

EFFECT OF NITRIFICATION INHIBITION ON NITROGEN USE
IN CORN (*Zea mays* L.) AND
GRAIN SORGHUM (*Sorghum bicolor* L.)

by

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To Elizabeth, Joyce and Thelma

This work is dedicated.

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INTRODUCTION

The large quantity of N needed for the production of non-leguminous crops has resulted in a tremendous amount of research dealing with the effectiveness of N fertilizers.

Source, rate, time and method of applying N fertilizers are among the variables which have received the most extensive investigation. Such studies have provided valuable information regarding the efficient use of N in the production of crops under a variety of soil and climatic conditions. Despite this fact, changes in crop production practices including cost of production necessitate periodic re-evaluation of certain fertilization techniques.

Several recent changes in corn production patterns in many parts of the world have created increased concern over the time of applying N fertilizers to this crop. Continued growth of the acreage of cultivated crops on individual farms has accentuated the importance of timing of field operations and the distribution of labor. The advantage of early planting of corn and the wide acceptance of this practice has reduced the time available for fertilizer application in the spring prior to planting. As a result of this and other changes, both farmers and fertilizer dealers have developed an increased interest in the possibilities of applying N in the fall for the following corn crop. Research data indicate that under most conditions

phosphorus and potassium fertilizers can be applied in the fall with little or no loss in nutritive value. Yield responses from applications of N have varied more with soil and seasonal weather conditions. Reduced efficiency of such applications has usually been associated with loss of nitrate-nitrogen ($\text{NO}_3\text{-N}$) by leaching or denitrification.

To further evaluate the efficiency of fall preplanting applications of N, field experiments were established at several locations in Kansas with the following objectives: (1) to evaluate the effects of a nitrification inhibitor (slowing the production of NO_3) on the yield of irrigated corn and dryland sorghum; (2) to compare fall and spring applications of NH_3N with and without nitrification inhibitor on yield and leaf composition of irrigated corn and dryland grain sorghum; and (3) to study N movement in the soil profile and investigate relationships between time of N application and N position in the soil.

LITERATURE REVIEW

A study of the influence of time of N application on final crop yield requires evaluation of many factors. Application of fertilizer N just prior to or during periods of rapid plant growth results in maximum uptake and utilization by the crop. Under these conditions, N recovery by corn and grain sorghum has been reported as approaching 80% of the applied N; however, recovery is more commonly in the range of 50% to 60%.

Nitrogen not used by a crop may be immobilized by microorganisms and subsequently become part of the organic matter, may remain in the inorganic form in the soil and be available for further crop use, or it may be lost from the soil profile. The mobile nitrate form may be leached from the root zone if precipitation or irrigation exceeds the soil water holding capacity and evapotranspiration demands. Excess soil moisture may contribute to poor aeration and result in anaerobic conditions favorable for denitrification, a process in which nitrates are biologically reduced to gaseous N compounds and become subject to loss from the soil.

Volatilization losses of ammonia can also be significant under some conditions if an ammonium or ammonia-forming fertilizer is placed on or near the soil surface.

The possibility of N losses by erosion exists where shallow incorporation of N fertilizers is practiced on

sloping soils.

The extent of N loss by these processes is clearly related to climatic conditions and the chemical and physical properties of the soil. The source of N fertilizer, the time, rate and method of application are also factors affecting possible loss of fertilizer N. In as much as possible the predominant mechanisms responsible for N-loss will be considered under different geographical and environmental conditions. First, the Southeastern states, secondly the Northeastern states, the Midwest and finally the Great Plains.

Factors Affecting Nitrogen Losses

Southeastern states. Soils in the southeastern United States do not freeze in the winter except for short periods. On the other hand, due to hot summers and low precipitation in the fall, there is less leaching than in the northeastern United States until the soils are wet in December and January (Val Bavel, 1956; Doss et al., 1962). Over the entire year, a smaller proportion of the rainfall is available for leaching, but the rainfall is higher than in the northeastern United States. Evaporation in the summer is high enough that nitrates near the surface in the medium textured soils are not moved very much (Karraker and Bartner, 1937), but nitrate in the deeper layers is subject to downward movement during both summer and winter. The presence of red clay subsoils in many areas retards leaching considerably. In medium-textured southern soils which do not

have red clay subsoils, it appears that evapotranspiration in the summer prevents most leaching, but nearly total loss of nitrogen occurs in the winter and early spring when effective rainfall is high.

Northeastern states. Much of the early work with lysimeters was carried out in the northeastern states. Results demonstrated large losses of nitrogen from bare soil but indicated that cover crops grown in the winter reduced the losses. Grass crops reduced the losses to negligible levels (Lyon and Bizzell, 1936; Bizzel, 1944). In general, soils in the northeastern United States are protected from leaching by freezing during the months of December, January, and February, but are more likely to lose nitrates in the summer. The soils have little tendency to absorb nitrate and evaporation losses are lower in the summer than in other sections of the country.

Midwest states. The behavior of nitrate in the midwestern soils is much different from the southeast during most of the summer growing season. It can be expected that low losses of nitrate occur because of the net upward water movement caused by evaporation. During the winter months, precipitation is quite low in the cornbelt as compared to the southeast. Many soils in the midwest remain frozen much of the winter. For this reason, it has been found that in some of these states (Illinois and Iowa) fall applied nitrogen is just as effective as spring applied nitrogen. The problem is that spring and early summer rainfall is high in the midwest

and both fall and spring applied nitrogen are likely to be lost in some years.

Stauffer (1942) found that about 40% of the precipitation reaching bare soils in Illinois is either leached through the soil or lost as runoff. This is somewhat lower than the excess water in the northeast. It appears that the permeability of many midwestern soils is fairly low when wet and this tends to protect them from the severe leaching observed in permeable soils. There is also a suggestion that because of wetter soils, denitrification is a much more serious problem in the midwest than in the southeast. However, it appears that losses of nitrates per quantity of water percolated are higher in the midwest than in the southeast (Owens, 1960; Kurtz et al., 1961). This seems reasonable since there are no absorption sites for nitrate on midwestern soils. In soils with a rather high cation exchange capacity per unit of colloid the negative charge will enhance leaching of nitrate.

Great Plains. In many respects behavior of nitrogen in the Great Plains is an extension of N behavior in midwestern soils. Rainfall distribution patterns are similar but lower in the Plains and evaporation is higher. Because of this, nitrate losses by leaching are generally considered to be negligible (Nelson and Uhland, 1955). In the Great Plains evaporation is so high that the water in the soils can not move fast enough to keep the soil surface moist (Weigand, 1962). This means the actual loss of soil moisture by leaching is

less than that of more humid regions. Secondly, much of the rain comes in very heavy storms. One heavy rain on a reasonably permeable soil can result in very deep movement of nitrate. Once nitrate moved from the top 60 centimeters (two feet) it will continue to move out of the soil even though it may be at a slow rate. Soils of the Great Plains are much more efficiently leached than midwestern soils since a higher proportion of the water in the soil cannot hold nitrate. Normally, large nitrogen losses are not the rule in the Great Plains, but on some soil types severe losses can occur.

Nitrogen Movement and Mineralization

Because of the high solubility of $\text{NO}_3\text{-N}$, the movement of nitrate within the soil profile is dependent upon the movement of water. Therefore, the permeability of the soil profile and how it influences water movement or percolation is important in understanding the potential for movement and loss of nitrate. Allison (1966) and Thomas (1970) showed that climatic factors, such as rainfall distribution and evapotranspiration are important parameters in considering $\text{NO}_3\text{-N}$ movement. During those periods when precipitation exceeds evapotranspiration, the downward movement of the surplus water will leach the soluble salts. Nitrate ions are important constituents. These salts may be carried beyond the rooting zone, where they are unavailable for plant growth, and may contribute to nitrates in ground waters.

Since water content and temperature affect N mineralization rates they are important factors related to $\text{NO}_3\text{-N}$ movement. Stanford and Epstein (1974) reported that N mineralization was related to the water content of the soil profile. Highest mineralization rates occurred between matric potentials of $-1/3$ to 0.1 bar, when 80% to 90% of the total pore space was filled with water. Stanford, et al. (1973) and Fenn, et al. (1974) observed that soil N mineralization rate is influenced profoundly by temperature within the range normally encountered under field conditions. Nitrogen mineralization rate constant for different soils, increased as the soil temperature increased from 0 to 35 degrees centigrade. Within this temperature range almost complete conversion of $\text{NH}_4\text{-N}$ to $\text{NO}_3\text{-N}$ was observed. Several investigators have reported that different kinds and concentrations of salts affect the release of soil N. Some also conclude that high concentrations of copper and calcium chloride salts inhibited nitrification of ^{15}N labelled ammonium more than sodium salts.

Nitrogen Losses

If the $\text{NO}_3\text{-N}$ is not utilized by plants or immobilized by microflora it may be lost by leaching or denitrification. Leaching and denitrification losses occur mainly when the fertilizer nitrogen is applied in nitrate form or after it converts to the nitrate form. Owens (1960) studied nitrogen transformation in soil and found out that 15-24 per cent of

the applied nitrogen was recovered by corn plant, 38 per cent remained in the soil, 5 to 20 per cent was lost by leaching and 33 per cent by denitrification. The quantity of nitrogen lost by leaching from the lysimeters he used was directly proportional to the amount of water moving through the soil profile, but the quantity of nitrogen lost by denitrification was not affected by different moisture treatments.

Grasser (1968) found that nitrogen added to the soil as nitrate had been lost from the surface soil after one month and that ammonium nitrogen was rapidly nitrified. Four-fifths of the ammonium sulphate applied in autumn for winter wheat at Rothamsted was nitrified after one month but nitrification was almost complete by three months. Shaw (1962), investigating the loss of mineral nitrogen from soils, stated that most of the nitrate disappears from the cultivated layer of the soil profile of heavy clay soils by leaching or denitrification, but in light sandy soils nitrate becomes distributed down through the profile by leaching. He also concluded that the total amount of $\text{NO}_3\text{-N}$ in the soil profile was directly related to the rate of nitrogen application and to the frequency of corn in the rotation. More leaching of $\text{NO}_3\text{-N}$ generally occurred between fall and spring than during the growing season.

Nitrification Inhibitors

One obvious technique that could be employed to reduce $\text{NO}_3\text{-N}$ loss due to leaching is to maintain applied N in the

less mobile NH_4^+ -N form. That is, to reduce nitrification. In the nitrification reaction, microorganisms, mainly of the genera Nitrosomonas and Nitrobacter, oxidize NH_4^+ -N to NO_2^- -N then to NO_3^- -N. The rate of this process is largely dependent on temperature, pH, moisture and texture of the soil. Nitrate ions are not absorbed by the clay fraction of most soils and are subject to leaching or if conditions permit, denitrification. This reaction has continually frustrated efforts of agriculturists who attempted to increase efficiency of fertilizer applied N.

Under most field conditions, nitrification is considered to be a rapid reaction with completion being reached within several days. If it were economically feasible to delay the rate of this conversion, a more efficient utilization of fertilizer N might result. Many agronomic benefits could be derived from this accomplishment. In most cases leaching and denitrification would be minimized. Fertilizer applications could be made earlier in the season without fear of lower efficiency. The action of a nitrification inhibitor could significantly reduce potential for NO_3^- -N pollution of underground water supplies. One method used for reducing nitrification is by adding chemicals to the fertilizers which act as biological inhibitors. To date, much research work has been done in this area.

Many compounds have been shown to inhibit nitrification in soils. However, most of them are not primarily used as nitrification inhibitors but as fungicides, herbicides or

fumigants. Stark (1939), working with chloropicrin, suggested that the length of the inhibition period was dependent on the dosage of the fumigant. The inhibition of nitrification resulted in an accumulation of ammonium nitrogen. Jacques et al. (1959) found that Thiourea, Ethyl urethane, Manzate and Zineb inhibit the formation of nitrate from ammonium sulfate. Thiourea and ethyl urethane were less effective inhibitors of the nitrification of ammonium added in the carbonate form. They concluded that the fungicide Ferbam inhibited the nitrite-oxidizing bacteria as well as the ammonium-oxidizing organisms.

Another compound which inhibits the nitrification reaction is sodium azide. Quastel and Scholefield (1949) reported that sodium azide is one of only two substances known to inhibit nitrification of pyruvic oxime in soil and that it is a vigorous respiratory poison. The effect of sodium azide on nitrification has also been reported by Hansson (1963). He established that the concentration of sodium azide in soil solution at 0.001 M can be used as a temporary nitrification inhibitor.

Hughes and Welch (1970) first reported the use of potassium azide (KN_3) as a nitrification inhibitor. They conducted experiments using six rates of potassium azide at two temperatures. They found that at both temperatures KN_3 was an effective nitrification inhibitor but it had no effect on nitrogen mineralization-immobilization relationships. At 30 degrees centigrade KN_3 did not prove to be an effective

nitrification inhibitor for soils with pH less than 6.0.

The compound 2-amino-4-chloro-6-methylpyrimidine has been found to suppress nitrification. The fate of this compound has been reported by Weir (1969). The amount of this inhibitor recovered from treated soil was a logarithmic function of time and was also a function of the clay content, the cation exchange capacity and the surface area of the soil.

N-Serve

The product N-Serve which contains 2-chloro-6-(trichloromethyl) pyridine as the active ingredient has a molecular weight of 230.9 and is a white crystalline solid with a melting point of 62-63 degrees centigrade. It has a low water solubility but is very soluble in methyl chloride and anhydrous ammonia. Nearly all research work conducted with this chemical has shown it to meet the criteria of an effective nitrification inhibitor.

In 1962 Swezey and Turner found that N-Serve additions increased the efficiency of ammonium sulfate, anhydrous ammonia, urea and aqua ammonia for cotton, sugar beets and sweet corn on an irrigated sandy loam soil in California. Growth and yield increases were considered to have been due to the inhibition of nitrification by the chemical and subsequent reduction in N losses by leaching. Other early work on N-Serve (Goring, 1962) showed the effectiveness of the compound in controlling nitrification of ammonium nitrate, ammonium sulfate, diammonium phosphate, anhydrous ammonia and

urea as N sources in a laboratory study. Turner and Nilsen (1964) showed that single applications of $\text{NH}_4\text{-N}$ plus N-Serve gave small but statistically significant yield increases when compared to the same amounts of N applied split into two or three applications. They concluded that by using N-Serve the extra cost of split N application could be avoided.

More recent work has continued to show the effectiveness and practicality of N-Serve as a nitrification inhibitor. Hughes and Welch (1970), in a field study on a silt loam at Urbana, Illinois, looked at the effects of N-Serve on nitrification of anhydrous ammonia by measuring concentrations of $\text{NH}_4^+\text{-N}$ in the retention zones at various times following application. N-Serve decreased the rate of nitrification at all locations within the retention zone. Kapusta and Varsa (1972) found that N-Serve, at 0.5 lb/A, has the potential of reducing the amount and depth of leaching of nitrates from fall-applied ammonia. Moore (1973), working with leafy vegetables in the San Luis Valley, Colorado, felt that N-Serve has a great potential for reducing nitrate enrichment of ground and surface waters and for reducing nitrate levels in plants.

Biological Effects of N-Serve

N-Serve nitrogen stabilizers are highly selective material for inhibiting Nitrosomonas bacteria which converts ammonium to nitrate nitrogen in soil but are reported to have no applicable effect on other soil bacteria, fungi or plant

seedlings at the concentration recommended for crops (Goring, 1962; Norris, 1972).

McKell and Whalley (1964), from their greenhouse test, recorded that N-Serve, at rates of 1-10ppm applied to soil before sowing, had little effect on survival of Rhizobium and nodulation of lucerne roots but at 20ppm it severely depressed seedling growth and caused deformation of root tips.

Loss of N-Serve

Redemann et al. (1964) reported that N-Serve is lost by two methods after being applied to the soil; by volatilization, and by decomposition to 6-Chloropicolinic acid. The rate of loss varied from soil to soil. They pointed out that the slowest rate of losses were obtained with soil which had high organic matter content. 6-Chloropicolinic acid, the residue of N-Serve, was studied by Redemann et al. (1965). Corn, lettuce, tomatoes, oats and carrots were planted in soil treated with 2-chloro-6-(trichloromethyl)-C¹⁴-pyridine, a "tagged" form of the active ingredient in N-Serve. They reported that the principal residue present was the hydrolysis product, 6-chloropicolinic acid, rather than 2-chloro-6-(trichloromethyl)-pyridine. They explained that the 6-chloropicolinic acid in soil was formed by hydrolysis of the 2-chloro-6-(trichloromethyl)-pyridine.

Nitrogen Fertilization

Numerous researchers have shown that nitrogen fertilization

is related to the amount of NO_3^- -N available for leaching or denitrification. NO_3^- -N concentration and form in a soil profile are directly related to the rate of N application. White and Pesek (1959) characterised forms and location of N in the soil profile resulting from N applied to corn the previous year. Under their experimental conditions the residual soil-N appeared to be chiefly in form of nitrates in the 6 to 21 inch layer. No appreciable quantities of residual NH_4^+ -N were found. Researchers have also reported that the percentage recovery by the crop of N applied in the field at various levels was influenced by both initial soil nitrate content and amounts of added N.

The effects of different sources, methods of application and rates of N on yield and soil NO_3^- -N have been studied by several investigators. Some of them reported that side dressing applications of N resulted in much higher grain yields than fall ploughed down applications (Allen et al., 1968; Mays et al., 1969; Giordano et al., 1970; Olsen, et al., 1970; Fox et al., 1974; Stephenson et al., 1974). Spring preplant application of N resulted in lower grain yields while postplant sidedress applications gave higher corn and sorghum yields and plant recovery of applied N.

MATERIALS AND METHODS

Experimental Site

Six of the experimental sites were selected to study the effect of nitrification inhibitor on the yields of irrigated corn sites (Kansas River Valley Experimental Field, Sandyland Experimental Field, Tribune Branch Experimental Station and Jim Sieman's Farm) are located in Shawnee, Stafford, Greeley and Harvey counties, respectively. The dryland sorghum sites (Ashland Agronomy Farm and Cornbelt Experimental Field) are located in Riley and Brown counties.

Soil type, soil test data and other information for each location are given in Table 1 and Table 2.

Design of Experiment

A randomised complete block design with four replications was used at all sites. Treatments included three or four rates, two dates of anhydrous ammonia application with or without N-Serve¹ and two or more other sources of N. The two dates of N application were fall and spring with rates of 0, 84, 169 and 252kg/ha on irrigated corn plots and 0, 45, 90, 134 and 179kg/ha on dryland sorghum plots.

Plots were 9m x 3m. N-Serve where added with N, was applied at a constant ratio of 230g active ingredient per 41kg N. The N-Serve was added to a special 20 liter pressure

¹Nitrification inhibitor.

Table 1. GENERAL INFORMATION ABOUT EXPERIMENTAL OPERATIONS AT EACH OF THE SITES

SITE	SOIL TYPE	DATE OF APPLICATION OF N		CORN OR SORGHUM HYBRID PLANTED	POPULATION Plants/ha
		FALL	SPRING		
Kansas River Valley Experimental Field Shawnee County	Sarpy loamy sand (Aridic Arguistolls)	January 13	April 2	Corn Pioneer 3184	59280
Sandyland Experimental Field Stafford County	Naron loamy sand (Typic Ustifluvents)	December 10	April 1	Corn Pioneer 3184	59280
Tribune Branch Experi- mental Station Greeley County	Richfield silt loam (Aridic Arguistolls)	November 20	March 23	Corn Pioneer 3306	59280
Jim Siemans Farm Harvey County	Farnum loam (Pachic Arguistolls)	---	April 5	Corn NC & 855X	58045
Ashland Agronomy Farm Riley County	Muir silt loam (Pachic Haplustolls)	November 5	March 26	Sorghum C42Y+	3.3 kg seed/ha
Cornbelt Experimental Field Brown County	Grundy silt loam (Aquic Argiudolls)	November 7	April 6	Sorghum Topaz	3.3 kg seed/ha

Table 2. INITIAL SOIL TEST DATA 1976

	Depth in cm	pH	Lime Requirement kg ECC/ha	Available P ppm	Exchange K ppm	Available N ppm	Available Zn ppm	OM %
Kansas River Valley Experimental Field	0-15	6.2	-----	20	290	10	1.5	---
Sandyland Experi- mental Field	0-15	6.3	7410	9	84	--	1.1	---
	15-60	6.4	-----	6	60	--	1.0	---
Tribune	0-5	7.7	-----	7.5	1150	--	0.7	---
Siemans Farm	0-15	6.8	-----	14.5	295	14	1.3	---
	15-60	6.9	-----	8.5	244	10	1.1	---
Ashland Agronomy Farm	0-15	5.8	-----	24	230	9.8	---	1.6
	15-60	6.1	-----	7.5	220	6.0	---	1.3
Cornbelt Experi- mental Field	0-15	6.0	-----	13	155	11.0	---	---
	15-60	6.6	-----	7.5	160	7.0	---	---

vessel which was subsequently filled with ammonia. Regular ammonia applications without N-Serve were made from a separate pressure vessel (100 liters).

Field experimental techniques. The fall N applications were not made until after the soil temperature at the 15cm depth was below 10 degrees centigrade. This practice is commonly recommended because nitrification is thought to practically cease below this temperature. Spring applications were made when soil conditions permitted field operations and proper sealing of the soil following ammonia injection. Actual application times are given in Table 3 and Table 4.

Anhydrous ammonia was included as an N carrier on all the sites. Ammonia was applied using a shank type applicator on 45cm centers with needle valve flow controls (Figure 1). The approximate point of NH_3 release was marked with twine rolled out through a tube just behind the injection knives. Other N carriers examined and compared to treatments involving N-Serve were calcium nitrate (15.5% N), N solution (28% N), urea (46% N), ammonium nitrate (34% N) and urea-ammonium sulphate (40% N, 4% S).

Precipitation data were secured from where the sites were located. A summary is given in Table 5.

Treatment evaluation criteria. Chemical analyses of corn and sorghum tissue samples were used to assess the nutrient status of plants as affected by the various treatments. The leaf opposite and below the ear was removed from eight corn plants within the harvest rows of each four row plot when the plants were approximately 75% silked. Using the same

Table 3. TREATMENTS INVOLVED IN THE IRRIGATED CORN STUDIES

KgN/ha	N Carrier	Time of Application	Location
0	---	---	All locations
84	Ammonia	Fall	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
168	Ammonia	Fall	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
84	Ammonia and N-Serve ¹	Fall	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
168	Ammonia and N-Serve	Fall	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
252	Ammonia and N-Serve	Fall	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
84	Ammonia	Spring	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
168	Ammonia	Spring	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm

Table 3. (continued)

KgN/ha	N Carrier	Time of Application	Location
252	Ammonia	Spring	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
84	Ammonia & N-Serve	Spring	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
168	Ammonia & N-Serve	Spring	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
252	Ammonia & N-Serve	Spring	Kaw Valley Exp. Field Sandyland Exp. Field Jim Siemans Farm
84	Calcium Nitrate	Fall	Kaw Valley Exp. Field
168	Calcium Nitrate	Fall	Kaw Valley Exp. Field
252	Calcium Nitrate	Fall	Kaw Valley Exp. Field
84	Calcium Nitrate	Spring	Kaw Valley Exp. Field
168	Calcium Nitrate	Spring	Kaw Valley Exp. Field
252	Calcium Nitrate	Spring	Kaw Valley Exp. Field
84	Urea Ammonia Nitrate ²	Fall	Sandyland Exp. Field

Table 3. (continued)

KgN/ha	N Carrier	Time of Application	Location
168	Urea Ammonia Nitrate	Fall	Sandyland Exp. Field
252	Urea Ammonia Nitrate	Fall	Sandyland Exp. Field
84	Urea Ammonia Nitrate plus N-Serve	Fall	Sandyland Exp. Field
168	Urea Ammonia Nitrate plus N-Serve	Fall	Sandyland Exp. Field
252	Urea Ammonia Nitrate plus N-Serve	Fall	Sandyland Exp. Field
84	Urea Ammonia Nitrate	Spring	Sandyland Exp. Field
168	Urea Ammonia Nitrate	Spring	Sandyland Exp. Field
252	Urea Ammonia Nitrate	Spring	Sandyland Exp. Field
84	Urea Ammonia Nitrate plus N-Serve	Spring	Sandyland Exp. Field
168	Urea Ammonia Nitrate plus N-Serve	Spring	Sandyland Exp. Field
252	Urea Ammonia Nitrate plus N-Serve	Spring	Sandyland Exp. Field

Table 3. (continued)

KgN/ha	N Carrier	Time of Application	Location
84	Urea	Preplant	Jim Sieman's Farm
168	Urea	Preplant	Jim Sieman's Farm
252	Urea	Preplant	Jim Sieman's Farm
84	Ammonia Nitrate	Preplant	Jim Sieman's Farm
168	Ammonia Nitrate	Preplant	Jim Sieman's Farm
252	Ammonia Nitrate	Preplant	Jim Sieman's Farm
84	Urea Ammonia Sulphate ³	Preplant	Jim Sieman's Farm
168	Urea Ammonia Sulphate	Preplant	Jim Sieman's Farm
252	Urea Ammonia Sulphate	Preplant	Jim Sieman's Farm
56	Ammonia	Fall	Tribune Branch Exp. Stat.
112	Ammonia	Fall	Tribune Branch Exp. Stat.
168	Ammonia	Fall	Tribune Branch Exp. Stat.
224	Ammonia	Fall	Tribune Branch Exp. Stat. ³
280	Ammonia	Fall	Tribune Branch Exp. Stat.
56	Ammonia	Spring	Tribune Branch Exp. Stat.

Table 3. (continued)

KgN/ha	N Carrier	Time of Application	Location
112	Ammonia	Spring	Tribune Branch Exp. Stat.
168	Ammonia	Spring	Tribune Branch Exp. Stat.
224	Ammonia	Spring	Tribune Branch Exp. Stat.
280	Ammonia	Spring	Tribune Branch Exp. Stat.
56	Ammonia and N-Serve	Spring	Tribune Branch Exp. Stat.
112	Ammonia and N-Serve	Spring	Tribune Branch Exp. Stat.
168	Ammonia and N-Serve	Spring	Tribune Branch Exp. Stat.
224	Ammonia and N-Serve	Spring	Tribune Branch Exp. Stat.
280	Ammonia and N-Serve	Spring	Tribune Branch Exp. Stat.

¹Nitrification inhibitor applied 230gm active ingredient per 41kg N.

²This material will be referred to as UAN.

³This material will be referred to as UAS.

Table 4. TREATMENTS INVOLVED IN THE GRAIN SORGHUM STUDY

KgN/ha	N Carriers	Time N Application
0	---	----
45	Ammonia	Fall
90	Ammonia	Fall
134	Ammonia	Fall
179	Ammonia	Fall
45	Ammonia and N-Serve	Fall
90	Ammonia and N-Serve	Fall
134	Ammonia and N-Serve	Fall
179	Ammonia and N-Serve	Fall
45	Ammonia	Spring
90	Ammonia	Spring
134	Ammonia	Spring
179	Ammonia	Spring
45	Ammonia and N-Serve	Spring
90	Ammonia and N-Serve	Spring
134	Ammonia and N-Serve	Spring
179	Ammonia and N-Serve	Spring

Figure 1. SHANK TYPE APPLICATOR USED IN INJECTING THE ANHYDROUS AMMONIA TREATMENTS IN THE FIELD EXPERIMENTS.

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Table 5. PRECIPITATION DATA

MONTH	Ks. River Valley Exp. Field	Sandyland Exp. Field	Tribune Branch Exp. Station	Jim Siemens Farm	Ashland Agronomy Farm	Corn belt Exp. Field
January	0.33	0.11	0.03	0.15	0.45	0.10
February	0.42	0.95	0.01	0.16	0.52	0.25
March	2.22	1.56	0.20	0.76	2.16	2.29
April	4.96	8.26	1.04	5.82	6.01	6.51
May	5.22	3.73	1.24	4.11	3.86	3.16
June	3.67	2.64	0.46	3.70	5.93	3.47
July	1.79	1.28	1.30	4.22	1.15	1.30
August	0.32	0.56	0.60	0.67	0.29	0.94
September	1.56	4.00	3.11	3.62	2.28	3.06
October	2.49	2.27	0.55	1.88	1.86	1.06
November	0.04	0.07	0.12	0.02	0.04	0.05
December	0.00	0.00	0.00	0.03	0.00	0.00
1976 Total	23.02	25.44	8.75	25.14	24.55	22.19
1975 Total	33.84	20.30	11.15	31.33	35.18	38.29

procedure, ten youngest fully emerged leaves were collected per sorghum plot, when the crop was at boot stage. These samples were dried at 49 degrees centigrade for three to four days and ground to pass through 20 mesh/cm stainless steel screen, and were analyzed for N.

Corn yield data were obtained by harvesting one of the center rows of each plot. The corn was hand harvested, shelled and weighed. Sorghum was either harvested by a combine (two center rows) or by hand (one center row). Plants harvested by hand were dried, threshed and weighed. Combine harvested grain was weighed in the field. Sub-samples from both harvested corn and grain sorghum were taken for determination of moisture content electronically. After an adjustment for moisture, grain yield were calculated on the basis of 15.5% and 12.5% moisture for corn and sorghum, respectively.

Soil sampling procedures. Soil samples were taken to study the relationship between nitrification in the soil profile and on yields of corn and sorghum. It was hoped that the rate of nitrification could be used to explain yield differences associated with the time of N application and the addition of N-Serve. Soil samples were collected from individual plots at different times, before application of treatments, just after application of treatments, at planting time, just prior to silking - the time when considerable uptake and utilization of N by plants occurs and at harvesting time. Thirty centimeter soil cores were taken and divided into 5cm increments. The samples were frozen as soon as possible by

placing in a freezer where the temperature was kept at 0 to -15 degrees centigrade. Soil samples were maintained at this temperature until chemical analyses for various forms of N were carried out.

Laboratory Procedures Leaf Analysis

After redrying the ground plant tissue samples at 65 degrees centigrade for 24 hours, 0.25g of sample was weighed into a digestion tube and 2mls of H_2SO_4 was added. Samples were placed under the hood. One milliliter of H_2O_2 was added and the tubes containing the mixture were then placed in an aluminum digestion block and heated to a temperature 625 to 650 degrees centigrade. The tubes were removed from the source of heat when they were filled half-way with fumes (approximately 45 minutes) and cooled for about 5 to 10 minutes. Addition of H_2O_2 and heating continued till the solution cleared. The tubes were then removed from the hot plate, cooled and diluted to 50mls with distilled water. The total N content of the plant tissue samples was measured colorimetrically. Reagents for this analysis were sodium salicylate (8.5%), sodium nitroprusside (0.03%) - known as Reagent A - and sodium dichlorosocyanurate in 0.6 NaOH - known as Reagent B.

Standard solutions of 0, 50, 100, 150, 200 and 250 ppm N as NH_4 were prepared from 1000ppm stock solution of $(\text{NH}_4)_2\text{SO}_4$. A color was then developed using the same dilutions used in the preparation of the samples and the curve on absorbance

0-1 was read on a zeroed spectrophotometer. The other concentrations of the solutions were read by setting the 50ppm standard at 0.1, 100 at 0.2, 150 at 0.3, and etc.

A 1:10 dilution of the digested and diluted tissue sample was prepared with distilled water. A second dilution of 0.5ml and 5.5mls of distilled water was also made. Two milliliters of each solution (Reagents A and B) were added and a color was allowed to develop in a period of two hours. The direct percent N was then read on the spectrophotometer at 660um.

Soil Analysis

Soil samples were removed from storage at 0 degrees centigrade, thawed and analyzed. A 5gm soil sample and 10mls of 2N KCL were placed in a micro-kjeldahl distillation flask. This flask was then attached to a steam distillation apparatus. One-tenth gram of heavy MgO was added to the KCL and the soil sample mixture and ammonia was driven off with steam. Thirty milliliters of distillate were collected in a 50ml Erlenmeyer flask containing 5mls of 2% H_3BO_3 -indicator solution. After addition of 0.2gm of Devardo's alloy to the distillation flask, another 30mls distillate was collected in a second 50mls Erlenmeyer flask also containing 5mls of 2% H_3BO_3 to determine $\text{NO}_2\text{-N}$ plus $\text{NO}_3\text{-N}$. The distillate/indicator solutions were then titrated with 0.00524 N H_2SO_4 . Parts per million of N ($\text{NH}_4^+\text{-N}$ + $\text{NO}_2\text{-N}$ + $\text{NO}_3^-\text{-N}$) were then calculated by the formula:

$$\text{ppm N} = \frac{\begin{array}{c} \text{mls of H}_2\text{SO}_4 \\ \text{on Sample -} \\ \text{H}_2\text{SO}_4 \text{ on Blank} \end{array} \times \begin{array}{c} \text{Normality} \\ \text{of acid} \end{array} \times (14\text{mg/meq}) \times (1000)}{\text{Sample Weight (gms)}}$$

Greenhouse Experiments

Effect of nitrification inhibitor on rate of nitrification and nitrate movement in soil. Several workers (Boswell, 1977; Stanley and Smith, 1956) have recognized that soil type, moisture content, temperature and depth of application of NH_4^+ -N play a major role in predicting the rate of nitrification and movement of nitrate in the soil profile.

The objective of this greenhouse study was to compare the effect of N-Serve on rates of nitrification in two soils (sand and silty clay loam) and on nitrate movement in percolating water. The two types of soil used in the study were an alluvial sand from the flood plain of the Kansas River and a Muir silty clay loam from the Ashland Agronomy farm, both in Riley county, Kansas.

Ten (10) kilograms of sand and 12 kilograms of silty clay loam were screened, weighed and packed into 60cm long by 15cm diameter PVC columns. Perforated plastic plates were glued to the bottom of these columns. Plastic tubes were fitted into the perforations to direct the flow of any leachate from the soil into collection bottles (Figure 2). An experimental ammonia applicator, Phillips Petroleum designed, was used to inject 0.303 mls and 0.606 mls of liquid ammonia with or without N-Serve, equivalent to nominal, uniform 75ppm and 150ppm N treatments, respectively (Figure 3). Table 6 describes

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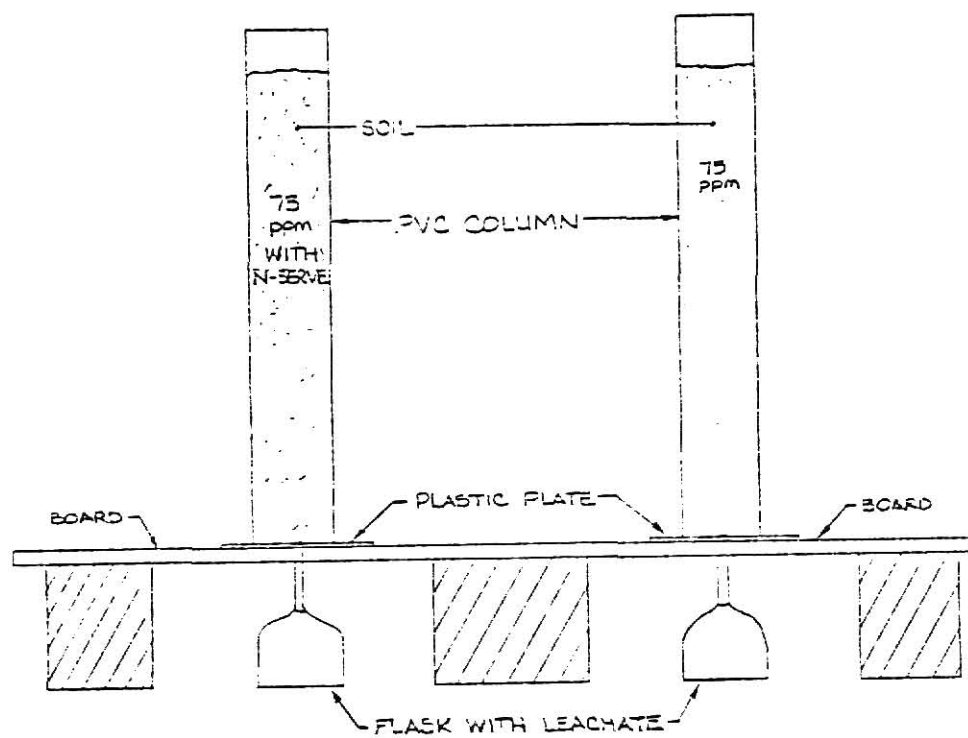


Figure 2. A DIAGRAM OF THE PVC COLUMNS SET UP FOR THE GREENHOUSE STUDY.

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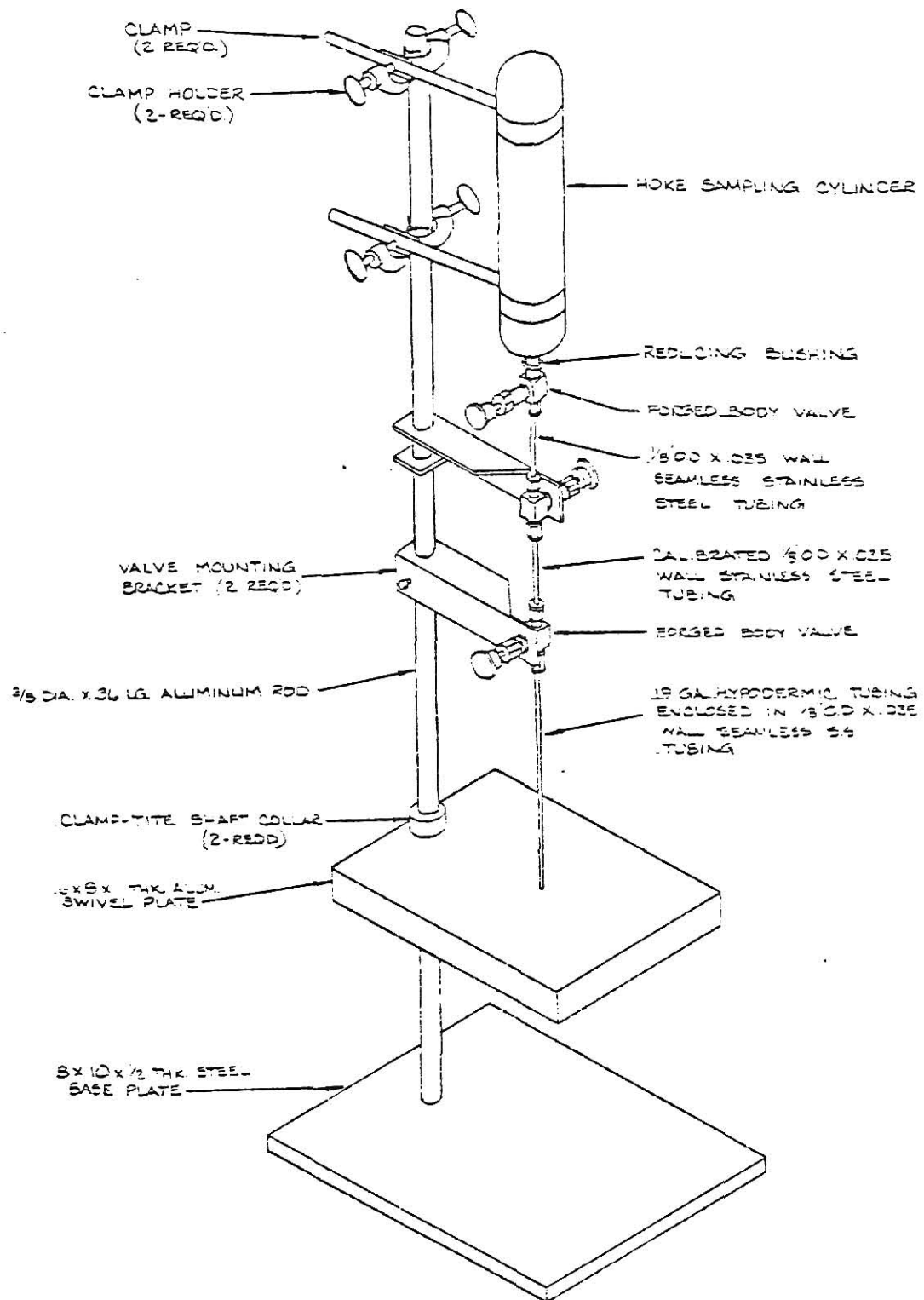


Figure 3. LIQUID ANHYDROUS AMMONIA APPLICATOR USED TO INJECT THE TREATMENTS (AMMONIA AND AMMONIA PLUS N-SERVE) IN THE GREENHOUSE STUDIES.

the characteristics of the greenhouse soil.

Twenty-five-hundredths milligram per column (equivalent of 125g active ingredient/acre) of N-Serve was dissolved in the respective amounts of ammonia before application. All treatments were replicated three times and the columns randomly arranged in the greenhouse. Treated soils in the columns were moistened by adding equal amounts of water and allowed to incubate for eight weeks. During the incubation period equal amounts of water were added at regular intervals (weekly) to the columns and leachates were collected in bottles. In order to stop further nitrification or other microbial activities in the collected leachates, 3-4 drops of Phynylmercuric acetate were added to the leachates in the bottles. Solutions in the bottles were brought to equal volumes (1 liter) and aliquots of 50mls were taken from each bottle. These were then analyzed for NH_4^+ -N and NO_3^- -N by the steam distillation method previously mentioned.

Soil temperature in the columns was monitored continuously through the life of the study by placing the sensor of a recording thermometer at a depth of 15cm, the depth at which anhydrous ammonia was released.

After the incubation period, six seeds of Bojac X56 variety of corn were planted in each column and thinned to three plants per column after emergence. The plants were harvested 21 days after emergence.

Supplementary to this study was another pot study conducted under the same greenhouse conditions. The pots

Table 6. INITIAL CHARACTERISTICS OF SOIL USED IN THE GREENHOUSE STUDIES

Soil Characteristics ¹	Soil Types	
	Sand	Muir Silty Clay Loam
pH	7.8	5.9
CaCO ₃ requirement, Kg/ha	---	3000
Available P, ppm ²	16	155
Ca, ppm	621	1574
Mg, ppm	14	298
Exch K, ppm ³	118	500
Organic matter (%)	0.2	2.1
CEC, meq/100g ⁴	3.51	14.63
Available N, ppm ⁵	1.7	26.1

¹All chemical analyses performed by KSU Soil Testing Laboratory.

²Available P was determined by extraction with 0.025 N HCL in 0.03 N NH₄F (Bray's P extraction procedure).

³Soils were extracted with 1 N ammonium acetate (NH₄OAc) using 1.5 soil to solution ratio.

⁴Estimated from the values CaCO₃, Ca, Mg, K.

⁵Determined by steam distillation method.

were filled with two kilograms of each soil type and treated with 0.606 mls of NH_3 , an equivalent of 150ppm N with and without N-Serve. Water was added to these pots at regular intervals at the same time and in relative amounts as water was added to the columns. The soils in the pots were sampled four times - one week after application of treatment, eight weeks (i.e. planting time for the columns), ten weeks and twelve weeks, respectively. Samples were taken directly from the center of the retention zone during the life time of the study and were analyzed by the steam distillation method for $\text{NH}_4\text{-N}$ and $\text{NO}_3\text{-N}$.

Statistical Procedures

Corn yields, leaf analysis data and soil N concentrations were evaluated using the analysis of variance (AOV) procedure given by Snedocor and Cochran (1967).

RESULTS AND DISCUSSION

Studies reviewed thus far indicate difficulty in predicting the influence of time of N application on the final grain yields of corn and sorghum and show that information relating nitrification of NH_3 to growth of the crop during the season is very limited. The main objective of this study was to measure the effects of time, rate of application and nitrification inhibition on yields of irrigated corn and dry-land grain sorghum. Chemical analyses of plants and soil samples were used to help explain treatment effects. Discussion of the results of corn and sorghum yield tests, leaf and soil sample analyses follows.

Corn Responses to Nitrification Inhibition

Visual responses of corn to nitrogen sources and rates were evident at all locations from the outset of the investigation. Plots which had received ammonia with the nitrification inhibitor tended to exhibit better early growth in the growing season at the Kaw Valley experimental site. These plants were darker green than the plots which received ammonia only. The visual evidence of this effect is presented in Figure 4. Comparing these treatments to $\text{Ca}(\text{NO}_3)_2$ applications, it was evident that plants which had received the leachable calcium nitrate were quite chlorotic early in the growing season and exhibited classic nitrogen deficiency



Figure 4. VISUAL EVIDENCE OF CORN RESPONSES TO N-SERVE AT THE EARLY STAGES OF GROWTH AT KAW VALLEY EXPERIMENTAL SITE.

symptoms. The visual growth differences which had been observed early in the season between ammonia and ammonia plus N-Serve treatments, however, largely disappeared by the time of harvest despite some differences which persisted in the first replication, suggesting an advantage for N-Serve (Figure 5).

Few visual differences between N-Serve and no N-Serve applied either in ammonia or N solution (UAN) were apparent at the other locations.

Corn grain yield data from both the Sandyland and Kaw Valley experimental field sites are presented in Tables 7 and 8. Treatments with N-Serve tended toward higher yields. However, statistical evaluation revealed that N-Serve did not give a significant response at the Kaw Valley site. The Sandyland location showed a significant positive effect of N-Serve.

Although the 1976 yields at Sandyland were considered low as compared to earlier years due to a severe problem with southwestern corn borer, there was a demonstration of highly significant and consistent effect of N-Serve. This could be attributed to the sandy texture of the soil coupled with irrigation that provided conditions conducive to nitrogen movement in the soil.

Comparing yields of ammonia treatments with those of calcium nitrate at the Kaw Valley site, it was observed that calcium nitrate treatments produced mean values which were less than those of ammonia (Table 8). Still, the differences



Figure 5. CROP APPEARANCE AT DOUGH STAGE AT KAW VALLEY EXPERIMENTAL FIELD, SHAWNEE COUNTY. (Note early N deficiency symptoms in treatments without N-Serve have disappeared.)

Table 7. EFFECT OF A NITRIFICATION INHIBITOR APPLIED IN AMMONIA ON YIELD AND LEAF COMPOSITION OF IRRIGATED CORN: SANDYLAND EXPERIMENTAL FIELD, STAFFORD COUNTY

Treatment kgN/ha	N carrier	Time N	Yield kg/ha	Leaf N %
0	-	-	1360	2.50
84	NH ₃	Fall	4100	2.93
168	NH ₃	Fall	4188	2.88
252	NH ₃	Fall	6508	3.23
84	NH ₃ + N-Serve	Fall	4452	3.22
168	NH ₃ + N-Serve	Fall	7286	3.46
252	NH ₃ + N-Serve	Fall	7279	3.64
84	NH ₃	Spring	6916	3.08
168	NH ₃	Spring	6345	3.10
252	NH ₃	Spring	7712	3.33
84	NH ₃ + N-Serve	Spring	6013	3.12
168	NH ₃ + N-Serve	Spring	7198	3.38
252	NH ₃ + N-Serve	Spring	7029	3.36
84	UAN	Fall	4282	2.98
168	UAN	Fall	5668	3.30
252	UAN	Fall	7480	3.40
84	UAN + N-Serve	Fall	6909	3.26
168	UAN + N-Serve	Fall	7536	3.33
252	UAN + N-Serve	Fall	7787	3.41
84	UAN	Spring	5505	2.92
168	UAN	Spring	7442	3.33
252	UAN	Spring	6709	3.32
84	UAN + N-Serve	Spring	6521	3.11
168	UAN + N-Serve	Spring	9066	3.38
252	UAN + N-Serve	Spring	8615	3.28
LSD _{.05} Treatment			2383	0.30
N-rate				
84 kg/ha			5586	3.08
168 kg/ha			6840	3.27
252 kg/ha			7392	3.37
LSD _{.05}			853	0.10

Table 7. (Continued)

	Yield kg/ha	Leaf N %
Nitrification inhibitor		
With N-Serve	7141	3.33
Without N-Serve	6069	3.15
LSD _{.05} N-Serve	696	0.08
Time of N Application		
Fall	6119	3.25
Spring	7091	3.23
LSD _{.05} Time	696	NS

Table 8. EFFECT OF NITRIFICATION INHIBITION ON THE YIELD AND LEAF COMPOSITION OF IRRIGATED CORN: KAW VALLEY EXPERIMENTAL FIELD, SHAWNEE COUNTY

Nitrogen kg/ha	N carrier	Time of Application	Yield kg/ha	Leaf N %
0	-	-	6477	2.73
84	NH ₃	Fall	9505	2.89
168	NH ₃	Fall	9323	2.89
252	NH ₃	Fall	10897	3.13
84	NH ₃ + N-Serve	Fall	9963	3.10
168	NH ₃ + N-Serve	Fall	8866	3.23
252	NH ₃ + N-Serve	Fall	9254	3.32
84	Ca(NO ₃) ₂	Fall	9091	2.58
168	Ca(NO ₃) ₂	Fall	9750	2.90
252	Ca(NO ₃) ₂	Fall	8872	2.77
84	NH ₃	Spring	10897	3.21
168	NH ₃	Spring	10665	3.26
252	NH ₃	Spring	9919	3.18
84	NH ₃ + N-Serve	Spring	10609	3.06
168	NH ₃ + N-Serve	Spring	10747	3.19
252	NH ₃ + N-Serve	Spring	10389	3.30
84	Ca(NO ₃) ₂	Spring	9399	2.97
168	Ca(NO ₃) ₂	Spring	9573	2.96
252	Ca(NO ₃) ₂	Spring	10383	3.03
LSD _{.05} Treatment			2245	0.28
N-Rate kg/ha				
48			9907	2.97
168			9812	3.09
252			9950	3.12
LSD _{.05}				
a/Non-significant at 5%				
N-carrier				
NH ₃			10201	3.11
NH ₃ + N-Serve			9969	3.20
Ca(NO ₃) ₂			9505	2.87
LSD _{.05} Material			NS	0.11

Table 8. (Continued)

	Yield kg/ha	Leaf N %
Time of N application:		
Winter	9499	2.99
Spring	10283	3.13
LSD .05 Time	746	0.09

were not significant at the five percent level. This might be due to the fact that the nitrogen of calcium nitrate which had been leached into the coarse textured soil by precipitation and irrigation waters was finally reached by the plant roots and translated into an acceptable yield (Figures 6 and 7).

Nitrogen concentrations in the plants tissue from the plots at Kaw Valley reflected the same trends as the yields. Tissue nitrogen increased with the higher rates of nitrogen application up to 168 kg of nitrogen per hectare. Ammonia plus N-Serve produced higher nitrogen concentrations in the leaf than did ammonia and much higher values than calcium nitrate (Table 8).

Effects of nitrification inhibitor on nitrogen content of the plant leaf at the Sandyland experimental field were similar to those at Kaw Valley. Use of N-Serve produced an overall mean increase in nitrogen concentration apparently through improved nitrogen efficiency and control of N movement in the soil.

EFFECT OF TIME OF N APPLICATION ON CORN

Data in Table 7 from the Sandyland field indicates an influence of time of N application on corn yield and concentration of N in the plant tissue. Yield responses also indicated that N-Serve did enhance N availability during the growing season. It was therefore not surprising that the spring nitrogen applications were generally superior to fall N applications on the coarse textured soil of Sandyland, but

Figure 6.

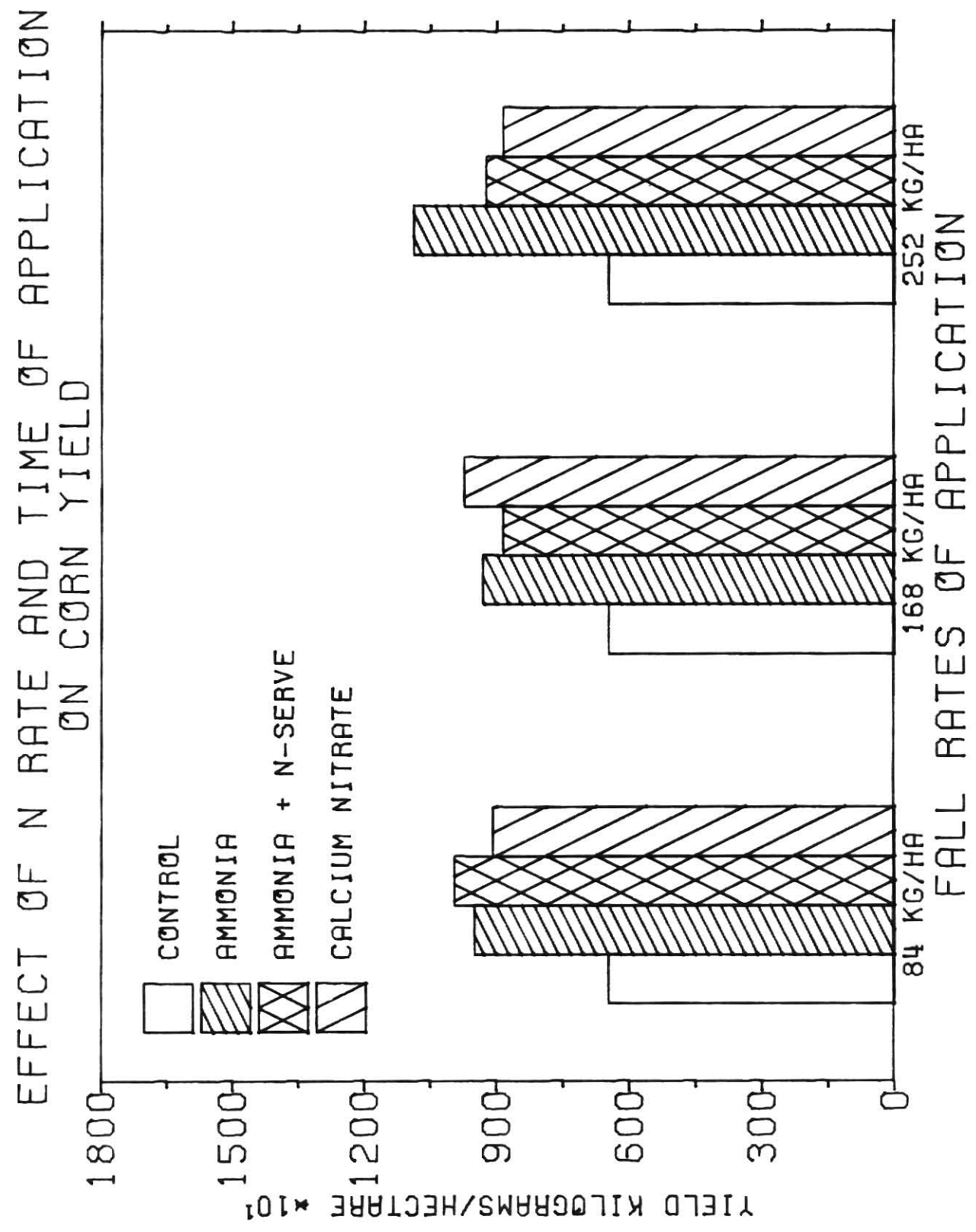
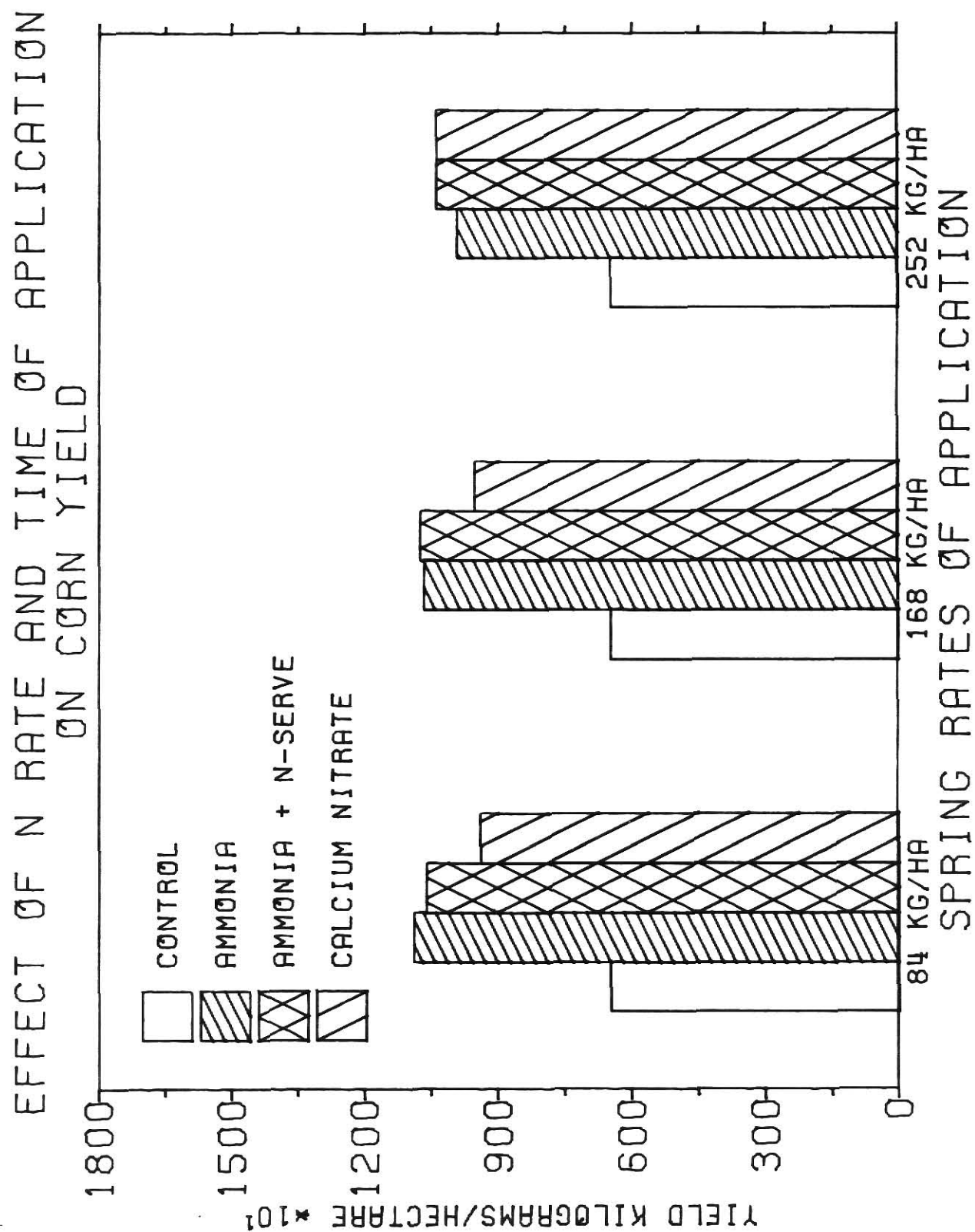


Figure 7.



N-Serve also exerted a positive effect on yields when included in spring N applications. N-Serve included in NH_3 showed less consistent effect at the Sandyland site than did N-Serve in N solution (UAN). This is not surprising, however, since UAN is comprised of about 75 percent ammoniacal N and 25 per cent nitrate N and is potentially more subject to leaching and/or denitrification. Further examination of the data at Sandyland indicates that spring N applications were superior to fall applications even when N-Serve was included in the formulation, particularly with UAN. It is somewhat surprising, however, that the sandy alluvial soil of Kaw Valley experimental field site did not show the same type of significant response. General recommendations for coarse-textured soils of this nature have been for spring applications of N. Apparently the use of the nitrification inhibitor did not totally overcome the problems of nitrogen movement which were encountered with fall applications.

Comparison of fall and spring nitrogen applications indicated that spring applications caused higher plant N.

Statistical analysis of leaf tissue-N data indicated generally higher N concentrations with spring N applications, significantly higher at the Kaw Valley site.

Nitrogen rate exerted significant effects at both Sandyland and Kaw Valley. N-Serve consistently increased N concentrations in the leaf tissue at both sites, significantly at the 5 percent level at Sandyland and at the 10 percent level at Kaw Valley. Higher leaf N values indicate higher

availability of N in the soil profile giving further support to the yield effects of N-Serve discussed earlier.

Comparing these studies on coarse-textured soils to one involving similar variables (N rates, time of N application, N-Serve) but situated on a fine textured Richfield-Ulysses silt loam soil with irrigated corn at the Tribune Branch Experimental Station, fall and spring nitrogen applications did not produce a consistent advantage for spring applications. In fact, yields were generally comparable between the two dates with no disadvantage for fall applications. Fall applied ammonia without N-Serve yielded as well as spring applied ammonia with N-Serve (Table 9). Earlier studies of nitrate movement through the soil at the Tribune Station did not indicate substantial leaching even with full irrigation. In light of the lack of leaching at this location, it is not surprising that nitrification inhibition designed to control both leaching and possible denitrification losses had little effect upon nitrogen efficiency. Over-irrigation on such soil pose more threat to nitrogen efficiency through denitrification than through leaching. Admittedly, little information is available on denitrification losses of N under irrigated conditions in the Great Plains area of the U.S.

A further test of the effectiveness of ammonia plus N-Serve was conducted on the Jim Siemans Farm in Harvey County with irrigated corn. The yield data shown in Table 10 indicate a higher yield for ammonia with N-Serve than with ammonia alone. However, when UAN was compared to ammonia plus N-Serve,

Table 9. EFFECT OF FALL AND SPRING NITROGEN APPLICATIONS
AND NITRIFICATION INHIBITOR ON YIELD OF IRRIGATED
CORN: TRIBUNE BRANCH EXPERIMENTAL STATION

Treatment kg/ha	Time of N Application	N-Serve	Yield kg/ha
0	-	-	7662
56	-	No	8822
112	-	No	11637
168	-	No	11706
224	-	No	10834
280	-	No	12759
56	Spring	No	9123
112	Spring	No	9386
168	Spring	No	10697
224	Spring	No	12954
280	Spring	No	12151
56	Spring	Yes	8458
112	Spring	Yes	9863
168	Spring	Yes	11819
224	Spring	Yes	10490
280	Spring	Yes	11324
LSD .05 Treatment			2483
56			8790
112			9624
168			11261
224			11719
280			11737
LSD .05 Rate			1812
NH ₃ Spring			10860
NH ₃ + N-Serve Spring			10389
LSD .05			NS
Time of application:			
Fall NH ₃			11154
Spring ³ NH ₃			10860
LSD .05			NS
Fall NH ₃			11154
Spring ³ NH ₃ + N-Serve			10389
LSD .05			NS

Table 10. NITROGEN MATERIAL AND NITRIFICATION INHIBITOR
EFFECTS ON YIELDS AND LEAF COMPOSITION OF IRRIGATED
CORN: JIM SIEMANS FARM, HARVEY COUNTY

Nitrogen kg/ha	N Material	Yield kg/ha	Leaf N %
0	-	5724	3.51
84	NH ₃	8019	4.01
168	NH ₃	8910	4.01
252	NH ₃	8000	3.98
84	NH ₃ + N-Serve	8590	4.10
168	NH ₃ + N-Serve	9800	3.97
252	NH ₃ + N-Serve	9518	4.03
84	Urea	6903	3.81
168	Urea	6859	4.00
252	Urea	8816	4.13
84	N Solution (UAN)	6226	4.01
168	N Solution (UAN)	6226	4.01
252	N Solution (UAN)	10120	4.06
84	NH ₄ NO ₃	7085	3.95
168	NH ₄ NO ₃	8527	3.94
252	NH ₄ NO ₃	7944	4.26
84	Urea-ammonium sulfate (UAS)	6759	3.61
168	Urea-ammonium sulfate (UAS)	8082	4.07
252	Urea-ammonium sulfate (UAS)	9518	3.91
LSD .05 Treatment		1768	0.30
N-carrier:			
	NH ₃	8308	4.00
	NH ₃ + N-Serve	9298	4.04
	Urea	7524	3.98
	UAN	8859	4.03
	NH ₄ + NO ₃	7856	4.05
	UAS	8120	3.86
	LSD .05	1003	NS
N-rate			
	84 kg/ha	7599	3.91
	168 kg/ha	8402	4.00
	252 kg/ha	8985	4.06
	LSD .05 N Rate	740	NS

there was no significant difference between those sources at this location.

Tissue samples collected from the plots did not show significant differences between nitrogen carriers (Table 10).

DRYLAND GRAIN SORGHUM RESPONSES TO NITRIFICATION

Yields of grain sorghum as affected by fall and spring ammonia applications with and without N-Serve are given in Tables 11 and 12 . The 1976 data were disappointing from the standpoint of N responses. Lack of response was due primarily to moisture stress and adequate soil N for the prevailing conditions. Since yield responses to N were poor, N-Serve applications were similarly ineffective. The analysis of variance of the sorghum yield data are presented in Table 13.

Results of leaf tissue analysis follow the trends observed in irrigated corn. Nitrogen concentration in leaves increased as high rates of N and N plus N-Serve were applied (Tables 11 & 12). Although the tissue analyses reflected generally higher values when N-Serve was included, analysis of variance revealed that N-Serve had no significant effect as an independent factor. Interaction among rate, N-Serve and time was significant at Ashland site (Table 13).

Soil Analysis

An attempt was made to assess the effects of N-Serve on N concentrations and rate of nitrification in the field by taking soil samples at different times during the growing

Table 11. YIELD AND LEAF COMPOSITION OF DRYLAND SORGHUM AS AFFECTED BY RATE, NITRIFICATION INHIBITOR AND TIME OF APPLICATION OF ANHYDROUS AMMONIA: ASHLAND AGRONOMY FARM, RILEY COUNTY

N treatment kg/ha	N carrier	Time of N application	Yield kg/ha	Leaf N %
0	-	-	6790	3.61
45	NH ₃	Fall	8884	3.60
90	NH ₃	Fall	7373	3.81
134	NH ₃	Fall	7957	3.74
179	NH ₃	Fall	7643	3.74
45	NH ₃ + N-Serve	Fall	8759	3.67
90	NH ₃ + N-Serve	Fall	7348	3.62
134	NH ₃ + N-Serve	Fall	7906	3.83
179	NH ₃ + N-Serve	Fall	7982	3.86
45	NH ₃	Spring	9129	3.60
90	NH ₃	Spring	7499	3.61
134	NH ₃	Spring	8540	3.73
179	NH ₃	Spring	7982	3.74
45	NH ₃ + N-Serve	Spring	8471	3.77
90	NH ₃ + N-Serve	Spring	8007	3.82
134	NH ₃ + N-Serve	Spring	8740	3.85
179	NH ₃ + N-Serve	Spring	7812	3.65
LSD .05 Treatment			NS	NS
N-rates				
45 kgN/ha			8809	3.66
90			7555	3.71
134			8289	3.79
179			7856	3.75
LSD .05 N Rate			815	NS
Nitrification inhibitor:				
NH ₃			8126	3.69
NH ₃ + N-Serve			8126	3.76
LSD .05			NS	NS
Time of application:				
Fall			7982	3.73
Spring			8270	3.72
LSD .05			NS	NS

Table 12. YIELD AND LEAF COMPOSITION OF DRYLAND SORGHUM
RATE, NITRIFICATION INHIBITOR AND TIME OF
APPLICATION OF ANHYDROUS AMMONIA: CORNBELT
EXPERIMENT FIELD, BROWN COUNTY

N treatment kg/ha	N carrier	Time of application	Yield kg/ha	Leaf N %
0	-	-	6966	2.37
45	NH ₃	Fall	6082	2.66
90	NH ₃	Fall	6245	2.99
134	NH ₃	Fall	6308	3.00
179	NH ₃	Fall	6000	2.92
45	NH ₃ + N-Serve	Fall	6496	2.70
90	NH ₃ + N-Serve	Fall	6345	2.87
134	NH ₃ + N-Serve	Fall	6840	3.12
179	NH ₃ + N-Serve	Fall	5963	2.96
45	NH ₃	Spring	5925	2.70
90	NH ₃	Spring	6627	2.86
134	NH ₃	Spring	6295	2.94
179	NH ₃	Spring	5950	2.89
45	NH ₃ + N-Serve	Spring	6063	2.76
90	NH ₃ + N-Serve	Spring	5969	3.08
134	NH ₃ + N-Serve	Spring	6351	2.94
179	NH ₃ + N-Serve	Spring	6333	3.13
LSD .05 Treatment			903	0.24
Rates:				
45			6138	2.71
90			6295	2.98
134			6452	3.00
179			6063	2.98
LSD .05 Rate			NS	0.12
Nitrification inhibitor:				
NH ₃			6176	2.87
NH ₃ + N-Serve			6295	2.95
LSD .05			NS	NS
Time of application:				
Fall			6282	2.90
Spring			6188	2.91
LSD .05			NS	NS

Table 13. ANALYSES OF VARIANCE OF YIELD AND LEAF N OF GRAIN
SORGHUM: ASHLAND AGRONOMY FARM

Source of variation	DF	Mean squares		F	
		Yield	Leaf N	Yield	Leaf N
Total	63	-	-	-	-
Replicates	3	1278.16	0.1351	-	-
Rate	3	1208.49	0.0471	3.61*	1.86
N-Serve	1	0.04	0.0631	0.00	2.49
Time	1	339.94	0.0026	1.01	0.10
Rate x N-Serve	3	75.57	0.0134	0.23	0.53
Rate x Time	3	110.01	0.0173	0.33	0.68
N-Serve x Time	1	4.57	0.0260	0.01	1.03
Rate x N-Serve x Time	3	74.40	0.0647	0.22	2.56*
Error	45	355.05	0.0253		

CORNFIELD EXPERIMENT FIELD

Source of variation	DF	Mean squares		F	
		Yield	Leaf N	Yield	Leaf N
Total	47	-	-	-	-
Replicates	2	96437.27	0.0550	-	-
Rate	3	9589.80	0.3218	1.22	17.32**
N-Serve	1	4408.33	0.0001	0.56	0.00
Time	1	2821.33	0.1017	0.36	5.48
Rate x N-Serve	3	5725.05	0.0065	0.73	0.35
Rate x Time	3	3682.50	0.0215	0.47	1.16
N-Serve x Time	1	5940.75	0.0093	0.57	0.50
Rate x N-Serve x Time	3	5055.14	0.0130	0.64	0.70
Error	30	7873.31	0.0186		-

*Significant at 5 percent level.

**Significant at 1 percent level.

season. In general, higher average soil N concentrations were associated with spring applied N and treatments where N-Serve was included. Control plots had significantly lower N concentrations than most of the treated plots (Table 14).

Regardless of whether N-Serve causes an increase in yield under different environmental conditions imposed on the plots, the presence of this nitrification inhibitor in the soil depressed the nitrate-nitrogen content in the soil for a period of time. This was related to the slower rate of conversion of ammonium-nitrogen to nitrate-nitrogen by microbial nitrification due to toxicity of N-Serve to Nitrosomonas. Slowed conversion of NH_4^+ to NO_3^- represents a means of reducing losses of nitrogen, where nitrogen leaching is a potential problem such as was the case at the Sandyland and Kaw Valley locations.

Ammonia applied to the coarse-textured soil of the Kaw Valley site was rapidly converted to nitrate by soil microbial activity which resulted in increased nitrate-nitrogen in the first 20 cm. of soil (Table 14).

The concentration of nitrate-nitrogen was lower in soil samples taken in June. This may be attributed to plant uptake of N or to nitrate-nitrogen moving out of the surface soil as fast as the ammonium-nitrogen was converted to the nitrate form.

Anhydrous ammonia plus N-Serve produced lower concentrations of nitrate-nitrogen in the early part of the season because the nitrification process was inhibited by N-Serve.

Table 14. N CONCENTRATIONS IN SOIL AT DIFFERENT DATES OF SAMPLING: KAW VALLEY
EXPERIMENTAL FIELD, SHAWNEE COUNTY

Depths	Nov 6		March 12		April 14		June 12		June 30	
	NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻	ppm:N NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻
CONTROL 0 kg N										
0-5	4.84	1.17	13.35	4.55	4.21	5.75	6.01	8.41	2.69	1.48
5-10	1.61	0.73	3.96	3.96	4.80	10.30	3.23	5.47	3.09	1.21
10-15	1.17	1.03	2.41	6.90	2.01	5.60	2.49	4.74	4.30	0.31
20-25	1.02	1.32	2.93	6.60	2.30	7.07	2.93	4.44	1.21	2.42
25-30	0.59	0.88	3.96	6.60	3.77	7.36	2.93	4.74	2.96	1.75
252 kg N Fall										
0-5	8.36	1.91	72.04	21.57	6.70	7.36	4.11	5.62	2.42	0.81
5-10	448.52	4.55	242.23	46.51	4.65	9.27	3.08	9.43	3.63	1.88
10-15	123.39	2.05	265.27	45.04	4.21	17.93	3.52	12.07	2.15	1.21
15-20	11.88	2.93	330.56	33.31	36.49	33.77	2.05	15.60	1.48	0.54
20-25	4.99	4.25	254.71	31.25	52.63	23.94	1.91	8.11	2.02	0.13
25-30	3.69	1.91	47.98	9.10	12.43	17.78	22.74	7.38	2.15	0.81
252 kg N + N-Serve Fall										
0-5	198.66	2.93	95.51	52.97	55.27	19.40	0.15	6.50	3.36	1.34
5-10	433.41	7.48	77.49	60.01	245.42	9.27	9.39	8.55	4.57	2.96
10-15	513.96	8.36	4.40	-	189.37	11.77	6.31	10.61	2.28	1.48
15-20	159.04	8.95	-	-	243.85	5.16	11.44	12.37	3.63	2.15
20-25	36.39	9.54	-	2.35	17.41	5.16	2.05	7.53	7.79	2.82
25-30	4.84	2.20	-	2.92	4.50	4.43	2.05	6.94	5.51	6.58

Table 14. (Continued)

Depths	Nov 6		March 12		April 14		June 12		June 30	
	NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻	ppm:N NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻
					252 kg N + N-Serve Spring					
0-5	-	-	7.78	4.70	255.10	11.77	11.15	13.79	3.09	1.34
5-10	-	-	16.14	3.52	367.49	8.10	4.40	10.85	4.03	1.61
10-15	-	-	3.08	3.96	323.47	10.30	5.87	11.30	4.17	0.81
15-20	-	-	3.52	5.43	8.61	5.60	5.28	12.91	3.22	0.67
20-25	-	-	2.20	4.42	5.97	5.16	4.55	12.91	2.82	1.21
25-30	-	-	2.49	4.70	5.68	4.72	1.76	8.66	2.42	0.94
252 kg N Spring										
0-5	-	-	3.69	3.23	11.55	22.48	5.57	12.03	4.30	1.34
5-10	-	-	4.84	2.93	144.77	61.06	4.25	13.64	3.36	1.75
10-15	-	-	2.64	2.35	144.48	35.39	1.91	8.07	2.69	0.54
15-20	-	-	3.37	4.40	3.04	4.87	1.91	7.19	2.02	-
20-25	-	-	1.61	3.23	0.98	4.43	1.61	9.54	1.75	-
25-30	-	-	2.93	2.49	1.57	4.58	1.76	7.63	1.48	0.67

Table 14 illustrates this phenomenon. Slowed nitrification resulted in movement of smaller amounts of nitrate-nitrogen through the profile as compared to the treatment without N-Serve. Spring N-Serve treatments produced a nitrate peak after 8-12 weeks and then dropped to a level about the same as the treatment without N-Serve.

Soil samples from the Sandyland plots (sandy surface underlain by a relatively heavy clay) showed the same trend (Table 15).

Statistical analysis of the data from plots which received 252 kg/ha with or without N-Serve at the Sandyland site is reported in Table 16. N-Serve, time of application and interactions among N-Serve, time of application, and date of sampling had highly significant effects on $\text{NO}_3\text{-N}$ concentration in the soil.

Soil analyses on plots used for the dryland sorghum studies showed similar results (Table 17). In plots receiving N-Serve with N treatments, soil nitrate-nitrogen concentration in the 0-15 cm. layer was lower during the early growing season but increased tremendously 4-8 weeks after planting.

Statistical analyses of soil N data from the plots at Ashland revealed that date of soil sampling, N-Serve, and the interaction between date of sampling, N-Serve, and time of N application were highly significant in nitrification of anhydrous ammonia to nitrate (Table 18).

Table 15. N CONCENTRATION IN SOIL AT DIFFERENT DATES OF SAMPLING: SANDYLAND EXPERIMENTAL FIELD, STAFFORD COUNTY

Depths cm	Nov 19		March 17 ppm:N		May 20	
	NH ₄ ⁺	NO ₃	NH ₄ ⁺	NO ₃	NH ₄ ⁺	NO ₃
Control 0 Kg N						
0-5	1.11	4.46	7.25	2.79	45.04	8.14
5-10	4.46	4.46	7.25	2.79	261.89	8.14
10-15	3.34	4.46	4.46	2.23	98.00	9.61
15-20	2.23	2.23	3.34	2.79	9.83	13.23
20-25	3.44	3.34	3.34	1.11	0.05	10.79
25-30	2.23	3.34	3.90	1.67	0.03	6.09
252 Kg N + N-Serve Fall						
0-5	4.46	5.57	26.76	8.92	1.47	4.33
5-10	7.80	6.69	10.59	0.44	5.65	
10-15	21.18	5.59	27.89	10.03	20.25	16.21
15-20	587.58	10.03	100.90	6.69	31.10	18.27
20-25	10.03	5.57	35.68	4.46	0.30	28.24
25-30	4.46	4.46	4.46	4.46	0.03	24.72
252 Kg N Fall						
0-5	4.46	5.57	15.61	22.30	1.17	3.45
5-10	5.57	5.57	81.39	22.30	0.44	3.45
10-15	150.52	6.69	85.85	31.22	-	8.58
15-20	21.18	5.59	92.54	45.71	-	12.98
20-25	14.49	4.46	31.22	25.64	-	8.29
25-30	14.49	4.46	12.26	23.64	-	12.54
252 Kg N + N-Serve Spring						
0-5	-	-	7.80	6.69	-	11.08
5-10	-	-	57.98	14.49	0.59	9.02
10-15	-	-	482.78	11.15	0.73	6.53
15-20	-	-	1322.34	15.61	0.59	4.91
20-25	-	-	35.69	4.46	0.73	3.15
25-30	-	-	35.69	5.57	128.23	4.62
252 Kg N Spring						
0-5	-	-	8.92	6.69	2.93	3.59
5-10	-	-	80.28	5.57	1.47	3.30
10-15	-	-	460.48	10.03	1.32	4.33
15-20	-	-	783.82	11.15	-	5.65
20-25	-	-	413.65	7.80	0.44	5.35
25-30	-	-	43.48	7.80	0.15	4.62

Table 16. ANALYSIS OF VARIANCE OF ppm SOIL N IN PLOTS WHICH RECEIVED 252 kgN/ha
WITH AND WITHOUT N-SERVE: SANDYLAND EXPERIMENT FIELD

Source of variation	DF	NH ₄ ⁺ MS	- N F	NO ₃ ⁻ MS	- N F
Depth	5	64467.973	3.097	37.024	3.524
Date	1	177243.750	8.514*	228.987	21.797**
N-Serve	1	3529.480	0.170	202.869	19.311**
Time	1	46797.437	2.248	266.209	25.340**
Depth x Date	5	51601.848	2.479	1.360	0.125
Depth x N-Serve	5	4343.894	0.209	21.349	2.032
Depth x Time	5	7863.555	0.378	5.618	0.535
Depth x N-Serve	1	3951.240	0.190	339.734	32.339**
Date x Time	1	107789.375	5.178	725.250	69.036**
N-Serve x Time	1	22359.422	1.074	417.129	39.706**
Depth x Date x N-Serve	5	3791.859	0.182	25.963	2.471
Date x N-Serve x Time	1	47522.109	2.283	378.338	36.014**
Depth x Date x Time	5	17146.499	0.824	20.470	1.948
Depth x N-Serve x Time	5	27535.199	1.323	8.925	0.850
Error	5	20816.949	-	10.505	-
Total	47	-	-	-	-

* Significant at 5 percent level.

** Significant at 1 percent level.

Table 17. N CONCENTRATION IN SOIL AT DIFFERENT DATES OF SAMPLING: ASHLAND
AGRONOMY FARM, RILEY COUNTY

Treatment	Depth	Nov 20		April 15		June 11	
		NH ₄ ⁺	NO ₃ ⁻	ppm:N NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻
0 kg control	0-5	3.34	4.45	5.57	4.46	3.48	28.64
	5-10	3.34	4.45	2.23	2.23	2.89	15.43
	10-15	3.34	3.34	1.67	2.23	1.86	11.91
	15-20	2.23	2.23	1.12	1.67	1.86	9.21
	20-25	2.23	1.11	0.01	1.11	2.01	6.19
	25-30	1.11	1.11	3.90	2.23	1.28	7.66
179 kg N + N-Serve							
179 kg N + N-Serve	0-5	45.71	20.07	360.14	4.46	108.38	83.07
	5-10	476.09	18.95	624.40	4.46	178.66	83.51
	10-15	445.98	20.07	172.82	10.03	41.77	65.47
	15-20	1.11	10.03	29.55	7.80	3.18	45.66
	20-25	8.92	5.57	15.61	7.80	5.82	32.89
	25-30	17.84	4.46	9.48	5.75	3.33	24.53
179 kg N							
Fall 179 kg N	0-5	123.76	20.07	221.88	15.05	3.77	23.94
	5-10	582.01	20.07	306.07	21.18	11.55	28.93
	10-15	20.07	12.26	39.82	27.87	4.36	43.16
	15-20	5.57	8.92	2.79	26.76	1.86	58.28
	20-25	4.46	4.46	11.71	23.41	1.57	52.41
	25-30	3.34	4.46	16.17	17.84	0.98	39.94

Table 17. (Continued)

Treatment	Depth	Nov 20		April 15		June 11	
		NH ₄ ⁺	NO ₃ ⁻	ppm:N NH ₄ ⁺	NO ₃ ⁻	NH ₄ ⁺	NO ₃ ⁻
179 kg N + N-Serve							
Spring 179 kg N + N-Serve	0-5	-	-	8.95	6.89	3.67	22.89
	5-10	-	-	640.87	7.04	2.05	21.13
	10-15	-	-	407.73	6.16	2.79	15.84
	15-20	-	-	6.01	6.18	2.20	10.86
	20-25	-	-	2.35	10.12	2.79	16.87
	25-30	-	-	2.49	8.07	2.35	10.56
179 kg N							
Spring 179 kg N	0-5	-	-	4.11	20.69	4.55	18.05
	5-10	-	-	298.13	16.58	3.37	19.22
	10-15	-	-	360.64	23.33	4.11	20.10
	15-20	-	-	4.25	19.81	3.67	19.66
	20-25	-	-	2.64	20.69	2.20	23.77
	25-30	-	-	2.35	2.64	2.05	15.84

Table 18. ANALYSIS OF VARIANCE OF PPM SOIL N IN THE PLOT WHICH RECEIVED
179 kg N/ha WITH AND WITHOUT N-SERVE: AGRONOMY FARM, RILEY COUNTY

Source	df	$\text{NH}_4^+ - \text{N}$		$\text{NO}_3^- - \text{N}$	
		MS	F	MS	F
Depth	5	1810.433	15.044**	71.768	3.713
Date	1	1093.857	9.089*	167.253	8.654*
N-Serve	1	80.550	0.699	537.874	27.829**
Time	1	2836.376	23.569**	35.329	1.828
Depth x Date	5	1510.589	12.552*	28.986	1.500
Depth x N Source	5	157.008	1.305	12.632	0.654
Depth x Date	5	244.729	2.034	19.059	0.986
Date x N Source	1	511.820	4.253	74.850	3.873
Date x Time	1	677.249	5.628	39.531	2.045
N-Source x Time	1	1607.997	13.362*	0.546	0.028
Depth x Date x N-Source	5	177.928	1.479	14.200	0.735
Date x N-Source x Time	1	37.630	0.313	417.127	21.582*
Depth x Date x Time	5	192.954	1.603	49.962	2.585
Depth x N-Source x Time	5	218.600	1.816	10.297	0.533
Error	5	120.343	-	19.328	
Total	47				

*Significant at 5 percent level.

**Significant at 1 percent level.

GREENHOUSE EXPERIMENT

Corn plant heights taken 21 days after planting are presented in Figure 8. Significant differences in plant heights were found between plants in the silty clay loam soil and plants in the sandy soil columns (Figure 9). This was due to the rapid downward movement of $\text{NO}_3 - \text{N}$ below the root zone of the seedlings in the coarse-textured soil. The silty clay loam, containing much smaller percentage of large pore space, permitted less leaching of the nitrate, with more N being retained in the root growing zone more N was available for plant use. This observation agrees with findings of Bates and Tisdale (1957). They expressed the movement of nitrates in the soil as a function of the porosity of the soil and the quantity of water added to it.

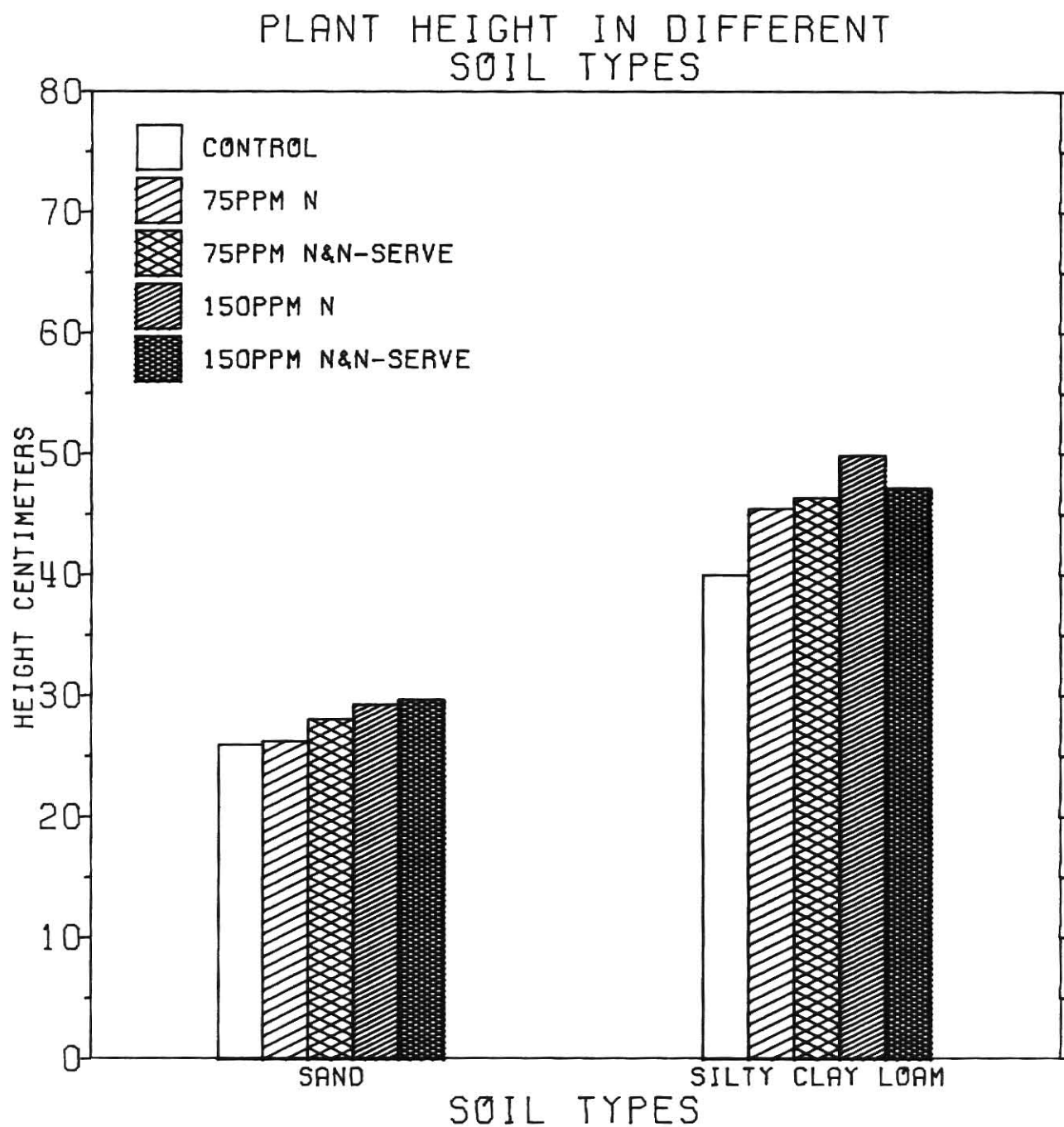
No differential response was apparent in heights of plants which received same amounts of N with or without N-Serve in the same type of soil.

Visual symptoms of N deficiency were observed on the control columns of both soils and also on plants which received 75 ppm N without N-Serve during the entire life of the study (Figures 10 and 11).

Although all treatments produced apparent N response (color) over the controls, the treatments with N-Serve had darker green color than the treatments without the nitrification inhibitor.

Data showing effects of N rates with and without N-Serve

Figure 8.



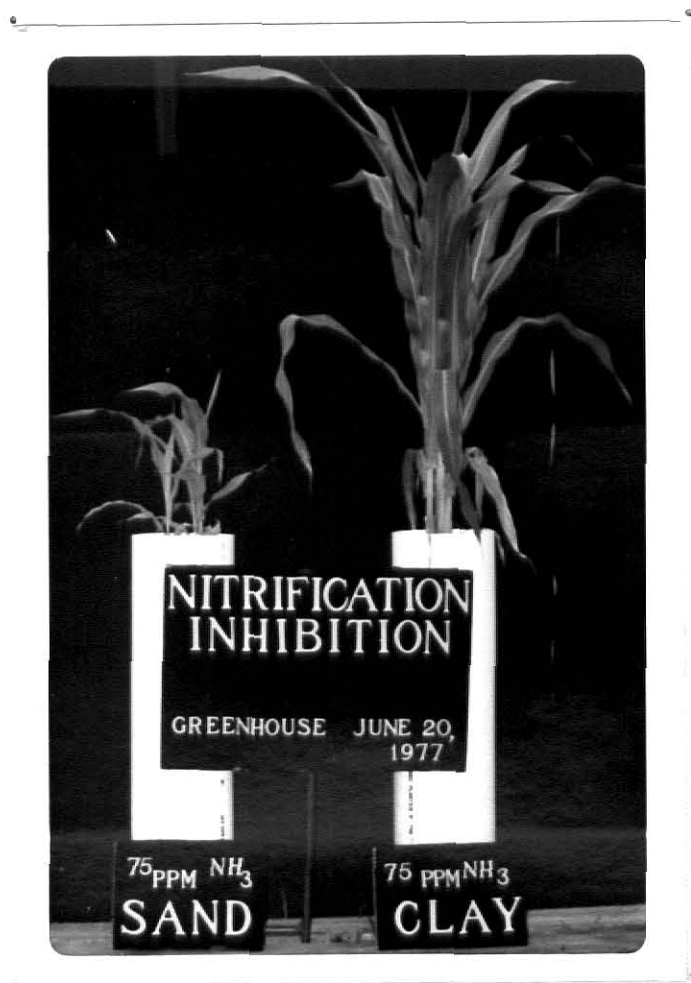


Figure 9. PLANT GROWTH 21 DAYS AFTER PLANTING IN TWO DIFFERENT SOILS IN THE GREENHOUSE STUDY.



Figure 10. VISUAL SYMPTOMS OF N DEFICIENCY IN PLANTS GROWING IN THE SANDY SOIL COLUMNS.

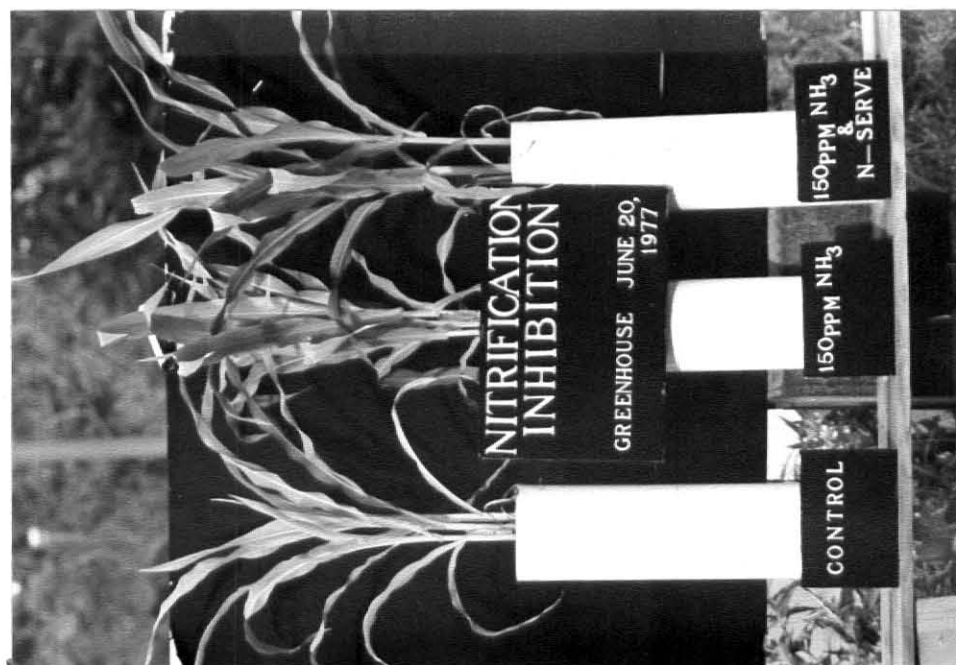


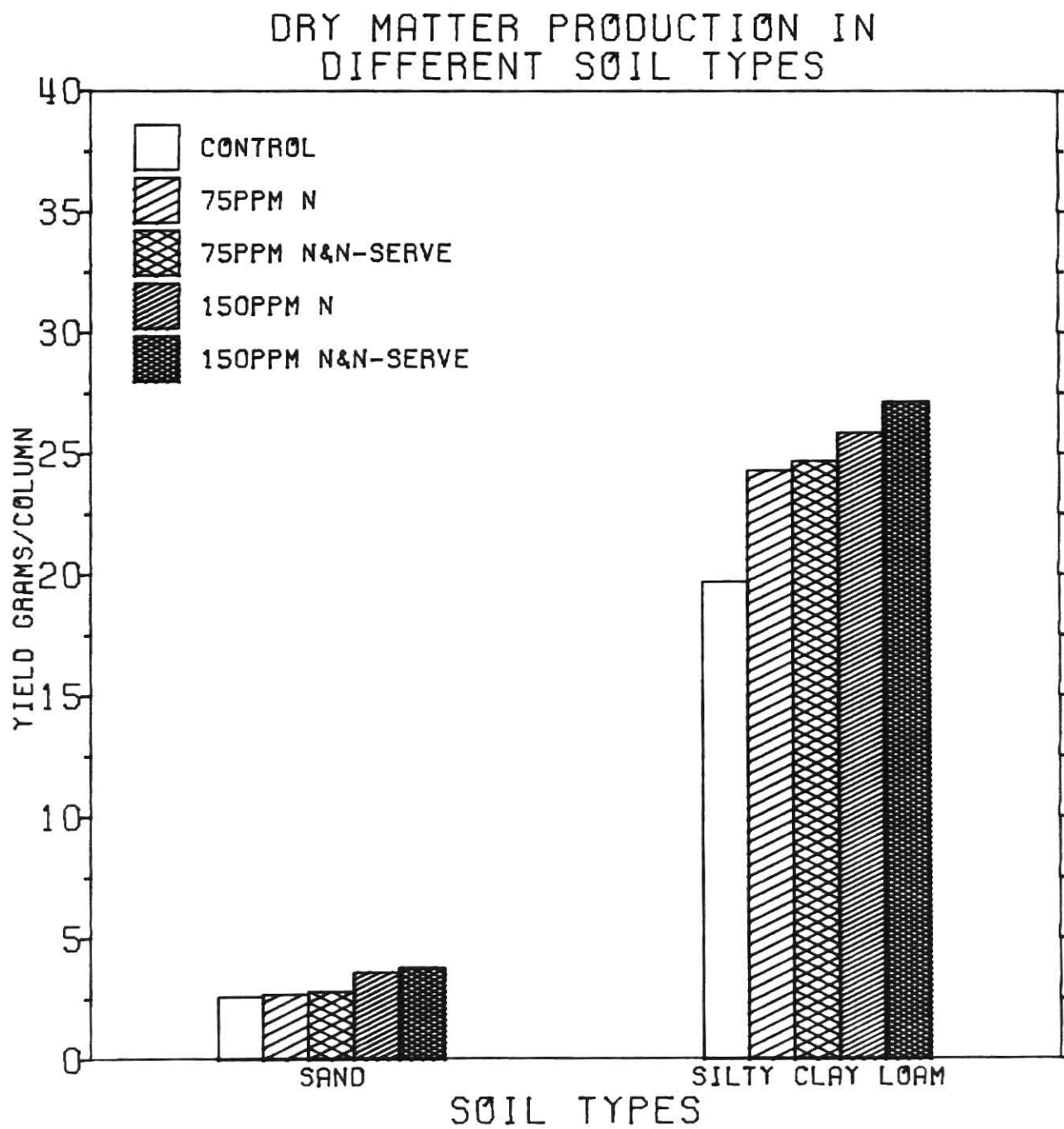
Figure 11. VISUAL SYMPTOMS OF N DEFICIENCY IN PLANTS GROWING IN THE SILTY CLAY LOAM COLUMNS.

on plant dry weight are presented in Figure 12. Increasing N application rates with N-Serve increased dry weights of 21-day corn seedlings. The lowest dry matter yield in the sandy soil (2.7 gm) was produced by the control column while the highest was from the 150 ppm N with N-Serve. The same trend was observed for dry matter production in the silty clay loam soil. The lowest yield (19.7 gm) came from the control and the highest (27.2 gm) from the 150 ppm N with N-Serve.

Nitrogen application effects on N, P and K concentrations in the plants are also shown in the Appendix. The higher N rates with N-Serve gave significantly higher N concentrations in corn grown on both soil types. Nitrogen varied from 0.96 percent to 1.58 percent. Generally, effects of N rate, N-Serve and soil type on P and K concentrations were negligible. No consistent trends were established.

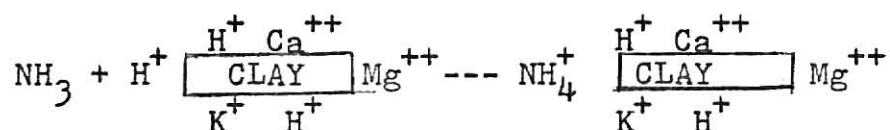
Results of the analyses of the leachate and soil analyses are shown in Appendix. Measurements indicate that there was little nitrification during the first two weeks following the injection of ammonia. This might be due to the fact that the nitrifying bacteria may have suffered from the sterilizing effect of ammonia. Although this phenomena was observed with all treatments, it was more pronounced with treatments receiving N-Serve. Nitrification was well under way after eight weeks but the amount of nitrification was notably less where N-Serve was included. Nitrate accumulation was continuing after twelve weeks in soil where N-Serve was included

Figure 12.



(Figures 13 and 14).

Figure 15 show a higher NH_4^+ ion concentration in the silty clay loam soil samples as compared to that in the sand even after a week of incubation. This was due to the low pH of the silty clay loam (5.9), the presence of higher amounts of organic matter and higher cation exchange capacity (Appendix). In this type of soil the injected ammonia was converted to NH_4^+ ions which were readily absorbed on the soil colloids. This process of adsorption itself slowed the movement of ammonia or ammonium ions in the soil.



The sandy soil had less organic matter, very low amounts of colloidal particles and a lower CEC which permitted more movement of ammonia, rapid nitrification of injected ammonia and more leaching of N.

The soil samples were taken from the center of the retention zone in order to sample multiple zones of nitrification activity relative to the point of injection.

This experiment substantiates results of the field studies, which showed that N-Serve was effective in inhibiting nitrification up to eight weeks or longer.

Appendix reveals higher N uptake in plants grown in N-Serve treated columns of sand. This reflected the higher efficiency of N fertilizer with N-Serve. Greater N efficiency

SAND

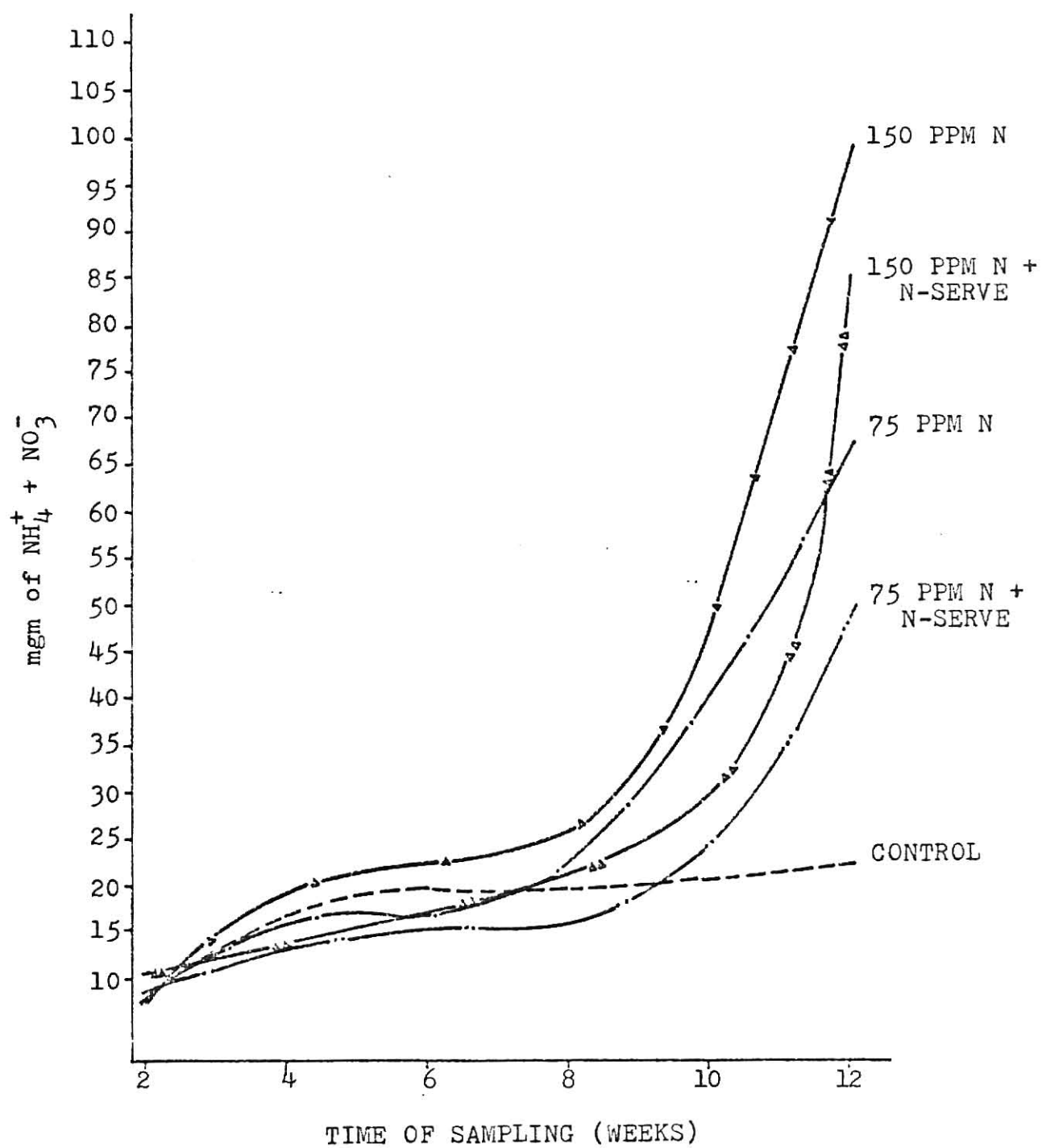


Figure 13. CUMULATIVE AMOUNTS OF $\text{NO}_3^- + \text{NH}_4^+$ IN LEACHATE FROM COLUMNS.

SILTY CLAY LOAM

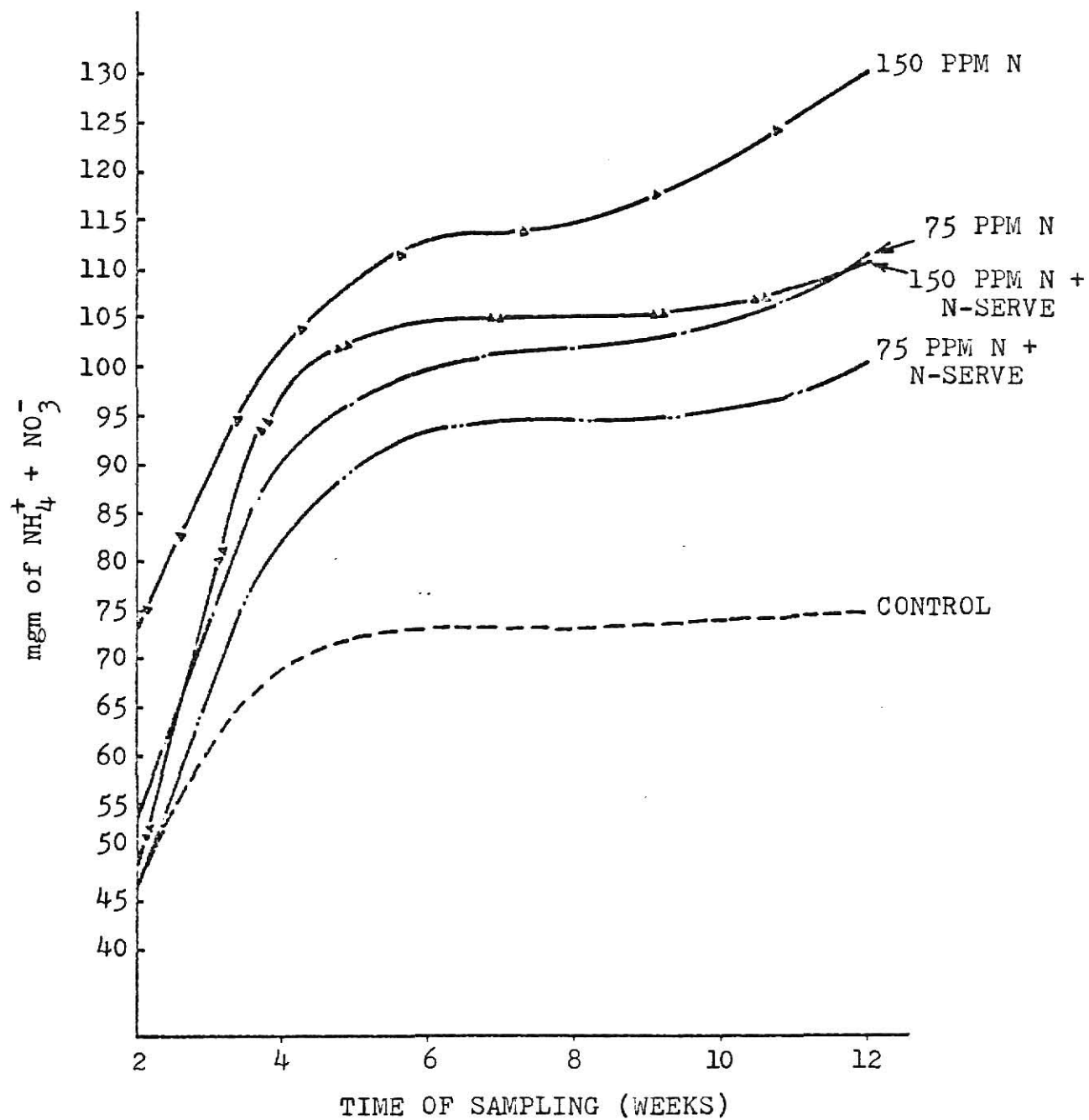


Figure 14. CUMULATIVE AMOUNTS OF $\text{NO}_3^- + \text{NH}_4^+$ IN LEACHATE FROM COLUMNS.

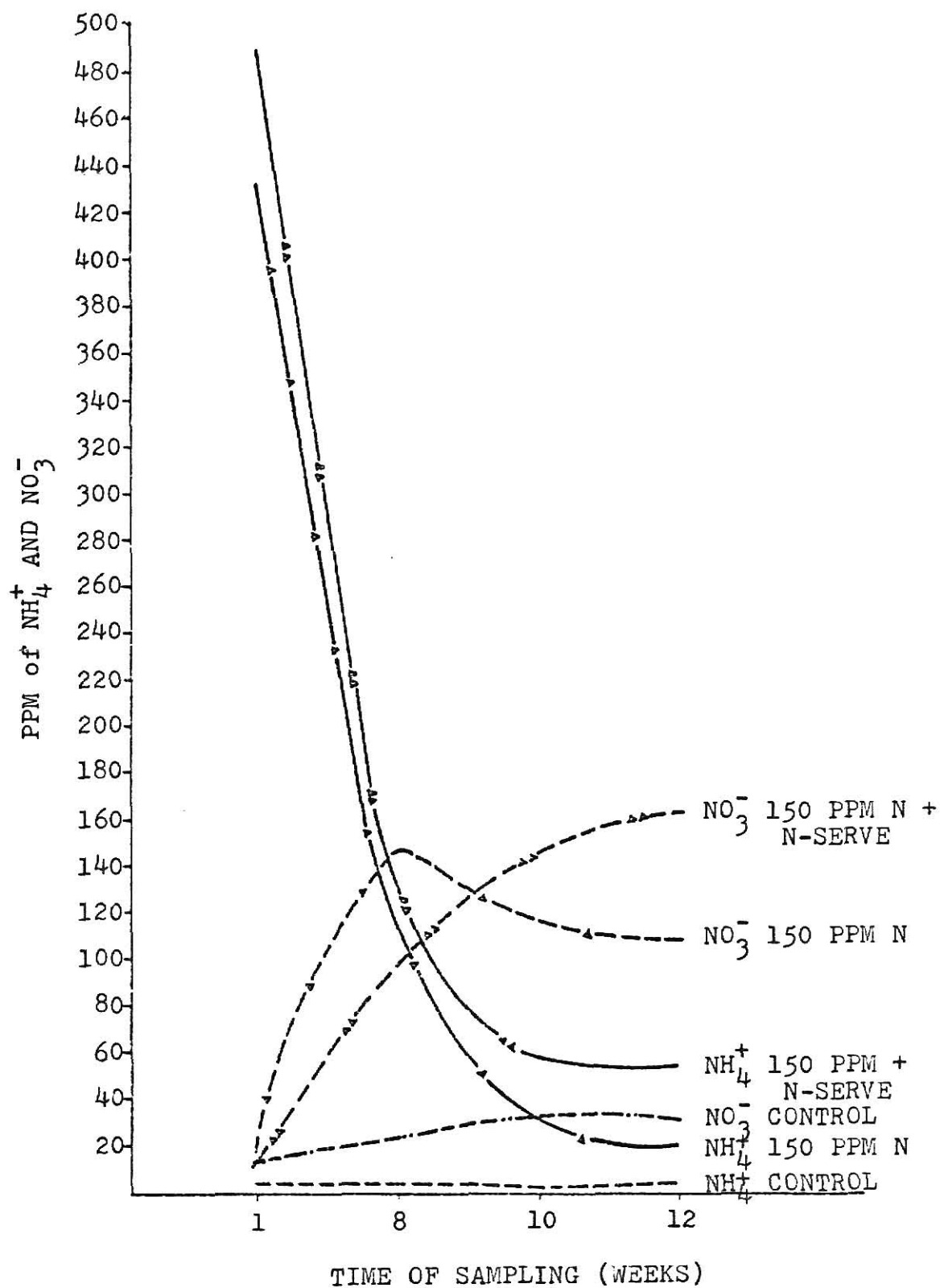


Figure 15. CONCENTRATION OF NH_4^+ -N AND NO_3^- -N IN SOIL SAMPLES FROM THE GREENHOUSE⁴POT STUDY³(SILTY CLAY LOAM)

was attributable to the reduced leaching of N from the sand columns, supported by the cumulative amounts of N in the leachate during the incubation period. N-Serve had a less pronounced effect on N efficiency on the silty clay loam soil due to higher N content of the soil and reduced percolation losses on N.

SUMMARY AND CONCLUSIONS

The influence of time of application of anhydrous ammonia on yields of corn and sorghum varied with individual site and soil types but response generally increased with later N application including N-Serve on coarse-textured soils.

Leaf composition data indicated that N-Serve produced a significant increase in leaf N on coarse-textured soils.

Statistical techniques indicated that a significant ($P=.05$) linear increase in leaf N was associated with progressively higher rates and later application dates on coarse-textured soil.

Chemical analyses of soil samples indicated considerable conversion of NH_4^+ - N to NO_3^- - N, some of which moved beyond the 30 cm. depth. Average soil N concentrations were higher with applications made in the fall and spring with N-Serve added to the treatment. It was also evident that coarser textured soils experienced faster nitrification and greater depth of NO_3^- - N movement which resulted in less total N in the surface 30 cm. Concentrations of NH_4^+ - N in the surface 15-20 cm. were significantly greater following applications with N-Serve in fall and spring.

Analysis also revealed the extreme difficulty of measuring N concentrations after application of anhydrous ammonia. The location of the NH_3 injection zone was difficult to locate due to tillage disturbance of markers. This situation

coupled with insect problems and moisture stress, made it impossible to establish any clearly defined relationship between position of N in the soil profile and grain yields.

Agriculturally, there are some advantages in inhibiting nitrification of fertilizer N added as ammonium nitrogen where nitrate may be lost by leaching or denitrification. N-Serve as a specific nitrification inhibitor was of use in improving the efficiency of N fertilizers. The data from this limited study, however, suggests that those advantages be restricted to textured, irrigated soils. More information is needed to evaluate the material on irrigated soils, high in clay.

Results of this study suggest that N-Serve inhibition of nitrification may also favor fall application of N on coarse-textured soils and therefore enable farmers to shift some of their spring work load to the fall.

Again more information is needed on soils high in clay as to effects of N-Serve on efficiency of fall applications for row crops.

LITERATURE CITED

- Allison, R.E. 1966. The Fate of Nitrogen Applied to Soils. *Advance Agron.* 18:219-258.
- Ansorge, H., S. Markert and R. Jauert. 1967. Inhibition of nitrification by some chemical preparations. *Albrecht-Thaer-Arch II.* (6) 509-516.
- Bates, T.E. and S.L. Tisdale. 1957. The movement of nitrate-nitrogen through columns of coarse textured soil materials. *Soil Sci. Soc. Amer. Proc.* 21:525-528.
- Bizzell, J.A. 1944. Lysimeter Experiments VI. The effects of cropping and fertilization on the losses of nitrogen from the soil. *Memoir* 256. Cornell Univ. Exper. Station, 14p.
- Boswell, F.C. 1971. Comparison of fall, winter or spring N-P-K fertilizer applications of corn. *Agron. J.* 63:905-907.
- Boswell, F.C. and O.E. Anderson. 1964. Nitrogen movement in undisturbed profiles of fallowed soils. *Agron. J.* 56:278-281.
- Bouldin, D.R. and D.J. Lathwell. 1968. Time of application is the key to crop nitrogen use. *New York's Food and Life Sci.* 1:9-12.
- Bremner, J.M. 1963. Determination of nitrogen in soils by the Kjeldahl Method. *J. Agron. Sci.*, 55:11-22.
- Bremner, J.M. 1965. Inorganic Forms of Nitrogen in C.A. Black (ed) *Methods of Soil Analysis.* Am. Soc. Agron., Madison, Wisconsin.
- Bremner, J.M. and D.R. Keeney. 1965. Steam Distillation method of determination of ammonium, nitrate and nitrite. *Anal. Chem. Acta* 32:485-495.
- Bundy, L.G., and J.M. Bremner. 1973. Inhibition of nitrification in soils. *Soil Sci. Soc. Amer. Proc.* 37:396-398.
- Cochran, V.L., R.I. Papendick, and W.M. Woody. 1973. Effectiveness of two nitrification inhibitors for anhydrous ammonia under irrigated and dryland conditions. *Agron. J.* 65:649-653.

- Doss, B.D., O.L. Bennett and D.A. Ashley. 1962. Evapotranspiration by irrigated corn. *Agron. J.* 54:497-498.
- Dumenil, L.R. Meldrum, and J. Pesek. 1954. When to fertilize? Fall of spring. *Iowa Farm Sci.* 9:571-574.
- Fenn, L.B., and D.E. Kissel. 1974. Ammonia volatilization from surface application of ammonium compounds on calcareous soil: II. Effect of temperature on rate of ammonium nitrogen application. *Soil Sci. Soc. Amer. Proc.* 38:606-610.
- Fox, R.H., H. Talleyrand, and D.R. Bouldin. 1974. Nitrogen fertilization on corn and sorghum grown in oxisols. *Agron. J.* 66:534-540.
- Gardner, W.R. 1965. Movement of nitrogen in soil. *American Society of Agronomy Monograph.* 10:550-572.
- Gasser, J.K.R. 1961. Transformation, leaching and uptake of fertilizer nitrogen applied in autumn and spring to winter wheat on a Heavy Soil. *J. Sci. Food Agric.* 12:375-380.
- Gasser, J.K.R. 1965. Effects of 2-Chloro-6 (trichloromethyl)-pyridine on the nitrification of ammonium sulphate and its recovery by ryegrass. *J. Agric. Sci.* 64:299-303.
- Gasser, J.K.R., and F.G. Hamlyn. 1968. The effects on winter wheat of ammonium sulphate with and without a nitrification inhibitor and of calcium nitrate. *J. Agric. Sci., Camb.* 71:243-249.
- Goring, C.A.I. 1962a. Control of nitrification by 2-Chloro-6 (trichloromethyl)-pyridine. *Soil Sci. Soc. Amer. Proc.* 93:211-218.
- Goring, C.A.I. 1962b. Control of nitrification of ammonium fertilizers and urea by 2-Chloro-6-(trichloromethyl)-pyridine. *Soil Sci.* 93:431-439.
- Hughes, T.D., and L.F. Welch. 1970. Potassium azide as a nitrification inhibitor. *Agron. J.* 62:595-599.
- Jacques, R.P., J.B. Robinson and F.E. Chase. 1959. Effects of Thiourea, Ethyl Urethane, and some Dithiocarbamate Fungicides on Nitrification in Fox Sandy loam. *Can. J., Soil Sci.* 39:235-243.
- Jansson, S.L. 1963. Balance sheed and residual effects of fertilizer nitrogen in a six year study with N¹⁵. *Soil Sci.* 95:31-37.

- Kapusta, G., and E.C. Varsa. 1972. Nitrification inhibitors-- Do they work? *Down to Earth*, 28(1):21-23.
- Karraker, B.H. and C.E. Bortner. 1937. Nitrogen leaching in soil on the Experimental Station Farm at Lexington. *Soil Sci. Soc. Amer. Proc.* 2:393-396.
- Koike, H. 1961. The Effect of fumigants on nitrate production in soil. *Soil Sci. Soc. Amer. Proc.* 25:204-206.
- Kurtz, L.T., L.D. Owens, and R.D. Hauk. 1961. Influence of moisture on the effectiveness of winter-applied nitrogen fertilizer. *Soil Sci. Soc. Amer. Proc.* 25: 40-43.
- Laboratory Procedures 1976. Compiled by D.D. Scott, D.L. Karlen, G. Raines, B.A. Hall and L.S. Murphy of Agronomy Department, Kansas State University, Manhattan, Kansas.
- Lyon, T.L. and J.A. Bizzell. 1936. Lysimeter experiments IV. Records for tanks 17 to 20 during the years 1922 to 1933 and for tanks 13 to 16 during the years 1913 to 1928. *Cornell University Agric. Exp. Stat. Memoir* 194.
- McCants, C.B., E.O. Skogley, and W.G. Woltz. 1959. Influence of certain soil fumigant treatments on the response of tobacco to ammonium and nitrate form of nitrogen. *Soil Sci. Soc. Amer. Proc.* 23:466-469.
- McKell, C.M., and R.D.B. Whalley. 1964. Compatibility of 2-Chloro-6-(trichloromethyl) pyridine with Medicago sativa L. inoculated with Rhizobium Meliloti. *Agron. J.* 56:26-28.
- Moore III, Frank D. 1973. A nitrogen management tool for leafy vegetables. *Down to Earth*. 28(4):4-7.
- Murphy, L.S., L. Maddux, P.J. Gallagher, B.A. Hall, G. Teneyck, R.A. Lamond, D.D. Scott and J.R. Turkson. 1976. Effects of nitrification inhibition on yield and leaf composition of irrigated corn. *Kansas Agric. Exp. Station Fertilizer Research Report of Progress*. #285:75-59.
- Murphy, L.S., and L.L. Schrader. 1966. Transformation of ammonia in the soil. Publication of Agronomy Workshop held on September 7, 1966. Sponsored by Kansas State University and Agricultural Ammonia Institute.
- Murphy, L.S., D. Whitney, and M. Lundquist. 1971. Evaluation of N carrier and time of application on irrigated corn. *Kansas State Agricultural Exp. Station Report* 183:147.

- Nelson, L.B., and R.E. Uhland. 1955. Factors that influence loss of fall applied fertilizers and their probable importance in different sections of the United States. *Soil Sci. Soc. of America Proc.* 19:492-496.
- Norris, M.G. 1972. A practical approach to better fertilizer nitrogen management. *Down to Earth.* 28(2):5-9.
- Olson, R.A., A.F. Dreier, D. Thompson, and P.H. Grabouski. 1964. Using fertilizer nitrogen effectively on grain crops. *Nebraska Agricultural Exp. Station Research Bull.* SB 479.
- Olson, R.J., R.F. Hensler, O.L. Attoe, S.A. Witzel and L.A. Peterson. 1970. Fertilizer nitrogen and crop rotation in relation to movement of nitrate nitrogen through soil profile. *Soil Sci. Soc. Amer. Proc.* 34:448-452.
- ✓ Owens, L.D. 1960. Nitrogen movement and transformation in soil as evaluated by lysimeter study utilizing isotopic nitrogen. *Soil Sci. Soc. Amer. Proc.* 34:448-452.
- Peterson, L.A., and O.J. Attoe. 1965. Importance of soil nitrate in determination of need and recovery of fertilizer nitrogen. *Agron. J.* 57:572-574.
- Pratt, P.F., W.W. Jones, and V.E. Hunsaker. 1971. Nitrate in deep soil profiles in relation to fertilizer rates and leaching volume. *J. Environ. Quality.* 1:97-102.
- Quastel, J.H., and P.G. Scholefield. 1949. Influence of organic nitrogen compounds of nitrification in soil. *Nature.* 164:1068-1072.
- Redeman, C.T., R.W. Meikle and J.G. Widofsky. 1964. The loss of 2-Chloro-6-(trichloromethyl) pyridine from soil. *J. of Agric. Food Chem.* 12(3):518-521.
- Redeman, C.T., R.T. Martin, J.D. Wien and J.G. Widofsky. 1965. Tracer studies of residues from 2-Chloro-6-(trichloromethyl) pyridine in plant. *J. of Agric. Food Chem.* 13(6):518-521.
- Sabey, B.R. 1968. The influence of nitrification suppressants on the rate of ammonium oxidation in midwestern U.S.A. *Field Soil.* *Soil Sci. Soc. Amer. Proc.* 32:675-679.
- Shattuck, G.E. and M. Alexander. 1963. A differential inhibitor of nitrifying microorganism. *Soil Sci. Soc. Amer. Proc.* 27:600-601.
- ✓ Shaw, K. 1962. Loss of mineral nitrogen from soil. *J. Agric. Sci.* 58:145-151.

- Snedecor, G.W., and W.G. Cochran. 1967. 6th edition. Statistical Methods. Iowa State University Press.
- Stanford, F. 1973. Rational for optimum nitrogen fertilization in corn production. J. Environ. Quality. 2:159-166.
- ✓ Stanford, G. and Epstein, E. 1974. Nitrogen mineralization water relation in soils. Soil Sci. Soc. Amer. Proc. 38:103-107.
- Stark, F.L., J.B. Smith, and F.L. Howard. 1939. Effect of chloropicrin fumigation on nitrification and ammonification in soil. Soil Sci. 48:433-442.
- Starr, J.L., F.E. Broadbent, and D.R. Nielsen. 1974. Nitrogen transformations during continuous leaching. Soil Sci. Soc. Amer. Proc. 38:930-935.
- Stauffer, R.S. 1942. Runoff, percolate and leaching losses from Illinois soils. J. Amer. Soc. Agron. 34:830-835.
- Stephenson, C.K., and C.S. Baldwin. 1969. Effect of time and method of nitrogen application and source of nitrogen on the yield and nitrogen content of corn (Zea mays L.). Agron. Journal. 61:381-384.
- Swezey, A.W., and G.O. Turner. 1962. Crop experiments on the effect of 2-Chloro-6-(trichloromethyl) pyridine for the control of nitrification of ammonium and urea fertilizers. Agron. J. 54:532-535.
- Thomas, G.W. 1970. Soil and climatic factors which affect nutrient mobility in soils: Accumulation and losses. Soil Sci. Soc. America. Madison, Wisconsin. 7-15.
- Thomas, G., and H. Miller. 1971. Effect of time of application of nitrogen on corn yields. Kentucky Agric. Exp. Station Res. Report. Misc. 394.
- ✓ Thomas, G.W., and A.R. Swoboda. 1967. Nitrate and Chloride movement in clay soils. Presented at the A.S.A. Meeting at Washington, D.C.
- Tisdale, S.L., and W.L. Nelson. 1975. Soil Fertility and Fertilizers, 3rd edition. MacMillan Publishing Company, Inc., New York.
- Turner, G.O., L.E. Warren, and F.G. Andriesson. 1962. Effect of 2-Chloro-6-(trichloromethyl) pyridine on the nitrification of ammonium fertilizers in field soil. Soil Sci. 94:270-273.

- Van Bavel, C.H.M. 1956. Agricultural drought in North Carolina. North Carolina Agric. Exp. Sta. Tech. Bull. 122.
- Weigand, C.L. 1962. Drying patterns of a sandy clay loam in relation to optimal depths of seeding. Agron. J. 54:473-476.
- Weir, C.C. 1969. The fate of 2-Amino-4-Chloro-6-methyl pyrimidine (nitrification inhibitor) in soil. Trop. Agriculture, Trin. 46:233-237.
- Wetselaar, R. 1962. Nitrate Distribution in tropical soils III. Downward movement and accumulation of nitrate in the subsoil. Plant Soil. 16:19-31.
- Wild, A. 1972. Nitrate leaching under bare fallow at a site in Northern Nigeria. J. Soil Sci. 23:315-324.
- Whitney, D., L.S. Murphy, V. Peterson. 1971. Effect of time, source and rate of nitrogen application on the yield of corn in Southeast Kansas. Kansas Agric. Exp. Stat. Report of Progress. 183:148.

A P P E N D I X

Table I. DRY WEIGHT (gm/column), PLANT HEIGHT (cm) AND N, P, K UPTAKE (mg/column) OF 21 DAY OLD CORN PLANTS AS AFFECTED BY N-SERVE AND RATE OF N APPLICATION IN THE GREENHOUSE

Treatment	SANDY SOIL									
	Dry weight column cm	Plant height cm	Concentration of nutrient in plant tissue				Nutrient uptake gm/column			
			%N	%P	%K		N	P	K	
Control	2.6	26.0	0.62	0.119	2.90		1.6	0.3		7.5
75 ppm N	2.7	26.3	0.87	0.134	3.03		2.3	0.4		8.2
75 ppm + N-Serve	2.8	28.1	1.00	0.146	3.22		2.8	0.4		9.0
150 ppm N	3.6	29.3	1.21	0.092	2.75		4.0	0.3		10.0
150 ppm + N-Serve	3.8	29.7	1.35	0.141	2.92		5.1	0.5		11.0
75 ppm	2.72	27.3	1.04	0.11	2.89		2.53	0.35		8.49
150 ppm	3.68	29.5	1.18	0.14	3.07		4.65	0.36		10.34
LSD .05 Rate	0.72	1.2	NS	NS	NS		1.06	NS		1.64
Ammonia	3.08	27.8	0.94	0.12	2.83		3.32	0.35		9.00
Ammonia + N-Serve	3.31	29.0	1.28	0.14	3.13		3.85	0.37		9.84
LSD .05 N-Serve	NS	NS	0.31	NS	0.19		NS	NS		NS

Table II. DRY WEIGHT (gm/column), PLANT HEIGHT (cm) AND N, P, L UPTAKE (mg/column) OF 21 DAY OLD CORN PLANTS AS AFFECTED BY N-SERVE AND RATE OF N APPLICATION IN THE GREENHOUSE

SILTY CLAY LOAM SOIL									
Treatment	Dry weight column gm	Plant height cm	Concentration of nutrient in plant tissue				Nutrient uptake gm/column		
			%N	%P	%K		N	P	K
Control	19.7	40.0	0.77	0.223	3.38		15.2	4.4	66.6
75 ppm N	24.3	45.5	0.84	0.213	3.54		20.4	5.2	86.0
75 ppm N + N-Serve	24.7	46.4	0.85	0.195	3.42		21.0	4.8	84.5
150 ppm N	25.9	47.2	1.04	0.197	3.48		26.9	5.1	90.1
150 ppm N + N-Serve	27.2	49.9	1.05	0.198	3.72		28.6	5.1	101.2
75 ppm N	24.2	46.2	0.83	0.19	3.48		20.50	4.98	85.50
150 ppm N	26.5	48.0	1.05	0.20	3.60		27.79	5.00	95.68
LSD .05	2.0	1.8	0.10	NS	NS		4.15	NS	9.19
Ammonia	25.1	46.2	0.93	0.19	3.51		23.78	4.96	88.24
Ammonia + N-Serve	25.6	48.0	0.94	0.20	3.57		24.50	5.03	92.94
LSD .05 N-Serve	NS	NS	NS	NS	NS		NS	NS	NS
Sand	3.20	28.37	0.94	0.13	2.98		3.59	0.36	9.42
Silty Clay Loam	25.36	47.15	1.11	0.20	3.54		24.14	5.00	90.59
LSD .05 Soil Type	1.17	1.03	0.14	0.03	0.11		2.01	0.16	4.69

Table III. CUMMULATIVE AMOUNTS OF $\text{NO}_3^- + \text{NH}_4^+$ IN LEACHATE FROM COLUMNS IN MgM

Treatment	TIME OF SAMPLING (SAND)					
	2nd week	4th week	6th week	8th week	10th week	12th week
Control	8.0	16.5	19.6	19.3	20.4	22.0
75 ppm N	7.8	15.8	16.6	22.2	40.3	66.3
75 ppm N + N-Serve	8.2	12.5	15.0	15.8	24.2	49.4
150 ppm N	7.4	19.1	22.3	25.4	47.3	98.0
150 ppm N + N-Serve	10.4	13.6	13.6	21.0	29.3	85.0

Treatment	TIME OF SAMPLING (SILTY CLAY LOAM)					
	2nd week	4th week	6th week	8th week	10th week	12th week
Control	45.0	69.1	73.0	73.0	73.8	79.5
75 ppm N	52.4	90.2	99.6	101.6	104.5	111.1
75 ppm N + N-Serve	45.1	82.0	93.4	94.3	95.4	100.2
150 ppm N	72.5	102.0	113.2	114.9	120.6	130.1
150 ppm N + N-Serve	47.9	97.0	104.5	105.1	106.0	110.6

Table IV. CONCENTRATION OF NH_4^+ - N AND NO_3^- - N IN SOIL SAMPLES FROM THE GREENHOUSE POT STUDY

Treatment	Time after NH_3 injection					
	1 week		8 weeks		10 weeks	
	NH_4^+	NO_3^-	NH_4^+	NO_3^-	NH_4^+	NO_3^-
Control Sand	3.34	2.23	1.17	3.23	1.03	0.80
150 ppm	30.66	2.23	3.81	69.03	0.80	9.35
150 ppm + N-Serve	35.68	2.23	38.22	36.09	1.83	27.76
Control Silky Clay Loam	3.34	12.26	3.52	23.40	1.35	32.93
150 ppm	432.03	19.51	113.34	146.79	30.11	116.16
150 ppm + N-Serve	490.02	13.38	125.44	99.04	57.98	146.24
					2.93	31.39
					19.95	108.42
					54.25	168.18

EFFECT OF NITRIFICATION INHIBITION ON NITROGEN USE
IN CORN (*Zea mays* L.) AND
GRAIN SORGHUM (*Sorghum bicolor* L.)

by

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A series of experiments was conducted to evaluate the effects of a nitrification inhibitor-(N-Serve) on the yields of irrigated corn and dryland sorghum in different soil types at different locations in Kansas. Nitrogen carriers used included anhydrous ammonia, calcium nitrate, urea, urea ammonium nitrate (UAN), and urea ammonium sulphate (UAS). The rates utilized were 0, 84, 168 and 252 kg/ha for irrigated corn and 0, 45, 90, 134 and 179 kg/ha for dryland sorghum.

These treatments were applied at two different times (fall and spring) in order to determine the most suitable time for N application. The nitrification inhibitor-N-Serve, was applied to treatments at the rate of 230 gm active ingredient per 41 kg of N. Excellent visual differences were evident for nitrogen sources and nitrogen rates. Plots which received ammonia with N-Serve exhibited better growth early in the growing season and were darker green than plots that received other N sources, especially calcium nitrate, without the N-Serve.

Yields of corn and sorghum from the various locations showed that treatments with the nitrification inhibitor tended toward higher yields, although statistically only the Sandy-land location produced significant differences.

Nitrogen concentrations in plant tissue reflected the same trend as the yields. Ammonia plus N-Serve produced higher nitrogen concentrations in leaves than did treatments without N-Serve.

Under greenhouse conditions, the addition of N-Serve to ammonia reduced leaching of N from sand columns. N-Serve had a less pronounced effect on leaching of N from a silty clay loam soil due to higher N content of the soil and reduced percolation losses of N in all treatments.

Results of these investigations showed that on coarse textured soils later application of high N rates which included N-Serve were associated with higher corn and sorghum yields and with greater N uptake.

Further evaluation of the nitrification inhibitor on fine textured soils is needed.