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Factors Affecting Fertilizer N and Soil N Transformations and Plant Recovery

Lynn K. Porter and William O'Deen

PROBLEM: One of the foremost problems confronting agronomists and farmers is the apparent low plant recovery (50 to 60%) of the fertilizer N applied. We need to develop technology that increases N use efficiency, i.e we need to increase plant assimilation and utilization of applied N and thereby lessens the amounts of fertilizer N released into water resources and the environment. One of our major tools for measuring plant recovery of N is isotopic ^{15}N. It is well known that the addition of ^{15}N fertilizer N causes a positive uptake of nontagged or soil N. Why this occurs is not known but several mechanisms have been advanced to explain the phenomenon. The understanding of this phenomenon is important because it affects our interpretation of ^{15}N data and what is really being assimilated by plants, what is being exchanged or interchanged with the biomass and organic matter of the soil, and what effect the fertilizer N has on mineralization and long-term N recovery (residual) by subsequent crops.

Another aspect of increasing the N use efficiency is the volatile losses of ammonia and amines from the foliar portions of the plants, especially after anthesis and during senescence and the loss of denitrification products (N_2, N_2O, and NO) from soils. We must measure the magnitude of these volatile losses and if the losses are serious then soil enviromental factors and plant genetics may need to be explored in order to find a means to limit such losses.

APPROACH: Greenhouse studies have been initiated to study mechanisms involved in the positive uptake of nontagged soil N when soils are fertilized with tagged nitrogen. The approach is to try and feed the ^{15}N salts into the plant so that the fertilizer salt doesn't cause pH, osmotic, exchange or interchange and rhizosphere effects in the soil. We also want to examine what effect soil microorganisms and rhizosphere organisms have on the phenomenon. In order to accomplish the above we have grown corn seedlings on sterile and nonsterile soil and then introduced ammonium sulfate into corn plants through a cotton wick into the corn stem. Also we are initiating a split root study where half of the root can be treated in a sterile sand or sand super-slupper media and the other half of the root is only exposed to soil. These studies are being conducted only on one soil in order to get detailed information on the possible mechanism or mechanisms. We then hope to expand to addtional soils with different nitrogen mineralization potentials to determine the magnitude of this effect in different soils.

In order to study volatile ammonia and amine losses from foliar plant parts, Mr. O'Deen working on his Ph.D. research has designed a special chamber where the aerial parts of winter wheat that has reached anthesis can be isolated from its growth medium. The continous free flow (12 L min^{-1}) open system was designed to attain low ultimate relative humidities of 10 to 20%. Entering air was purified and dried and then surfaces

of 0.1 M HCl were used to trap evolved ammonia and amines both within the chamber and from the air flowing from the chamber. The total ammonia and amines are measured and portions of the solutions perserved in order to look at the various types of amines evolved.

Other investigators (Drs. G. L. Hutchinson and W. Guenzi) in the Soil-Plant Nutrient Research Unit have been measuring the emissions of N_2, N_2O, and NO from both natural and agricultural ecosystems and and Dr. A. R. Mosier, et al. has been measuring N_2 and N_2O in a phytotron system and their research results are briefly mentioned.

In addition to these studies we are trying to improve ^{15}N techniques for the recovery of ammonia for isotope analysis. One of the greatest needs in the Indo-U.S. initiative is to devise a cheap and simple method for the recovery of ammonia from Kjeldahl digests and soil extractant solutions. Hopefully such a method will improve ^{15}N technology and be especially helpful to equipment poor Indian scientists. During the year we have examined two systems. One is an evacuated Erlenmeyer flask and the other is a masonary jar system. The recovery of ammonia by diffusion at 80°C from different ammonium sulfate concentrations was determined and when it was determined that we were obtaining quantitative recovery we explored for cross-contamination. This was accomplished by diffusing one mg ^{15}N-NH_4-N in each flask which was followed by natural abundance NH_4-N to determine if any cross-contamination occured.

RESEARCH FINDINGS - CY 85: The wicking up of tagged ammonium sulfate through cotton treads didn't produce any positive uptake of soil N. However, the introduction of ammonium salts into the stem of the corn plant did produce drastic morphological changes in corn roots compared to plants that hadn't received any ammonium sulfate. Since the corn primordia exist in the stem of the plant we did considerable damage to the plant by running the wick through these tissues. It is possible that the wick technique would work on dicots since their primordia exists in apex meristematic tissue and the cotton threads in dicot tissue probably would not be so injurious to the plant.

Gaseous losses of ammonia and amines from heavily fertilized winter wheat yielded a sensitive double-peaked emission curve over a 90 day period after anthesis, Fig. 1. The 90 day average plant emission was 1.8 mg N m^{-2} day^{-1} representing a crop loss of 1.6 kg N ha^{-1}. The volatile N loss represented 3.1% of the total N contained in the foliar plant parts inside the chamber.

Drs. Hutchinson and Guenzi working with various sites (coniferous forest, shortgrass prairie, deciduous forest, and a cultivated fallow field have observed under well-aerated conditions that soil NO emissions were usually several times larger than soil N_2O emissions. The order of the emissions from the various sites was coniferous forest >> native shortgrass prairie > deciduous forest $\geq$ fallow agricultural field.

Dr. A. Mosier et al. have been attempting to assess the role of growing plants on fertilizer and soil N denitrification utilizing ^{14}C and ^{15}N in a phytotron. They have found that even though significant quantities of

plant C remain in the soil, little of the plant-derived C was utilized for denitrification. Even when nitrate concentrations were maintained at relatively high levels throughout the growth period, N losses were less from planted soils than from unplanted soils until the end of the growth period when root biomass began to decrease and root decay begins to provide energy source to hetertrophic denitrifying organisms.

The percent recovery of ammonia in the two different diffusion systems is given in table 1. Recovery in both systems is excellent. However, both systems showed cross contamination. Starting with a atom % ^{15}N of 9.5 the diffusion systems were contaminated. This was followed with rinsing with either deionized water or 1N HCl rinse and then 1 mg N normal abundance ammonia (.372 atom % ^{15}N) was diffused in the differently rinsed systems. In the vacuum flasks the mean of 4 reps for recovered N was .4305 atom % ^{15}N with HCl rinse and with deionized water was .4175. In the Mason Jars it was .4032 for the HCl rinse and unacceptable in both cases and we are now exploring various rinses that we hope can remove the adsorbed ammonium.

FUTURE PLANS: 1) Greenhouse studies on the effect of tagged N on the positive uptake of soil N will continue. Studies will involve a split root technique to separate the effects of the tagged salt from the soil and sterilized soil. 2) Mr. O'Deen will continue the chemical analyses for a second study that has been completed on volatile ammonia and amines from foliar wheat parts. Qualitative analyses will be completed for types of amines being evolved. 3) Will explore various means (2% HF, alcholic-KOH, 1M acetic acid-ethanol, 1M formic acid-ethanol) to eliminate cross contamination in the diffusion systems.

Publication: O'Deen, W. A. and L. K. Porter. 1986. Continous flow system for collecting volatile ammonia and amines from senescing winter wheat. Agron. J. (In Press).

Also enclosed is a listing of publications and abstracts prepared by the scientists in the Soil-Plant Nutrient Research Unit during 1985 and 1986, even though their research was not funded by AID.

Table 1. Recovery of ammonia by diffusion in an evacuate Erlenmeyer flask and a masonary jar.

µg N as $(NH_4)_2SO_4$ added	% N recovered Erlenmeyer	% N recovered mason jar
200	99.5	-
500	100.4	98.2
1000	106.4	99.0
2000	97.7	102.7
3000	-	101.9
4000	104	-

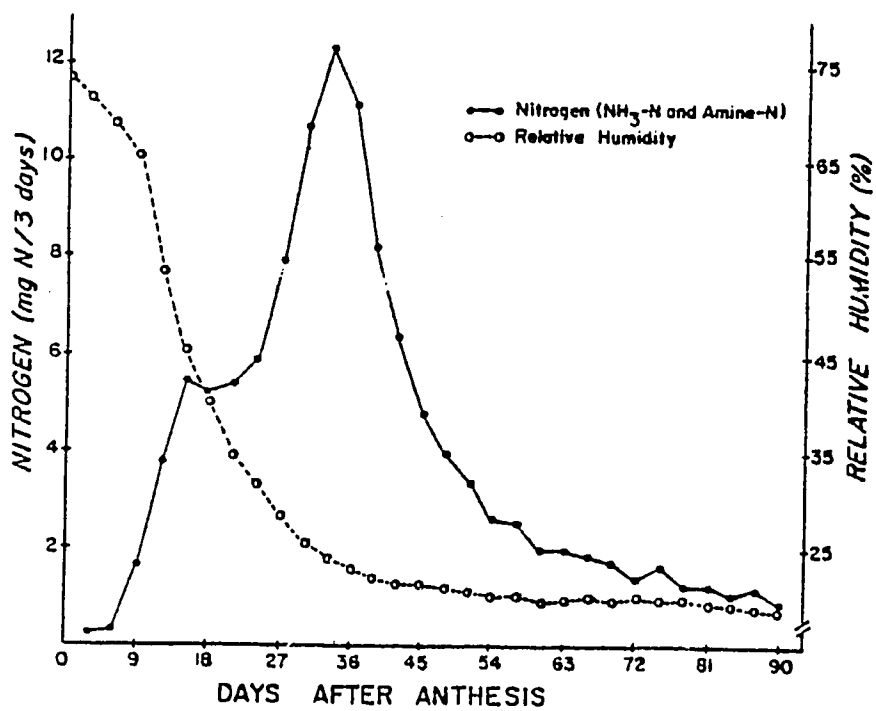

Fig. 1. Volatile N (ammonia and amines) and relative humidity with time following anthesis.

Soil-Plant Nutrient Research

Publications

Haider, K., A. R. Mosier and O. Heinemeyer. 1985. Phytotron experiments to evaluate the effect of growing plants on denitrification. Soil Sci. Soc. Am. J. 49:636-641.

Heinemeyer, O., K. Haider and A. R. Mosier. 1985. Phytotron studies to determine plant utilization, immobilization and losses of fertilizer, soil and crop residues nitrogen. Agron Abstr. p. 157. (Abstract)

Hunter, W. J. 1985. Soybean stem in vivo nitrate reductase activity. Ann. Bot. 55:759-761.

Hunter, W. J. 1985. A high performance gas chromatographic method for the estimation of nodule indole auxins. 10th North Am. Rhizobium Conf. p. 22. (Abstract)

Hunter, W. J. 1985. Influence of the Rhizobium inoculum upon the amount and form of 3-indoleacetic acid present in soybean root nodules. 10th North Am. Rhizobium Conf. p. 40. (Abstract)

Hunter, W. J. and T. J. Poll. 1985. Bradyrhizobium japonicum clones resistant to 5-methyl tryptophan. Abstr. of the Annual Meeting of the Am. Soc. of Microbiology. p. 244. (Abstract)

Mosier, A. R., and O. Heinemeyer. 1985. Current methods used to estimate N_2O and N_2 emissions from field soils. Denitrification in the Nitrogen Cycle. In H. Golterman (ed.), NATO ASI-Series. Plenum Press, London. pp. 79-99.

Mosier, A. R. and W. J. Parton. 1985. Denitrification in a shortgrass prairie: A modeling approach. In Planetary Ecology. D. Caldwell, E. Brierley, J. A. Brierley (eds.). Van Norstrand Reinhold, Inc., Princeton, N. J. pp. 441-460.

Mosier. A. R., F. M. Melhuish, and W. S. Meyer. 1985. Direct measurement of denitrification using acetylene blockage and infrared gas analysis in a root zone lysimeter. In Root Zone Limitations to Crop Production in Clay Soils. W. A. Muirhead (ed.), Australian Soc. of Soil Sci. Inc. pp. 101-115.

Mosier, A. R., K. Haider, and O. Heinemeyer. 1985. Field and phytotron assessment of the effect of crop plants on denitrification 7th Int. Symposium on Environmental Biogeochemistry. p. 67. (Abstract)

Mosier, A. R., W. D. Guenzi, K. Haider, and O. Heinemeyer. 1985. Field studies to assess the effect of actively growing plants on denitrification. Agron Abstr. p. 160. (Abstract)

Norstadt, F. A. and H. R. Duke. 1985. Soil Profiles: Nitrogen conversion and salt motility altered by feedlot manure management. Soil Sci. Soc. Am. J. 49:658-664.

Publications (cont'd)

Norstadt, Fred A. and Harold R. Duke. 1985. Soil Profiles: Nitrogen conversion and salt motility altered by feedlot manure management. Soil Sci. Soc. Am. J. 49:658-664.

Norstadt, F. A. and H. R. Duke. 1985. Feedlot Pollution: It's what's underneath that counts. Crops and Soils 37:17-20

Norstadt, F. A. and H. R. Duke. 1985. How feedlot pollution is checked by stratified soil profiles. pp. 14-17. In Feed Industry. AFMA Daily (Am. Feed Manufacturers Assoc.), May 15.

Norstadt, F. A. and Bryce F. Payne, Jr. 1985. Soil nitrogen is linked to water-stable aggregates. Agrichemical Briefing. 3(11):3-4.

Norstadt, F. A. and Bryce F. Payne, Jr. 1985. Anaerobic microsites in microaggregates: Further qualitative and quantitative data. Agron. Abstracts. p. 160.

Norstadt, F. A. and L. K. Porter. 1985. Earth-surfaced feedlots: Soil conditions needed to reduce pollution. p. 63-71. In CSU Beef Program Report. Animal Sciences, Colorado State University, April.

Parton, W. J. and L. K. Porter. 1985. Nitrogen-cycling models. In Proceedings of the Natural Resource Modeling Symposium. D. G. DeCoursey (ed.). pp. 192-196. USDA Pub. ARS-30.

Payne, B. F., Jr. and F. A. Norstadt. 1985. Anaerobic microsites and water-stable soil aggregates: A conceptual model of their development in well-drained soils. Agron. Abstr. p. 160. (Abstract)

Westermann, D. T., L. K. Porter, and W. A. O'Deen. 1985. Nitrogen partitioning and mobilization patterns in bean plants. Crop Sci. 25:225-229.

Soil-Plant Nutrient Research

1986 Manuscripts and Abstracts Pending

Haider, K, A. R. Mosier, and O. Heinemeyer. Phytotron experiments to evaluate the effect of growing plants on denitrification. II. High nitrate concentrations. (In Peer Review to be submitted to SSSAJ)

Hunter, W. J. A high performance gas chromatographic method for the estimation of indole-3-acetic acid content of plant materials. (Submitted to J. Chromatogr.)

Mosier, A. R., W. D. Guenzi, and E. E. Schweizer. Soil losses of N_2 and N_2O from irrigated crops in Northeastern Colorado. Soil Sci. Soc. Am. J. (In Press)

Hunter, W. J. Free and conjugated IAA content of legume root nodules. Suppl. Plant Physiol. (In Press)

Hutchinson, G. L. and W. D. Guenzi. Biogenic production and loss of nitric and nitrous oxides from aerobic soils. Eighth Rocky Mtn. Meeting of Am. Chem. Soc. June 8-12, Denver, CO. (Abstract) (In Press)

Hutchinson. G. L., W. D. Guenzi, and A. C. Tortoso. Nitric oxide emissions from natural and agricultural ecosystems. Second Int. Symp. Biosphere-Atmosphere Exchange. Mar. 16-21, Mainz, FRG. (Abstract) (In Press)

Hutchinson, G. L., W. D. Guenzi, and A. C. Tortoso. Nitric oxide emissions from natural and agricultural ecosystems. Atmos. Environ. 9:0000-0000. (In Press)

Meyer, W. S., H. D. Barrs, A. R. Mosier, and N. L. Schafer. Response of maize to three short-term periods of waterlogging at high and low nitrogen levels on two soil types. (In Peer Review to be submitted to Irrigation Science)

Mosier, A. R., W. D. Guenzi, and E. E. Schweizer. Field denitrification estimation by ^{15}N and acetylene inhibition techniques. Soil Sci. Soc. Am. J. (In Press)

Mosier, A. R., W. D. Guenzi, and E. E. Schweizer. Soil losses of N_2 and N_2O from irrigated crops in Northeastern Colorado. Soil Sci. Soc. Am. J. (In Press)

Mosier, A. R., K. Haider, and O. Heinemeyer. Phytotron and field assessment of the effect of actively growing crops on soil nitrogen transformations. Int. Soc. Soil Sci., Hamburg, W. Germany, Aug. 13-20, (Abstract) (In Press)

Mosier, A. R., K. Haider, and O. Heinemeyer. Field and phytotron assessment of the effect of crop plants on denitrification. Proceedings of the Seventh International Symposium on Environmental Biogeochemistry. (In Journal Review).

1986 Manuscripts and Abstracts Pending (cont'd)

Mosier, A. R., W. S. Meyer, and F. M. Melhuish. Effect of irrigation method on the recovery of ^{15}N fertilizer in a slowly permeable clay soil cropped with maize. Aust. J. Soil Research. (In Press)

Norstadt, Fred A. and Harold R. Duke. Feedlot Pollution: What's on Top and Beneath Counts. In CSU Beef Program Report. Animal Sciences, Colorado State University, Special Series. (In Review)

O'Deen, W. A. and L. K. Porter. Continous flow system for collecting volatile ammonia and amines from senescing winter wheat. Agron. J. (In Press).

O'Deen, W. A. and L. K. Porter. Gravimetric Kjeldahl methodology and a continuous flow system for collecting volatile ammonia and amines from senescing winter wheat. (Abstract submitted to Pacific Div. AAAS and WSSS)

Parton, W. J., A. R. Mosier, and D. S. Schimel. Nitrous oxide production by nitrification and denitrification in a shortgrass stepe. (In Peer Review to be submitted to Biogeochemistry)

Schimel, D. S., S. Simkins, T. Rosswall, A. R. Mosier, and W. J. Parton. Scale and the measurement of N gas fluxes from terrestrial ecosystems. (In Peer Review prepared for Proceedings of the SCOPE Symposium on Temporal and Spatial Variability)