SLOW RELEASE NITROGEN FERTILIZER AND DYNAMICS IN SOIL SYSTEMS. PART I. INCUBATION STUDY

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Abstract

A lab study was conducted at Southern Illinois University soil fertility research facility to investigate the effects of soil type on the nitrogen (N) release dynamics. The objective of this study was to identify the effect of soil type on the release rate of N from slow release nitrogen (SRN) fertilizers under controlled conditions (moisture and temperature). Two contrasting soils from Iowa and Georgia (pH and mineralogy) were combined with 500 mg kg_{-1} of SRN or urea and kept for 90 days under growth incubation conditions. Sequential extractions were performed, and ammonium-N (NH_4+-N) and nitrate-N (NO_3- -N) forms were determined using 2M potassium chloride (KCl). The samples were analyzed using a discrete analyzer (SISTEA Co.) that included a cadmium reduction system for the determination of NO_3-N. The results indicated a dramatic effect of soil type on the release of both NH_4+ and NO_3^- N forms. The largest N transformations occurred within the first 10 days for both types of fertilizers; urea and SRN. This can be explained with SRN because 30-40% of its content is a mixture of urea with ammonium compounds, quick release N fertilizers. The slow release N fertilizer extended the conversion of N forms for over 30 days over commercial urea. The NH_4-N peak release was close to 7 days in urea for both soil types. The NH_4-N release tendency was not dominated for a peak with the SRN; instead there was a two peak tendency for both soils. However, there was a large accumulation (> 200 mg kg-1) of NH_4-N over an extended period of time in the Georgia soil. This large NH_4-N may induce undesirable growth conditions for either sensitive ammonium crops or initial stages of crop development such as germination and seedling. The observation was also present in Iowa soil but to a lesser extent (<50 mg kg-1). The release of NO_3-N showed a slower transformation of SRN vs. urea up to 60 days in both soils. Afterwards, no differences were observed between urea and SRN, indicating a better release than urea of at least 30 days longer under the experimental conditions.

Introduction

Corn is the main consumer of nitrogen (N) in the US, making up about 45% of total consumption. Today, Illinois and Iowa produce close to 40% of the corn in the US. Anything that either Iowa or Illinois does to increase N efficiency in cropping systems will have a large impact on the total N pollution in the US. Most of the excess N applied as fertilizer will accumulate in our streams, waterways, lakes, and other water resources. Nitrogen fertilizers are identified as the main source of nitrate contamination in water resources (Goolsby, et al 1999). These excess levels of N are producing enormous problems within the state of Illinois and beyond (Rouse et al, 1999).

The fate of applied N fertilizer on soils depends upon the soil properties, climatic conditions of the region, type of fertilizer used, and management practice in the field. Among all the variables affecting N pollution, the type of fertilizer used and the management practices are the easiest to address. Traditional quick N release fertilizers have shown very poor environmental performance (Easton and Petrovic, 2004) but a "good" economic return to the corn producer occurs due to the low price of these fertilizers. However, today the reality is different.

Nitrogen prices are on the rise and will most likely continue to increase due to the continuous and steady increase in natural gas prices, the main raw material used for manufacturing N fertilizer. Additionally, environmental concerns and legislation have brought N once again to the public eye. There is limited research focusing on alternative types of N fertilizers that may enhance uptake, such as SRN fertilizers in commercial crop production. Several field researches suggest that such fertilizers might enhance a better N release, and N efficiency usage in high value crops (Guertal, 2000; Guillard and Kopp, 2004). There exists a tremendous need to investigate alternative N fertilizer technologies that are capable of reducing our N surplus.

Complex interactions in the soil-plant system count for losses of N in the environment. All the mechanisms used in the system to reduce the concentration of N when it is not needed by the plant will permit an increase in the N use efficiency (NUE) (Shaviv, 2000). Generally, there is a bi modal pattern of N requirement in most crops, one big demand at planting time, and a second demand when crops are close to the production of reproductive structures. Current fertilizers used in production do not accomplish this plant demand, and re-application has been the management alternative. However, this is not always a viable option, because the unpredictable summer weather may restrict the access to the field. This variable has made this practice very unpopular and almost nonexistent in real crop production. Slow release nitrogen fertilizers, are fertilizers that can be designed to fit the crop N needs. Currently, most of the SRN fertilizers have an advance chemical and engineering component, but most of them lack of the field effectiveness and performance because they have ignored the soil-plant-solution system in their design.

Slow release N fertilizers are fertilizers; primarily urea because of it is the cheapest and most versatile N available source, modified by either chemical or physical engineering processes. The modification can be either physical restriction of dissolution with a polymer coating (Hassan et al 1990), or a reacted product with polymer forms, (Shaviv, 2000) or a combination, absorbents (Purcell Ind., personal communication)

The optimal design and management of SRN fertilizers still requires understanding of the two simultaneous processes involved in the dispersion of the active compound in the soil: (i) the release rate of the compound into the surrounding soil compared to traditional N fertilizers and (ii) its subsequent nitrogen biochemical transformations, and degradation within the soil. Those processes are relatively unique in each type of soil. Research information derived from experimental studies of these processes is not available yet. We intend to address these concerns in our research project. Previous research conducted by Hernandez and collaborators in non published data indicated that basic physical and chemical soil characteristics have an impact on the rate of release of most SRN fertilizers, and might be the key information for manipulating N fertilizer technology that intent to increase NUE.

Approach

Two soils, one from Iowa (Webster series, pH 6.5) and the other from Georgia (Lloyd series, pH 5.4) were collected, air dried, grinded, and sieved (2 mm) and incubated under controlled conditions (temperature 24o C and moisture approximately 30% w/w). The incubation consisted of adding to 40 g of soil an equivalent N content of 500 mg kg-1 soil. The N sources utilized were urea solution and methylene-triazone-urea type (solution) fertilizers. Afterwards, the soil-fertilizer mixture was transferred to an incubator. Sequential extractions of soil nitrate and ammonium release from the soil-fertilizer mixture was collected during a period of soil incubation at a following times: 1, 2, 3, 7, 14, 21, 35, 49, 62, 76, and 92 days from the beginning of the incubation using standard method (2M potassium chloride).

The resulting extracting solutions were analyzed for N forms content (ammonium and nitrate) using a discrete analyzer (Sistea, Co). The experimental design was completely randomized. The mean was analyzed using ANOVA (SAS Ins. 2003) and the means separated using LSD test (p>F, 0.05 or less). The objective of this study was to determine the release rate and N (ammonium/nitrate) forms transformation in two contrasting soils when mixed with slow release nitrogen fertilizer

Results

The results indicate a dramatic effect of soil type on the release of both NH_4 and NO_3-N forms. The largest slope of release rate N-NH_4 forms occurred within the first 10 days for both type of fertilizers, urea and SRN. This result can be explained with SRN because 30-40% of its content is a mixture of commercial urea with ammonium compounds, typical quick release N fertilizers. The NH_4-N peak release was about 7 days in urea for both soil types. In the SRN, the NH_4-N release was not dominated for a peak; instead there were two peaks for both soils Georgia and Iowa. The first peak observed, was similar to that from urea, and a second peak around 41 days of initiation the incubation. However there was a large accumulation (> 200 mg kg-1) of NH_4-N over an extended period of time in the Georgia soil. This large NH_4-N may induce undesirable growth conditions for either sensitive ammonium crops or initial stages of crop development such as germination and seedling. The observation was present in Iowa soil but less intense (<50 mg kg-1). The release of NO_3-N showed a slower transformation of SRN vs. urea up to 60 days in both soils, Iowa and Georgia. Afterwards, no differences were observed between urea and SRN, indicating a better release than urea of at least 30 more days under the experimental conditions.

Commercial urea solution was transformed (hydrolyzed) into NH_4 within the first 7 days in Georgia and Iowa soils (Figs. 1, 3). Afterwards, in urea treatments, 90% of the conversion from N-NH_4+ to N-NO_3- took place the first 21 days of incubation in both soil types (Figs. 2, 4). Finally, no detectable N-NH_4 was found in the system after 33 days of incubation. No appreciable changes on N-NO_3^- production was observed after 41 days of incubation. The results also indicated that the release rate N-NH_4+ and N-NO_3- forms had an extended release over 30 days when SRN was used versus urea. The study found that soil pH and soil type played an important role in the nitrogen transformation of SRN and urea. There was an evident accumulation of ammonium in the Georgia soil during the first 45 days of incubation (Figure 1).

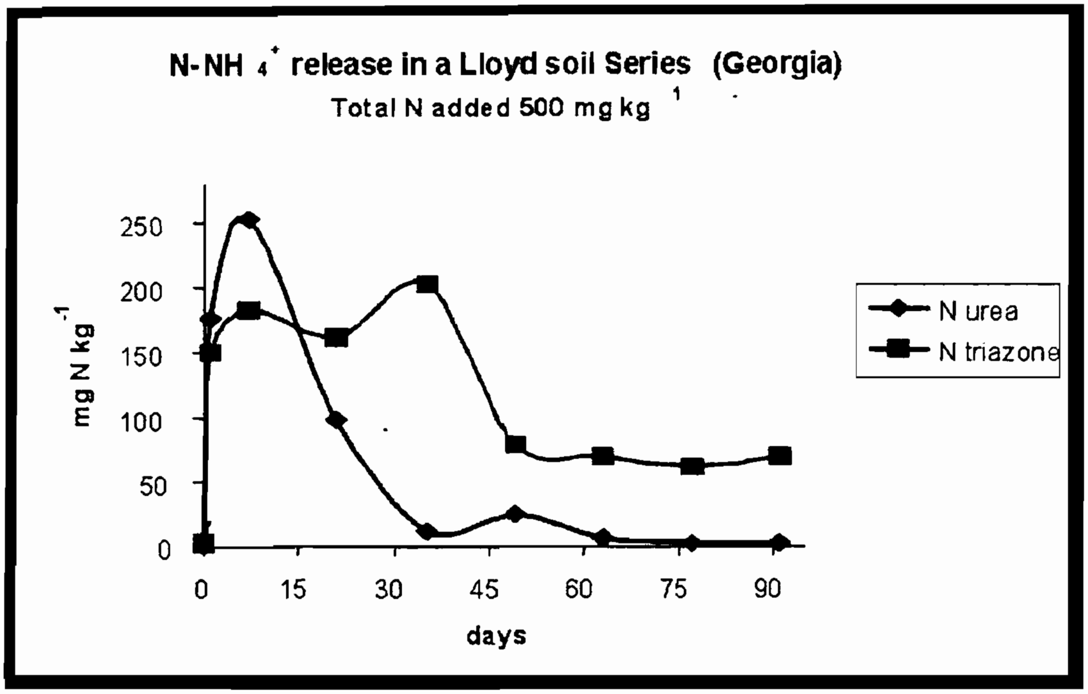

Figure 1. Nitrogen release as ammonium from urea and ure-methylene-triazone type fertilizer in an acid soil from Georgia.

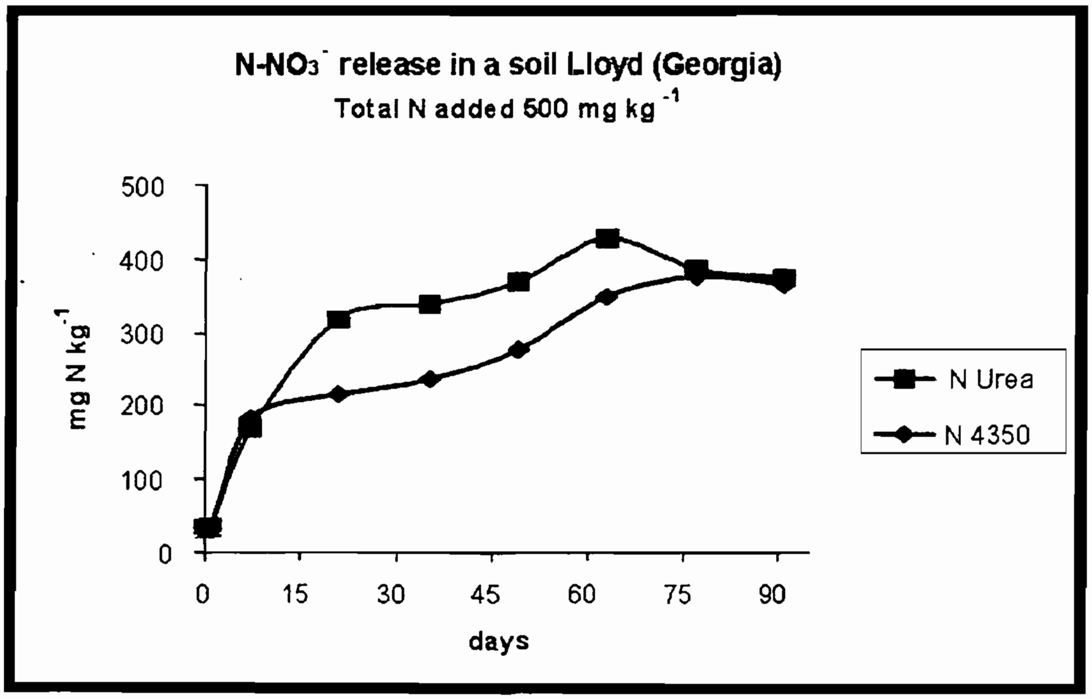

Figure 2. Nitrogen release as nitrate from urea and ure-methylene-triazone type fertilizer in an acid soil from Georgia.

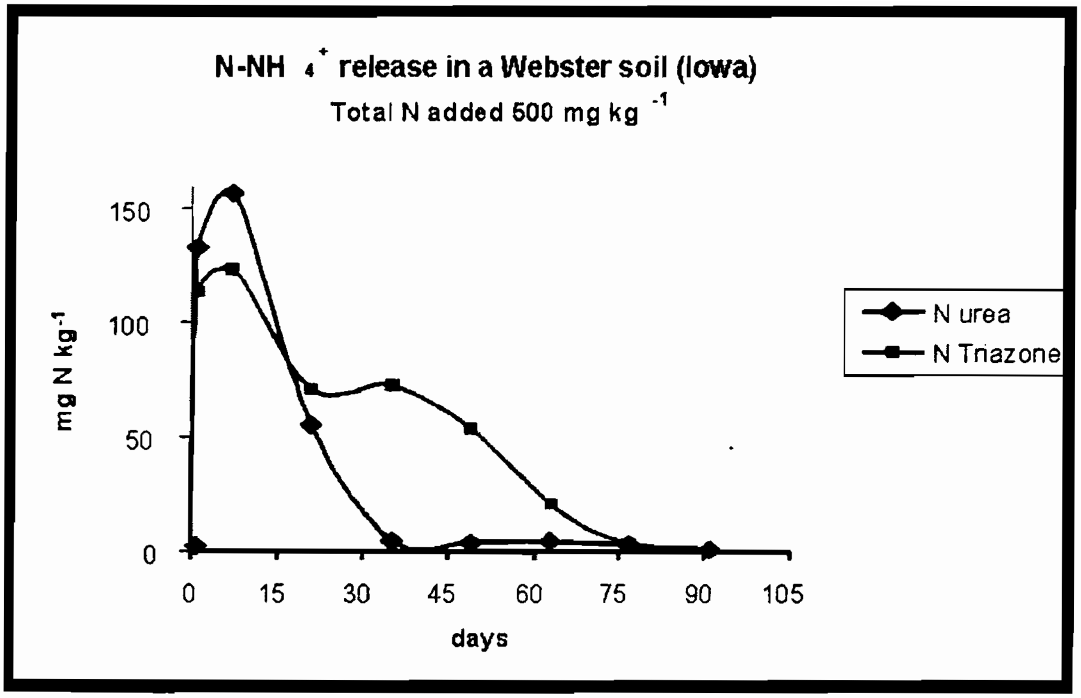

Figure 3. Nitrogen release as ammonium from urea and ure-methylene-triazone type fertilizer in a neutral soil from Iowa.

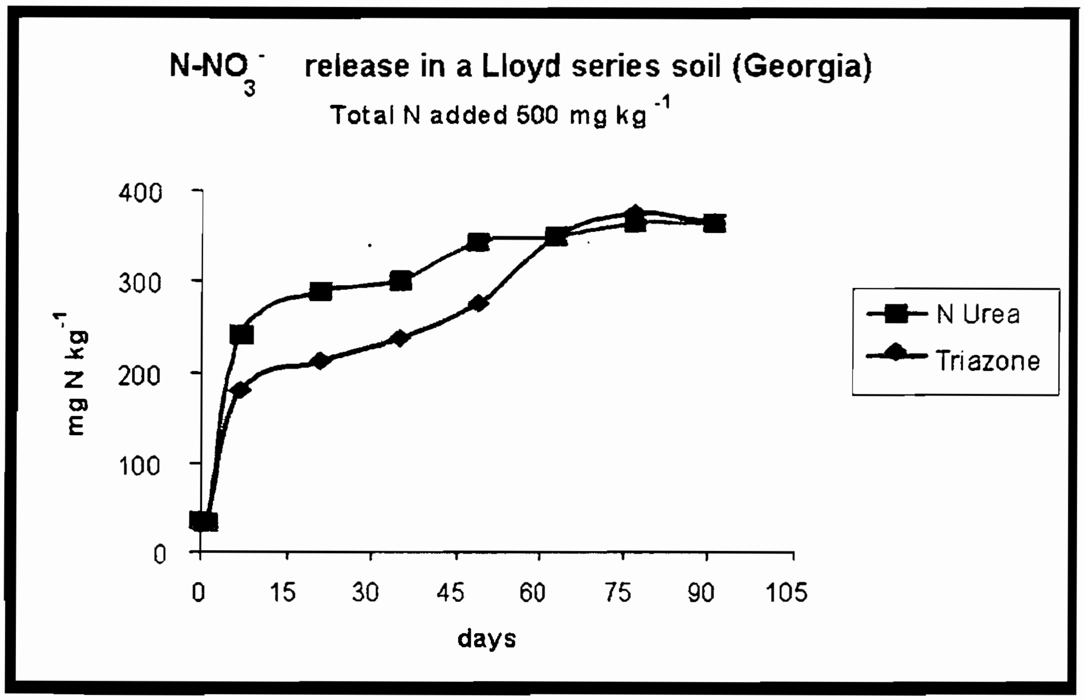

Figure 4. Nitrogen release as nitrate from urea and methylene-triazone-urea type fertilizer in a neutral soil from Iowa.

This suggests potential ammonium toxicity to sensitive crops when SRN are applied under these conditions, particularly at initial crop stages such as germination and seedling. In the Iowa soils such accumulation was observed as well (Figure 3). However, the concentration was under 50 mg kg-1, a condition with less toxicity potential than Georgia soil. This may indicate that in the Iowa soil there was a more efficient transformation of SRN from ammonium to nitrate and no major effects of nitrification were observed. The SRN had a defined and different release patterns than urea had (Figs. 1, 3). The SRN fertilizer presented two $N\text{-}NH_4^+$ release peek profiles in the release rate curve for both soils (Figs. 1, 4). The intensity of the first peek was similar to that presented by urea, and the second peak was observed after 35 days of incubation (Figs. 1, 3). The conversion from $N\text{-}NO_3^-$ to $N\text{-}NH_4^+$ took place in more than 49 days (Figs. 2, 4). No appreciable changers on $N\text{-}NO_3^-$ production was observed after 62 days of incubation in either soil, Georgia or Iowa. This suggests that under our experimental conditions the release rate of SRN was extended almost 30 days longer than regular urea in Iowa and Georgia soils.

Conclusions

The soil type had an effect on the rate of nitrogen transformation over the time with SRN fertilization, without any visible effects on urea. Under Georgia soil conditions, there was an important accumulation of ammonium during the first 30 days. This may indicate that application of this fertilizer under these conditions may produce a toxicity effect on sensitive ammonium crops. It was observed in both soils, Georgia and Iowa that the SRN fertilizer extended the conversion N forms for over 30 days over commercial urea.

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Our cover: To world food security and agricultural production, the Haber-Bosch process has been the most economical means for fixation of nitrogen for fertilizer. Fritz Haber won the Nobel Prize for Chemistry in 1918 and Carl Bosch shared the prize in 1931.