Dec 2nd, 12:00 AM

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H. Mark Hanna
*Iowa State University*, hmhanna@iastate.edu

Paul M. Boyd
*U.S. Army Corps of Engineers*

James L. Baker
*Iowa State University*

Thomas S. Colvin
*Iowa State University*

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FERTILIZER APPLICATION: NH₃ OPENER LOSSES AND UNIFORMITY ISSUES

H. Mark Hanna
Extension Ag Engineer
Agricultural and Biosystems Engineering Department

Paul M. Boyd
Hydraulic Engineer
U.S. Army Corps of Engineers, Omaha District Office

James L. Baker
Professor Emeritus
Agricultural and Biosystems Engineering Department

Thomas S. Colvin
Agricultural Engineer
USDA Agricultural Research Service, National Soil Tilth Laboratory

Abstract
Anhydrous ammonia (NH₃) is injected below the soil surface during application to limit loss to the atmosphere. Application at a shallower depth may reduce tractor horsepower or allow greater speed which could increase field capacity of equipment if NH₃ losses are held to acceptable levels. Losses of NH₃ during, and for one hour after, field application were measured from a typical knife injector treatment operated at a 15-cm (6-in.) depth and 8 km/h (5 mi/h) travel speed and from a single-disc injector operated at shallower depths (5 and 10 cm (2 and 4 in.)) and a range of travel speeds (8, 12, and 16 km/h (5, 7.5, and 10 mi/h)).

NH₃ losses during application as measured with a hood over the single-disc injector were 3 to 7% in clay loam, silty clay loam, and loam soils and 21 to 52% in a coarser-textured fine sandy loam soil. Applying with a knife injector at deeper depth resulted in losses of 1 to 2% across all soil types. NH₃ losses measured during an hour after application with stationary collection over the injection trench were 1% or less for all treatments. Losses during application were 5 to 55 times greater than during the first hour after application.

Introduction
Nitrogen (N) losses during anhydrous ammonia (NH₃) application have detrimental environmental effects to the atmosphere and are a lost input for the crop producer. Several researchers have reported effects of application depth, soil moisture content, and soil texture on NH₃ losses. Many of these studies were conducted in the laboratory rather than the field. Stanley and Smith (1956) recommended NH₃ should be applied at a depth of 10 cm (4 in.) and 20 cm (8 in.) for heavy- and light-textured soils, respectively. They found small losses at gravimetric soil moisture contents of 15 - 18% on a silt loam soil. Losses increased with drier or wetter soil. Contrary to popular belief, Jackson and Change (1947) found application depth and
soil moisture to be of minor importance in NH₃ losses. In a later study, Stanley and Smith (1958) reported NH₃ losses increased as application depth decreased from 10 cm (4 in.). Significant losses occurred despite the absence of visible white vapors. Baker et al. (1959) found negligible NH₃ losses when application was at a depth of 10 cm (4 in.) or greater and moisture content was optimum. Fenn and Kissel (1976) reported NH₃ losses from a calcareous soil increased as application depth decreased, with substantial losses (20%) at 7.5 cm (3 in.) application depth on a silty clay loam soil. Blue and Eno (1952, 1954) observed NH₃ losses as high as 75% from a coastal plain sandy soil in a laboratory study. Stanley and Smith (1956) found losses from an air-dried sandy soil to be greater than losses from silt loam or clay soils. Abo-Abda (1985) measured NH₃ losses during field application with a knife and a point injector fertilizer applicator (PIFA). Percentage NH₃ losses increased with decreasing depth and application rate, but were unaffected by speed from 4.8 to 8.0 km/h (3.0 to 5.0 mi/h).

Although speed effects on NH₃ loss at speeds below 8 km/h (5 mi/h) may be small, to pull injection knives at faster speeds (e.g. greater than 9.6 km/h (6 mi/h)) and depths of 15 to 20 cm (6 to 8 in.) commonly used to avoid losses requires significant tractor horsepower. If NH₃ could be applied at a more shallow depth and at field speeds of 12 to 16 km/h (7.5 to 10 mi/h) without adverse consequences, equipment operators could more rapidly apply NH₃ without significantly increasing tractor horsepower requirements. Newer tractor features such as auto-steering and improved suspension systems suggest future field speeds may increase.

An experiment was conducted to determine NH₃ loss from the soil to the atmosphere for applications made with a prototype single-disc fertilizer injector operated at shallow depths and equal or faster speeds compared with loss from a conventional knife injector.

Materials and Methods

Treatments

Seven fertilizer injector treatments included six treatments with a single-disc fertilizer injector and one treatment with a conventional knife injector. The single-disc injector was operated at three application speeds, (8, 12, and 16 km/h (5, 7.5, and 10 mi/h)), for two application depths, (5 and 10 cm (2 and 4 in.)). The prototype single-disc injector used a spring-loaded closing wheel. Figure 1 shows drawings of the basic arrangement of disc opener, depth gauging wheel, and closing wheel. Figure 2 is a photograph of a prototype single-disc injector based on these drawings and which was tested in the field by mounting it on a toolbar frame. The closing disc size used in tests (as shown in figure 2) was somewhat larger than shown in the sketches of figure 1. The disc opener was 46 cm (18 in.) in diameter with an adjacent 34 x 7.5 cm (13.5 x 3 in.) depth gauging wheel. The release point for fertilizer application tube depth could be adjusted in a range of 2.5 to 10 cm (1 to 4 in.) below the soil surface. The closing wheel was 33 x 5 cm (13 x 2 in.). A 6 mm (0.25 in.) diameter fertilizer tube delivered NH₃ near the bottom edge of the disc-opener. This injector was an experimental design and has never been commercially available.
Figure 1. Single-disc injector with depth wheel and spring-loading closing wheel, side and rear views (actual closing wheel used was larger than shown in sketches).

In addition, a conventional NH$_3$ knife with closing discs operated at 8 km/h (5 mi/h) and 15 cm (6 in.) application depth was used to compare with the single-disc injector treatments, representing a commonly used injector for NH$_3$. The knife (Banjo TK 10) was 1.9 cm (0.75 in.) wide. A 6 mm (0.25 in.) diameter fertilizer tube released fertilizer at the bottom edge of the knife. The closing discs (DMI, Goodfield, IL) were mounted with concave sides facing the furrow. Downspring pressure kept the discs in contact with the soil surface.

Field Plots and Calibration

The seven treatments were applied to 11 replicated blocks differing in locations, soils, and soil conditions as indicated in table 1. Iowa soils in replications 1 and 2 were Webster silty clay loam and Clarion loam, respectively, located at the Iowa State University Agronomy and Agricultural Engineering Research Center near Boone, IA. Iowa soil in replications 7 through 11 was Hanlon fine sandy loam located near Ames. The Texas soil, Pullman clay loam, in replications 3 through 6 was located near South Plains, TX, at Marble Brothers Farm. Plots were 152 m (500 ft) long and 0.76 m (2.5 ft) wide.
Figure 2. Single-disc injector with depth wheel and spring-loaded closing wheel mounted on toolbar frame (collection hood removed).

Table 1. Location, soil type, previous soil condition, and application date of replications.

<table>
<thead>
<tr>
<th>Replication</th>
<th>Location</th>
<th>Soil type</th>
<th>Soil condition</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Iowa</td>
<td>Webster silty clay loam</td>
<td>No till</td>
<td>10-Nov-00</td>
</tr>
<tr>
<td>2</td>
<td>Iowa</td>
<td>Clarion loam</td>
<td>No till</td>
<td>10-Nov-00</td>
</tr>
<tr>
<td>3</td>
<td>Texas</td>
<td>Pullman clay loam</td>
<td>Tilled</td>
<td>20/21-Dec-00</td>
</tr>
<tr>
<td>4</td>
<td>Texas</td>
<td>Pullman clay loam</td>
<td>Tilled</td>
<td>20/21-Dec-00</td>
</tr>
<tr>
<td>5</td>
<td>Texas</td>
<td>Pullman clay loam</td>
<td>CRP</td>
<td>20/21-Dec-00</td>
</tr>
<tr>
<td>6</td>
<td>Texas</td>
<td>Pullman clay loam</td>
<td>CRP</td>
<td>20/21-Dec-00</td>
</tr>
<tr>
<td>7</td>
<td>Iowa</td>
<td>Hanlon fine sandy loam</td>
<td>No till</td>
<td>21-Jun-01</td>
</tr>
<tr>
<td>8</td>
<td>Iowa</td>
<td>Hanlon fine sandy loam</td>
<td>No till</td>
<td>21-Jun-01</td>
</tr>
<tr>
<td>9</td>
<td>Iowa</td>
<td>Hanlon fine sandy loam</td>
<td>No till</td>
<td>21-Jun-01</td>
</tr>
<tr>
<td>10</td>
<td>Iowa</td>
<td>Hanlon fine sandy loam</td>
<td>No till</td>
<td>21-Jun-01</td>
</tr>
<tr>
<td>11</td>
<td>Iowa</td>
<td>Hanlon fine sandy loam</td>
<td>No till</td>
<td>21-Jun-01</td>
</tr>
</tbody>
</table>

*a*Fine-loamy, mixed, mesic Typic Haplaquolls.
*b*Previous crop was soybean.
*c*Fine-loamy, mixed, mesic Typic Hapludolls.
*d*Fine, mixed, thermic, Torrertic Paleustolls
*e*Previous crop was cotton.
*f*Soil previously in Conservation Reserve Program mixed grasses.
*g*Coarse-loamy, mixed, mesic Cumulic Hapludolls.
Application rate after adjustment of the NH\textsubscript{3} regulator (A-3300 Nitropacer; CDS John Blue Co., Huntsville, AL) was determined prior to runs of that treatment by trapping NH\textsubscript{3} flow exiting the regulator through a hose and attached pipe inserted into water for 30 sec. The amount of NH\textsubscript{3} was determined gravimetrically and application rate calculated from the rate of NH\textsubscript{3} flow and applicator field speed.

**Measurements and Apparatus**

Measurements were made of NH\textsubscript{3} loss during the moment of field application and also during a roughly one hour time period immediately after application for each treatment within each replicated block. Measurement of NH\textsubscript{3} loss during field application was based on a technique developed by Abo-Abda (1985). In summary, air was drawn from a hood surrounding the single fertilizer injector as it injected NH\textsubscript{3} into the soil. A small known proportion of this main air flow exiting the hood was aerated through an acid solution to trap NH\textsubscript{3}. The solution was later analyzed in the laboratory for NH\textsubscript{3} concentration.

Single knife and single-disc fertilizer injectors were mounted on an adjustable-height toolbar frame. Injectors did not operate in tractor-wheel tracks except for replications 1 and 2. Hoods constructed around each injector were of slightly different dimensions to accommodate injector geometry. Both hoods had 15 cm (6 in.) long flexible rubber-belted skirting to avoid ambient wind near the soil surface from disrupting a negative (gauge) pressure inside the hood created by the main air flow. Main air flow was exhausted from the hood by a 7.1 m\textsuperscript{3}/min (250 ft\textsuperscript{3}/min) centrifugal fan (Jabsco, model 354000, Costa Mesa, CA) through an 81-mm (3.19-in.) polyvinyl-chloride (PVC) schedule 40 pipe (figure 3). Main air flow was measured before and after each test plot run with a 81-mm (3.19-in.) diameter linear-velocity vane anemometer (Davis Instruments Linear Velocity Anemometer). Sample air flow for NH\textsubscript{3} trapping was taken from the main air flow stream through 4.8 mm (0.19 in.) diameter Tygon tube, perforated with five 3 mm (0.13 in.) diameter holes and mounted on a diameter, perpendicularly across the PVC pipe carrying the main airflow. The air sampling system, connected by 4.8 mm (0.19 in.) diameter Tygon tubing, consisted of a 0.5-L/min (0.018-ft\textsuperscript{3}/min) pressure-compensated sample air pump (MiDan Co., Pulse Pump III), a rotometer to measure sample air flow, and a Pyrex #12C glass-tube-air-diffuser into a 25-mm by 305-mm (1 in. by 12 in.) cylindrical sample bottle filled with 150 mL (5.1 oz) of 0.5 N hydrochloric (HCl) acid solution. During field operation, air underneath the hood exited in the main air flow. Sample air flow was taken from the main air flow stream after it passed through the centrifugal fan during about 120 m (400 ft) of applicator travel. Sample air traveled through the rotometer, air pump, and was bubbled through the acid solution in the sample bottle before being vented to the atmosphere (figure 4).
Immediately after application, NH$_3$ loss from the soil surface of the application trench was sampled for the next hour using a stationary collection system. Chemical shelf paper sprayed with 15 mL of 0.5 N HCl solution was mounted in the bottom of a 30 x 41-cm (12 x 16-in.)
aluminum pan with the plastic face of the shelf paper facing the pan. The pan was set upside-
down over the application trench within approximately three to five seconds after application.
After approximately 60 min, the paper was removed from the pan and placed in a 3.8-L (1-gal)
glass jar with 1000 mL of deionized water to dissolve the NH₃. A single collection pan was used
in each test plot for the first six replications (table one) and four collection pans were used and
the values averaged in each test plot for all other replications. The masses of acid and water
added to the sample bottles and jars, respectively, were determined gravimetrically.

The amount of NH₃ collected in the acid solutions was determined later in a wet laboratory
analysis using a colorimetric method.

Calculations and Statistical Analyses

To determine loss during application, calculations were based on mass of NH₃ measured in
the sample air flow and then adjusted to loss collected in main air flow from the hood by the
ratio of main-to-sample air flow. The amount of NH₃ collected in the sample bottle during
application was multiplied by the ratio of main air flow to sample air flow. This amount of NH₃
lost during application was then expressed as a percentage of that flowing through the regulator
and injector during the time the sample was collected. To determine loss from the soil surface
immediately after application (for the hour beginning a few seconds after injection), the amount
of NH₃ collected on the acid-treated paper was divided by the amount of NH₃ applied through
the injector to the soil underneath it for the time the injector was traveling through the sample
area. This loss was also expressed as a percentage. Using these procedures, the lower limit of
detection for N was 0.10% of that applied during and 0.01% of that applied after application.

The experiment was a randomized complete block design with all treatments applied within
each replication. Two statistical analyses were done each using an analysis of variance. One
was a factorial analysis of the six single-disc treatments (three speeds and two depths). A
second analysis was done with all seven treatment combinations including the conventional
knife application. Specific statistical contrasts were used to compare all single-disc treatments
as well as discrete levels of depth and speed (main effects) of the single-disc operation with the
knife treatment. Least significant differences are shown but conclusions were drawn based on
significance in analysis of variance.

Results and Discussion

NH₃ application rate was targeted for 168 kg N/ha (150 lb N/ac) assuming the injector would
be operated with 76-cm (30-in.) spacing, a typical row width for corn production. Measured
application rates ranged from 164 to 177 kg N/ha (146 to 158 lb N/ac) except for four test runs
at 12 km/h (7.5 mi/h) in replications one and two where the application rate was 198 kg N/ha
(177 lb N/ac). Soil gravimetric moisture content was 18.7% for the silty clay loam soil, 18.2%
for the loam soil, 24.1% for the clay loam soil, and 14.4% for the fine sandy loam soil at the time
of application. Moisture within each replicated soil block appeared to be relatively uniform from
near the surface to application depth and close to, but below field capacity.

Although it was desired to measure loss after application for exactly 60 min, nine of 77
measurements were longer than 70 min. It was initially considered to adjust loss after
application to a loss per hour rate. Losses during application were many times greater, however,
suggesting that most losses after application probably occurred within the first few minutes or even seconds. Because analysis of loss after application adjusted to a per hour value resulted in the same conclusions and nearly identical results, data are reported simply as total loss after application during the time NH$_3$ was collected.

In initial analyses pooling data from all soil types, it was noted that losses at application with the single-disc injector appeared to be considerably greater in the fine sandy loam (table 2). This agreed with Stanley and Smith's (1956) finding of greater losses in sandy than in silt loam or clay soils. In the hour after application, NH$_3$ loss was significantly greater in silty clay loam and loam soils than in the clay loam soils (table 2). Losses greater than 15% at the time of application were somewhat unexpected, but comparable to those observed by Fenn and Kissel (1976) on a silty clay loam at 7.5 cm (3 in.) application depth. Blue and Eno (1952, 1954) observed losses as great as 75% on a sandy soil. The combination of shallow application depth of the single-disc injector and coarse soil type probably contributed to the high losses that were measured.

Another factor contributing to high losses may have been heat from the application equipment that was transferred to the NH$_3$ during application. In order to change sample bottles, measure main air flow, and set up equipment, the time between individual plot runs was usually at least five min and at times longer. Ambient air temperature during replications seven through eleven was near 21 °C (70 °F). As NH$_3$ flowed through the regulator to only a single injector, heat energy from application equipment warming back to ambient temperature was probably able to evaporate more of the NH$_3$ from the liquid phase to the gas phase during flow through the applicator than would be expected in colder weather, with more injectors being supplied by the regulator, or for a longer duty-cycle during application. For example, mass flow rates of NH$_3$ from the tank through the regulator and manifold to an 11-injector applicator would be 11 times as great as through a single injector applicator. Abo-Abda (1985), comparing a PIFA injector operated at 13 and 18 cm (5 and 7 in.) and a conventional knife, reported losses greater than 15% at application in 9 of 78 field plots. During a mid-August application, mean losses for treatments with the PIFA injector operated at these deeper depths ranged from 7 to 12% in a medium-textured soil.

When soil type was divided between fine sandy loam (coarse-textured soil; replications 7 through 11) and those soils that were more finely textured than fine sandy loam (fine-textured soil; replications 1 through 6), there was a statistically significant interaction between these two major soil groups and injector treatments. Losses at application for the single-disc treatments averaged 27 percentage points greater in the fine sandy loam soil than for the other soils, but losses for the knife treatment were slightly lower (0.4 percentage point) in the fine sandy loam soil than for the other soils. Because of this interaction, results have been analyzed and reported separately for fine-textured soils (silty clay loam, loam, and clay loam) and coarse-textured (fine sandy loam) soils.
Table 2. Ammonia loss by soil texture and replication as percent of applied (all treatments).

<table>
<thead>
<tr>
<th>Soil texture</th>
<th>Tillage</th>
<th>Replication</th>
<th>Loss at application</th>
<th>Loss after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silty clay loam</td>
<td>No till</td>
<td>1</td>
<td>5.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Loam</td>
<td>No till</td>
<td>2</td>
<td>4.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Clay loam</td>
<td>Tilled</td>
<td>3</td>
<td>4.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Clay loam</td>
<td>Tilled</td>
<td>4</td>
<td>4.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Clay loam</td>
<td>CRP</td>
<td>5</td>
<td>3.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Clay loam</td>
<td>CRP</td>
<td>6</td>
<td>3.5</td>
<td>0.3</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>No till</td>
<td>7</td>
<td>24.9</td>
<td>0.6</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>No till</td>
<td>8</td>
<td>26.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>No till</td>
<td>9</td>
<td>27.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>No till</td>
<td>10</td>
<td>28.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>No till</td>
<td>11</td>
<td>28.9</td>
<td>0.7</td>
</tr>
</tbody>
</table>

LSD<sub>0.05</sub> 9.5 0.5

*Least significant difference between treatments at a 95% level of confidence.

Fine-Textured Soils

Within the factorial analysis of the single-disc injector only, NH<sub>3</sub> losses were not significantly affected by either depth or speed during application (table 3). After application, NH<sub>3</sub> losses were unaffected by speed but somewhat surprisingly were greater at the four-inch depth of the prototype than at the two-inch depth. Loss from the soil surface in the three to five seconds between passage of the applicator and initial placement of and collection by the catch container on the surface could have been significant considering that 5 to 12 times as much NH<sub>3</sub> was lost during passage of the injector as was lost in the subsequent hour. This unmeasured loss may have been significantly greater at the two-inch depth giving rise to the unexpected results.

Table 3. NH<sub>3</sub> loss for single-disc fertilizer injector fine-textured soils as percent of applied (factorial).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Loss at application</th>
<th>Loss after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed, mi/h</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>5</td>
<td>5.9</td>
<td>0.6</td>
</tr>
<tr>
<td>7.5</td>
<td>4.7</td>
<td>0.6</td>
</tr>
<tr>
<td>10</td>
<td>3.7</td>
<td>0.5</td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Depth, in.</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>2</td>
<td>5.1</td>
<td>0.4</td>
</tr>
<tr>
<td>4</td>
<td>4.4</td>
<td>0.8</td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td>NS</td>
<td>0.4</td>
</tr>
</tbody>
</table>

*Least significant difference between treatments at a 95% level of confidence.
Table 4. \( \text{NH}_3 \) loss for both fertilizer injectors for fine-textured soils as percent of that applied (7 treatments).

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Speed, mi/h</th>
<th>Depth, in</th>
<th>Loss at application</th>
<th>Loss after application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype</td>
<td>5</td>
<td>2</td>
<td>6.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Prototype</td>
<td>5</td>
<td>4</td>
<td>5.4</td>
<td>1.1</td>
</tr>
<tr>
<td>Prototype</td>
<td>7.5</td>
<td>2</td>
<td>4.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Prototype</td>
<td>7.5</td>
<td>4</td>
<td>5.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Prototype</td>
<td>10</td>
<td>2</td>
<td>4.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Prototype</td>
<td>10</td>
<td>4</td>
<td>2.7</td>
<td>0.5</td>
</tr>
<tr>
<td>Knife</td>
<td>5</td>
<td>6</td>
<td>1.6</td>
<td>0.1</td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt;</td>
<td></td>
<td></td>
<td>3.9</td>
<td>0.6</td>
</tr>
</tbody>
</table>

*Least significant difference between treatments at a 95% level of confidence.

Comparing the single-disc injector with the conventional knife, \( \text{NH}_3 \) losses at application with the single-disc injector operated at shallower depths and the same or faster speeds were at times statistically greater than the knife (table 4). In specific statistical contrasts between the knife and main effects of speed and depth of the single-disc injector, losses at application were significantly greater if the single-disc was operated at a slower speed (8 km/h; 5 mi/h) or a shallower depth (5 cm; 2 in.). Losses were statistically greater (3.2 percentage points) when all single-disc treatments as a group were contrasted with the knife treatment. \( \text{NH}_3 \) losses after application were also at times statistically greater for the single-disc as compared to the knife injector. In specific statistical contrasts between the knife and main effects of the single-disc injector, losses after application were significantly greater if speed was 8 or 12 km/h (5 or 7.5 mi/h) or depth was 10 cm (4 in.). Also losses were statistically greater (0.6 percentage points) when all single-disc treatments were contrasted with the knife treatment. \( \text{NH}_3 \) loss during passage of the knife injector was 30 times greater than the small loss in the hour after application.

**Coarse-Textured Soils**

Losses at the time of application of the single-disc injector were 30 to 55 times those during the hour after application (table 5). Within the factorial analysis of the single-disc treatments, losses at application were 16 percentage points greater at an application depth of 5 cm (2 in.) than 10 cm (4 in.). Losses were 14 percentage points higher at 8 and 16 km/h (5 and 10 mi/h) than at 12 km/h (7.5 mi/h). This effect of reduced losses at an intermediate speed was unexpected. At 12 km/h (7.5 mi/h) speed may have been fast enough to limit the time for \( \text{NH}_3 \) to escape between passage of the injector and closing wheel, yet slow enough to minimize disruption of soil in the furrow and allow for adequate closing. Losses after application were unaffected by speed but were statistically lower (0.4 percentage point) when \( \text{NH}_3 \) was applied at a 10-cm (4-in.) depth than at a 5-cm (2-in.) depth. Lower losses at a greater application depth were also reported by Stanley and Smith (1958), Fenn and Kissel (1976), and Abo-Abda (1985), but the effect of depth was opposite of what was found in the fine-textured soil.
Comparing all treatments, losses at application were considerably greater (20 to 48 percentage points) for the single-disc injector than the knife injector (table 6). Losses at application were statistically less for the knife than any of the single-disc treatment combinations or main effects of depth and speed. Similarly, losses after application were statistically greater (average of 0.7 percentage point) for treatment combinations and main effects of the single-disc injector than for the knife (loss below the detection limit). Considering total losses by adding together loss at and after application, the single-disc injector had losses 21 to 52 percentage points greater than the knife injector (depending on depth and speed of the single-disc injector).

### Summary

Within the range of test conditions (application rates targeted for 168 kg N/ha (150 lb N/ac)), the following findings are supported:

- **NH₃** losses during application with the single-disc injector as a percentage of that applied were greater in the fine sandy loam (coarse-textured) soil, ranging from 21 to 52%, than...
in finer textured soils (clay loam, silty clay loam, loam) where losses ranged from 3 to 7%. Losses at application for the knife injector, 1 to 2% were similar between soils.

**Fine-Textured Soils:**

- About 5 to 30 times as much NH$_3$ was lost at application during passage of the injector as during the first hour after application. Losses at application were statistically greater when all single-disc treatments were compared to a knife injector. Losses were statistically greater than the knife injector when single-disc treatments were applied at shallow depth (5 cm (2 in.)) or slower speed (8 km/h (5 mi/h)).

- Losses after application were statistically greater (0.6 percentage points) when all single-disc treatments were compared to a knife injector, and were statistically greater if speed was 8 or 12 km/hr (5 or 7.5 mi/hr) or depth was 10 cm (4 in.).

**Coarse-Textured Soils:**

- About 30 to 55 times as much NH$_3$ was lost during passage of the injector as during the first hour after application. Total losses at and after application were considerably greater for single-disc treatments than the knife. Total losses ranged from 21 to 52 percentage points greater for single-disc injector treatments (combinations of 8, 12, and 16 km/h speeds and 5- and 10-cm depths (5, 7.5, and 10 mi/h speeds and 2- and 4-in. depths)) than for the knife treatment (8 km/h and 15-cm depth (5 mi/h and 6-in. depth)).

- For the single-disc injector, losses at application were observed to be about 16 percentage points greater during application at a 5-cm (2-in.) depth than a 10-cm (4-in.) depth. At an intermediate application speed of 12 km/h (7.5 mi/h) loss during application was 14 percentage points less than at speeds of 8 or 16 km/h (5 or 10 mi/h).

- For the single-disc injector, losses after application were unaffected by speed but were 0.4 percentage points less at an application depth of 10 cm (4 in.) rather than 5 cm (2 in.).

**References**


