Project Number: SW10-050

Project Title: Enhancing no-till cropping system sustainability by minimizing ammonia-N losses from chemical and biological inputs

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Summary: 100 words

Ammonia (NH_3) volatilization from chemical fertilizer and legume green manure nitrogen (N) inputs represents a significant pathway of N loss to the environment. On-farm measurements of NH losses from these sources have rarely been conducted. This Research and Education project is quantifying NH_3 losses following urea fertilization and legume green manure termination using a micrometeorological method, and evaluating strategies to minimize losses. Studies are being conducted on private-farms with input from growers. Results are being shared with the agricultural community at field days, workshops, and in popular media. Currently, there is a large gap in knowledge about the magnitude of NH_3 losses from farms in the Northern Great Plains (NGP). This project will help bridge this gap, thereby improving agricultural sustainability and environmental quality.

Objectives/Performance Targets

1. Quantify on-farm ammonia loss from urea fertilizer applications (chemical) and legume termination (biological) from NGP dryland cropping systems.

Our performance target will be to determine the fraction of applied urea fertilizer that is lost as NH_3 for applications to winter wheat applied between fall to early spring. Two or three different application timing dates will be compared at each farm site, e.g. Oct, Dec-Jan, and March-Apr. We have conducted preliminary studies that indicate losses can be quite large from cold soils (up to 40%). Our study will identify the environmental and soil conditions that are most conducive to high NH3 losses. Our second performance target will be to determine the fraction of N in legume manure that is lost as NH3 following its termination by glyphosate spraying and mowing. Most studies on NH3 volatilization have utilized enclosures or chambers rather than the micrometeorological techniques being proposed here. Micrometeorological approaches are widely recognized as providing more reliable estimates of gas N losses than enclosures, because they do not disturb the environment or soil processes that affect gas exchange at the ground, provide continuous measurements over time, and provide a measure of gas loss over a larger footprint than enclosures (Denmead, 1983).

2. Identify mitigation strategies or production practices that will minimize ammonia-N losses where losses are found to be significant from inorganic and organic N inputs.

Our performance target is to mitigate NH3 losses to ≤ 5% of the N input. We will evaluate different mitigation strategies based on comments and input received from our participating cooperators, area growers and agricultural-professionals. For example, our urea studies may evaluate: i)

subsurface urea banding at seeding; ii) pre-plant broadcast applications followed by direct seeding; and iii) enhanced efficiency fertilizers that include urease inhibitors. Under strategy 'i', most no till air-seeders have the capacity to apply both fertilizer and seed. Placement of fertilizer urea below the soil surface is a known strategy for mitigating NH3 emissions to the air. Under strategy 'ii', many air-drills are configured with hoe-style openers that create considerable disturbance at the soil surface. The level of disturbance may be sufficient to cover urea prills on the soil surface, thereby mitigating NH3 losses. Under strategy 'iii,' enhanced efficiency fertilizers have gained popularity in recent years because of their potential to enhance crop N use efficiency. Recently, NRCS programs such as the Conservation Stewardship Program (CSP) have targeted agricultural air quality issues including NH3 pollution. The CSP provides enhancement points to growers for adopting practices that improve air quality including enhanced N fertilizers that contain urease inhibitors.

Few reports are found in the literature that utilized micrometeorological methods to quantify NH3 volatilization losses in the field from legume green manures. Therefore, we make no prejudgments about what we might find. Incorporation of crop residue is the most effective approach for mitigating NH3 losses. Under a strict no till scenario tillage is not an option; however, this practice may need to be considered should NH3 losses prove significant.

3. Develop and execute an educational outreach program to producers and agricultural professionals that will improve their understanding of on-farm N cycles and N loss mitigation, thereby leading to enhanced sustainability and environmental quality.

Our performance target is to achieve direct contact with 1000 people (or people-hrs) and indirect contact with another 5,000 people through radio, news releases, and trainings by ag-professionals and farmer to farmer communication. Our education outreach programs will target ag-professionals who are involved in outreach to their grower clients. Therefore we anticipate there will be a multiplier effect to our direct contact hours.

Accomplishments/Milestones

Our project is proceeding on-time and on target. Field studies have been conducted at five locations since this project's inception according to the protocol described in the proposal. These five field studies conducted to date were established to directly address Objectives/Performance Targets # 1 and 2 . In addition, we have been engaged in an active educational outreach program to producers and professional as stated under Objective/Performance Target #3. A barometer of our success is the accumulated contact hours with producers in our region. Currently, we have accumulated 800 contacts or 80% of our final target. A brief summary of our research results and education outreach program is provided below.

Research Results

<u>Fall 2010: preplant urea application to mitigate ammonia losses</u>

Interest in investigating this mitigation strategy came as a result of our discussions with growers at meetings and one-on-one visits. During these meeting growers asked if the disturbance created by their air-seeders configured with hoe-style openers was sufficient to cover urea prills on the soil surface, thereby mitigating NH_3 losses. This research directly benefits growers by addressing a management question that affects economic return from fertilizer and net income.

Field experiments were conducted at three no-till wheat farm sites (Campaigns 13, 14, and 15) in northern Montana during fall 2011, according to the protocol outlined in the proposal. Urea was applied as a pre-plant (< two hours prior of seeding) and post-plant (< two hours following seeding). The post-plant urea treatment was included as a positive control to assess the potential for NH_3 loss from urea without incorporation. Photographs from the field sites reveal the level of disturbance created by air-drills differed appreciably at two field sites (Figure 1) where similar style hoe-openers (Figure 2) were used. The higher disturbance created at Campaign 14 compared to Campaign 13 may have been a result of high soil moisture conditions at seeding.

Campaign 13 (lower disturbance)

Campaign 14 (higher disturbance)

Figure 1. Disturbance created by the air-drill differed considerably at the two sites.

Figure 2. Narrow style openers were used at Campaign site 13 and 14.

Ammonia losses are summarized in Figure 3 over individual campaigns. The largest NH_3 loss weeks typically occurred during periods of soil drying, or wet to dry soil moisture cycles. For example, during Campaign 13 precipitation equivalent to 0.60 cm and 1.52 cm fell 1 d and 5 d post-fertilization, respectively. These events wetted the soil surface but then were followed by a period of surface drying (Figure 4). Previous research has shown that significant NH_3 fluxes are often associated with a dry-down period of the soil surface. This was consistent with the observation from this past fall. Total cumulative N losses from the pre-plant urea treatment were equivalent to 18.7 and 20.6% of the applied N rate

(100 kg N ha^{-1}) for Campaigns 13 and 14, respectively. The results showed the disturbance created by the air-seeder did not mitigate volatilization losses as the losses from pre-plant urea were similar to the unincorporated post-plant urea treatment. These initial results were somewhat disappointing, particularly Campaign 14, as visual inspection of the field site indicated that a large fraction of the urea prills were covered with soil. This study will be repeated again in 2011. Campaign 15 was conducted at a field site northwest of Have. The openers used by the grower at this field site were approximately 10 cm wide and created considerably more disturbance than at Campaign 13 and 14. Surface soil moisture conditons were very dry on the date of fertilization and precipitation was very light over the course of the 8 wk study. Ammonia emissions from this field site were nominal even where urea was not incorporated. Hence, the results from this test site were inconclusive .

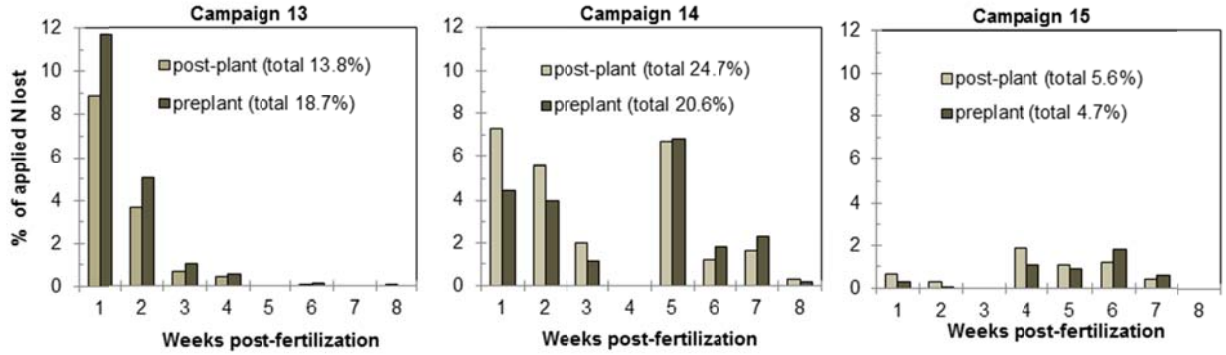


Figure 3. Weekly NH_3 losses from urea applied pre-plant and post-plant at north Havre (Campaign 13), Kremlin (Campaign 14), and northwest Havre (Campaign 15) field sites on September 15, September 27, and October 7, respectively.

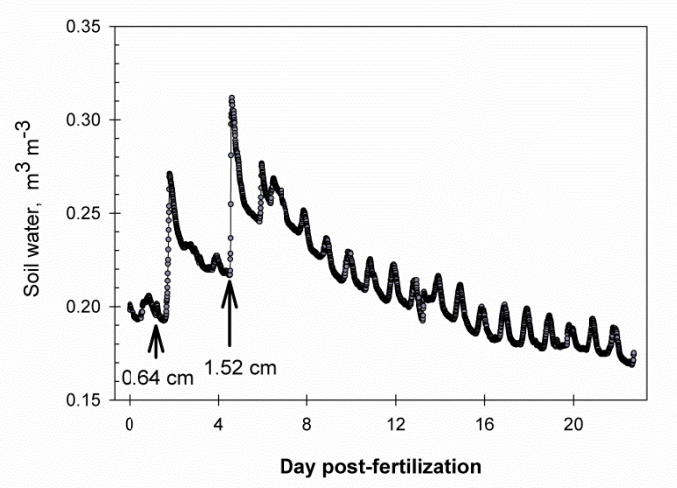


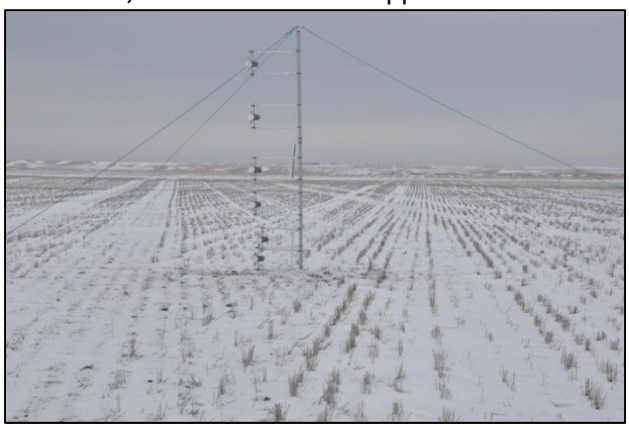
Figure 4. Soil water content (2.5 cm depth) vs. d post-fertilization during Campaign 13. Precipitation events and magnitude indicated by arrows.

Winter 2011: urea applications to snow

Growers in Montana frequently surface-apply urea during the winter. A question that has been asked of us during grower meetings is whether NH_3 volatilization losses from urea are mitigated if applications are made to snow-covered soils. This question is being addressed in our study.

This past winter we conducted NH_3 volatilization measurements following urea application to a field site with a modest snow-pack (Figure 5 -left). The study included two treatments; urea and NBPT-coated urea (or Agrotain coated urea) applied at 100 kg N ha^{-1} and was run according to the protocols described in the proposal. Results of the trial (Campaign 16) are summarized in Figure 6. Cumulative NH_3 losses equivalent to 20.7% of the application rate (100 kg N ha^{-1}) were observed from urea over an 8-wk period. Losses were particularly large during the second week (7-14 d post-fertilization) when the snow-pack disappeared (see Figure 5 – right) and the surface soil conditions followed a wet to dry cycle. Coating urea with Agrotain provided approximately two weeks of volatility protection and reduced NH_3 losses by approximately 50% over untreated urea. The active ingredient in Agrotain is N-(*n*-butyl) thiophosphoric triamide (NBPT), a urease inhibitor, and which is known to mitigate N volatilization from urea. Results from this study are consistent with previous trials (Engel et al., 2011) and indicate that significant NH_3 losses can occur when urea is surface applied to cold and/or snow-covered soils. It should be noted that surface daily-soil temperatures average 2 °C during the second week of the study when cumulative losses of 10% of the applied N rate occurred.

March 2, 2011 – fertilization application date



March 9, 2011

Figure 5. Urea was surface-applied to a snow-covered (0.89 cm water) winter wheat field site near Denton, Montana on March 2, 2011 (left). Field site 1-wk post-fertilization on March 9, 2011 (right).

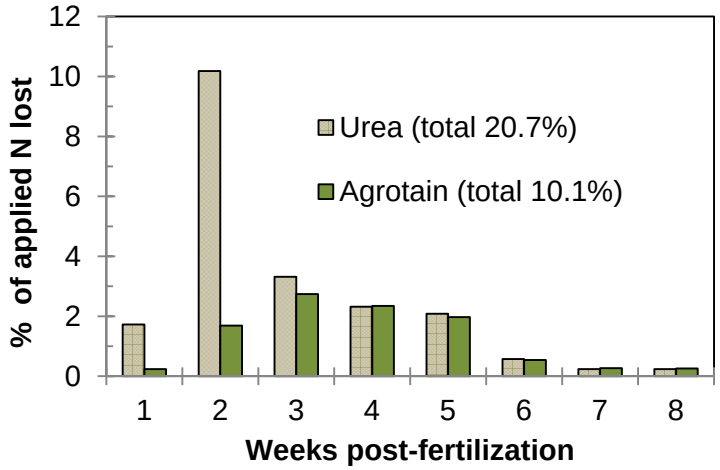


Figure 6. Weekly NH_3 losses (expressed a percentage of applied N) from surface-applied urea and grotain-coated urea at a field site near Denton, Montana. Campaign 16. Fertilizer was applied on March 2, 2011.

Summer 2011 – Ammonia volatilization from pea green manure

Field peas (Pisum sativum) are Montana's most important alternate crop for diversifying dryland wheat rotations. Inclusion of green manure peas in rotations provides N to the soil; however, their termination at an immature growth stage has been reported to result in volatilization losses of NH_3 which will diminish their fertility benefits as well as represent an important contribution of atmospheric NH_3.

Field studies conducted this summer were initiated to learn whether termination of peas by mowing and herbicide spraying would lead to significant NH_3 losses. Studies were established at a dryland field near Havre, Montana. Peas were terminated on July 6 by mowing (Figure 7) and herbicide spraying (2,4-D amine). Pea biomass was estimated to be 3600 kg ha^{-1} from hand-clip samples (0.60 m^2) collected within each plot. Measurements of NH_3 emission from the terminated peas revealed no detectable NH_3 losses from either the mow or herbicide-spray treatments. This study will be repeated again next year, but these early results reveal that Montana growers are likely not losing significant N from this biologic source as a result of green manuring.

Figure 7. Field peas were terminated at the early-pod stage (July 6, 2011) by mowing at this field site near Havre, Montana.

Education outreach program

- *Pre-survey*: A 19 question survey, or a link to the online survey, was sent to all members of the Montana Grain Growers Association, Wyoming Wheat Growers Association, and Idaho Grain Producers Association in late Fall 2010 to determine their current nitrogen management practices, knowledge of urea volatilization, and preferred media for receiving research results.
  - ✓ A total of 147 surveys were returned.
  - ✓ Approximately 50% of applied urea is being broadcast without incorporation.
  - ✓ The average estimate of urea volatilization loss was close to what we have measured (~22%), but the range was high (5 to 100%) suggesting room for education.
  - ✓ Approximately 37% did not know the worst case weather conditions for urea application.

- ✓ Respondents primarily preferred to receive results via email (27%), workshops (24%), or newsletters (17%).

- *Publications:* most of our publications will be written and distributed the last year of the study so that we have more firm recommendations and results, but we have started on a few.
  - ✓ A referred journal article entitled "AMMONIA VOLATILIZATION FROM UREA AND MITIGATION BY NBPT FOLLOWING SURFACE APPLICATION TO COLD SOILS" will appear in in Soil Science Society of America Journal in the November- December 2011 issue.
  - ✓ We have begun the first stages of editing our regional Extension publication, "Management of urea to minimize volatilization" (Jones et al., 2007) to reflect our research findings.

- *Presentations*
  - ✓ Since the project's inception (July 2010), we have presented the study findings 18 times to a range of audiences that included growers, crop advisers, Extension Agents, and scientists (Table 1). Total direct contact at these presentations has totaled approximately 800 people or 80% of our performance target of 1,000 direct contacts for the entire study.

Table 1. Oral presentations given from July 2010-present on urea volatilization.

Meeting	Location	Date
International Agricultural Forum	Yangling, China	02-Nov-2010
American Society of Agronomy	Long Beach, CA	03-Nov-2010
Grower Meeting	Glasgow, MT	16-Nov-2010
Montana Grain Growers Conv.	Great Falls, MT	02-Dec-2010
Nitrogen Conference	Havre, MT	12-Dec-2010
Grower Meetings (3)	Choteau, Shelby, Ft. Benton, MT	3-4 Jan-2011
Crop Pest Management School	Bozeman, MT	06-Jan-2011
Montana Agri-Business Convention	Great Falls, MT	26-Jan-2011
Grower Meeting	Malta, MT (via web)	07-Feb-2011
Alberta Soil Science Workshop	Calgary, AB	16-Feb-2011
Grower Meeting	Denton, MT	02-Mar-2011
Agriculture Extension Agent Update	Bozeman, MT	13-Apr-2011
Northern Ag Res Center Field Day	Havre, MT	28-June-2011
Central Ag Res Center Field Day	Moccasin, MT	07-July-2011
Grower Farm Tour	Poplar, MT	24-July-2011
Grower Meeting	Glasgow, MT	25-July-2011

- ✓ Our research project was also mentioned at seven grower meetings in Idaho in February 2011, and at the Wyoming Wheat Growers Association annual meeting in December 2010.
- ✓ We will present results from the survey at the 2011 American Society of Agronomy Annual Conference in October 2011.

- ✓ We will present a portion of our recent results at the Great Plains Soil Fertility Conference in Denver (March 2012).

- *Web-based materials*
  - ✓ We have posted a streaming video of one of Dr. Jones's presentations on urea volatilization on the ammonia volatilization portion of his website: http://landresources.montana.edu/soilfertility/ammonvolat.html

- *Educational program evaluation plan*: At our first two producer education programs, we asked audience members several questions to improve our programs.
  - ✓ The average attendee understanding increased from 2.75 (1 – poor, 5 – excellent) prior to the program to 4.02 after the program.
  - ✓ Approximately 80% of respondents said they would make a management change based on the presentation.
  - ✓ 100% said they would share the results with at least one other person.
  - ✓ Approximately 60 comments were received on how to make the educational program and research more worthwhile. We have incorporated some of these comments into our educational outreach plan and our research plans.
  - ✓ At our last two presentations in July 2011 we used Turning Point's clicker system to assess the worth of the program. The audience's understanding of volatilization increased in 91 to 100% of respondents and 71 to 90% will make a management change based on our results.

Impact and Contributions/Outcomes

Our ammonia volatilization has garnered considerable interest and support by the agricultural community in Montana. This past year we conducted grower surveys on the impact of our research on production practices. Evaluations from two seminars (i.e. Montana Grain Growers Association Convention and Nitrogen Conference) indicated that 80% of the respondents will likely change a management practice based on what they learned at the seminar; and 100% of the respondents said they will share what they have learned with at least one other person. As described in our proposal, outcomes and impacts of this project will be gauged from the results of surveys, as well as the personal contact hours accumulated over the course of this study. The results of our surveys, evaluations, and discussions with growers indicate this project is having a large impact on growers in this region. There are several reasons why this may be so. First, the information presented is relevant to management practices in the region (i.e. 50% of our survey respondents say they applied urea without incorporation). Second, nitrogen fertility and nitrogen inputs typically represent a grower's largest annual cost input. Third, nitrogen is the fertilizer nutrient most often limiting crop yield and quality in NGP cropping systems. Therefore, management of this input to maximum crop efficiency is important to a grower's bottom line as well as environmental quality. Most importantly, several growers and crop advisers have told us that they have changed their urea management practices to minimize volatilization. This has likely increased their grain yield, grain protein, and net revenue.