Broadcast	38.4	2580	14.2	.304
84	20	UAN	Knife	Broadcast	39.1	2628	14.0	.302
84	20	UAN	Broadcast	Broadcast	37.2	2500	13.6	.272
84	20	UAN	Dribble	Dribble	44.7	3004	14.4	.327
84	20	NH_3	Knife	Band	35.2	2365	14.0	.316
84	20	UAN	Knife	Band	35.2	2365	14.2	.318
84	20	UAN	Broadcast	Band	32.3	2171	14.1	.319
84	20	UAN	Dribble	Band	34.4	2312	14.2	.311
84	20	NH_3+N-Serve	Knife	Knife	46.7	3138	14.6	.295
			Treatment	$LSD_{(.05)}$	6.1	410	1.0	.076
Mean Values:		N Method	Knifed NH_3		31.9	2144	14.3	.286
			Knifed UAN		33.2	2231	14.4	.299
			Broadcast UAN		30.1	2023	14.0	.286
			Dribble UAN		34.1	2292	14.3	.311
				$LSD_{(.05)}$	NS	NS	NS	NS
		P Method	0 P		22.8	1532	14.6	.284
			Broadcast P		39.8	2675	14.0	.290
			Knifed P		41.8	2809	14.3	.314
			Band P		34.2	2298	14.1	.313
				$LSD_{(.05)}$	2.9	195	0.5	NS

Table 30. EFFECTS OF METHODS OF N AND P APPLICATION ON WINTER WHEAT YIELD AND GRAIN COMPOSITION. (Ellsworth Co., 1977)

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N-Method	Application P-Method	Yield bu/A	Yield kg/ha	Grain % Protein	Grain %P
0	0	---	-----	-----	38.0	2554	13.9	.388
84	0	NH_3	Knife	-----	43.2	2903	14.2	.416
84	0	UAN	Knife	-----	39.6	2661	14.4	.382
84	0	UAN	Broadcast	-----	41.6	2796	14.0	.364
84	0	UAN	Dribble	-----	42.4	2849	14.8	.461
84	20	NH_3	Knife	Knife	57.8	3884	14.3	.480
84	20	UAN	Knife	Knife	54.6	3669	14.3	.414
84	20	NH_3	Knife	Broadcast	52.6	3535	14.5	.410
84	20	UAN	Knife	Broadcast	52.4	3521	15.0	.411
84	20	UAN	Broadcast	Broadcast	59.6	4005	14.3	.397
84	20	UAN	Dribble	Dribble	57.9	3891	14.7	.563
84	20	NH_3	Knife	Band	49.8	3347	14.2	.347
84	20	UAN	Knife	Band	45.2	3037	14.0	.364
84	20	UAN	Broadcast	Band	47.6	3199	14.6	.382
84	20	UAN	Dribble	Band	50.8	3414	14.2	.384
84	20	NH_3+N-Serve	Knife	Knife	45.1	3031	14.9	.385
			Treatment	$LSD_{(.05)}$	8.3	558	0.7	.149
Mean Values:		N-Method	Knifed NH_3		48.5	3259	14.3	.391
			Knifed UAN		45.7	3071	14.5	.386
			Broadcast UAN		49.6	3333	14.3	.381
			Dribble UAN		50.4	3387	14.5	.469
				$LSD_{(.05)}$	NS	NS	NS	.086
		P-Method	0 P		41.7	2802	14.4	.406
			Broadcast P		55.6	3736	14.6	.445
			Knifed P		56.2	3777	14.3	.447
			Band P		48.3	3246	14.2	.369
				$LSD_{(.05)}$	4.4	296	NS	.075

Table 31. EFFECTS OF METHODS OF N AND P APPLICATION ON WINTER WHEAT YIELD AND GRAIN COMPOSITION. (Labette Co., 1977)

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N-Method	Application P-Method	Yield bu/A	Yield kg/ha	Grain % Protein	Grain %P
0	0	---	-----	-----	26.4	1774	12.6	.409
84	0	NH_3	Knife	-----	37.7	2533	13.0	.354
84	0	UAN	Knife	-----	37.3	2507	9.7	.366
84	0	UAN	Broadcast	-----	31.4	2110	8.7	.381
84	0	UAN	Dribble	-----	39.0	2621	12.4	.323
84	20	NH_3	Knife	Knife	44.6	2997	12.1	.336
84	20	UAN	Knife	Knife	44.6	2997	12.6	.360
84	20	NH_3	Knife	Broadcast	43.0	2890	12.1	.502
84	20	UAN	Knife	Broadcast	44.8	3011	11.8	.340
84	20	UAN	Broadcast	Broadcast	39.0	2621	11.4	.334
84	20	UAN	Dribble	Dribble	40.6	2728	11.7	.330
84	20	NH_3	Knife	Band	41.3	2775	12.0	.318
84	20	UAN	Knife	Band	45.2	3037	12.1	.330
84	20	UAN	Broadcast	Band	40.9	2748	11.4	.370
84	20	UAN	Dribble	Band	42.5	2856	12.1	.333
84	20	NH_3+N-Serve	Knife	Knife	48.6	3266	12.4	.378
			Treatment	$LSD_{(.05)}$	4.5	302	1.4	.072
Mean Values:		N-Method	Knifed NH_3		40.7	2735	12.4	.325
			Knifed UAN		42.4	2849	11.2	.345
			Broadcast UAN		37.1	2493	10.5	.362
			Dribble UAN		40.7	2735	12.1	.328
				$LSD_{(.05)}$	2.4	161	0.8	NS
		P-Method	0 P		36.3	2439	11.0	.356
			Broadcast P		41.9	2816	11.8	.326
			Knifed P		44.6	2997	12.4	.348
			Band P		42.5	2856	11.9	.338
				$LSD_{(.05)}$	2.1	141	0.7	NS

Table 32. EFFECTS OF METHODS OF N AND P APPLICATION ON WINTER WHEAT LEAF TISSUE COMPOSITION. (Ellsworth Co., 1977)

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N-Method	Application P-Method	April 1 %N	April 1 %P	April 1 %K
0	0	---	-----	-----	3.91	.195	3.55
84	0	NH_3	Knife	-----	3.90	.160	3.40
84	0	UAN	Knife	-----	4.02	.188	3.61
84	0	UAN	Broadcast	-----	4.11	.176	3.64
84	0	UAN	Dribble	-----	4.08	.185	3.61
84	20	NH_3	Knife	Knife	4.74	.302	3.94
84	20	UAN	Knife	Knife	4.62	.288	3.88
84	20	NH_3	Knife	Broadcast	3.92	.191	3.58
84	20	UAN	Knife	Broadcast	4.02	.197	3.62
84	20	UAN	Broadcast	Broadcast	4.20	.218	3.64
84	20	UAN	Dribble	Dribble	4.68	.246	3.97
84	20	NH_3	Knife	Band	4.18	.214	3.67
84	20	UAN	Knife	Band	4.06	.210	3.61
84	20	UAN	Broadcast	Band	4.00	.214	3.66
84	20	UAN	Dribble	Band	3.96	.216	3.68
84	20	NH_3+N-Serve	Knife	Knife	4.68	.302	3.67
			Treatment	$LSD_{(.05)}$	0.39	.018	NS
Mean Values:		N-Method	Knifed NH_3		3.99	.188	3.55
			Knifed UAN		4.03	.198	3.61
			Broadcast UAN		4.10	.203	3.65
			Dribble UAN		4.24	.216	3.75
				$LSD_{(.05)}$	NS	.010	NS
		P-Method	0 P		4.03	.178	3.56
			Broadcast P		4.20	.213	3.70
			Knifed P		4.67	.295	3.91
			Band P		4.05	.213	3.66
				$LSD_{(.05)}$	NS	.009	NS

Table 33. EFFECTS OF METHODS OF N AND P APPLICATION ON WINTER WHEAT LEAF TISSUE COMPOSITION. (Dickinson Co., 1977)

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N-Method	Application P-Method	April 1 %N	April 1 %P	April 1 %K
0	0	---	-----	-----	3.58	.215	2.98
84	0	NH_3	Knife	-----	4.14	.230	3.32
84	0	UAN	Knife	-----	4.07	.231	3.38
84	0	UAN	Broadcast	-----	3.98	.220	3.24
84	0	UAN	Dribble	-----	4.05	.188	3.37
84	20	NH_3	Knife	Knife	4.50	.280	3.28
84	20	UAN	Knife	Knife	4.02	.276	3.10
84	20	NH_3	Knife	Broadcast	4.06	.224	3.39
84	20	UAN	Knife	Broadcast	3.92	.214	3.17
84	20	UAN	Broadcast	Broadcast	3.72	.216	3.12
84	20	UAN	Dribble	Dribble	3.79	.239	3.30
84	20	NH_3	Knife	Band	4.12	.242	3.22
84	20	UAN	Knife	Band	4.07	.234	3.24
84	20	UAN	Broadcast	Band	3.70	.244	3.12
84	20	UAN	Dribble	Band	3.80	.228	3.29
84	20	NH_3+N-Serve	Knife	Knife	4.36	.328	3.19
			Treatment	$LSD_{(.05)}$	0.29	.044	0.22
Mean Values:		N-Method	Knifed NH_3		4.10	.232	3.31
			Knifed UAN		4.02	.226	3.26
			Broadcast UAN		3.80	.227	3.16
			Dribble UAN		3.88	.215	3.31
				$LSD_{(.05)}$	0.13	NS	0.12
		P-Method	0 P		4.06	.217	3.32
			Broadcast P		3.87	.221	3.24
			Knifed P		4.25	.277	3.18
			Band P		3.93	.237	3.22
				$LSD_{(.05)}$	0.11	NS	NS

Table 34. EFFECTS OF METHODS OF N AND P APPLICATION ON WINTER WHEAT LEAF TISSUE COMPOSITION. (Reno Co., 1977)

N-Rate kg/ha	P-Rate kg/ha	Nitrogen Carrier	Application N-Method	Application P-Method	April 1 %N	April 1 %P	April 1 %K
0	0	---	-----	-----	3.80	.168	3.48
84	0	NH_3	Knife	-----	3.44	.165	3.13
84	0	UAN	Knife	-----	3.84	.165	3.58
84	0	UAN	Broadcast	-----	3.87	.175	3.54
84	0	UAN	Dribble	-----	3.88	.174	3.63
84	20	NH_3	Knife	Knife	3.71	.252	3.27
84	20	UAN	Knife	Knife	3.87	.232	3.44
84	20	NH_3	Knife	Broadcast	3.78	.197	3.62
84	20	UAN	Knife	Broadcast	3.82	.200	3.69
84	20	UAN	Broadcast	Broadcast	3.72	.195	3.66
84	20	UAN	Dribble	Dribble	3.72	.212	3.70
84	20	NH_3	Knife	Band	3.80	.194	3.59
84	20	UAN	Knife	Band	3.84	.195	3.61
84	20	UAN	Broadcast	Band	3.77	.198	3.53
84	20	UAN	Dribble	Band	3.94	.202	3.56
84	20	NH_3+N-Serve	Knife	Knife	4.02	.234	3.71
			Treatment	$LSD_{(.05)}$	NS	.032	NS
Mean Values:		N-Method	Knifed NH_3		3.67	.185	3.45
			Knifed UAN		3.83	.187	3.63
			Broadcast UAN		3.79	.189	3.57
			Dribble UAN		3.85	.196	3.63
				$LSD_{(.05)}$	NS	NS	NS
		P-Method	0 P		3.76	.170	3.47
			Broadcast P		3.76	.201	3.67
			Knifed P		3.80	.241	3.35
			Band P		3.84	.197	3.57
				$LSD_{(.05)}$	NS	.010	NS

Fig. 16. Visual responses of winter wheat to methods of nitrogen and phosphorus application, 1977. 84 kg N/ha (75 lbs N/A) and 20 kg P/ha (40 lbs P_2O_5/A). Top, 0 P vs. knifed N and P, Ellsworth Co.; Center, knifed N and P vs. knifed N and banded P, Ellsworth Co.; Bottom, knifed N and P vs. knifed N and broadcast P, Reno Co. Note the superior growth resulting from the knifed placement.


N-P METHODS
75 N UAN KNIFED
0 P_2O_5 40
KNIFED
ELLSWORTH CO APRIL 15,1977


N-P METHODS
75 N UAN KNIFED
KNIFED 40 BAND
P_2O_5
ELLSWORTH CO APRIL 15,1977


N-P METHODS
75 N NH_3 KNIFED
40
KNIFED P_2O_5 BCAST
RENO CO KANSAS APRIL 15,1977

were equally effective in their ability to promote luxuriant plant growth of winter wheat when simultaneously injected with APP. This indicates that over ammoniation of APP was not the only factor inducing the increased nitrogen and phosphorus availability. It seems, from these observations, that the ammonium ion exerts some influence on the rate of APP decay. Late spring rains tended to compensate for the increased growth associated with the knifed-knifed applications of nitrogen and phosphorus as harvest approached.

At the Reno county location there were no significant differences between effects of methods of nitrogen application on grain yield, protein or grain phosphorus concentrations (Table 31). When methods of phosphorus application were evaluated for effects on yield, broadcasting of phosphorus was significantly more effective than banded phosphorus. No-phosphorus applications were inferior to all methods of phosphorus application.

All methods of phosphorus application produced significantly lower grain protein than no-phosphorus controls. There were no significant differences in the phosphorus concentrations in the grain that could be attributed to methods of phosphorus application.

Ellsworth data shows no yield or protein responses to methods of nitrogen application. Dribbling UAN solution, allowing the solution to fall from the removed nozzle openings, produced a marked increase in the amount of phosphorus in the grain when compared to other methods of nitrogen application. Broadcast and knifed phosphorus produced a significant increase in yield when compared to banded phosphorus. However, banded phosphorus was significantly better than no phosphorus. Knifed and broadcast phosphorus applications were significantly more productive than plots which received no phosphorus in terms of increased phosphorus concentrations in the grain. Methods of phosphorus application had no significant effect on grain protein.

At the Labette county site, yields indicated that broadcast UAN solution applied pre-plant was significantly inferior to the other nitrogen application methods. Knifed anhydrous ammonia and a dribble application of UAN solution produced significantly higher protein levels in the grain than did knifed or broadcast applications of UAN solution. Phosphorus levels of the grain were unaffected by nitrogen application methods. Knifed phosphorus applications were significantly superior to broadcast and band applications as well as no-phosphorus plots in effects on grain yield. All three phosphorus application methods produced significantly more protein than the no-phosphorus treatments. However, no significant differences in grain protein at the 5% confidence level were noted between methods of phosphorus application. Grain phosphorus levels were not affected by method of nitrogen or phosphorus application.

At the Reno county location (Table 33), knifed phosphorus applications were significantly superior to broadcast and band applications in terms of the phosphorus concentrations in the leaf tissue. All three application methods resulted in significantly higher phosphorus levels in the leaf tissue than when no phosphorus was applied. Nitrogen application methods had no effect on nutrient levels in the leaf tissue.

Dribble applications of UAN solution, averaged across all phosphorus application methods, resulted in significantly higher phosphorus concentrations in the leaf tissue than other methods of nitrogen application at the Ellsworth county location (Table 32). Broadcast and knifed UAN solution treatments were both significantly superior to knifed anhydrous ammonia in terms of leaf tissue phosphorus concentrations. Nitrogen and potassium concentrations were unchanged by the various nitrogen and phosphorus application methods. Knifed phosphorus applications were far superior to other methods of application when compared for phosphorus concentrations in the leaf tissue.

The data from the Dickinson county location (Table 34) revealed that knifed anhydrous ammonia and knifed UAN solution applications resulted in a significant increase in the nitrogen concentrations of the leaf tissue when compared to other nitrogen application methods. Broadcast UAN solution applications were significantly lower than the other nitrogen application methods in comparisons of potassium concentrations in the leaf tissue.

Knifed phosphorus applications again produced a significant increase in the phosphorus concentrations of the leaf tissue at Dickinson county. Both broadcast and band phosphorus applications produced significantly lower nitrogen levels in the leaf tissue in comparisons to applying no phosphorus. This was probably due to a dilution effect. Non-significant phosphorus concentration differences (5% level) were recorded between methods of phosphorus application, although the knifed treatments tended strongly higher.

Trends were essentially the same in 1977 from the simultaneous nitrogen and phosphorus application method studies as were found in 1975 and 1976. There are several things which merit extra attention in the 1977 studies, however. A single treatment involving N-Serve in conjunction with the dual knifed application of anhydrous ammonia and APP was included in these studies. The inclusion of N-Serve produced some very pronounced effects at all locations during the spring growth of the wheat. At all locations, the plots receiving the N-Serve treatment showed excellent visual growth responses and were superior to knifed-broadcast, knifed-dribble or knife-band applications of nitrogen and phosphorus.

Nitrogen concentrations of the leaf tissue were significantly higher in the treatment receiving the N-Serve addition when compared to essentially all other treatments at Dickinson county, and was higher, though not significantly, than all other treatments at Reno county (Tables 33 and 34). At Ellsworth county there were also indications of increased leaf nitrogen concentrations when N-Serve was added to a dual knife application of nitrogen and phosphorus (Table 32).

Phosphorus concentrations of the leaf tissue tended to increase with the addition of N-Serve. Phosphorus concentrations of the leaf tissue were significantly higher in the dual knife applications of anhydrous ammonia with N-Serve and phosphorus at Dickinson county than with conventional surface and knifed applications which seperated the fertilizers.

At the Ellsworth and Labette county sites, the N-Serve treatments were superior in grain production to any other nitrogen-phosphorus application method (Tables 32 and 34). The effect of N-Serve on visual growth responses, grain phosphorus levels, leaf nitrogen and phosphorus concentrations and grain yield seems to be due to the fact that N-Serve delays the nitrification of the ammonium ion to nitrate. The persistence of ammonium ions in the soil zone of the APP may aid in the maintaining of the APP in the ammonium polyphosphate form and keeping it from degrading to ammonium and a calcium phosphate compound. This may increase the length of time that both the nitrogen and phosphorus are in an available form in the root zone. Further examination of a possible interaction between nitrogen and phosphorus is warranted in future research studies.

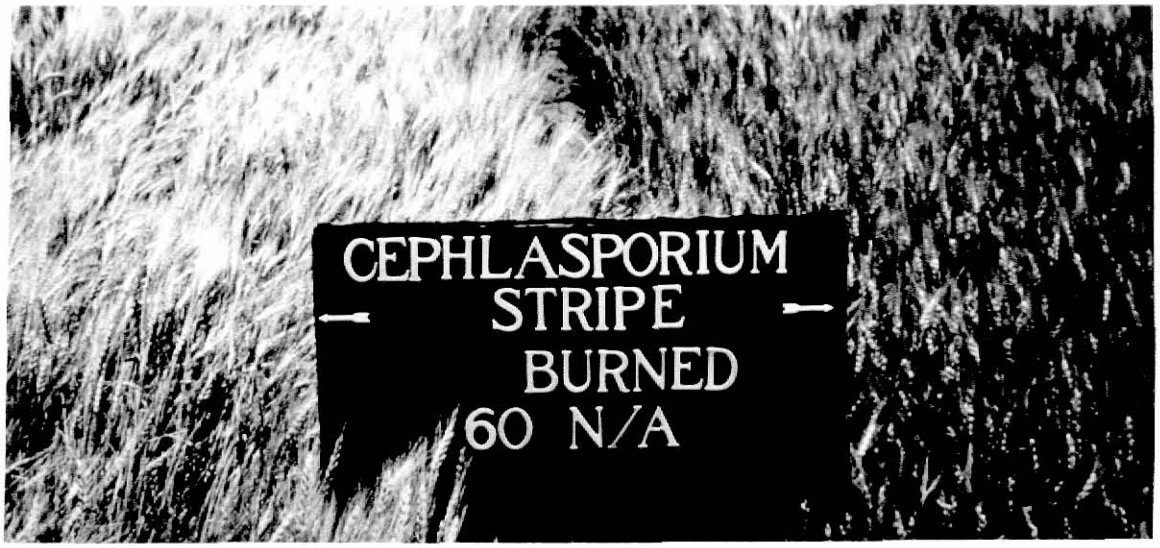
Effect of Cultural Practices on Cephalosporium Stripe Infections of Winter Wheat

Cephalosporium stripe is a fungal disease that has been increasing in severity since it was first detected in Kansas in 1972. Figures 17 and 18 show the symptoms associated with the disease in the vegetative and reproductive stages of the wheat plant. *Cephalosporium* stripe is most severe in continuous cropped wheat areas such as south central Kansas. Early observations by plant pathologists led to the belief that the severity of the disease may be eased by higher applications of nitrogen. It was also considered possible that nitrogen form might affect the severity of the disease. Several fungal pathogens such as *Fusarium roseum* f. sp. *cerealis* and *F. oxysporum* f. sp. *pisi* can be rapidly destroyed under laboratory conditions and severely reduced under field conditions by supplying large rates of ammonium-nitrogen (Huber and Watson, 1974). It was hoped that

Fig. 17. Symptoms of Cephalosporium stripe infection in winter wheat during vegetative and early reproductive stages of growth. (Sedgwick Co., 1976). Note the yellowish stripe extending down the mid rib of the leaf.


CEPH.
STRIPE

Fig. 18. Effects of stubble burning on the severity of *Cephalosporium* stripe infection in winter wheat. (Sedgwick Co., 1976). Note the more uniform head development in the burned area. Many unfilled heads are visible in the two lower pictures where the infection was more severe.


CEPHLASPORIUM
STRIPE
BURNED
60 N/A


CEPHLASPORIUM
STRIPE
UNBURNED
60 N/A

N-Serve may exert an influence on the severity of the disease by supplying mainly ammonium-nitrogen to the plant. Studies of these variables were conducted in the south central counties of Sedgwick and McPherson.

In 1976 a variety and nitrogen study was conducted at the McPherson (#1) and Sedgwick county locations. A crop residue burning study was also conducted next to the original study area at the Sedgwick county site.

At both locations and for all three studies, infection severity ratings increased as the nitrogen rate was increased (Table 35-38). Severity ratings were made on May 5, 1976. At this date, the symptoms were quite apparent but had not killed any of the plants. The increase in the severity ratings may not indicate an absolute increase in the disease but may be complicated by two factors. The low nitrogen plots may not have displayed the symptoms of the disease as well as the high nitrogen plots because of a geneeal chlorosis due to nitrogen deficiencies and the effects of earlier diseases such as barley yellow dwarf. Another factor may be the increased vigor of the plants in the high nitrogen plots. Because of this vigor they may have been better able to withstand the effects of the disease.

Yields on all three studies were significantly higher as the nitrogen rate was increased. At the Sedgwick county location both the burned and unburned areas showed no significant yield increase as the nitrogen rate went above 34 kg N/ha (Tables 36-38). The same was true at the McPherson (#1) county location, but the yields did not level out until the nitrogen rate went above 67 kg N/ha (Table 35).

Table 35. EFFECTS OF N-RATE AND VARIETIES ON THE SEVERITY OF *CEPHALOSPORIUM* STRIPE INFECTION IN WINTER WHEAT. (McPherson Co., 1976)

N-Rate kg/ha	Variety	Yield bu/A	Yield kg/ha	% Protein	Ceph. Rating
0	Sage	24.6	1653	11.8	3.3
0	Sturdy	13.5	907	12.0	4.0
0	Centurk	31.3	2103	10.6	2.0
0	Tam 101	17.1	1149	12.4	3.0
0	Cloud	19.2	1290	11.4	1.7
0	Eagle	18.8	1263	12.0	1.7
0	Gage	28.9	1942	11.6	2.0
34	Sage	36.8	2473	11.2	4.7
34	Sturdy	20.0	1344	12.5	5.7
34	Centurk	37.6	2526	10.1	4.3
34	Tam 101	25.7	1727	13.4	4.0
34	Cloud	30.4	2043	11.2	3.7
34	Eagle	29.1	1956	11.4	2.7
34	Gage	37.7	2533	10.2	3.0
67	Sage	36.0	2419	12.3	4.3
67	Sturdy	23.0	1546	12.6	6.7
67	Centurk	43.9	2950	11.0	4.3
67	Tam 101	31.1	2090	14.3	5.3
67	Cloud	40.8	2742	11.8	4.3
67	Eagle	32.2	2164	12.2	3.3
67	Gage	40.5	2722	12.2	2.7
101	Sage	30.7	2063	13.4	5.3
101	Sturdy	23.7	1593	13.2	7.3
101	Centurk	38.3	2574	12.0	4.3
101	Tam 101	30.4	2043	13.4	5.3
101	Cloud	34.1	2292	12.0	4.7
101	Eagle	35.5	2386	12.5	4.3
101	Gage	31.8	2137	11.7	4.7
Treatment $LSD_{(.05)}$		9.0	605	1.2	1.5

Table 35. (continued)

		Yield bu/A	Yield kg/ha	% Protein	Ceph. Rating
Mean Values:					
N-Rate	0	21.9	1472	11.7	2.5
	34	31.0	2083	11.4	4.0
	67	35.4	2379	12.6	4.4
	101	32.1	2157	12.4	5.1
	$LSD_{(.05)}$	3.4	228	0.5	0.6
Variety	Sage	32.0	2150	12.2	4.4
	Sturdy	20.1	1351	12.6	5.9
	Centurk	37.8	2540	10.9	3.8
	Tam 101	26.1	1754	13.4	4.4
	Cloud	31.1	2090	11.6	3.6
	Eagle	28.9	1942	12.0	3.0
	Gage	34.7	2332	11.4	3.1
	$LSD_{(.05)}$	4.5	302	0.6	0.8

Table 36. EFFECTS OF N-RATE AND VARIETIES ON THE SEVERITY OF CEPHALOSPORIUM STRIPE INFECTION IN WINTER WHEAT - UNBURNED STUDY. (Sedgwick Co., 1976)

N-Rate kg/ha	Variety	Yield bu/A	Yield kg/ha	% Protein	Ceph. Rating
0	Sage	13.2	887	15.0	3.3
0	Sturdy	6.1	410	15.3	3.7
0	Centurk	13.5	907	13.9	3.0
0	Tam 101	4.4	296	16.9	3.7
0	Cloud	12.8	860	14.2	3.0
0	Eagle	10.2	685	16.6	2.3
0	Gage	15.4	1035	13.6	3.0
34	Sage	16.1	1082	14.7	4.7
34	Sturdy	4.3	289	16.7	4.7
34	Centurk	15.6	1048	14.9	5.0
34	Tam 101	6.7	450	16.5	4.7
34	Cloud	15.6	1048	13.4	3.7
34	Eagle	11.8	793	16.4	5.3
34	Gage	18.4	1236	13.6	2.7
67	Sage	18.0	1210	15.7	4.3
67	Sturdy	9.4	632	17.5	5.0
67	Centurk	23.8	1599	15.2	4.0
67	Tam 101	8.0	538	17.9	4.7
67	Cloud	14.2	954	15.2	3.7
67	Eagle	14.5	974	16.6	4.3
67	Gage	18.8	1263	14.6	3.7
101	Sage	17.3	1163	15.9	4.3
101	Sturdy	7.4	497	14.6	6.0
101	Centurk	18.2	1223	15.0	4.7
101	Tam 101	7.5	504	17.1	5.7
101	Cloud	12.2	820	16.2	5.0
101	Eagle	15.6	1048	16.3	5.0
101	Gage	18.7	1256	15.2	4.7
Treatment $LSD_{(.05)}$		6.4	430	1.5	1.5

Table 37. EFFECTS OF N-RATE AND VARIETIES ON THE SEVERITY OF *CEPHALOSPORIUM* STRIPE INFECTION IN WINTER WHEAT - BURNED STUDY. (Sedgwick Co., 1976)

N-Rate kg/ha	Variety	Yield bu/A	Yield kg/ha	% Protein	Ceph. Rating
0	Sage	33.6	2258	13.5	2.3
0	Sturdy	18.0	1210	14.9	2.7
0	Centurk	38.0	2554	12.3	1.7
0	Tam 101	8.6	578	17.0	2.7
0	Cloud	30.6	2056	12.2	1.7
0	Eagle	18.3	1230	13.8	1.3
0	Gage	25.7	1727	12.8	1.0
34	Sage	35.2	2365	13.6	2.7
34	Sturdy	21.2	1425	15.7	3.0
34	Centurk	41.7	2802	12.9	2.7
34	Tam 101	14.3	961	16.3	3.0
34	Cloud	37.1	2493	13.2	2.3
34	Eagle	24.1	1620	15.0	2.3
34	Gage	38.9	2614	13.3	1,7
67	Sage	34.6	2325	14.4	4.3
67	Sturdy	21.1	1418	15.2	3.7
67	Centurk	40.3	2708	13.4	2.7
67	Tam 101	16.3	1095	15.5	4.0
67	Cloud	35.8	2406	13.1	2.7
67	Eagle	29.7	1996	14.8	2.3
67	Gage	31.5	2117	13.4	2.0
101	Sage	36.5	2453	14.1	3.7
101	Sturdy	24.4	1640	15.0	3.3
101	Centurk	43.8	2943	13.8	2.7
101	Tam 101	19.8	1331	15.6	3.7
101	Cloud	30.5	2050	13.2	2.3
101	Eagle	26.8	1801	15.3	3.3
101	Gage	36.6	2460	13.4	2.0
Treatment $LSD_{(.05)}$		10.0	672	1.1	1.3

Table 38. MEAN VALUES FOR THE EFFECTS OF N-RATE AND VARIETIES ON THE SEVERITY OF CEPHALOSPORIUM STRIPE INFECTION IN WINTER WHEAT. (Sedgwick Co., 1976)

		Yield bu/A	Yield kg/ha	% Protein	Ceph. Rating
Unburned Study					
N-Rate	0	10.8	726	15.1	3.1
	34	12.6	847	15.2	4.4
	67	15.2	1021	15.8	4.2
	101	13.8	927	16.1	5.0
	$LSD_{(.05)}$	2.4	161	0.6	0.6
Variety	Sage	16.1	1082	15.3	4.2
	Sturdy	6.8	457	16.0	4.8
	Centurk	17.8	1196	14.8	4.2
	Tam 101	6.7	450	17.1	4.7
	Cloud	13.7	921	14.7	3.8
	Gage	17.8	1196	14.2	3.5
	Eagle	13.1	880	16.5	4.2
	$LSD_{(.05)}$	3.2	215	0.7	0.8
Burned Study					
N-Rate	0	24.7	1660	13.8	1.9
	34	30.4	2043	14.3	2.5
	67	30.0	2016	14.3	3.1
	101	31.2	2097	14.3	3.0
	$LSD_{(.05)}$	3.8	255	0.4	0.5
Variety	Sage	35.0	2352	13.9	3.2
	Sturdy	21.2	1425	15.2	3.2
	Centurk	40.9	2748	13.1	2.4
	Tam 101	14.8	995	16.1	3.3
	Cloud	33.5	2251	12.9	2.2
	Gage	33.2	2231	13.2	1.7
	Eagle	24.7	1660	14.7	2.3
	$LSD_{(.05)}$	5.0	336	0.5	0.7
Burned vs. Unburned					
	Burned	29.0	1949	14.2	2.6
	Unburned	13.1	880	15.5	4.2
	$LSD_{(.05)}$	1.7	114	0.2	0.3

Protein also tended to increase with increasing nitrogen application rates. The 0 kg N/ha rate produced significantly less protein than the three higher nitrogen rates in the unburned stubble study in Sedgwick county (Table 36). For the burned study (Table 37), the 67 kg N/ha and 101 kg N/ha rates resulted in significantly higher protein levels than the 0 or 34 kg N/ha rates. The McPherson (#1) county site produced the same type of results as the unburned study in Sedgwick county (Table 35).

Varietal differences were very pronounced in all three of the studies. At McPherson (#1) county (Table 35), Sage, Sturdy and Tam 101 received significantly higher severity ratings than did the rest of the varieties. Sturdy had the highest severity rating and was significantly higher than all other varieties. Centurk and Gage produced more grain than the rest of the varieties, while Sage, Cloud and Eagle yielded significantly more grain than Tam 101 or Sturdy. Sturdy was significantly lower in grain production than all the other varieties.

Protein contents of the grain were generally the lowest in the varieties producing the highest grain yields. This effect was evident in all three studies and is a classic example of the dilution effect of high yields on grain protein. Tam 101 had the highest protein content while Sage, Sturdy and Eagle produced a significantly higher protein percentage than Centurk, Cloud and Gage. Centurk was significantly lower in grain protein than any other variety (Table 35).

On the unburned study at the Sedgwick county site (Table 36), the trends were very similar to those at the McPherson (#1) county site with only some minor shuffling of the varieties.

Sturdy and Tam 101 were significantly lower yielding than any of the other varieties. Centurk and Gage were the highest yielders and were significantly higher yielding than any other variety except Sage.

Tam 101 was significantly higher in grain protein than all other varieties except Eagle (Table 36). Eagle was significantly higher than all other varieties in comparisons to grain protein except for Sturdy. Gage was the lowest in protein content but not significantly lower than Cloud or Centurk.

Severity ratings were also significantly different in this study when varieties were compared. As expected, Sturdy and Tam 101 received the highest severity rating but were not significantly higher than Eagle, Centurk or Sage. Gage and Cloud were significantly lower in severity ratings than Tam 101 and Sturdy but not the rest of the varieties.

The burned stubble study at the Sedgwick county site, provided results that were very similar to the results obtained from the unburned studies (Table 37). Figure 19 shows the yields of the seven varieties for both the burned and unburned stubble studies. Centurk was significantly higher yielding than any of the other varieties. Tam 101 and Sturdy were the lowest as far as yield is concerned, although Sturdy was not significantly lower than Eagle. Sage, Cloud and Gage were all significantly higher yielding than Sturdy, Eagle and Tam 101.

Tam 101 was significantly higher in protein than all other varieties, due to a lack of dilution caused by the lower yields. Sturdy was the next highest in protein and was significantly higher than the remaining varieties. Centurk, Cloud and Gage

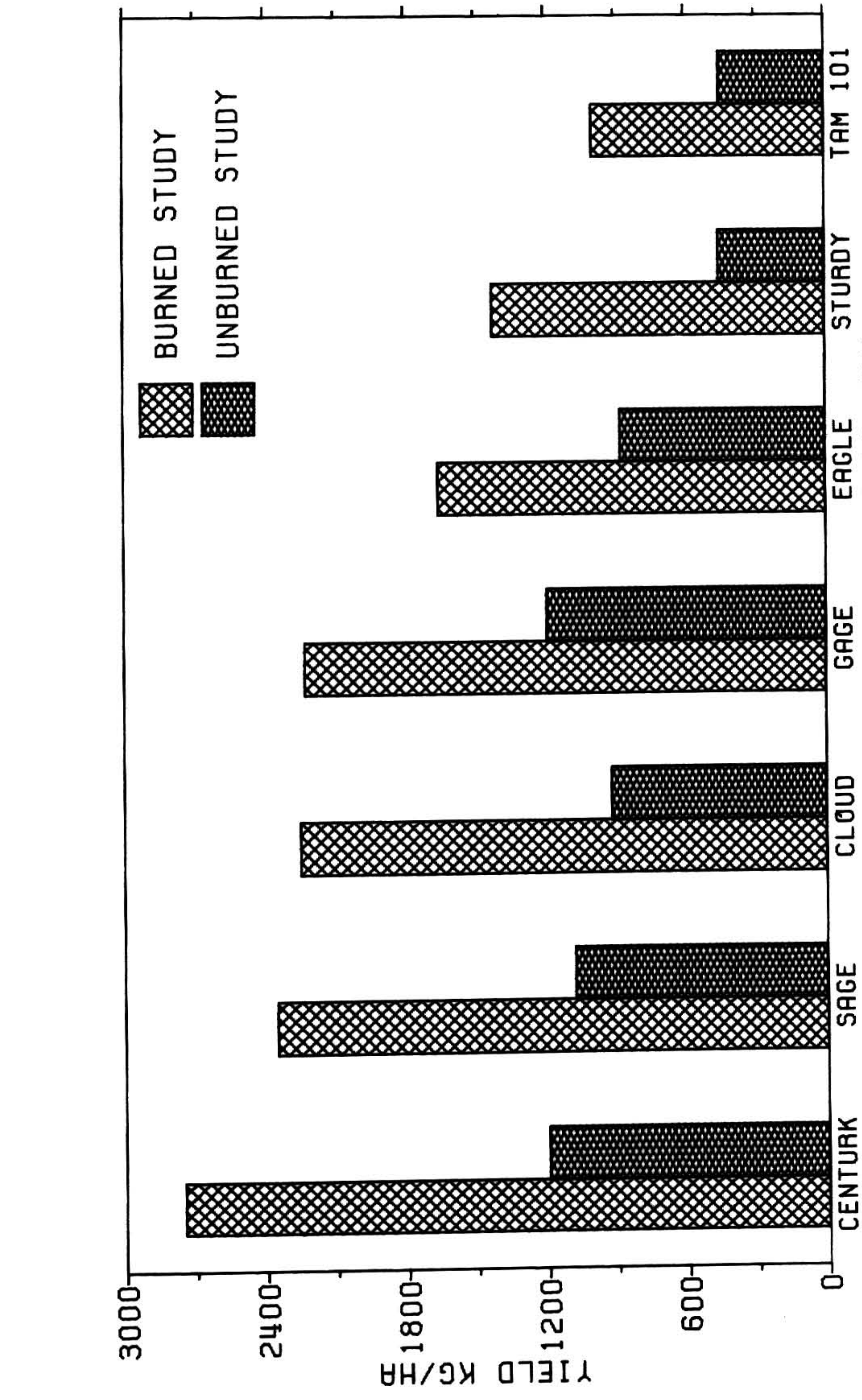


FIG. 19 EFFECTS OF BURNING ON CEPHALOSPORIUM STRIPE. SEDGWICK CO. 1976

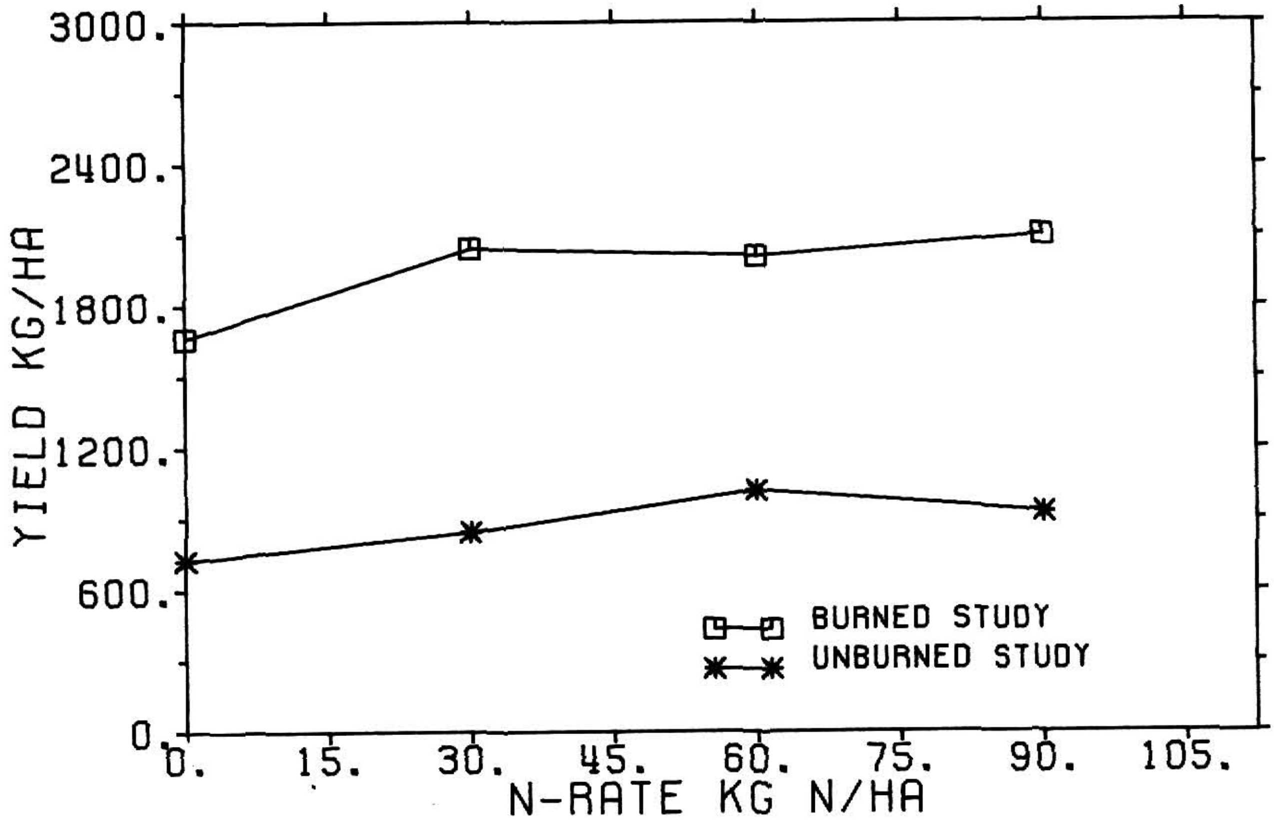
were the lowest in protein content, being significantly lower than the remaining varieties. Eagle had a higher protein content than did Sage.

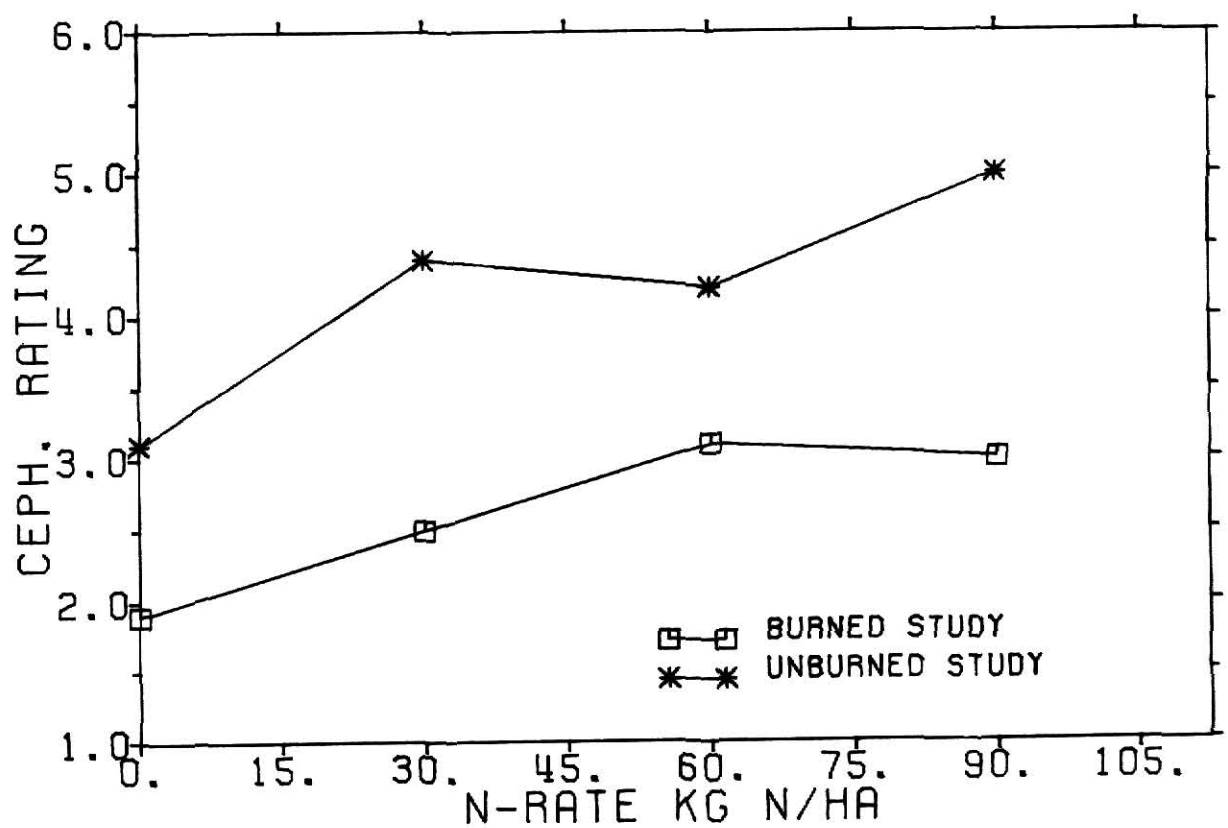
Gage received the lowest severity ratings while Centurk, Cloud and Eagle were significantly lower than the ratings received by Sturdy, Sage and Tam 101 (Table 37).

There was a startling difference when the burned and unburned stubble studies at Sedgwick county were compared. Burning the stubble increased the yields of all varieties by an average of 121% (Fig. 20). The average Cephalosporium stripe severity rating was reduced from 4.2 to 2.6 by stubble burning (Fig. 20). While a strictly valid statistical test was not possible due to a lack of randomization of burning, the studies were analyzed on a combined basis for the burning effect. It is obvious that the practice of burning the previous crops residue decreased the severity of the Cephalosporium stripe infection (Fig. 19).

A second type of Cephalosporium stripe study was conducted in 1976 at the McPherson (#1) county location which included the effects of N-Serve on the severity of Cephalosporium stripe infection. Cephalosporium stripe ratings and time of nitrogen application data from this study are presented in Table 16. N-Serve effects on Cephalosporium stripe ratings were studied at this location. Sturdy received significantly higher ratings than did Eagle. Eagle outyielded Sturdy by 155% and was superior due to the greater susceptibility of Sturdy to Cephalosporium stripe. Spring applications of nitrogen significantly increased the severity rating when compared to a pre-plant nitrogen application. However, there was no significant effect on yield when

Fig. 20. Effects of burning on the severity of *Cephalosporium* stripe infection of winter wheat as indicated by severity ratings and grain yield. (Sedgwick Co., 1976).


3000.
2400.
1800.
1200.
600.
0.
YIELD KG/HA
BURNED STUDY
UNBURNED STUDY
0.
15.
30.
45.
60.
75.
90.
105.
N-RATE KG N/HA


6.0
5.0
4.0
3.0
2.0
1.0
CEPH. RATING
BURNED STUDY
UNBURNED STUDY
0.
15.
30.
45.
60.
75.
90.
105.
N-RATE KG N/HA

when time of nitrogen application was examined. The increase in the severity ratings with the higher nitrogen rates may have been due to the luxuriant growth associated with the spring nitrogen applications.

N-Serve treatments significantly lowered the severity ratings when compared to anhydrous ammonia without N-Serve and calcium nitrate (Fig. 21). Nitrogen rate had no effect on the severity ratings. Yield and protein data from this study were discussed earlier with the N-Serve studies and is presented on Table 16.

The results of the 1977 Cephalosporium stripe studies conducted in Sedgwick county are presented in Tables 39-41. Objectives were similar to the 1976 efforts with the exception of time of seeding being introduced. Nitrogen rate had no effect on the yields obtained from the unburned study and only a slight effect on yields from the burned study. The 34, 67 and 101 kg N/ha rates were significantly higher in grain protein than the plots receiving no nitrogen (Table 40).

Nitrogen rate had a significant effect on grain protein in the unburned area (Table 39). The 101 kg N/ha rate produced significantly higher protein contents of the grain than the three lower rates. The 34 and 67 kg N/ha nitrogen rates were also significantly higher in protein than the plots receiving no nitrogen. In the burned study, the plots receiving no nitrogen had significantly lower protein levels than the plots receiving nitrogen. Gage was significantly superior to Eagle in grain yields on the unburned study (Table 39). Varietal differences were most apparent in the study which had the burned stubble variable.

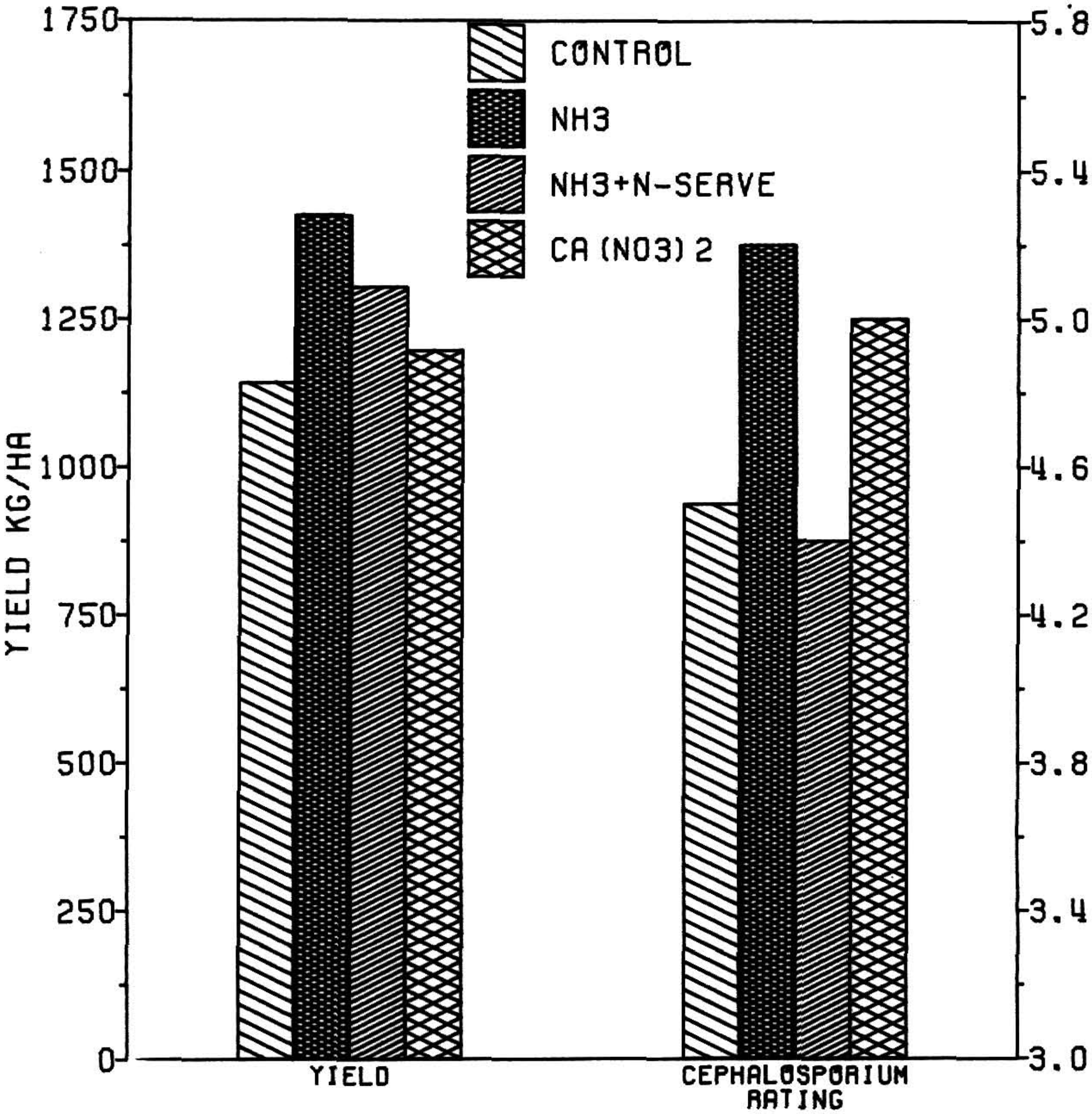


FIG. 21 EFFECTS OF N-SERVE ON CEPHALOSPORIUM STRIPE INFECTION AND YIELD. MCPHERSON CO. 1976

Table 39. EFFECTS OF N-RATES, VARIETIES AND DATE OF PLANTING ON THE SEVERITY OF *CEPHALOSPORIUM* STRIPE INFECTION OF WINTER WHEAT - UNBURNED STUDY. (Sedgwick CO., 1977)

N-Rate kg/ha	Variety	Date of Planting	Yield bu/A	Yield kg/ha	% Protein
0	Sturdy	Sept. 20	33.3	2238	11.5
0	Sturdy	Oct. 10	25.0	1680	13.5
0	Eagle	Sept. 20	24.7	1660	11.5
0	Eagle	Oct. 10	32.7	2197	12.7
0	Gage	Sept. 20	35.5	2386	11.2
0	Gage	Oct. 10	35.8	2406	12.6
34	Sturdy	Sept. 20	30.3	2036	13.1
34	Sturdy	Oct. 10	27.7	1861	14.4
34	Eagle	Sept. 20	30.6	2056	13.0
34	Eagle	Oct. 10	30.8	2070	14.1
34	Gage	Sept. 20	35.1	2359	12.8
34	Gage	Oct. 10	29.6	1989	14.5
67	Sturdy	Sept. 20	29.3	1969	13.6
67	Sturdy	Oct. 10	26.9	1808	14.3
67	Eagle	Sept. 20	28.9	1942	13.4
67	Eagle	Oct. 10	25.4	1707	14.6
67	Gage	Sept. 20	33.6	2258	13.9
67	Gage	Oct. 10	26.1	1754	15.0
101	Sturdy	Sept. 20	32.9	2211	13.9
101	Sturdy	Oct. 10	28.5	1915	14.8
101	Eagle	Sept. 20	26.8	1801	13.7
101	Eagle	Oct. 10	24.2	1626	15.4
101	Gage	Sept. 20	31.0	2083	14.0
101	Gage	Oct. 10	29.6	1989	15.4
		Treatment $LSD_{(.05)}$	8.5	571	0.9

Table 40. EFFECTS OF N-RATE, VARIETIES AND DATE OF PLANTING ON THE SEVERITY OF *CEPHALOSPORIUM* STRIPE INFECTION OF WINTER WHEAT - BURNED STUDY. (Sedgwick Co., 1977)

N-Rate kg/ha	Variety	Date of Planting	Yield bu/A	Yield kg/ha	% Protein
0	Sturdy	Sept. 20	25.2	1693	12.7
0	Sturdy	Oct.10	21.8	1465	13.5
0	Eagle	Sept. 20	26.0	1747	12.2
0	Eagle	Oct. 10	32.4	2177	12.9
0	Gage	Sept. 20	34.6	2325	11.1
0	Gage	Oct. 10	35.6	2392	12.6
34	Sturdy	Sept. 20	30.9	2076	13.4
34	Sturdy	Oct. 10	24.3	1633	14.2
34	Eagle	Sept. 20	30.5	2050	13.6
34	Eagle	Oct. 10	31.6	2124	14.4
34	Gage	Sept. 20	36.7	2466	13.3
34	Gage	Oct. 10	33.9	2278	14.7
67	Sturdy	Sept. 20	33.5	2251	14.1
67	Sturdy	Oct. 10	26.7	1794	14.3
67	Eagle	Sept. 20	34.8	2339	14.3
67	Eagle	Oct. 10	33.0	2218	15.2
67	Gage	Sept. 20	39.9	2681	14.0
67	Gage	Oct. 10	36.4	2446	15.3
101	Sturdy	Sept. 20	36.4	2446	13.7
101	Sturdy	Oct. 10	26.3	1767	13.2
101	Eagle	Sept. 20	31.7	2130	14.4
101	Eagle	Oct. 10	29.2	1962	15.0
101	Gage	Sept. 20	39.3	2641	13.9
101	Gage	Oct. 10	37.2	2500	15.1
	Treatment	$LSD_{(.05)}$	7.6	511	1.4

Table 41. MEAN VALUES FOR THE EFFECTS OF N-RATE, VARIETY AND DATE OF PLANTING ON THE SEVERITY OF CEPHALOSPORIUM STRIPE INFECTION IN WINTER WHEAT. (Sedgwick Co., 1977)

		Yield bu/A	Yield kg/ha	% Protein
Unburned Study				
N-Rate	0	31.2	2097	12.2
	34	30.7	2063	13.7
	67	28.4	1908	14.1
	101	28.8	1935	14.6
	$LSD_{(.05)}$	NS	NS	0.4
Variety	Sturdy	29.2	1962	13.7
	Eagle	28.0	1882	13.6
	Gage	32.0	2150	13.7
	$LSD_{(.05)}$	3.0	202	NS
Date of Planting	Oct. 10	28.5	1915	14.3
	Sept. 20	31.0	2083	13.0
	$LSD_{(.05)}$	NS	NS	0.2
Burned Study				
N-Rate	0	29.3	1969	12.5
	34	31.3	2103	13.9
	67	34.1	2292	14.5
	101	33.4	2244	14.2
	$LSD_{(.05)}$	3.1	208	0.6
Variety	Sturdy	28.2	1895	13.6
	Eagle	31.2	2097	14.0
	Gage	36.7	2466	13.8
	$LSD_{(.05)}$	2.7	181	NS
Date of Planting	Sept. 20	32.3	2171	13.4
	Oct. 10	30.7	2063	14.2
	$LSD_{(.05)}$	NS	NS	0.4
Burned vs. Unburned				
	Burned	32.0	2150	13.8
	Unburned	29.6	1989	13.6
	$LSD_{(.05)}$	1.7	114	NS

Gage produced significantly more grain than both Eagle and Sturdy, while Sturdy produced significantly less grain than Eagle (Table 40). There were no significant differences in grain protein in either study.

Later planting (October 10) produced significantly higher protein contents in the grain than the September 20 planting date in both studies due to a dilution effect of slightly higher yields associated with the September 20 planting date. Planting date produced no significant differences in grain yields in either study, however (Table 41).

Though the differences were not as dramatic as they were in 1976 burning the stubble provided an increase in yield as compared to not burning the stubble. In 1977, the burned and unburned studies were interchanged as compared to their location in 1976. The area burned in 1976 was not burned in 1977, and the area burned in 1977 was not burned in 1976. Although the disease was not as severe during the 1977 crop year as in 1976, an increase of 8% in yield is still substantial (Table 41). Part of the reason for less severe disease losses may be due to the type of weather which occured during the flowering and grain filling period in 1977. Plenty of moisture was available at these times and the plants were not under a moisture stress during the time when the disease normally interferes with the water transport system. Also, there were fewer plants showing the symptoms of the disease in late April and early May.

Burning definitely aided in the control of the disease with very dramatic varietal differences being apparent. Nitrogen rate did not seem to enhance the severity of the disease or ease the symptoms although high nitrogen plants were more vigorous. Nitrogen rate responses were recorded under field conditions however. Late planting did not seem to significantly affect the severity of Cephalosporium stripe in the 1977 crop. Results of this study indicate that this disease cannot be fully controlled by fertilization practices and that the problem may be more in the area of plant pathology and wheat breeding.

Greenhouse and Growth Chamber Studies

The results of the field studies prompted several greenhouse and growth chamber studies. The results obtained from the field studies indicated increased phosphorus uptake and plant growth when ammonium-nitrogen and APP (11-16-0) were applied in the same soil retention zone. The results also indicated that N-Serve increased the affects of dual knife applications of nitrogen and phosphorus in comparison to ammonium-nitrogen without N-Serve. It was considered that other anions, such as sulfate, may also be more efficient when applied in the same retention zone with the ammonium-nitrogen. In all of the greenhouse and growth chamber studies conducted, water was not a limiting factor to maximum plant growth. The phosphorus-nitrogen interaction was also examined, by soil analysis, in three of the studies conducted.

The results of the first greenhouse study are presented in Table 42. A silty loam soil was used in this study (Table 1). Anhydrous ammonia with N-Serve significantly increased the concentration of phosphorus in the first tissue samples when compared to anhydrous ammonia alone. This trend continued for the

Table 42. EFFECTS OF N-SERVE, N-RATE, PHOSPHORUS AND SULFUR ON THE LEAF TISSUE COMPOSITION AND DRY MATTER PRODUCTION OF WINTER WHEAT. (Spring 1976, Greenhouse Study)

N-Rate ppm	Nitrogen Carrier	N-Serve	P-Rate ppm	S-Rate ppm	5/24 %N	5/24 %P	6/18 %N	6/18 %P	Dry Wt. (gms) 5/24	Dry Wt. (gms) 6/18
0	---	---	0	0	4.26	.244	2.63	.197	3.40	1.83
30	NH_3	No	0	0	4.71	.303	3.01	.194	3.40	1.82
30	NH_3	No	40	0	4.76	.321	3.13	.181	3.33	1.83
30	NH_3	No	40	20	4.41	.331	3.02	.199	3.73	1.86
60	NH_3	No	0	0	4.39	.272	2.95	.172	3.70	1.81
60	NH_3	No	40	0	4.62	.312	3.10	.186	3.40	1.85
60	NH_3	No	40	20	4.20	.330	3.18	.218	3.73	1.80
90	NH_3	No	0	0	4.52	.283	3.07	.282	3.45	1.81
90	NH_3	No	40	0	4.65	.312	3.20	.231	3.57	1.84
90	NH_3	No	40	20	4.64	.316	3.28	.223	3.77	1.83
30	NH_3	Yes	0	0	4.75	.289	3.16	.180	3.60	1.79
30	NH_3	Yes	40	0	4.66	.363	2.66	.227	3.93	1.83
30	NH_3	Yes	40	20	4.63	.409	2.74	.235	4.00	1.83
60	NH_3	Yes	0	0	5.01	.288	3.42	.195	3.50	1.83
60	NH_3	Yes	40	0	4.92	.363	3.10	.231	3.83	1.84
60	NH_3	Yes	40	20	4.80	.392	3.31	.217	3.77	1.83
90	NH_3	Yes	0	0	5.16	.252	3.36	.180	3.33	1.82
90	NH_3	Yes	40	0	5.17	.384	3.46	.247	3.77	1.84
90	NH_3	Yes	40	20	4.84	.358	3.40	.227	3.93	1.85
		Treatment $LSD_{(.05)}$			0.56	.066	0.42	.032	0.29	NS

Table 42. (continued)

		5/24		6/18		Dry Wt. (gms)	
		%N	%P	%N	%P	5/24	6/18
Mean Values:							
Nitrogen Carrier	NH_3	4.54	.309	3.10	.199	3.57	1.82
	NH_3+N-Serve	4.88	.344	3.18	.216	3.74	1.83
	$LSD_{(.05)}$	0.19	.022	NS	.011	0.10	NS
N-Rate	30	4.65	.336	2.95	.203	3.67	1.82
	60	4.66	.326	3.18	.203	3.66	1.83
	90	4.83	.317	3.30	.216	3.64	1.83
	$LSD_{(.05)}$	NS	NS	0.17	NS	NS	NS
N-P-S Treatments	N	4.76	.281	3.16	.186	3.50	1.81
	NP	4.80	.342	3.11	.217	3.63	1.84
	NPS	4.59	.356	3.16	.220	3.82	1.83
	$LSD_{(.05)}$	NS	.027	NS	.013	0.12	NS

second sampling date. The concentration of nitrogen in the leaf tissue was also increased with the addition of N-Serve on the second leaf tissue samples. In addition, anhydrous ammonia with N-Serve also produced significantly larger dry weights than anhydrous ammonia for the second tissue harvest date.

Nitrogen rate influenced the amount of nitrogen found in the leaf tissue in the first samples taken. The 60 and 90 ppm nitrogen rates produced significantly higher nitrogen concentrations in the leaf tissue in comparisons made to the 30 ppm nitrogen rate. All other comparisons of plant growth and composition to nitrogen rate were non-significant for both sampling dates.

Comparisons between nitrogen (N), nitrogen-phosphorus (NP) and nitrogen-phosphorus-sulfur (NPS) applications were also tested. Most of the nitrogen was applied as anhydrous ammonia. The N treatment alone was significantly inferior to both the NP and NPS treatments in producing higher phosphorus concentrations in the plant tissue for both harvest dates. The NPS treatment resulted in significantly higher dry matter harvest weights than both the N and NP treatments for the second harvest date. The NP treatments produced significantly more dry matter than the N treatment alone. All other comparisons in the study resulted in non-significant differences.

The second study provided some very interesting data. Tables 43-45 present the results obtained in this growth chamber study. A complete description and analysis of the sandy soil used in this study can be found in Table 1. N-Serve produced no significant effects on plant composition or soil analysis com-

Table 43. EFFECTS OF N-SERVE, N-RATE, PHOSPHORUS AND SULFUR ON THE LEAF TISSUE COMPOSITION OF WINTER WHEAT. (Fall 1976, Growth Chamber Study)

N-Rate ppm	Nitrogen Carrier	N-Serve	P-Rate ppm	S-Rate ppm	November 16			December 6		
					%N	%P	%K	%N	%P	%K
0	---	---	0	0	1.84	.302	3.40	1.14	.271	3.08
30	NH_3	No	0	0	2.76	.301	3.74	2.15	.373	3.68
30	NH_3	No	40	0	2.28	.461	3.51	1.87	.447	3.05
30	NH_3	No	40	20	2.51	.281	2.37	1.55	.344	2.50
60	NH_3	No	0	0	3.11	.281	3.31	2.35	.367	3.79
60	NH_3	No	40	0	3.19	.426	3.27	2.73	.613	3.86
60	NH_3	No	40	20	2.97	.288	1.99	1.75	.245	1.80
90	NH_3	No	0	0	3.60	.313	2.74	2.67	.368	3.72
90	NH_3	No	40	0	3.73	.574	3.04	3.51	.666	3.56
90	NH_3	No	40	20	3.46	.308	1.93	2.08	.244	1.66
30	NH_3	Yes	0	0	2.46	.247	3.68	2.09	.367	3.59
30	NH_3	Yes	40	0	2.66	.497	3.58	2.12	.515	3.76
30	NH_3	Yes	40	20	2.54	.289	2.44	1.43	.280	2.37
60	NH_3	Yes	0	0	3.84	.294	2.71	2.58	.403	3.57
60	NH_3	Yes	40	0	3.39	.533	3.32	2.65	.587	3.80
60	NH_3	Yes	40	20	2.98	.288	2.06	1.75	.237	1.81
90	NH_3	Yes	0	0	4.19	.337	2.52	3.23	.368	3.46
90	NH_3	Yes	40	0	3.77	.538	3.14	2.77	.558	3.82
90	NH_3	Yes	40	20	3.55	.336	2.27	2.10	.252	1.80
			Treatment $LSD_{(.05)}$		0.57	.083	0.46	0.56	.108	0.72

Table 44. EFFECTS OF N-SERVE, N-RATE, PHOSPHORUS AND SULFUR ON DRY MATTER PRODUCTION AND NITRATE AND AMMONIUM ION CONCENTRATIONS IN THE SOIL. (Fall 1976, Growth Chamber)

N-Rate ppm	Nitrogen Carrier	N-Serve	P-Rate ppm	S-Rate ppm	Dry Wt. (gms) Nov. 16	Dry Wt. (gms) Dec. 6	ppm N NH_4^+	ppm N NO_3^-
0	---	---	0	0	1.18	1.39	2.7	1.3
30	NH_3	No	0	0	1.34	1.62	1.2	0.6
30	NH_3	No	40	0	1.57	1.36	2.7	1.6
30	NH_3	No	40	20	2.67	2.63	1.7	0.1
60	NH_3	No	0	0	1.29	1.57	2.7	0.1
60	NH_3	No	40	0	1.40	1.26	8.7	1.3
60	NH_3	No	40	20	2.93	3.12	1.5	0.9
90	NH_3	No	0	0	1.61	1.52	6.6	0.5
90	NH_3	No	40	0	1.57	1.42	7.7	1.8
90	NH_3	No	40	20	2.94	3.68	2.8	0.1
30	NH_3	Yes	0	0	1.33	1.41	1.8	1.7
30	NH_3	Yes	40	0	1.59	1.47	2.4	0.1
30	NH_3	Yes	40	20	2.70	2.41	1.5	1.2
60	NH_3	Yes	0	0	1.51	1.53	5.1	0.7
60	NH_3	Yes	40	0	1.47	1.67	6.2	0.9
60	NH_3	Yes	40	20	2.90	3.30	4.2	1.4
90	NH_3	Yes	0	0	1.40	1.61	5.1	1.2
90	NH_3	Yes	40	0	1.67	1.76	6.7	1.7
90	NH_3	Yes	40	20	2.82	3.88	2.3	2.3
		Treatment $LSD_{(.05)}$			0.18	0.37	4.3	1.9

Table 45. MEAN VALUES FOR THE FALL 1976 GROWTH CHAMBER STUDY.

		November 16			December 6			PPM N	
		%N	%P	%K	%N	%P	%K	NH_4^+	NO_3^-
N-Carrier	NH_3	3.07	.359	2.88	2.30	.408	3.07	4.0	0.7
	NH_3+N-Serve	3.26	.373	2.86	2.30	.397	3.11	3.9	1.3
	$LSD_{(.05)}$	NS	NS	NS	NS	NS	NS	NS	NS
N-Rate	30	2.54	.346	3.22	1.87	.388	3.16	1.9	0.9
	60	3.25	.352	2.78	2.30	.409	3.11	4.7	0.9
	90	3.72	.401	2.61	2.73	.410	3.00	5.2	1.3
	$LSD_{(.05)}$	0.23	.034	0.19	0.23	NS	NS	1.8	NS
N-P-S Additions	N	3.33	.296	3.12	2.51	.375	3.63	3.8	0.8
	NP	3.17	.505	3.31	2.61	.564	3.63	5.7	1.2
	NPS	3.00	.298	2.18	1.78	.267	1.99	2.3	1.0
	$LSD_{(.05)}$	0.23	.034	0.19	0.23	.044	0.30	1.8	NS

		Total Uptake						Dry Wt. (gms)	
		November 16			December 6				
		mg N	mg P	mg K	mg N	mg P	mg K	11/16	12/6
N-Carrier	NH_3	58.7	6.7	51.5	43.5	7.3	55.4	1.92	2.02
	NH_3+N-Serve	61.9	7.0	52.4	46.2	7.6	59.3	1.93	2.12
	$LSD_{(.05)}$	NS	NS	NS	2.6	NS	NS	NS	NS
N-Rate	30	46.9	6.3	56.3	32.4	6.7	54.5	1.87	1.82
	60	60.9	6.5	49.5	44.6	7.5	56.9	1.92	2.08
	90	73.1	7.7	50.1	57.6	8.3	60.5	2.00	2.31
	$LSD_{(.05)}$	5.3	0.8	4.8	3.2	0.9	7.0	NS	0.15
N-P-S Additions	N	47.0	4.2	43.9	38.5	5.8	56.4	1.41	1.54
	NP	49.0	7.8	51.0	38.6	8.4	54.3	1.54	1.49
	NPS	84.9	8.4	61.0	57.5	8.3	61.3	2.83	3.17
	$LSD_{(.05)}$	5.3	0.8	4.8	3.2	0.9	NS	0.18	0.15

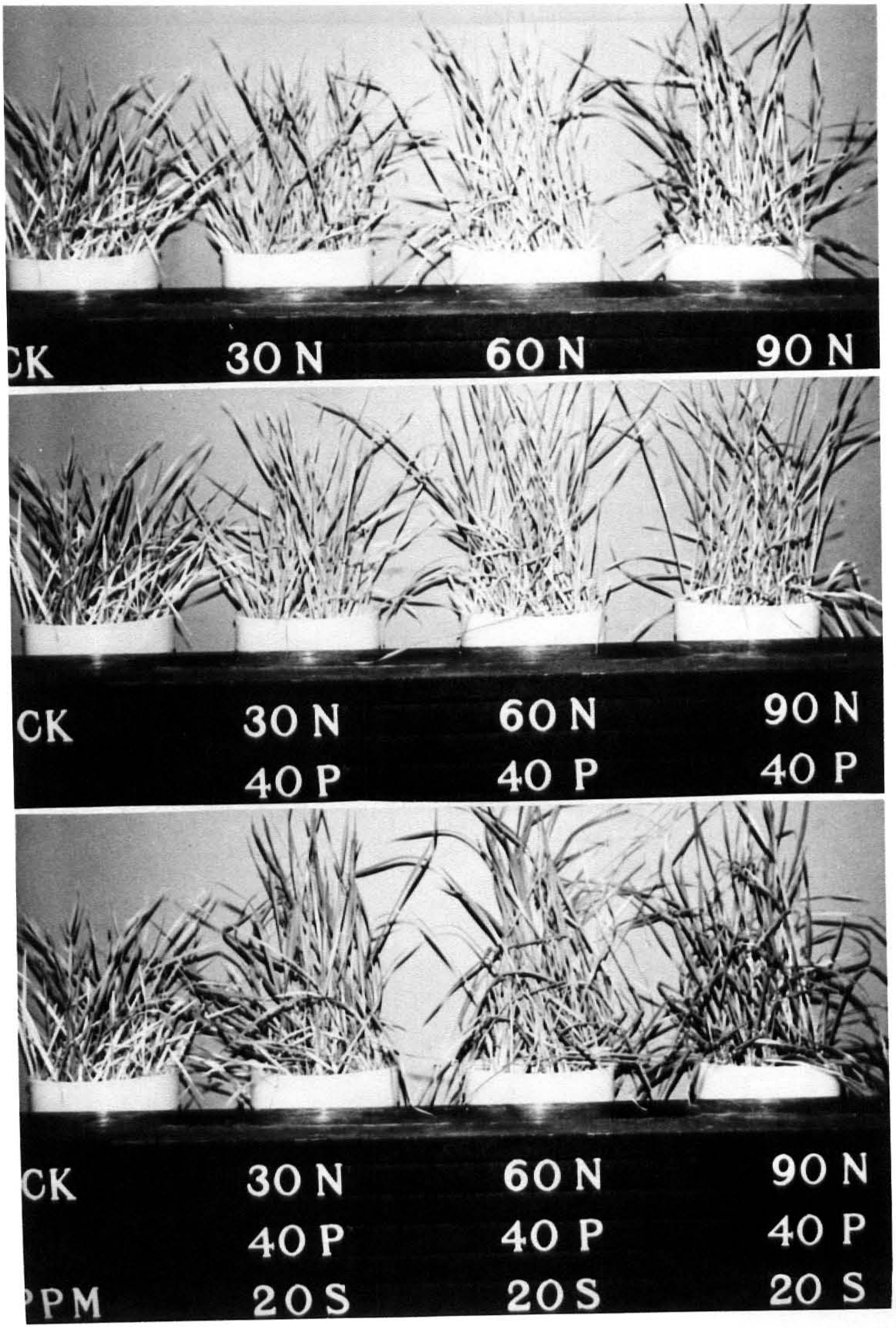
parisons.

Applied nitrogen rate increased the nitrogen concentrations in the leaf tissue as the rate of applied nitrogen was increased for each increment of 30 ppm. In the first samples, each increase of 30 ppm nitrogen in the application rate produced a significant increase in nitrogen concentrations in the leaf tissue material. For the second sampling date, a significant response to nitrogen rate occured only as the rate of nitrogen applied went above 60 ppm.

Phosphorus concentrations in the plant tissue were significantly greater at the 90 ppm nitrogen rate for the first harvest samples than either the 30 or 60 ppm nitrogen rate. Phosphorus concentration responses to nitrogen were non-significant for the second harvest date. Potassium concentrations in the leaf tissue from the first date were significantly lower when the nitrogen was increased from 30 to 60 ppm. No significant difference in potassium concentration existed between the 60 and 90 ppm nitrogen treatments. No significant potassium responses to nitrogen application rate was noted for the second sampling harvest date.

Nitrogen application rate significantly affected the amount of ammonium ions present in the soil at the conclusion of the study (Tables 44-45). There were more ammonium ions present in the soil from the 60 and 90 ppm nitrogen rates than for the 30 ppm rate. Figure 22 shows that the 0 and 30 ppm nitrogen application rates were becoming deficient in nitrogen by the time the first leaf tissue harvest was conducted. There were essentially no difference in the nitrate ion concentrations in the soil ac-

Fig. 22. Effects of nitrogen rate, phosphorus and sulfur on the growth of winter wheat under growth chamber conditions. Top, 30, 60 and 90 ppm nitrogen; Center, 30, 60 and 90 ppm nitrogen and 40 ppm phosphorus; Bottom, 30, 60 and 90 ppm nitrogen, 40 ppm phosphorus and 20 ppm sulfur. (Fall 1976, growth chamber study).


CK
30 N
60 N
90 N
CK
30 N
40 P
60 N
40 P
90 N
40 P
CK
30 N
40 P
20 S
60 N
40 P
20 S
90 N
40 P
20 S
PPM

ross all nitrogen application rates at the end of the study. The dry weight of the second tissue harvest material was significantly greater with each successive 30 ppm nitrogen increase in the nitrogen rate at the first harvest date.

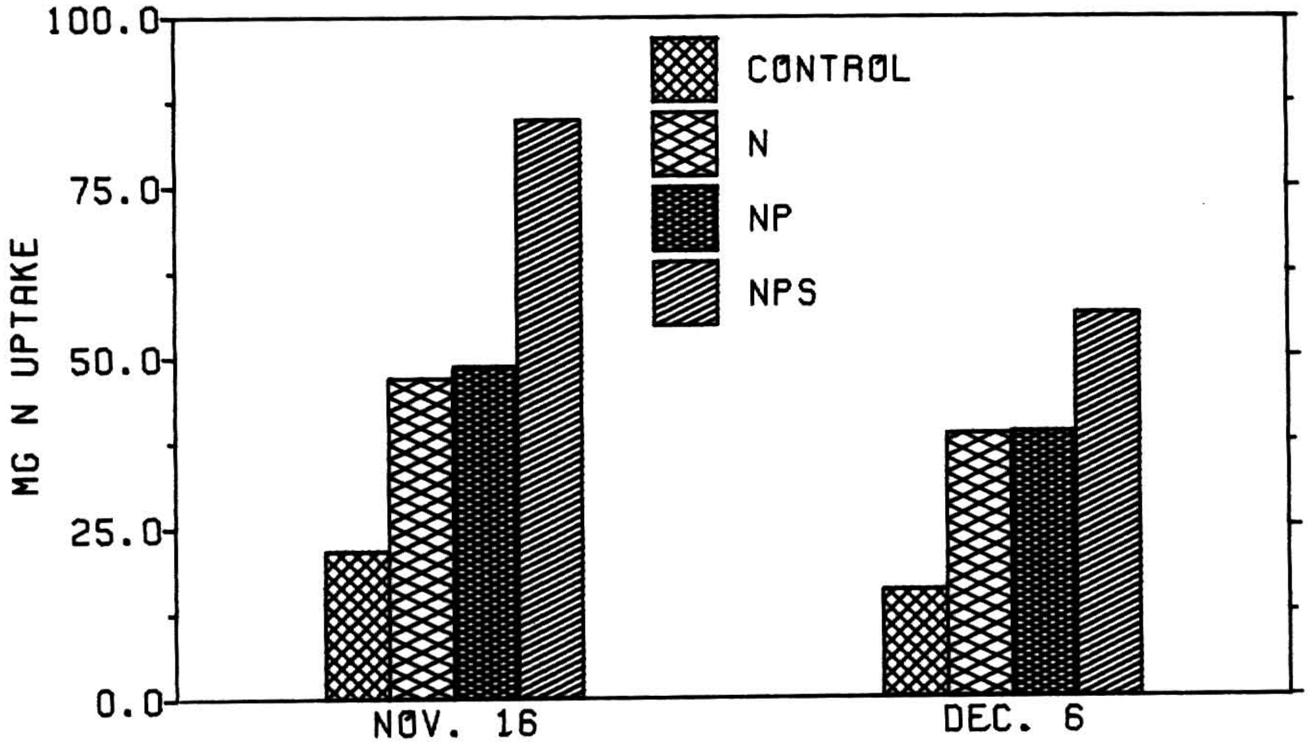
The effects of N, NP and NPS applications in the growth chamber study were very interesting. The nitrogen concentrations in the leaf tissue from the N treatments alone were significantly higher than those found in the NPS treated pots for the first harvest date (Table 45). The same sort of effect occured in the second harvest samples. The nitrogen levels of both the N and NP treated samples were significantly higher than those of the NPS treatment. This was simply a dilution effect that occured because of differences in dry weight production. NPS applications resulted in a highly significant increase in dry weights when compared to the N and NP treatments. Table 46 presents the data for the amounts of nutrients absorbed per pot for this study. Figure 23 demonstrates how the concentration of nitrogen in the leaf tissue compared to the total uptake of nitrogen per pot.

Phosphorus concentrations in the harvested leaf tissue were dramatically influenced by N, NP and NPS treatments. The NP applications significantly increased the phosphorus concentrations in the leaf tissue as compared to N or NPS applications at both sampling dates. Nitrogen alone produced significantly higher leaf tissue phosphorus concentrations than the NPS application at the second harvest date. This again was a dilution effect. Figure 24 indicates how the concentration of phosphorus present in the tissue compared to the actual uptake of phosphorus from

Table 46. EFFECTS OF N-SERVE, N-RATE, PHOSPHORUS AND SULFUR ON TOTAL NUTRIENT UPTAKE IN WINTER WHEAT. (Fall 1976, Growth Chamber Study)

N-Rate ppm	N-Serve	Nitrogen Carrier	P-Rate ppm	S-Rate ppm	November 16 mgm N	November 16 mgm P	November 16 mgm K	December 6 mgm N	December 6 mgm P	December 6 mgm K
0	---	---	0	0	21.6	3.6	40.1	15.8	3.8	42.8
30	No	NH_3	0	0	36.5	4.0	50.0	34.6	6.0	59.4
30	No	NH_3	40	0	36.0	7.4	55.1	24.7	5.8	39.9
30	No	NH_3	40	20	66.7	7.5	62.9	40.6	8.9	64.7
60	No	NH_3	0	0	39.9	3.6	42.9	36.9	5.7	59.4
60	No	NH_3	40	0	44.7	5.9	45.6	34.6	7.7	48.8
60	No	NH_3	40	20	87.3	8.5	58.3	54.7	7.6	56.3
90	No	NH_3	0	0	57.1	5.0	44.7	40.2	5.7	56.9
90	No	NH_3	40	0	58.6	9.0	47.9	48.8	9.4	51.5
90	No	NH_3	40	20	101.6	9.0	56.4	76.8	9.0	61.3
30	Yes	NH_3	0	0	32.3	3.3	49.1	29.5	5.2	50.7
30	Yes	NH_3	40	0	42.1	7.7	56.0	30.8	7.5	55.4
30	Yes	NH_3	40	20	67.7	7.7	64.9	34.4	6.7	56.9
60	Yes	NH_3	0	0	57.4	4.5	41.5	39.6	6.1	54.7
60	Yes	NH_3	40	0	49.8	7.9	49.0	44.3	9.9	63.3
60	Yes	NH_3	40	20	86.4	8.4	59.8	57.4	7.8	59.0
90	Yes	NH_3	0	0	58.7	4.7	35.2	50.3	6.0	57.0
90	Yes	NH_3	40	0	63.0	8.9	52.4	48.2	9.8	67.0
90	Yes	NH_3	40	20	99.8	9.5	64.0	81.2	9.8	69.3
		Treatment $LSD_{(.05)}$			12.6	2.0	11.7	7.7	2.2	NS

Fig. 23. Effects of N, P and S on the nitrogen concentration in the leaf tissue and total nitrogen uptake by winter wheat plants. (Fall 1976, growth chamber study).


100.0
75.0
50.0
25.0
0.0
MG N UPTAKE
CONTROL
N
NP
NPS
NOV. 16
DEC. 6

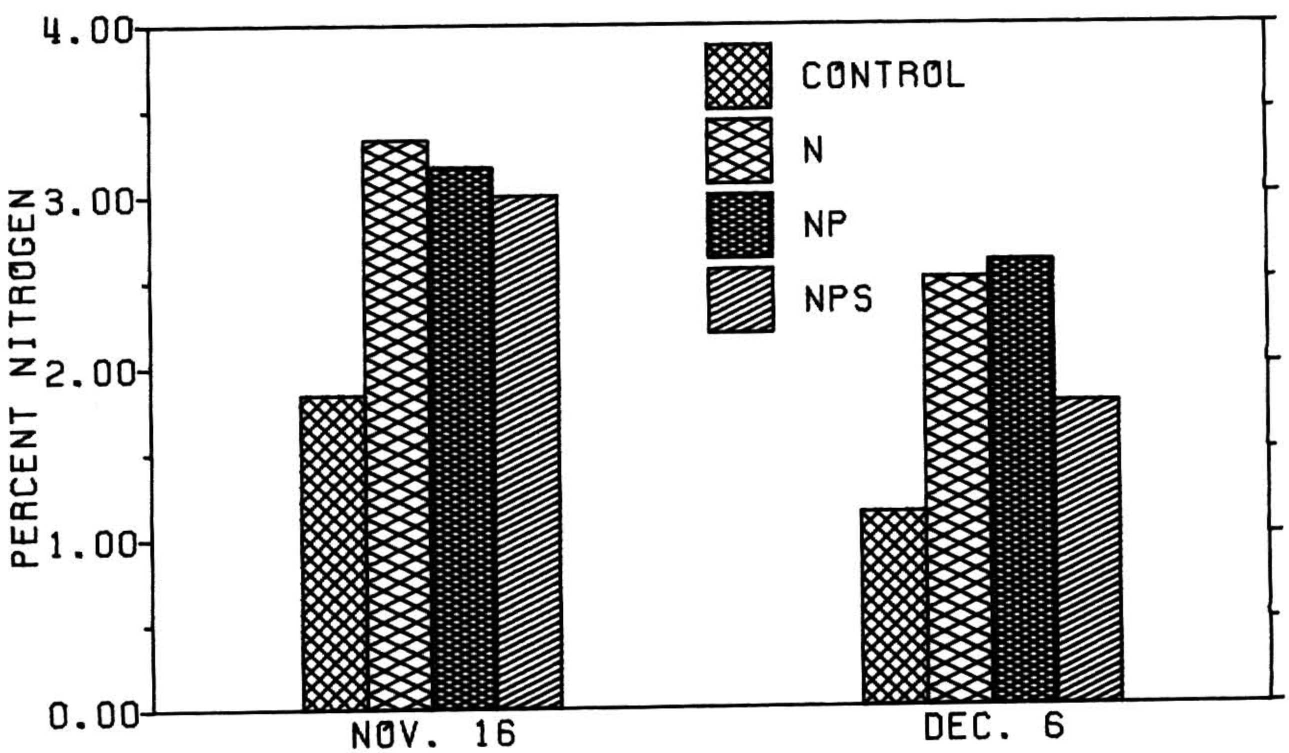
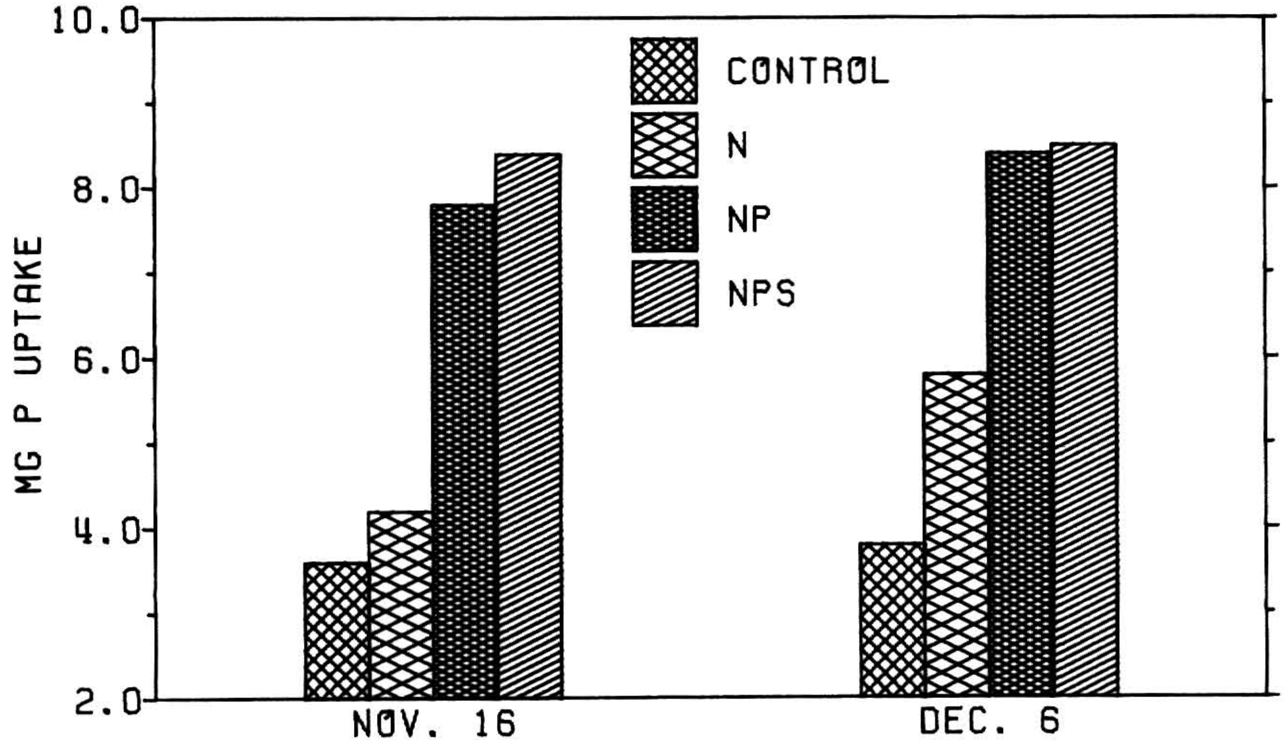
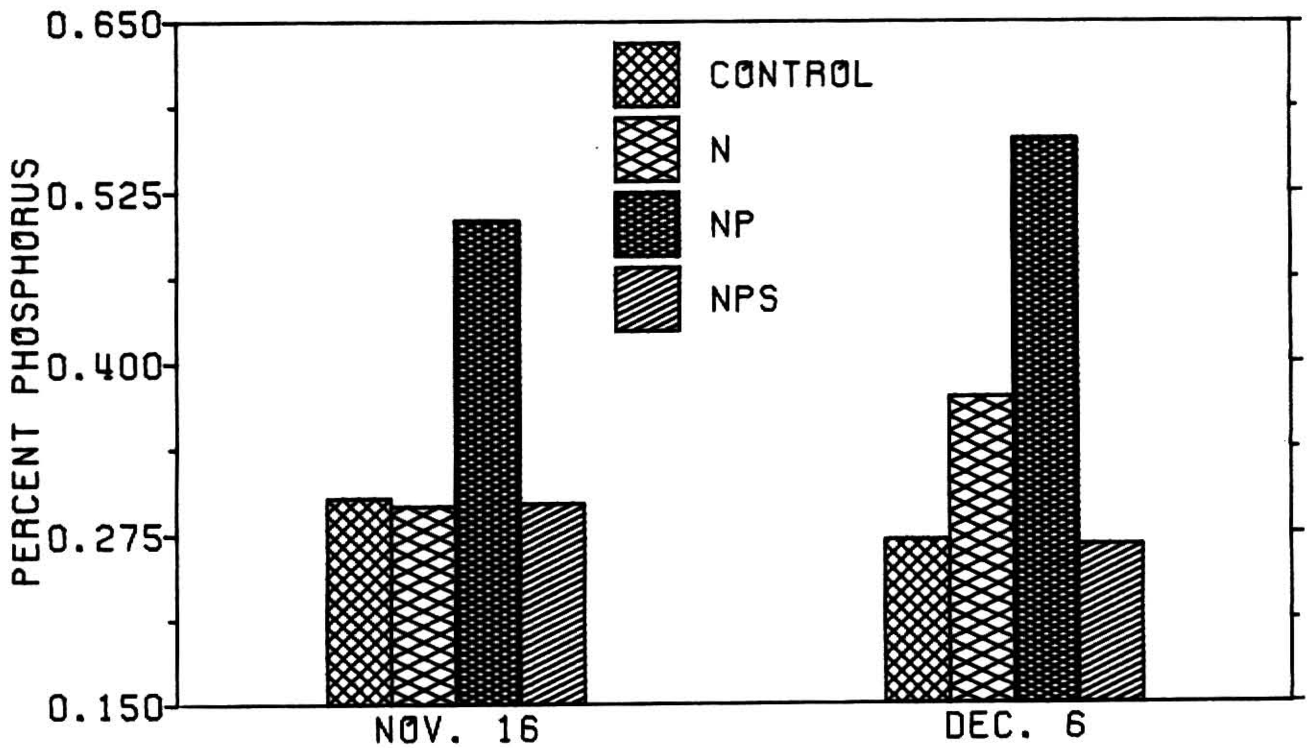

4.00
3.00
2.00
1.00
0.00
PERCENT NITROGEN
CONTROL
N
NP
NPS
NOV. 16
DEC. 6

Fig. 24. Effects of N, P and S on the phosphorus concentrations in the leaf tissue and total phosphorus uptake by winter wheat plants. (Fall 1976, growth chamber study).


10.0
8.0
6.0
4.0
2.0
MG P UPTAKE
CONTROL
N
NP
NPS
NOV. 16
DEC. 6

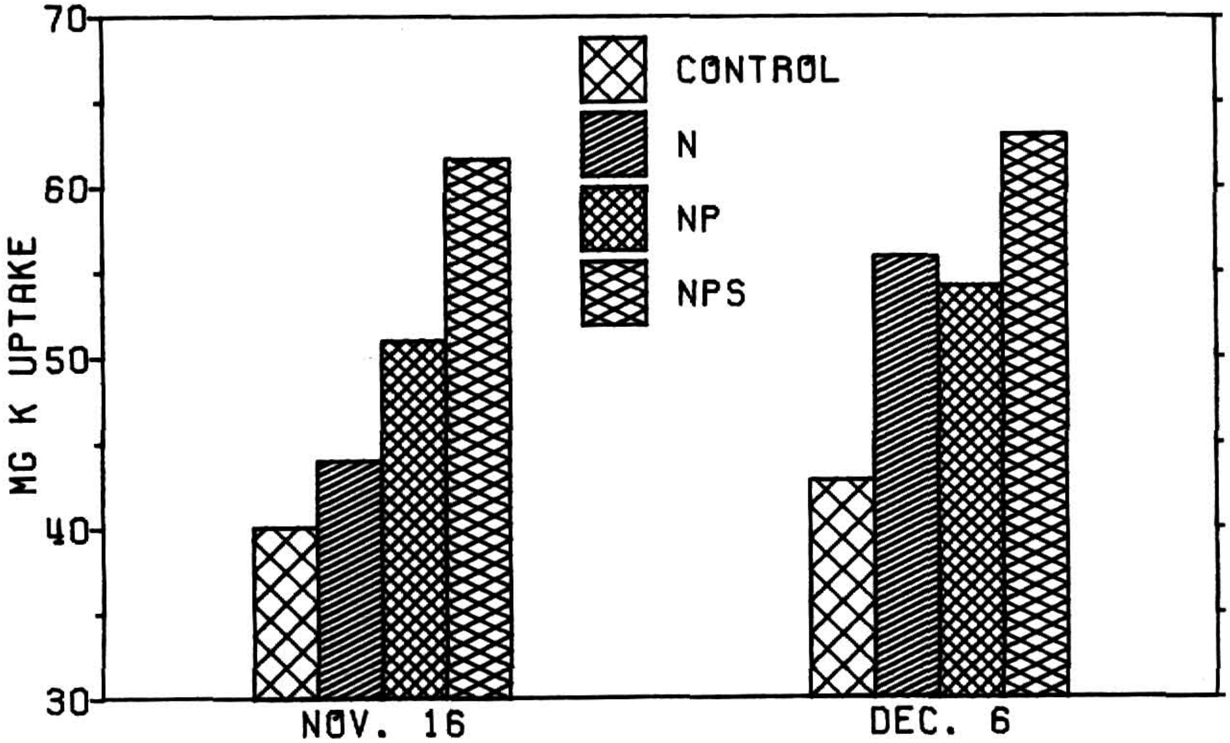

0.650
0.525
0.400
0.275
0.150
PERCENT PHOSPHORUS
CONTROL
N
NP
NPS
NOV. 16
DEC. 6

each pot. Even though there was less vegetative growth in the pots receiving the NP treatments as compared to the NPS application, essentially the same amount of phosphorus was taken up by the plants of both treatments. This was not true for potassium and lends suport to the theory of a nitrogen-phosphorus interaction when both nutrients are placed in the same soil retention zone.

Potassium concentrations in the leaf samples for both sampling dates followed the same trends as nitrogen. Both N and NP applications resulted in higher potassium concentrations in the leaf tissue than the NPS treatment for both harvests. Figure 25 shows how the dilution effect inverts this relationship since higher potassium uptake occurred with the greater plant growth from the NPS treatments.

Another surprising result of this study was the significantly higher ammonium ion concentration in the NP treatments when compared to N and NPS applications (Table 45). It would seem logical to expect the same ammonium ion concentrations in the N and NP application treatments at the end of the study because essentially the same amount of nitrogen was taken up by the plants of both treatments. Apparently the nitrogen from the N application had migrated away from the initial point of application while the NP nitrogen had not. This point also lends strength to the notion of the existence of a nitrogen-phosphorus reaction in the soil retention zone. Figure 26 shows the significant increase in dry matter production of the NPS application in comparison to the N and NP treatments with and without the inclusion of N-Serve.

Fig. 25. Effects of N, P and S on the potassium concentrations in the leaf tissue and total potassium uptake by winter wheat plants. (Fall 1976, growth chamber study).


70
60
50
40
30
MG K UPTAKE
CONTROL
N
NP
NPS
NOV. 16
DEC. 6

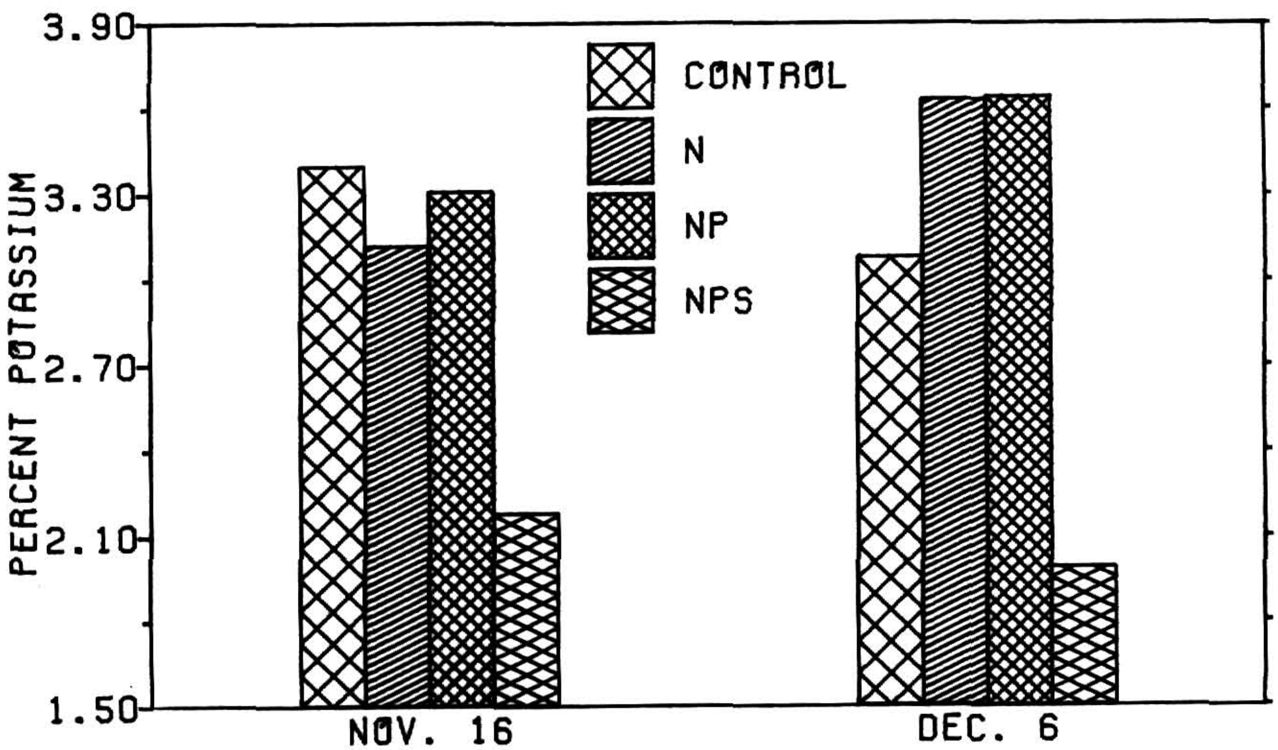
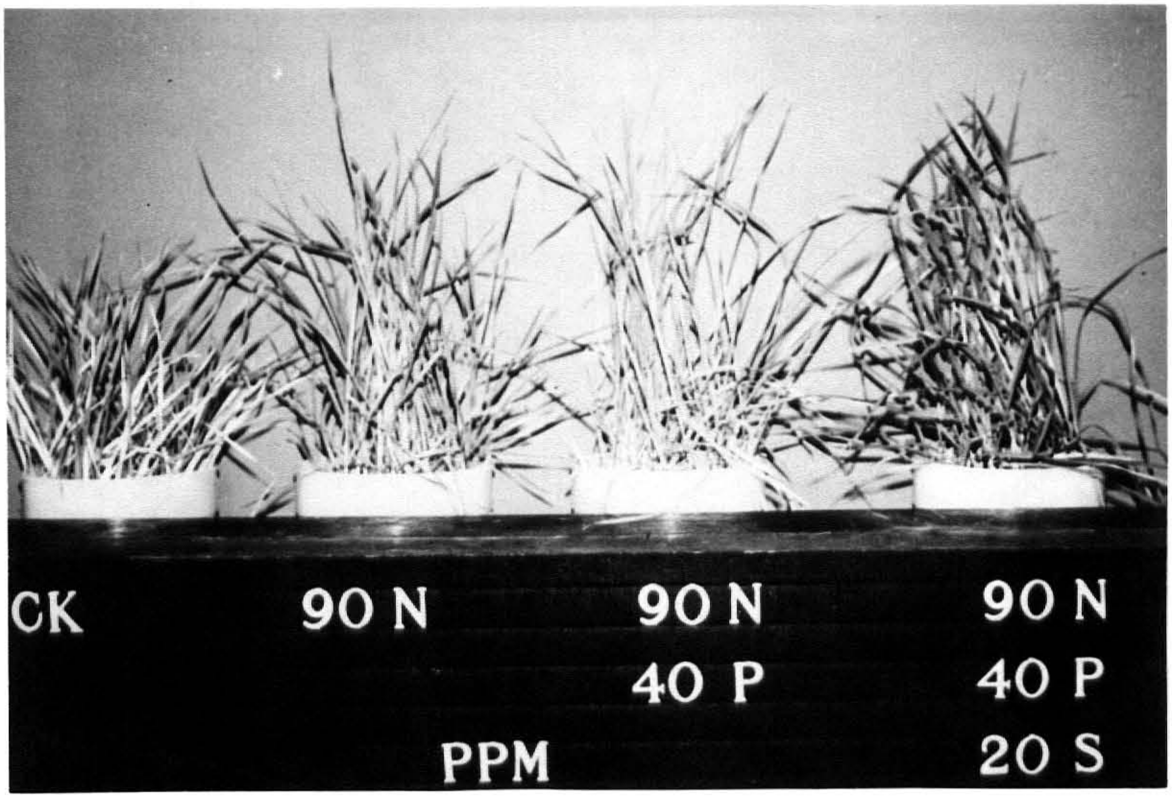
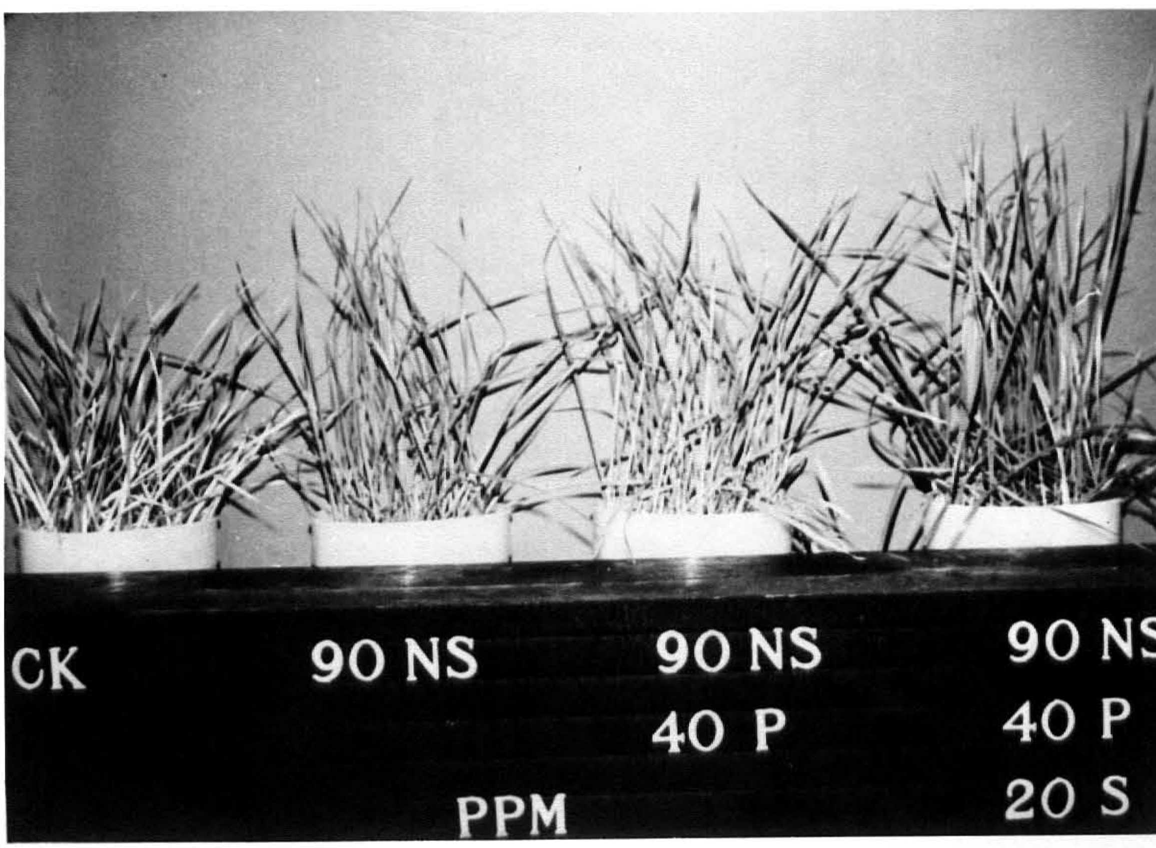

3.90
3.30
2.70
2.10
1.50
PERCENT POTASSIUM
CONTROL
N
NP
NPS
NOV. 16
DEC. 6

Fig. 26. Effects of nitrogen, phosphorus, sulfur and N-Serve on the growth of winter wheat under growth chamber conditions. (Fall 1976, growth chamber study).


CK
90 N
90 N
40 P
90 N
40 P
20 S
PPM


CK
90 NS
90 NS
40 P
90 NS
40 P
20 S
PPM

Tables 47 and 48 shows the results of the third greenhouse study. Nitrogen concentrations in the plant tissue of both harvest dates were significantly increased by the use of anhydrous ammonia. N-Serve did not affect tissue nitrogen concentrations for either date. Anhydrous ammonia with N-Serve significantly increased the phosphorus concentrations of the tissue from the second harvest when compared to no nitrogen and anhydrous ammonia without N-Serve. Anhydrous ammonia significantly increased the tissue phosphorus concentrations as compared to no nitrogen but had no effects on potassium concentrations of either sampling date material.

Both knifed and broadcast applications of phosphorus resulted in higher nitrogen concentrations in the tissue of the second harvest date in comparison to an application of no phosphorus. Broadcast and knifed applications of phosphorus resulted in higher phosphorus concentrations in both harvest date tissue samples when compared to a 0 phosphorus application rate. Phosphorus broadcast applications resulted in higher tissue phosphorus concentrations in comparison to knifed applications. This presumably was due to the large mass of roots produced in both treatments being confined to the small volume of the pots. Wheat crowns were used for this study and quickly became "root bound" in the pots. This mass of roots enabled the plants to absorb the broadcast phosphorus from the entire soil volume very quickly while the plants receiving knifed applications were absorbing phosphorus with relatively fewer roots. In similar studies, it would be adviseable to use a larger soil mass.

A significant decrease in the potassium concentrations of

Table 47. EFFECTS OF N-SERVE, N-CARRIER, P-RATE AND METHOD OF P APPLICATION ON THE LEAF TISSUE COMPOSITION OF WINTER WHEAT. (Spring 1977, Greenhouse Study)

N-Rate ppm	Nitrogen Carrier	P-Rate ppm	Method of P Application	March 17 %N	March 17 %P	March 17 %K	April 8 %N	April 8 %P	April 8 %K
0	---	0	-----	2.56	.163	2.76	1.69	.260	2.56
0	---	40	Broadcast	2.60	.420	2.67	1.65	.435	2.41
0	---	40	Knife	2.54	.420	2.47	1.59	.378	2.23
90	NH_3	0	-----	5.07	.221	2.63	4.53	.117	2.15
90	NH_3	40	Broadcast	5.69	.482	2.29	4.82	.577	2.37
90	NH_3	40	Knife	5.20	.389	2.19	4.84	.504	2.18
90	NH_3+N-Serve	0	-----	4.99	.221	2.59	4.34	.182	2.11
90	NH_3+M-Serve	40	Broadcast	5.13	.509	2.08	5.21	.673	2.38
90	NH_3+N-Serve	40	Knife	5.24	.327	2.34	5.61	.587	2.09
		Treatment	$LSD_{(.05)}$	0.56	.063	0.54	0.57	.056	0.47
Mean Values:									
	Nitrogen	0 N		2.57	.334	2.64	1.64	.358	2.40
		NH_3		5.32	.364	2.37	4.73	.419	2.23
		NH_3+N-Serve		5.12	.352	2.34	5.05	.480	2.20
			$LSD_{(.05)}$	0.32	NS	NS	0.33	.032	NS
	Phosphorus	0 P		4.21	.202	2.66	3.52	.206	2.27
		Broadcast P		4.47	.470	2.34	3.89	.562	2.39
		Knife P		4.33	.379	2.34	4.01	.490	2.17
			$LSD_{(.05)}$	NS	.036	0.31	0.33	.032	NS

Table 48. EFFECTS OF N-SERVE, N-CARRIER, P-RATE AND METHOD OF P APPLICATION ON THE NITRATE AND AMMONIUM ION CONCENTRATIONS IN THE SOIL. (Spring 1977, Greenhouse Study)

N-Rate ppm	Nitrogen Carrier	P-Rate ppm	Method of P Application	Feb. 24 NH_4^+	Feb. 24 NO_3^-	March 4 NH_4^+	March 4 NO_3^-	March 25 NH_4^+	March 25 NO_3^-	April 20 NH_4^+	April 20 NO_3^-
90	NH_3	0	-----	68.0	4.4	67.9	3.9	64.3	4.3	47.7	6.0
90	NH_3	40	Broadcast	75.8	4.5	72.4	4.5	60.1	2.4	42.0	3.6
90	NH_3	40	Knife	190.2	3.1	124.1	5.3	115.4	4.7	76.4	6.0
90	NH_3+N-Serve	0	-----	62.7	3.6	69.2	4.4	62.7	3.6	55.0	2.4
90	NH_3+N-Serve	40	Broadcast	73.4	4.0	67.0	5.0	58.4	1.8	45.6	2.4
90	NH_3+N-Serve	40	Knife	199.1	5.9	104.4	4.5	102.1	3.1	73.3	1.8
<u>Mean Values:</u>											
	<u>Nitrogen</u>	NH_3		111.3	3.9	88.1	4.6	79.9	3.8	55.4	5.2
		NH_3+N-Serve		111.7	4.5	80.2	4.6	74.6	2.8	58.0	2.2
	<u>Phosphorus</u>	0 P		65.4	4.0	68.6	4.2	63.5	4.0	51.4	4.2
		Broadcast P		74.6	4.1	69.7	4.8	59.2	2.1	43.8	3.0
		Knife P		194.6	4.5	114.2	4.9	108.8	3.9	74.8	3.9

the first harvest leaf tissue material resulted when phosphorus was applied by both methods as compared to no phosphorus. This was attributed to a dilution effect caused by more plant growth with the phosphorus applications. There were no significant differences in the potassium concentrations found in the second leaf tissue samplings.

Figure 27 demonstrates the trend in the ammonium concentrations in soil resulting from two application methods and nutrient sources used in this study. The general downward trend of the ammonium ion concentrations with time was due to the outward diffusion of the ammonium ions away from the point of initial application. It is interesting to note how high the ammonium levels are when anhydrous ammonia is knifed with APP as compared to broadcast APP applications. There did seem to be a trend of N-Serve inhibiting the nitrification of the ammonium nitrogen applied. With the passage of time, the nitrate ion concentration declined or remained constant in the N-Serve treatments, while they decreased with time when N-Serve was not added.

The data from the fourth greenhouse study are presented in Table 49. The trend for all treatments in this study was a decrease in the ammonium ion concentrations while the nitrate ion levels increased. The knifed ammonia-phosphorus applications resulted in higher ammonium ion concentrations at each sampling than the knifed ammonia-broadcast phosphorus treatments. Figure 28 shows the different application method combinations of APP used in this study and the ammonium ion concentration remaining in the retention zone at the various time intervals.

N-Serve tended to increase the amount of ammonium ions rem-

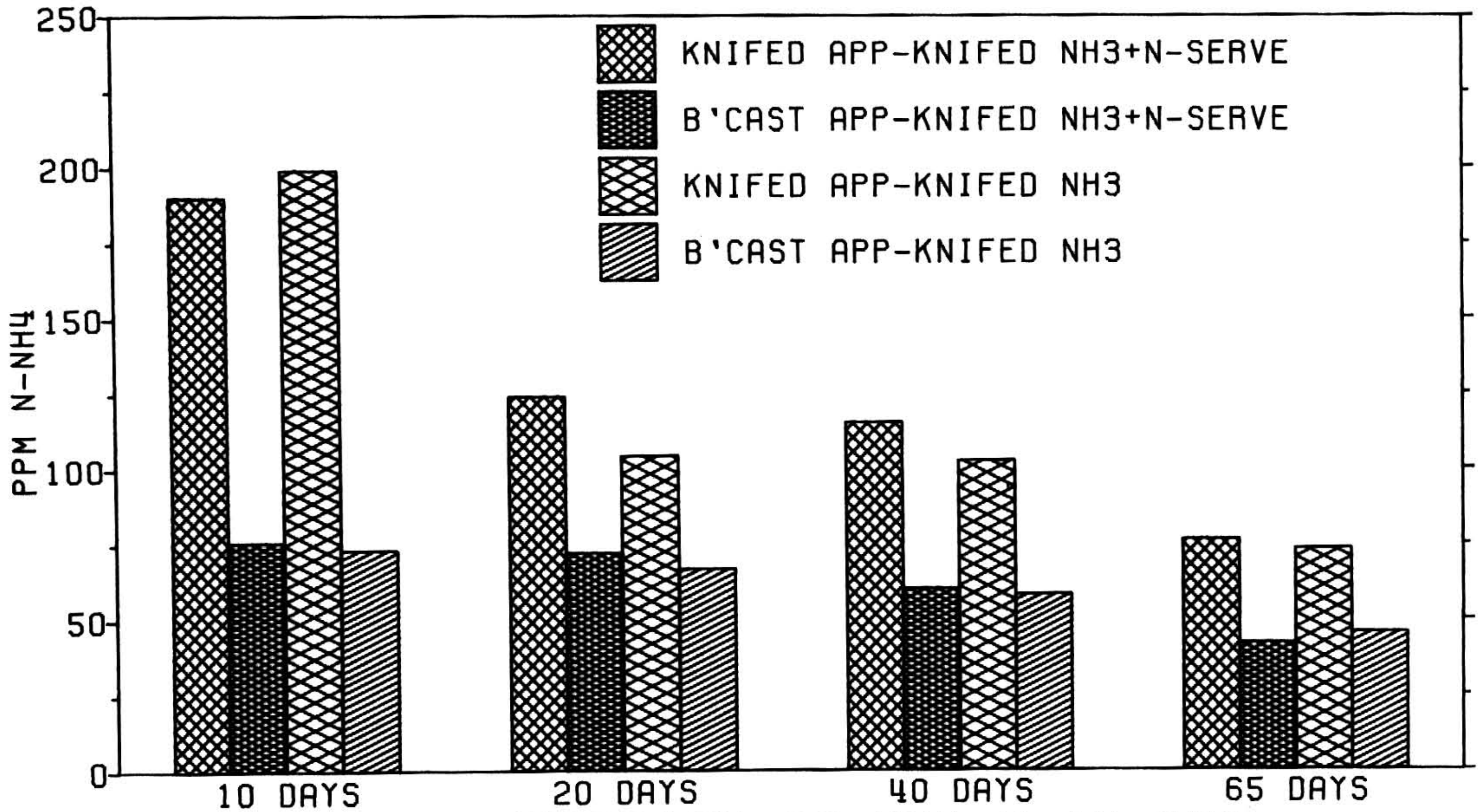


FIG. 27 CONCENTRATION OF NH4-N IN SOIL FOLLOWING APPLICATION. SPRING 1977 GREENHOUSE STUDY

Table 49. EFFECTS OF N-SERVE, P-SOURCE AND METHOD OF P APPLICATION ON THE NITRATE AND AMMONIUM ION CONCENTRATIONS IN THE SOIL. (Summer 1977, Greenhouse Study)

N-Serve	P Source	Method of P Application	June 22 NH_4^+	June 22 NO_3^-	July 6 NH_4^+	July 6 NO_3^-	July 15 NH_4^+	July 15 NO_3^-	July 27 NH_4^+	July 27 NO_3^-	August 3 NH_4^+	August 3 NO_3^-
No	---	-----	159.3	34.9	98.2	93.5	94.3	89.1	94.6	74.6	99.4	98.2
No	APP	Broadcast	163.0	32.7	134.7	71.1	87.3	79.6	85.9	63.5	94.7	97.0
No	APP	Knife	228.6	43.5	162.9	86.4	97.6	98.3	70.0	90.0	75.9	109.4
No	H_3PO_4	Broadcast	191.5	44.2	101.1	58.2	86.3	67.2	77.0	76.4	82.3	91.1
No	H_3PO_4	Knife	193.3	74.3	115.8	94.1	104.3	121.7	99.4	138.2	75.3	170.5
Yes	---	-----	173.4	67.3	132.3	48.8	121.9	51.6	98.9	54.7	94.7	75.9
Yes	APP	Broadcast	134.4	81.3	131.1	33.5	119.7	38.3	87.6	34.7	91.7	52.3
Yes	APP	Knife	206.5	36.4	141.1	70.6	131.1	80.3	110.6	81.5	102.9	84.1
Yes	H_3PO_4	Broadcast	175.8	47.8	122.9	74.7	97.9	63.2	84.1	52.9	97.0	45.9
Yes	H_3PO_4	Knife	163.5	44.3	163.5	99.4	137.3	93.6	126.4	80.6	133.5	98.2
Mean Values:												
NH_3			187.1	45.9	122.5	80.7	94.0	91.2	85.4	88.5	85.5	113.2
NH_3+N-Serve			182.8	55.4	138.2	65.4	121.6	65.4	101.5	60.9	104.0	101.3
NH_3 - Knife P			211.0	58.8	139.4	90.2	101.0	110.0	84.7	114.1	75.6	140.0
NH_3 - B'cast P			177.2	38.4	117.9	64.6	86.8	73.4	81.4	70.0	88.5	94.0
NH_3+N-Serve - Knife P			215.2	40.4	152.3	85.0	134.2	87.0	118.5	81.0	118.2	91.2
NH_3+N-Serve - B'cast P			155.1	64.6	127.0	54.1	108.8	50.8	85.8	43.8	94.4	49.1
APP			183.1	48.5	142.4	65.4	108.9	74.1	88.5	67.4	91.3	85.7
H_3PO_4			196.2	52.6	125.8	81.6	106.4	86.4	96.7	87.0	97.0	101.4

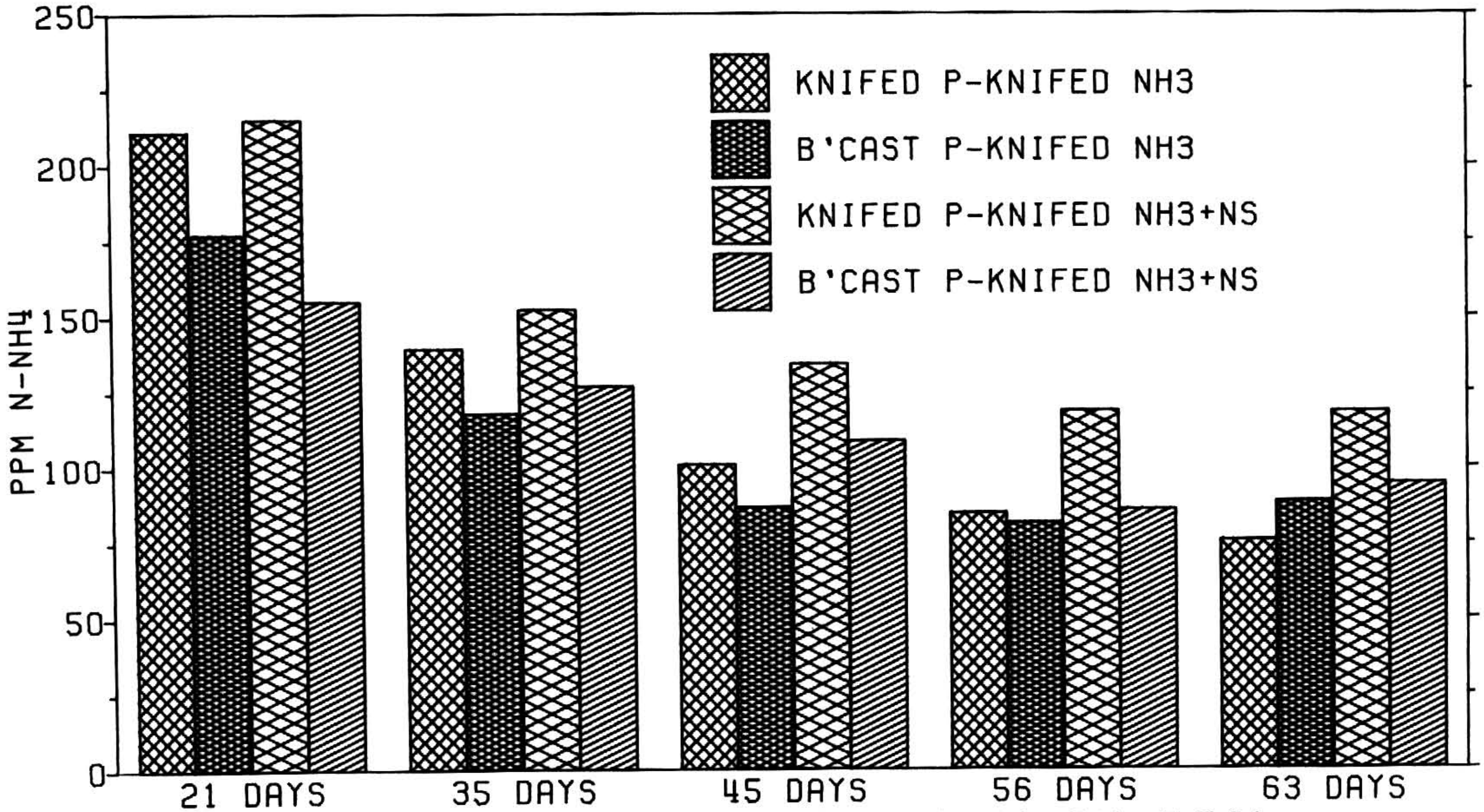


FIG. 28 CONCENTRATION OF NH4-N IN SOIL FOLLOWING APPLICATION. SUMMER 1977 GREENHOUSE STUDY

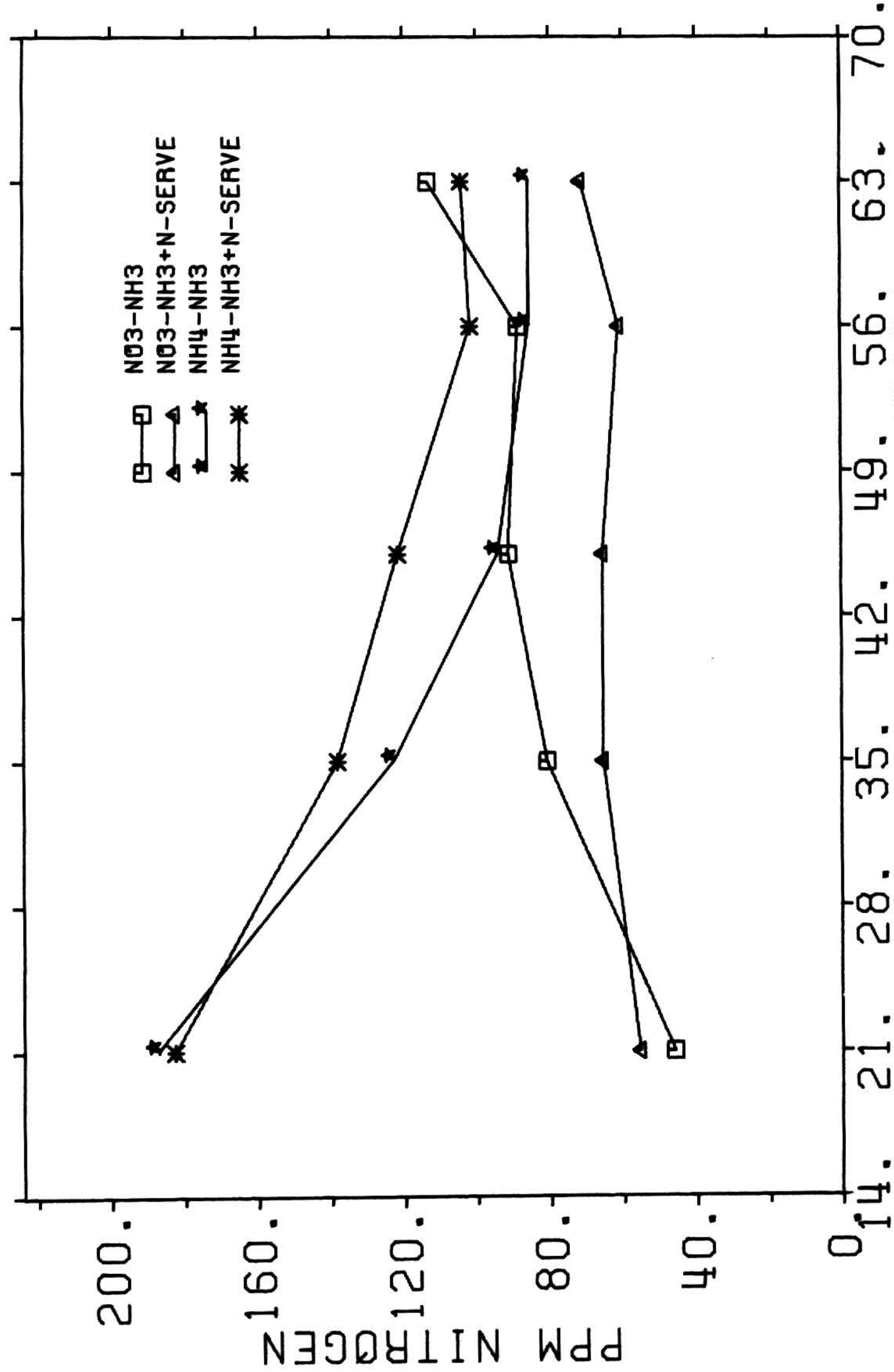
aining in the original application zone and lowered the amount of nitrate ions detected in comparison to anhydrous ammonia without N-Serve (Fig. 29).

The results of this study indicate that orthophosphoric acid solutions as well as APP have some type of effect on ammonium ions that seems to retain the nitrogen in the ammonium ion form when simultaneously knifed into the same soil location. All of the greenhouse studies indicate that more work is warranted in the area of nitrogen-phosphorus applications.

The hydrolysis products of ammonium pyrophosphate, a major constituent of APP, may be altered by the presence of large concentrations of ammonium ions in the vicinity of APP. In calcareous soils, the main product of this hydrolysis may be calcium-ammonium pyrophosphate, an insoluble compound. By applying large amounts of ammonium ions in the soil zone of the APP, this hydrolysis may be slowed or changed altogether. This same type of reaction may also occur in soils containing free iron or aluminum in the soil system. This might be true in low pH soils. In these type of soils, insoluble iron or aluminum phosphate compounds may result from the hydrolysis of ammonium pyrophosphate.

N-Serve may contribute to this effect by prolonging the time that the phosphate is in cotact with ammonium ions. More research into the possible effects of dual knifing anhydrous ammonia and APP fertilizers is needed to determine the reaction products in all types of soil systems (Murphy, 1977).

Fig. 29. Effects of N-Serve on the nitrate and ammonium nitrogen concentrations in the soil following a knifed anhydrous ammonia application. (Summer 1977, greenhouse study).


NO3-NH3
NO3-NH3+N-SERVE
NH4-NH3
NH4-NH3+N-SERVE
DAYS AFTER APPLICATION
14.
21.
28.
35.
42.
49.
56.
63.
70.
PPM NITROGEN
0
40.
80.
120.
160.
200.

SUMMARY AND CONCLUSIONS

The nitrification inhibitor N-Serve did not affect yield, protein content or nutrient concentrations of the leaf tissue of winter wheat. Although it did result in an inhibition of nitrification, there did not seem to be any agronomic advantage in keeping the nitrogen in the ammonium form under the climatic conditions studied. Because of the relatively low rainfall in most sections of Kansas, conditions necessary for nitrogen loss by leaching or denitrification are not present in the majority of years. This was true of sandy soils also, a condition where leaching might be expected. It was also true in the heavy textured soils of southeast Kansas which are underlayed with a relatively impenetrable hard pan layer just under the soil surface, a logical place for denitrification.

Applied nitrogen did affect the yield, protein content and nitrogen concentrations of winter wheat leaf tissue. Generally all of these components tended to increase with increasing rates of nitrogen through a rate of 101 kg N/ha.

Control of Cephalosporium stripe infection of winter wheat was not determined to be directly related to fertilization practices. However, a relationship that may exist is a decline in severity of the effects of the disease with adequate nitrogen application rates. N-Serve, when used with ammoniacal fertilizers slightly reduced the severity of the disease by furnishing more ammonium nitrogen instead of nitrate nitrogen to the plant. Nitrogen rate affected the severity of yield decreases due to Cephalosporium stripe by producing a healthy, more vigorous plant which partially overcame the effects of the disease.

By far the most promising cultural practice studied in the control of Cephalosporium stripe was varietal selection and burning of the previous crop residue. Stubble burning may not be recommended every year, but is a short term control measure that may be used. The selection of varieties that are better able to withstand the stress of Cephalosporium stripe infection seems to be a logical step in the reduction of yield losses due to Cephalosporium stripe. Tam 101 and Sturdy seemed to be particulary susceptible to Cephalosporium stripe infection. While they were not found to be entirely resistant to Cephalosporium stripe Centurk, Gage, Sage and Eagle were not as susceptible as were the other varieties tested.

Fertilization efficiency in general was more affected by a nitrogen-phosphorus placement interaction. Studies of dual nitrogen-phosphorus applications have served the purpose of providing background information for future efforts. Trends from these studies cannot be overlooked. A dual knifed application of anhydrous ammonia and APP was generally superior to separate nitrogen and phosphorus applications that separated the nutrient sources in the soil. Yields and protein content were increased by knifing the nitrogen and phosphorus into a small, single retention zone. Using N-Serve to delay the nitrification of ammonium to nitrate produced generally higher phosphorus adsoption and higher yields.

Growth chamber and greenhouse work suggests the same effect of N-Serve may result with the use of orthophosphoric acid solutions. High concentrations of ammonium for extended periods of are suspected of modifying phosphorus fixation in calcareous soils. The same may be true in lower pH soils containing free iron or aluminum. More research in this area is needed in the future.

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NITRIFICATION INHIBITION (N-SERVE) EFFECTS ON WINTER WHEAT (TRITICUM AESTIVIUM L.) YIELD AND DISEASE SUSCEPTIBILITY (CEPHALOSPORIUM STRIPE).

by

DALE F. LEIKAM

B.S., Kansas State University, 1973

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

1977

Several types of studies were conducted in 1976 and 1977 to evaluate the effectiveness of the nitrification inhibitor N-Serve in regard to its effects on yield, protein, tissue composition and the incidence and severity of Cephalosporium stripe infection in winter wheat. Nitrogen carriers utilized were anhydrous ammonia, urea, urea-ammonium nitrate solution (UAN solution) and calcium nitrate. Nitrogen rates used were 34, 67 and 101 kg N/ha, applied pre-plant or as a late winter topdress. N-Serve was applied at a constant rate of 0.56 kg active ingredient per 101 kg of applied nitrogen.

Generally there were no visual responses associated with the use of N-Serve during either the vegetative or reproductive stages of the wheat growth. No responses of grain yield was observed by the inclusion of N-Serve during either year. Likewise, protein content of the grain was not responsive to the addition of N-Serve to the fertilizer materials.

Tissue composition responses to N-Serve were generally small, with N-Serve neither consistently increasing or decreasing nitrogen, phosphorus or potassium concentrations of the leaf tissue. This trend held true for all samplings made throughout the spring growth period of the wheat crop.

Increasing nitrogen rates usually resulted in increased grain yield, protein levels and nutrient concentrations of the leaf tissue. Dual knifed applications of ammoniacal fertilizers with ammonium polyphosphate (APP) normally increased grain yields and leaf tissue phosphorus concentrations.

The addition of N-Serve to the nitrogen source enhanced this effect and tended to further increase grain yields and tissue phosphorus concentrations. This effect was very apparent when dual knifed applications of nitrogen and phosphorus were compared to application methods that seperated the two nutrient sources.

N-Serve did significantly reduce the visual symptoms associated with Cephalosporium stripe infection of winter wheat. This reduction in the visual symptoms did not result in higher grain yields when comparisons of anhydrous ammonia and anhydrous ammonia with N-Serve were made. There were very pronounced varietal differences in respect to the severity of Cephalosporium stripe of winter wheat. Sturdy and Tam 101 were severely affected by Cephalosporium stripe infection while Centurk, Gage and Sage exhibited more resistance to the disease.

Burning of the previous crop residue resulted in the largest increase in yield as a control measure used in the reduction of Cephalosporium stripe infection. Increases in yield due to burning the previous crop stubble averaged 121% in 1976. Increasing nitrogen rates seemed to enhance the severity of the visual symptoms but still produced a positive response in grain yield. Planting date did not affect either the severity of the disease or the grain yields obtained from the infected wheat crop. There was also an indication that the use of N-Serve to provide the wheat plant more ammonium-nitrogen may also reduce the severity of Cephalosporium stripe.