FIELD ESTIMATION OF AMMONIA VOLATILIZATION FROM SURFACE-APPLIED UREA

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Accurate estimation of the potential for NH_3 volatilization from urea-based fertilizers is an important step in optimizing N use efficiency from these fertilizers. Published estimates of NH_3 volatilization from surface-applied urea vary widely. Citations listing losses from 2% on up to 80% from various systems can be found. Consequently, many growers, to protect themselves, will apply urea at higher than recommended rates, assuming some arbitrary level of loss will occur. The objectives of the research reported here were to examine the magnitude of NH_3 loss from both bare soil and high residue conditions in Kansas, and to compare two methods of estimating NH_3 loss in the field.

One experiment was conducted in the summer of 1983, in which 120 kg N ha^{-1} was applied as a 20% N urea solution to a bare, fine sandy loam soil. Two experiments were conducted in the fall of 1983 in which 200 kg N ha^{-1} as 28% N UAN solution was applied to a silt loam soil covered with 8.7 Mg ha^{-1} wheat straw residue. In all three experiments, two methods of estimating NH_3 loss in the field were compared; a micrometeorological method and a microplot method. The micrometeorological method involved the measurement of atmospheric NH_3 concentration and horizontal wind speed at several heights above a circular fertilized field. Advantages of this method include the lack of influence of the measuring system on the field environment and sensitivity to climatic variables, such as windspeed. The microplot method involved the use of steel cylinders pushed into the soil to which fertilizer was applied at the same rate as the field in general. A lid was periodically closed over the microplot and air was drawn over the plots into an acidic trap. Advantages of the microplot method include the small area needed, ability to compare loss from several treatments, and the ability to replicate treatments.

Results from the first field study are given in Fig. 1. Fertilizer was applied to the soil soon after a rain, so the soil was initially quite moist. Due to the high evaporative demand at this time of the year (July), the soil dried rapidly. Very little NH_3 loss was measured by either method until after the first irrigation. At that time, a small amount of water (5 mm) was applied to stimulate urea hydrolysis. Following the first irrigation, the amount of urea present in the soil declined rapidly as hydrolysis occurred, accompanied by an increase in the amount of NH_3 loss detected by the micrometeorological method. Loss measured by the microplot method was much less, showing a slow, steady rate of loss essentially unaffected by irrigation. It is likely that the method of irrigation for the microplots, using a syringe to apply water at the same rate as the field but in a shorter time period, may have leached the urea deep enough into the soil to reduce NH_3 loss. Total loss measured by the micrometeorlogical method approached 20 kg N ha^{-1}, while loss measured by the microplot method was 7 kg N ha^{-1}.

Results from the second and third field studies are given in Figures 2 and 3. In both studies, 28% N UAN solution was applied to wheat stubble over soil which had a water content near field capacity. Throughout the duration of both experiments, the soil underneath the straw remained quite moist, while the water content of the straw fluctuated. Periodic sampling to determine the rate of urea hydrolysis and the location of fertilizer N indicated that most of the fertilizer remained on the straw until rain or irrigation washed the fertilizer into the soil or stimulated urea hydrolysis. In the second study (Fig. 2), most of the NH_3 volatilizing soon after application was considered to be from either free NH_3 in the solution or from the ammoniacal fraction of the fertilizer. Little urea hydrolysis had occurred three days after application. Following a light irrigation (2.5 mm), rapid evolution of NH_3 was detected by both methods. This level of NH_3 loss was sustained for only a short period, as 33 mm rain fell the next morning.

Similar results were found in Study 3 (Fig. 3) in which the field was irrigated lightly almost from the start in an attempt to sustain high rates of urea hydrolysis and NH_3 loss. Both methods showed a peak of NH_3 loss following irrigation, followed by a decline in loss rates as the straw water content declined the next day. In both the second and third studies, the pattern of NH_3 loss detected by both methods were similar, but the levels of loss measured by the microplot method were generally several times less than the loss levels measured by the micrometeorological method. The most likely source of error for the microplot method was the protrusion of the microplot cylinder above the soil surface (~ 2 cm), and the manner in which air was drawn over the microplot. The air was pulled in through ports at the top of the lid, which may have allowed a laminar airflow to develop inside the lid, with a layer of air in the residue which was relatively static. This condition would allow only a portion of the NH_3, that which diffused into the flowing air, to be measured.

Total NH_3 loss measured by the microplot method during the period of measurement was approximately 2 kg N ha^{-1} in both Studies 2 and 3, while the micrometeorological method measured losses of 15 kg N ha^{-1} in Study 2 and 33 kg N ha^{-1} in Study 3.

In order to more clearly understand the interactions among soil moisture, urea hydrolysis, water evaporation and NH_3 loss, a lab experiment was conducted in which urea was applied to the surface of a moist, sandy loam soil in acrylic chambers at a rate equivalent to 200 kg N ha^{-1}. Static traps were placed in the chambers to sorb NH_3 and CO_2. After 48 h, the traps were removed and humid or relatively dry air was passed over the soil in the chambers for the following 24 h. Concentrations of NH_3 in the airstream leaving the chambers was monitored during this period. At 48 and 72 h, soil in selected chambers was sampled in 2 mm increments and analyzed for pH, urea-N, NH_4-N and NO_3-N.

The flow of moist air (92% RH) over the soil surface limited soil drying during the period from 48 to 72 h, while the relatively dry air (42% RH) caused substantial drying to occur (Fig. 4). Rapid drying of the soil was found to rapidly decrease the rate of NH_3 loss from the soil

(Fig. 5). Drying of the soil also reduced the amount of urea that hydrolyzed during the period from 48 to 72 h to practically zero. As soil drying and upward soil water flow occurred, urea was transported back to the soil surface after initially diffusing into the soil (Fig. 6). As long as the soil at the surface remained dry enough to inhibit urea hydrolysis, the urea present at the surface was not susceptible to N loss by volatilization. This condition would remain until the soil surface water content increased to levels adequate to support hydrolysis.

Practical implications from these field and lab experiments are that urea or urea-containing fertilizers broadcast on dry soil or dry residue are not likely to lose significant quantities of N by NH_3 volatilization. Even if the soil is initially moist, the potential for NH_3 volatilization may be limited if rapid drying occurs to the point that urea hydrolysis is inhibited.

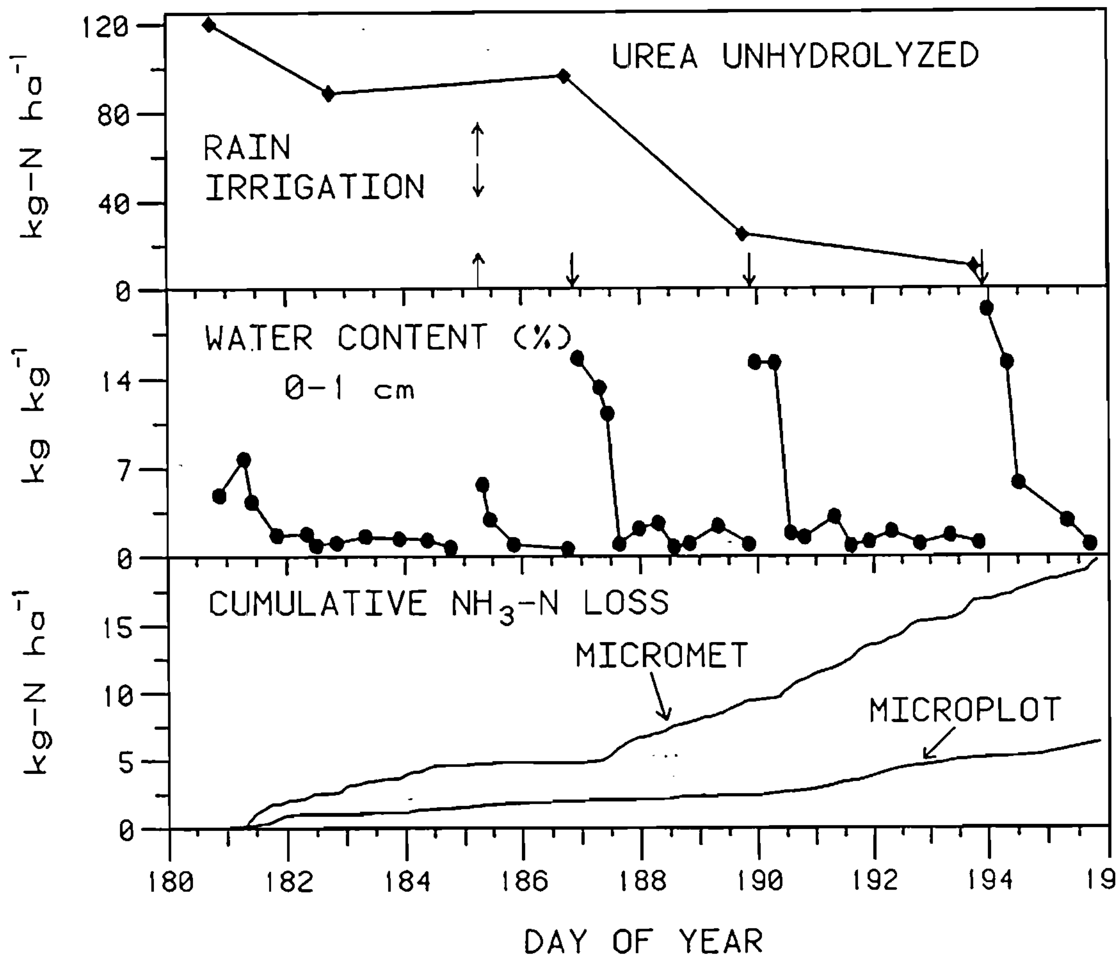

Figure 1. Urea hydrolysis, soil surface water content and cumulative NH_3-N loss, Study 1.

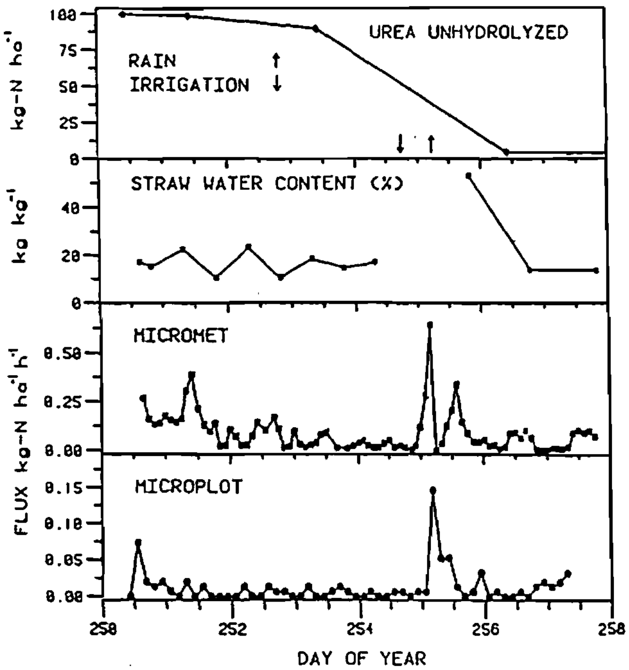

Figure 2. Urea hydrolysis, straw water content and NH_3-N flux, Study 2.

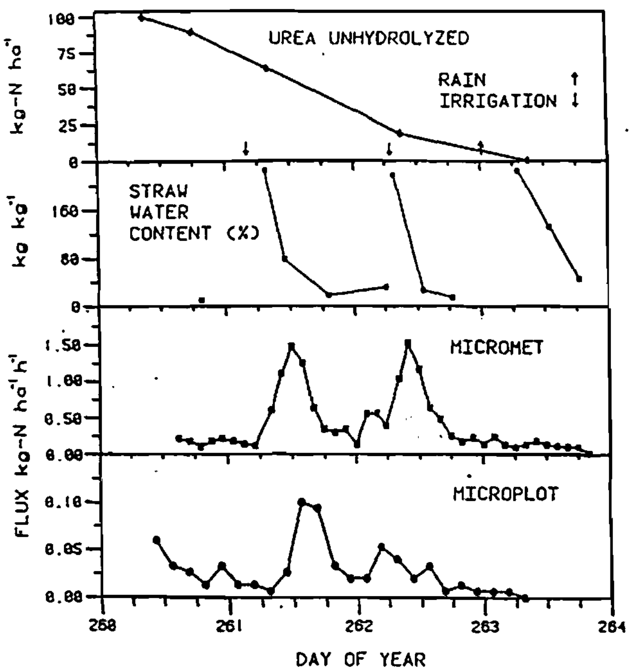

Figure 3. Urea hydrolysis, straw water content, and NH_3-N flux, Study 3.

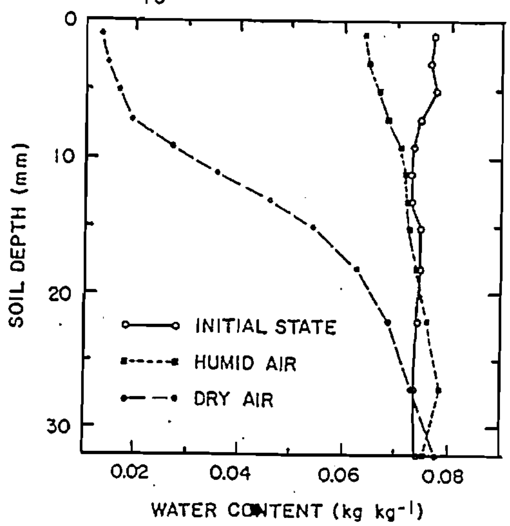

Figure 4. Soil water content with depth, Lab study.

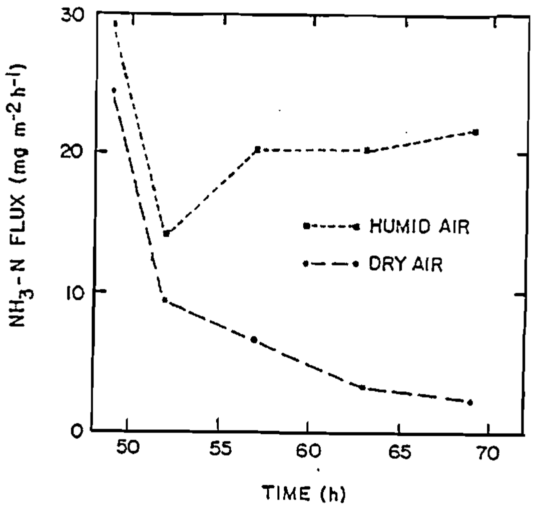

Figure 5. Ammonia flux with time following airflow initiation, Lab study.

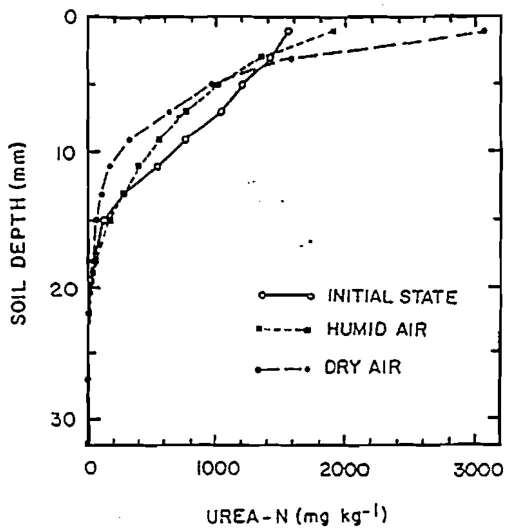

Figure 6. Soil urea-N concentration with depth, Lab study.

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