Gaseous ammonia losses following nitrogen fertilization

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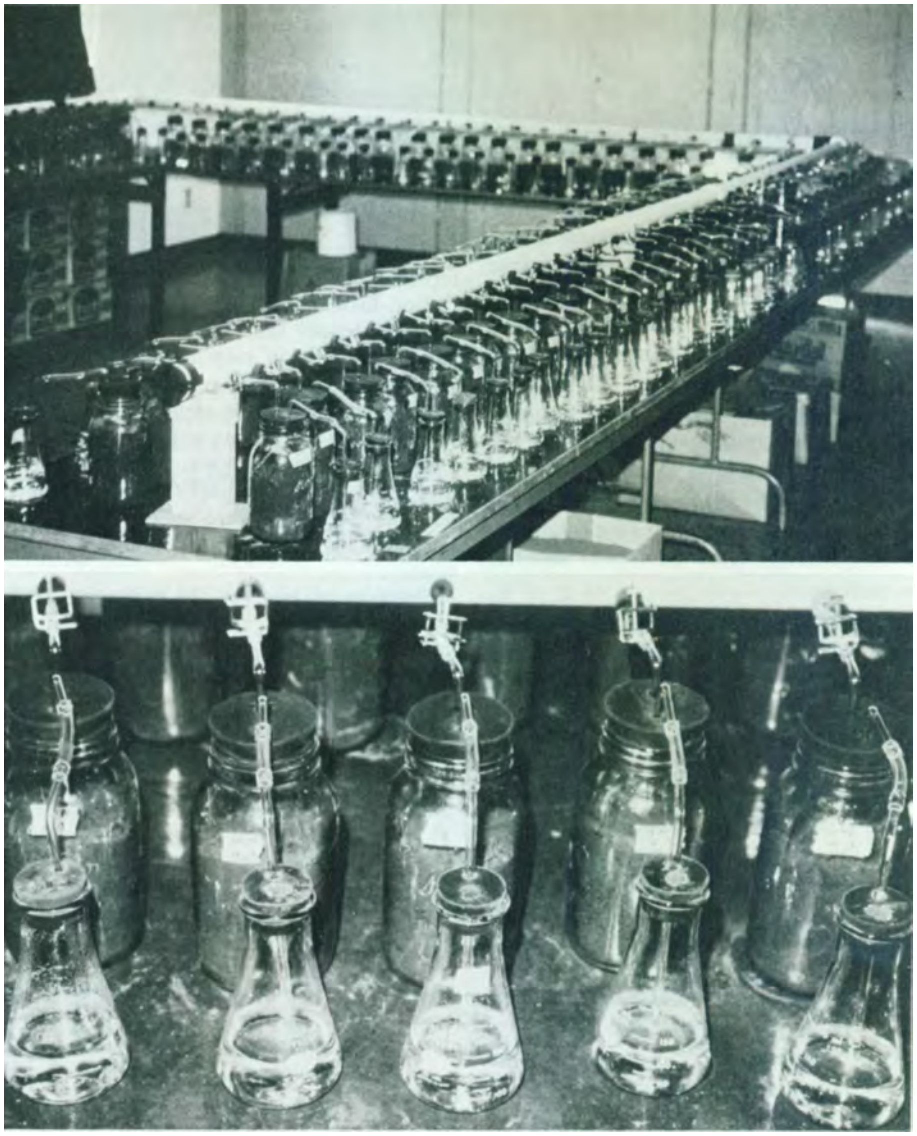

Above: Experiment set-up — 25 soils with several variables of nitrate and placement. Below: Quart jars with soil; flasks containing sulfuric acid to catch the ammonia gas coming over the jars.

Fertilizer nitrogen can be lost when gaseous ammonia volatilizes following surface application of fertilizer. Application efficiency is maximized when the applied nitrogen goes directly to the plant or remains available in the local soil environment. Ammonia volatilization is one mechanism that can significantly reduce application efficiency.

Our primary objective was to measure the amount of nitrogen lost as ammonia gas following application of urea fertilizer. A series of laboratory experiments was conducted to measure loss and to evaluate conditions resulting in volatilization losses of ammonia. Soil characteristics, soil moisture, humidity, wet-dry soil cycles, fertilizer placement, and several rates of application were considered in an attempt to clarify mechanisms involved in volatilization losses of applied nitrogen. (Characteristics of soils used in experiments are shown in the table.)

Humidity and soil moisture

In the summer of 1976 an experiment was conducted in Stanislaus County to assess nitrogen loss by ammonia volatilization. It consisted of a laboratory comparison of three fertilizer rates (0, 100, 200 pounds N/acre as urea) and three placements (surface, incorporated in the top inch, and placed 2 to 3 inches deep). Soils were placed in quart jars and held at a moisture level between field capacity and saturation level. Air that was high in relative humidity was passed over the soils for six days. Volatilized ammonia was flushed from the jars by the air stream and was captured from the air as it passed through a sulfuric acid trap.

With surface placement of fertilizer at the highest rate, no more than 5 percent of the applied nitrogen was lost as volatilized ammonia (see table). These data indicate that with high relative humidity and high soil-moisture levels, volatilization losses are minimal.

Work conducted at the University of California, Davis, aided in clarifying humidity and soil-moisture findings. On a Dinuba sandy loam soil, ammonia volatilization loss from soil at field capacity (⅓ bar) was compared with loss from saturated soil—with both low relative-humidity air and high relative-humidity air flowing over the soils.

Results from experiments at Davis support the earlier findings in Stanislaus County: high relative-humidity air flowing over saturated soil results in less than 5 percent loss of applied nitrogen (fig. 1).

When Dinuba sandy loam soil was held at field capacity with low relative-humidity air flowing over the soil surface, losses approached 8 percent of the applied nitrogen. Soil held at field capacity with a high relative-humidity air flow resulted in intermediate losses of nitrogen (fig. 1). Most ammonia volatilization loss from the Dinuba sandy loam soil occurred within 10 days following the application of urea fertilizer.

Soil Characteristics

Soil	pH	ECe (milli mhos/cm)	% Sand	% Silt	% Clay	Ca + Mg (me/l)	Na (me/l)	N loss, percent of applied N*
Dinuba sandy loam	6.35	1.12	73.6	18.4	8.0	8.6	2.6	2.04
Foster sandy loam	7.55	1.92	60.6	29.4	10.0	16.8	2.4	2.00
Hanford loamy sand	6.30	0.61	80.6	15.4	4.0	4.2	1.9	4.06

*200 lbs. N/acre applied to the soil surface as pelletized urea.

Fertilizer rate and placement

An additional experiment comparing the effects of various fertilizer rates and placements was conducted using a Foster sandy loam soil. Nitrogen losses from the surface and 1½-inch-deep urea applications were measured as volatilized ammonia and compared at rates of 100, 200, and 300 pounds of actual nitrogen per acre. Soils were moistened to field capacity (⅓ bar) and a low relative-humidity air flow was used. Throughout the course of this experiment the low-humidity air flow was drying the soils. Remoistening was done periodically to restore the soils to field capacity moisture level.

Experiments on the Foster sandy loam soil compared volatilization losses for surface versus 1½-inch-deep urea applications. At the highest application rate, fertilizer placement 1½ inches deep resulted in a 23-fold decrease in the percentage of nitrogen lost when compared with surface application (fig. 2). When fertilizer was placed at the lower application rates (100 and 200 pounds N), the 1½-inch-deep placement resulted in an even greater reduction in percent of nitrogen lost. After urea is applied to the soil surface it absorbs water, hydrolizes to ammonium carbonate, and ammonia is free to volatilize into the atmosphere. When fertilizer is incorporated, ammonia is contained by the soil, captured in the soil solution, and can be bound to soil colloids as ammonium ions before loss to the atmosphere can occur.

Fertilization rate influences the amount of ammonia loss: greater loss with increased fertilization can be anticipated. In addition, as fertilization rate increases the actual percentage of nitrogen lost also increases. When fertilization was increased from 200 to 300 pounds N/acre, the percentage of applied nitrogen lost nearly doubled from 19 percent to 36 percent (fig. 2). This increase may be the result of higher ammonia concentration: soil is unable to adsorb and hold high concentrations of ammonia as efficiently as it does lower concentrations.

Wet-dry soil cycles

Wet-dry soil cycles proved to be most interesting with respect to ammonia volatilization losses. Foster sandy loam soil and Hanford loamy sand were used to investigate different soil responses to rewetting and resulting loss. Apparatus and procedures were the same as used in previous experiments. Urea was surface-applied to soils at field capacity with a low relative-humidity air stream passing over the soil surface. Both soils were remoistened at 18 and 33 days following the application of urea.

Patterns of loss for the two soils were quite different, largely because of differing soil characteristics (see table).

Most of the volatilization loss sustained by Foster sandy loam soil occurred within one week of fertilizer application. Rewetting the soil at 18 and 33 days had little or no effect on loss (fig. 3). Foster sandy loam is a slightly alkaline calcareous soil. The high pH and Ca + Mg levels result in more ammonia driven off initially. Ammonia remaining after the initial period of loss was bound in the soil and unavailable for further loss following rewetting.

Hanford loamy sand soil sustained two main periods of loss, the second occurring immediately following rewetting. A third minor peak of loss occurred following the second rewetting (fig. 3). Hanford loamy sand, with its low pH and low Ca + Mg levels, is an acidic soil with low exchange capacity. Ammonia remained in the soil solution longer with less ammonia bound to soil colloids. This, in addition to lower initial loss, resulted in further losses following remoistening of the Hanford loamy sand soil.

Conclusions

Research by other workers has shown that alkaline or sandy soils generally have a significant potential for nitrogen loss through ammonia volatilization. Our data from experiments with Foster sandy loam and Hanford loamy sand indicate that under low humidity and wet-dry soil-moisture cycling substantial nitrogen losses do occur from these sandy soils. However, under high humidity and high soil-moisture conditions, surface-applied nitrogen losses may be less than 5 percent.

More efficient application of fertilizer nitrogen can be achieved provided good management practices are followed. On alkaline or sandy soils, nitrogen loss will be minimized if fertilizer is incorporated rather than left on the soil surface. Incorporation can be accomplished by shanking the fertilizer or by discing following application.

Application rate data (shown in fig. 2) illustrate that rate or concentration of fertilizer will affect the percentage of nitrogen loss. When fertilizer is left on the soil surface, a larger percentage of fertilizer loss may occur if fertilizer is concentrated in bands rather than evenly distributed over the entire soil surface.

Very sandy soils may experience ammonia volatilization losses of nitrogen even after a surface-applied fertilizer has been watered in. (This is illustrated in fig. 3 with data from experiments on Hanford loamy sand soil.) To effectively minimize nitrogen losses from high-pH sandy soils it is best to incorporate the fertilizer.

Additional research

Investigations are continuing at the Land, Air and Water Resources Department, University of California, Davis, to determine the effects of typical fall weather conditions on ammonia volatilization losses from surface-applied fertilizers. A field study evaluating fertilizer loss and timing effects on nitrogen response in fruit trees is being conducted in a Stanislaus County peach orchard.

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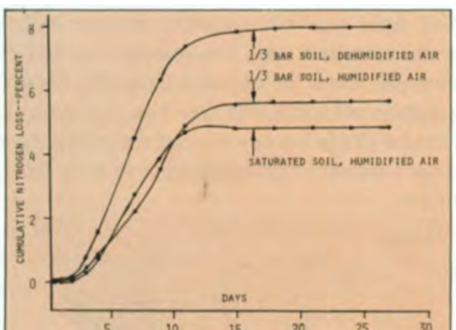

Fig. 1. Ammonia volatilization loss from a Dinuba sandy loam shown as a percent of 200 pounds N/acre from surface applied urea. Humidity and soil moisture effects.

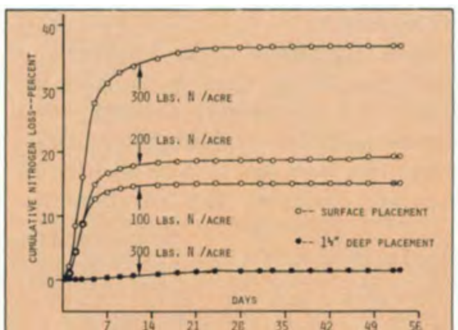

Fig. 2. Ammonia volatilization loss from a Foster sandy loam shown as a percent of nitrogen applied. Urea application rate and placement effects.

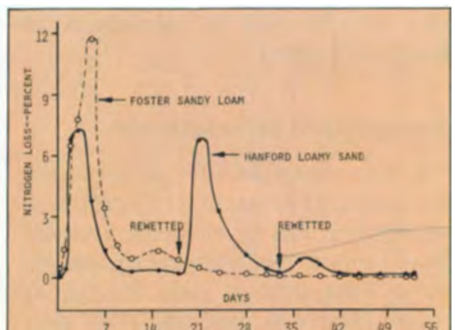

Fig. 3. Ammonia volatilization loss shown as a percent of 300 pounds N/acre applied to the soil surface as urea. Soil effects on loss pattern.