Survey of Nitrogen Fertilizer Use on Corn in Minnesota

Peter Bierman[1], Carl Rosen[1], Rod Venterea[1, 2], John Lamb[1]

[1]University of Minnesota – Department of Soil, Water, and Climate
[2]United States Department of Agriculture – Agricultural Research Service

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Executive Summary

A survey was conducted in the spring of 2010 to characterize the use of nitrogen (N) fertilizer on field corn by Minnesota farmers in the 2009 growing season. Detailed information on N fertilizer management practices was collected from interviews with 1496 farmers distributed across all of the corn growing regions in the state. Their total corn acreage represented about 7% of the corn acres harvested in Minnesota in 2009. This report summarizes data on: 1) N fertilizer rates, 2) Major N sources, 3) Application timing of the major N source, 4) Use of nitrification inhibitors, additives, and specialty N fertilizer formulations, 5) Fertilizer placement and incorporation practices, 6) Use of starter fertilizer, split and sidedress applications, and other N sources such as ammonium phosphates, 7) N fertilization of irrigated corn, and 8) Use of soil testing as a fertility management tool. Many of the survey results are reported as statewide averages, but where regional differences occurred the data are broken down and presented separately for different parts of the state. This survey provides the most comprehensive set of data on N fertilizer use on corn that has been collected in Minnesota. The information can be used to target research and education programs to improve N management for both production and environmental goals. Overall results indicate that N fertilizer use by Minnesota corn farmers is generally consistent with University of Minnesota Extension N management guidelines.

Introduction

A farmer survey of nitrogen (N) fertilizer use on field corn in Minnesota was conducted as part of a research project investigating emissions of the greenhouse gas nitrous oxide (N_2O) from agricultural soils and the contribution of N fertilizers as a source of N for these emissions. The project was carried out by scientists from the USDA-Agricultural Research Service Soil & Water Research Management Unit, the Department of Soil, Water, & Climate at the University of Minnesota, and University of Minnesota Extension. Funding was provided by the USDA National Research Initiative Competitive Grants Program (NRI). Objectives of the project were to:

1. Develop improved methods and protocols for monitoring direct and indirect N_2O emissions from fertilized soils,
2. Quantify the effectiveness of alternative agricultural management practices for mitigating N_2O emissions and related N losses, and
3. Disseminate information obtained from the above activities to agricultural producers, industry, conservation officials, and other stakeholders that encourages improved management practices to reduce impacts on air quality.

The N-use survey was designed to support Objective #3 and collect current information on N management practices with respect to: 1) application rates (lb N/acre), 2) timing (fall or spring, single or multiple applications), 3) method (surface or subsurface), and 4) chemical form. Knowledge of current N management practices was necessary to form a basis for developing effective educational tools, decision-support tools, and Extension programs to improve N management. The survey was restricted to N management on corn because corn is the most widely grown crop in Minnesota that requires N application and the majority of the N fertilizer applied in the state is used in corn production. Project personnel collaborated with the

Minnesota Department of Agriculture (MDA) to develop survey questions and MDA worked with the USDA National Agricultural Statistics Service (NASS), Minnesota Field Office to conduct the survey. This survey was supported by the MDA using dollars provided by the Clean Water Fund (from the Clean Water, Land and Legacy Amendment).

Survey Methods

Farmers in the survey were from a database of the Minnesota Field Office of NASS. An initial pool of 7,000 farmers was randomly selected by NASS from their database of about 31,000 Minnesota farmers who have recently grown corn. The survey was carried out through phone interviews conducted at the North Dakota Field Office of NASS in Fargo. Interview staff were the same experienced interviewers that are routinely used to perform the regular surveys conducted by NASS. The survey consisted of 42 questions and it took about one-half hour to complete the interview with farmers who were able to finish the entire survey. Interviews and follow-up calls necessary to clarify some of the responses were conducted between February and June of 2010.

Interviewers were able to contact 4,461 of the initial pool of 7,000 farmers. Those not contacted were called more than once, but failed to answer the phone. Of the farmers contacted, 3,358 grew corn in 2009. The 2,769 farmers who continued the interview grew corn on 656,312 acres in 2009. Manure had been applied to 32% of these acres in the previous five years. The focus of the survey was use of manufactured N fertilizers, so to avoid the complicating effects of previous manure application on N fertilizer rates the farmers were asked to report on an average field with no manure applied in the last five years. The 866 farmers who did not have a field where no manure had been applied in the last five years were eliminated. Also eliminated were 407 of the remaining farmers who did not have a field where they knew the total amount of N applied per acre. This left 1,496 farmers, who grew corn on 482,812 acres in 2009. The survey results reported below are from this subsample of Minnesota corn farmers.

There were survey participants from 74 of Minnesota's 87 counties and they were distributed across all of the major corn growing regions in the state (Fig. 1). Their total corn acreage represents about 6.8% of the 7.15 million corn acres harvested in Minnesota in 2009 (NASS Minnesota Field Office, 2010). The number of corn acres on surveyed farms was different than the distribution of corn acres reported for all Minnesota farms growing corn in 2007 (Table 1). About 44% of surveyed farms grew more than 250 acres of corn, compared with 31% of all Minnesota corn farms in the 2007 Census of Agriculture (NASS, 2009). This suggests that surveyed farms were slightly larger than the state-wide average, although some of the difference could have been due to increases in farm size between 2007 and 2009.

Before interviewers began asking the series of questions on specific aspects of N fertilizer use, they instructed farmers to "think about an average corn field you planted in 2009 with no manure or compost applied in the last five years" and to answer questions in relation to that specific field. If fertilizer was applied at more than one rate or at a variable rate in this field, they were asked to report a field average rate. Therefore, responses of individual farmers in this survey represent their "average" or "typical" N management practices. In some cases farmers may have strayed from the "average field" restriction, especially as the interview progressed, and some of their answers may have reflected the entire range of the N management options they employed.

All data in this report are expressed as averages among the participating farmers for the individual fields they are reporting on. They are averages among these fields and data are not adjusted to account for differences in field size. Data analysis also does not reflect differences among the farmers in their total acreage of corn.

Many of the survey results are reported as statewide averages, but where regional differences occurred the data are broken down and presented separately for different parts of the state. For this purpose, the state was divided into the regions defined in the publication *Best Management Practices for Nitrogen Use In Minnesota* (Lamb et al., 2008) These divisions are based on geographic differences in soil parent material and climate. There are five regions: 1) Northwestern, 2) Coarse-textured Soils, 3) Southwestern and West Central, 4) South Central, and 5) Southeastern. The regions are mapped in Fig. 1. The original publication used the term "Irrigated and Non-irrigated Sandy Soils" for one of the regions, which is changed to "Coarse-textured Soils" in this report.

Survey Results

The average size of the corn fields reported on by farmers in this survey was 81 acres. The average yield of these fields over the previous three corn crops was 159 bushels/acre (Table 2).

Average N rates

The overall average N fertilizer rate for all surveyed fields was 140 lb N/A (Table 2). Average rates varied across the different BMP regions of the state, ranging from 129 to 146 lb N/A. The lowest rates were in the Northwestern and Coarse-textured Soils regions and the highest average N rate was in the South Central region. Differences in N rates for the different regions may have been caused by differences in productivity potential. Average yields for the previous three corn crops in the surveyed fields ranged from 127 to 174 bu/A across the different BMP regions (Table 2) and there was a strong correlation between previous corn yield and average N rate ($r = 0.98$). The productivity potential of the soil is an important factor in the determination of University of Minnesota Extension N rate guidelines (Rehm et al., 2006). For a crop of corn following corn in a year with an N price to crop value ratio of 0.10, the maximum return to N fertilizer on a highly productive soil would occur at a rate of 140 lb N/A. Under the same conditions, the maximum return to N fertilizer on a soil with medium productivity would occur at a rate of 120 lb N/A.

The effect of productivity potential on N fertilizer rate is evident in the differences between irrigated and non-irrigated corn fields in the Coarse-textured Soils region (Table 2). Average yield for the previous three corn crops was 36 bu/A greater in irrigated fields than in non-irrigated fields and the average N rate was 24 lb N/A greater. About 8.1% of the surveyed corn fields in the Coarse-textured Soils region were irrigated.

The amount of N fertilizer applied varied with the preceding crop (Table 3), although differences were not as great as might have been expected. For corn following soybeans, which accounted for about 75% of all fields in the survey, the state-wide average N rate was 140 lb N/A. When corn followed corn, the average N rate was 145 lb N/A. These results suggest that many farmers did not take full advantage of the N supplying capacity of soybeans. Soybeans are a leguminous crop capable of fixing atmospheric N, and N requirements for corn are commonly about 30 lb N/A lower following a healthy soybean crop (Rehm et al., 2006). Another possibility is that farmers were not as aggressive in choosing N rates for corn following corn as they were for corn following soybeans, and that they did not apply enough N to corn following a previous corn crop.

Alfalfa is a legume with an even greater capacity to fix N than soybeans and N requirements for corn following alfalfa are frequently less than the average N rates of 97 lb N/A for the first year of corn, and 129 lb N/A for the second year of corn, found in this survey. Following alfalfa crops with good to excellent stands, University of Minnesota guidelines suggest an N credit of 100 to 150 lb N/A for 1st year corn and 50 to 75 lb N/A for 2nd year corn (Rehm et al., 2006). This survey included only 30 fields of 1st year corn following alfalfa, and 30 fields of 2nd year corn following alfalfa, so survey results may have been skewed by factors such as a higher than normal number of fields where the alfalfa stand was poor. The methods used to conduct the survey may also have caused N rates for corn following alfalfa to be underestimated. Fields that did not receive any N fertilizer were not included in the survey, so corn following an excellent stand of alfalfa that could supply all of the N needed by the crop would have been excluded. Therefore, no zero N fertilizer fields were used to calculate the average N rate for corn following alfalfa, but it is not known how many fields like this were included in the survey sample.

The average N rate for corn following a crop other than soybeans, corn, or alfalfa was 131 lb N/A. The survey did not provide information on what was included in the category “Other”, so it is not clear why the average N rate was lower than for corn following corn or soybeans. It may have resulted from the fact that 63% of the fields where corn followed “Other” crops were in the Northwestern and Coarse-textured Soils regions, which had the lowest average N rates (Table 2).

For 23% of farmers the field they reported on was fertilized using variable rate application methods, so the N rate they reported for the survey was an average for the field. When asked whether they applied the same amount of N on all fields with similar crop rotations and no manure applied in the last five years, 29% of the farmers reported that they used different N rates on some fields.

The overall average N fertilizer rate of 140 lb N/A found in this survey was similar to the statewide average of 139 lb N/A reported by NASS for the 2005 crop year in their most recent survey of N fertilizer use in Minnesota (NASS, 2006). Both of these rates were greater than the average N rates of 108 to 122 lb N/A reported by NASS for Minnesota in the five-year period from 1999 to 2003 (NASS, 2000-2004). The surveys by NASS did not exclude fields where both manure and commercial N fertilizer were applied, which would probably result in lower average N rates than a survey like the one reported on here where manured fields were excluded.

Major N sources

Anhydrous ammonia and urea were the most commonly used chemical forms of N (Fig. 2). About 91% of survey participants used one of these fertilizers to apply the majority of the N used on their average field. Anhydrous ammonia was used by 46.3% of the farmers, while 44.9% used urea. Liquid N products, defined by the survey as UAN (urea-ammonium nitrate) solutions, were the major N source for about 6.5% of the farmers. The remaining 2.4% of the farmers either used another fertilizer as their major N source or did not know the major source of N applied to their typical field. The survey did not ask for additional information on what may have been included in the category "Other" for the major N source.

The major N source varied across the different BMP regions (Figs. 3 to 7). Urea was the dominant N source in the Northwestern (79%) and the Coarse-textured Soils (67%) regions, where only about 20% of farmers used anhydrous ammonia as their major N source. The greatest use of anhydrous ammonia was in the South Central region (64%), where urea was used as the major N source by about 29% of the farmers. The second highest rate of anhydrous ammonia use was in the Southwestern and West Central region (48%), where nearly as many farmers (43%) used urea as their major N source. In the Southeastern region, 55% used urea as their major N source and 35% used anhydrous ammonia. The Southeastern region had the greatest use of liquid N fertilizers with 9% of the farmers using them as their major N source. None of the surveyed farmers in the Northwestern region used liquid N as the major N source on the average field they reported on.

The three major N sources tended to be applied at different rates, with differences in both the amount of N applied from the major N source and the total N rate after including all N applications (Table 4). Average N rates (state-wide) from the three major sources were 132 lb N/A from anhydrous ammonia, 123 lb N/A from urea, and 113 lb N/A from liquid N. Total N rates were 146 lb N/A when anhydrous ammonia was the major N source, 136 lb N/A when urea was the major N source, and 131 lb N/A when liquid N was the major N source. Differences in N rate were probably affected by differences in the price of N among the three major N sources. The cost per unit of N is highest for liquid N, lowest for anhydrous ammonia, and intermediate for urea. As the price of N goes up, the N rate providing the maximum economic return goes down (Rehm et al., 2006).

Another factor in the greater N rates for anhydrous ammonia compared with urea may have been differences in productivity potential of the fields involved. Average yields for the previous three corn crops were 168 bu/A for the fields fertilized in 2009 with anhydrous ammonia and 152 bu/A for the fields fertilized with urea. Differences in productivity potential were not a factor in the fields fertilized with liquid N having the lowest N rates, since their average yield for the previous three corn crops was 162 bu/A.

Application timing of the major N source

About 59% of the surveyed farmers applied the majority of their N fertilizer in the spring, 32.5% did their main N application in the fall, and about 9% used sidedress (beside the row after plant emergence) applications for the majority of their N (Fig. 8). For sidedress applications, the survey did not ask whether the major N source was applied in a single application or in a series of split sidedress applications.

Application timing varied considerably, depending on the major N source. Anhydrous ammonia was applied 63% of the time in the fall and 28% of the time in the spring (Fig. 9), whereas urea was applied 90% of the time in the spring and only 4% of the time in the fall (Fig. 10). For farmers using liquid N as their major N source, 7% made fall applications, 71% made spring applications, and 23% made sidedress applications (Fig. 11).

Application timing of the major N source also varied across the different BMP regions of the state (Fig. 12). Spring N applications dominated in the Northwestern (89%), Coarse-textured Soils (70%), and Southeastern (88%) regions, fall and spring applications were equally common in the Southwestern & West Central region (about 47%), and in the South Central region 43% of surveyed farmers made their major N application in the fall and 53% in the spring. Sidedressing the major N source was most common in the Coarse-textured Soils region (25%), was not used at all in the Northwestern region, and was used by 4 to 7% of surveyed farmers in the other three regions.

Application timing is an important criteria differentiating BMPs for N use in various parts of Minnesota. In the Coarse-textured Soils and Southeastern regions, which have the highest leaching potential, fall application is not a recommended practice for any of the N sources (Rehm et al., 2008a; Randall et al., 2008a). About 5% of surveyed farmers in both of these regions made their major N application in the fall (Fig. 12), primarily as anhydrous ammonia, so there is some potential for increasing NUE in these regions by eliminating this practice. This potential may be limited in the Coarse-textured Soils region, where some of the fall N was probably applied to finer-textured soils present in the region.

In the South Central region, less than 5% of urea and liquid N applications were in the fall, but 63% of anhydrous ammonia was fall-applied. Fall N application is not a recommended BMP in this region (Randall et al., 2008b), although fall application of anhydrous ammonia is an acceptable practice if it includes a nitrification inhibitor. Use of nitrification inhibitors is discussed in the next section.

Use of N-Serve® with anhydrous ammonia

N-Serve® is a nitrification inhibitor that can be applied with anhydrous ammonia to delay the conversion of ammonium-N to nitrate-N. This can reduce N losses from nitrate leaching or denitrification. Overall, about 20.8% of the farmers applying anhydrous ammonia used N-Serve® (Table 5). The additional cost of applying N-Serve® may be a barrier to more widespread use, but there were important regional differences and differences related to the timing of anhydrous ammonia application.

Use of N-Serve® was most common in the South Central BMP region, where it was included with 35.1% of all anhydrous ammonia applications. It was used with about 15.6% of the anhydrous ammonia applications in the Southeastern region, 15.6% in the Coarse-textured Soils region, 6.7% in the Southwestern and West Central region, and 0% in the Northwestern region.

The risk of N loss is greatest with fall application, because of the long time period between N application and crop uptake, and use of N-Serve® was most common in the fall. N-Serve® was included with 28.6% of anhydrous ammonia applications made in the fall, 7.4% of spring applications, and 8.3% of sidedress applications (Table 5). Over 95% of the fall anhydrous ammonia applications were in the South Central or the Southwestern and West Central regions, but there were large differences in the use of N-Serve® between these two regions. N-Serve® was included with 51.1% of fall anhydrous ammonia applications in the South Central region and only 6.6% of fall applications in the Southwestern and West Central region. This is consistent with greater rainfall and greater potential for leaching and gaseous N losses in the South Central region and University of Minnesota Extension best management practices for N use (Randall et al., 2008b; Rehm et al., 2008b).

Use of additives and specialty formulations of urea or liquid N fertilizers

There are a number of additives and specialty formulations of urea and urea-containing liquid N fertilizers that are designed to reduce N loss. Volatilization losses of ammonia-N can occur after breakdown of urea by the enzyme urease. As with anhydrous ammonia, N losses from nitrate leaching or denitrification can occur after nitrification of ammonia/ammonium-N to nitrate-N. Gaseous N losses can also occur during nitrification itself. Products to delay these reactions and reduce the potential for N losses were used by only 8.3% of the farmers who applied urea or liquid N fertilizers as their major N source (Fig. 13). Agrotain®, a urease inhibitor that can be combined with dry urea or liquid N fertilizers, was the most commonly used additive; but it was used by only 4.2% of the farmers who applied these fertilizers. Nutrisphere® contains a water soluble polymer that is intended to protect against N losses from both volatilization and leaching. It can also be combined with both dry urea and liquid N fertilizers, but it was used by only 1.1% of the farmers who applied urea or liquid N fertilizers as their major N source. ESN® is a slow release form of N where the release of urea is physically delayed by a polymer coating on urea granules that slowly degrades. ESN® was used by 1.0% of these farmers. Super U® is a form of urea that contains inhibitors of both urease and nitrification. It was used by 0.3% of the farmers applying this group of N fertilizers as their major N source. “Other” unspecified additives were used by 1.7% of these farmers. Herbicides were probably included in this category. Use of additives and specialty formulations of urea and urea-containing liquid N fertilizers may be limited by the added costs, as well the uncertain effectiveness of some of these products.

Although their overall use across the state was low, 46% of the farmers who used additives and specialty formulations of urea and urea-containing liquid N fertilizers were in the Coarse-textured Soils BMP region of the state. This is logical, since the potential for nitrate leaching is greatest on these soils. In this region, 15% of the farmers who applied urea or liquid N fertilizers as their major N source used an additive or specialty formulation. They used Agrotain 74% of the time, presumably for non-incorporated sidedressed urea to prevent ammonia volatilization as described in the next section.

Incorporation of urea and liquid N fertilizers

Soil incorporation of urea and urea-containing liquid N fertilizers is an effective method of reducing loss of N through volatilization, although the amount of time urea remains on the surface of the soil is an important factor. The University of Minnesota Extension best management practice is to incorporate urea-containing fertilizers within three days or less following application (Randall et al., 2008b). About 75% of fall urea applications, 94% of spring applications, and 58% of sidedress applications were incorporated in less than 24 hours (Table 6). About 17% of fall applications and 40% of sidedress applications were never incorporated. Some of these may have been on irrigated fields and were watered in.

Because spring was the most common time to apply urea (Fig. 10), about 89% of all urea applications were incorporated within 24 hours (Table 6). This varied slightly throughout the state. The 24-hour incorporation rate was 100% in the Northwestern BMP region, 94% in the South Central and Southeastern regions, 88% in the Southwestern and West Central region, and 82% in the Coarse-textured Soils region. The lower rate in the Coarse-textured Soils region may have been affected by the inclusion of irrigated fields where urea was watered in after application.

All fall-applied liquid N and about 95% of spring and sidedress liquid N applications were incorporated in less than 24 hours (Table 7). The remaining spring and sidedress applications were incorporated, but incorporation occurred more than 24 hours after application.

Starter fertilizer

Nitrogen was applied in starter fertilizer by 58% of the surveyed farmers (Fig. 14). The average starter N rate was 15 lb N/A, although this varied with the physical form of the fertilizer applied. Liquid fertilizer was used by 53% of the farmers applying starter at an average N rate of 11 lb N/A. The other 47% of the farmers applying starter used a granular fertilizer at an average rate of 20 lb N/A.

Different regions of the state tended to use different forms of starter (Table 8). Liquid starter dominated in the South Central, Southwestern and West Central, and Northwestern regions. Granular starter was more common in the Southeastern and the Coarse-textured Soils regions. These results are consistent with use of granular starter fertilizers in areas where potassium application is more likely to be needed.

Rates of N applied with liquid starter were lowest in the Northwestern region, but were similar across the rest of the state. Rates of N applied with granular starter tended to be greater in the Coarse-textured Soils and the Southwestern and West Central regions than in the South Central and the Southeastern regions.

Ammonium phosphate

Nitrogen was applied as part of the phosphorus fertilizers monoammonium phosphate (MAP) and diammonium phosphate (DAP) by 57% of the surveyed farmers (Fig. 15). The average rate of N applied through MAP or DAP was 22 lb N/A. About 65% of these farmers used DAP and 35% used MAP, 55% of the applications were made in the spring and 45% in the fall, and 91% of the applications were incorporated. There was probably some overlap (double-counting) in the reporting on use of starter fertilizers and use of ammonium phosphates applied in the spring.

Split and sidedress N applications, other N sources

Farmers were also asked if they made other N applications not included in previous questions, such as "split applications, sidedress, or other forms of fertilizer containing N". About 4% of the farmers made such applications (Fig. 16), at an average N rate of 30 lb N/A. Seventeen percent of these applications were ammonium nitrate, 33% were ammonium sulfate, 23% were urea or liquid N fertilizers, 17% were unknown N sources, and the remaining 10% were from a variety of other products. These data exclude the 9% of farmers who reported using sidedress applications for their major N source (Fig. 8), some of which may have included a series of split sidedress applications.

Irrigated corn

The survey included 37 farmers who reported on an average corn field that was irrigated. This was 2.5% of the total number of farmers surveyed (Fig. 17). The 2007 Census of Agriculture reported that 4.1% of the Minnesota farms growing corn used irrigation (NASS, 2009). About 54% of the farmers in this survey who grew irrigated corn were in the Coarse-textured Soils region. The irrigated corn in other parts of the state was presumably also grown on coarse-textured soils in those regions. The number of farmers reporting on irrigated corn in this survey may not have been a large enough sample to draw reliable conclusions about average N management practices on irrigated corn in Minnesota.

The average N rate for irrigated corn was 151 lb N/A, which was greater than the overall average rate applied by all surveyed farmers of 140 lb N/A. This may have been caused by greater than average productivity potential of the irrigated corn fields included in the survey. Their average yield for the last three corn crops was 169 bu/A, compared with the overall survey average of 159 bu/A. As previously discussed in the "Average N rates" section, the differences in yield (36 bu/A) and N rate (24 lb N/A) between irrigated and non-irrigated corn in the Coarse-textured Soils region were even larger than these overall averages (Table 2).

Anhydrous ammonia and urea were the most commonly used chemical forms of N on irrigated corn (Fig. 18). Anhydrous ammonia was used as the major N source by 46% of the farmers reporting on irrigated corn and urea was the major N source for 43% of them. These percentages are very similar to the state-wide averages for use of these N sources (Fig. 2). Liquid N fertilizers supplied the majority of the N used on about 11% of the irrigated corn fields, which was more than twice their overall rate of use state-wide.

Application timing of the major N source was different for irrigated corn (Fig. 19) than the state-wide distribution of N timing reported by all surveyed farmers (Fig. 8). The largest difference was for sidedress applications, which supplied the majority of the N fertilizer used by 54% of the farmers reporting on irrigated corn compared with only 8% of all surveyed farmers. There was also a large difference in fall N applications. Less than 3% of the farmers reporting on irrigated corn applied the majority of their N in the fall, compared with nearly 35% of all surveyed farmers. Spring applications of the major N source were used by 43% of the farmers reporting on irrigated corn and 53% of all surveyed farmers. On a state-wide basis, the timing of N fertilizer application varied considerably depending on the major N source (Figs. 9 to 11), but similar variability among N sources in application timing did not occur on irrigated corn. In addition to the 54% of irrigated corn fields where the major N source was sidedressed in single or multiple applications, about 5% of the irrigated fields received a supplemental application of sidedressed N.

Fertigation was used by 19% of the farmers growing irrigated corn, meaning that some of the N was applied through the irrigation water. Irrigated corn that was fertigated received greater overall N rates (163 lb N/A) than irrigated corn that was not fertigated (148 lb N/A), although it is not clear how much of the extra N was applied through fertigation since none of these farmers reported their fertigation rates. Information was also not obtained on the number of times each of these farmers used fertigation.

The timing of N fertilizer application on irrigated corn was consistent with University of Minnesota Extension best management practices for N use on coarse-textured soils (Rehm et al., 2008b). Coarse-textured soils have a high potential for N leaching losses, so minimizing the amount of time between N application and crop uptake is a key factor in N management guidelines. Irrigated corn growers reduced the risk of N losses by avoiding fall N applications and applying N when the crop was actively growing through sidedressing and fertigation.

Soil testing

Soil testing was used as a fertility management tool by most of the farmers in the survey. About 84% of the surveyed fields had been tested in the last five years (Table 9). Farmers employed a variety of methods to collect soil samples for testing and many of them had used more than one method on their surveyed field in the last five years. More than one-half of the farmers had used traditional, random sampling methods. Almost 31% had used grid or zone sampling methods, which provide a basis for applying variable fertilizer rates within a field.

The two survey questions on soil sampling provided contradictory results on use of the nitrate-N soil test. When farmers were asked “Which methods did you use to soil sample this field within the last five years?” and given the five options listed in Table 9, less than 1% selected “Nitrate”. However, when asked “Did you take a soil nitrate sample from this field within the last five years?”, almost 47% of farmers said “Yes” (Fig. 20). The large discrepancy between these two answers may be due to ambiguity in the first question asking about the nitrate soil test. For this question there may have been some confusion about the “Nitrate” option summarized in Table 9, since “Nitrate” refers to a type of soil test and the other options are methods of selecting where in a field soil samples are collected for testing.

Use of the nitrate-N soil test was most common in the western part of the state (Table 10). About 60% of the farmers in the Northwestern and the Southwestern and West Central regions used the nitrate test, compared with about 40% of the farmers testing for nitrate-N in the

Southeastern, Coarse-textured Soils, and South Central regions. These differences are not surprising. The test measures residual nitrate-N in the field after the previous crop and is used to adjust N fertilizer recommendations for the next crop. In the drier western part of the state, leaching of nitrate is less likely to occur and the nitrate test has long been recommended to account for residual N (Rehm et al., 2006). It is also routinely used for sugar beets grown in that part of the state (Lamb et al., 2001). A spring nitrate test was developed more recently for other parts of the state, but it is recommended for a more limited range of conditions (Rehm et al., 2006) and its use by 40% of farmers outside of western Minnesota was probably greater than expected. It could be that many farmers in those parts of the state are not familiar with the nitrate-N soil test and answered the second question under the assumption that an N test would have been included with the standard set of soil fertility tests.

Conclusions

This survey provides the most comprehensive set of data on N fertilizer use on field corn that has been collected in Minnesota. It includes detailed information on application rates, timing, placement, and the chemical form of the fertilizer used. The number of farmers successfully interviewed and their distribution across the state indicates that the results can be used to accurately characterize current N fertilizer management practices in the state. This information can be used to target research and education programs to improve N management for both production and environmental goals. An important conclusion from the survey data is that N fertilizer use by Minnesota corn farmers is generally consistent with University of Minnesota Extension N management guidelines.

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Rehm, George, Gyles Randall, John Lamb, Roger Eliason. 2006. *Fertilizing Corn in Minnesota*. Publication #FO-0379O, University of Minnesota Extension.

Table 1. Number of corn acres grown on surveyed farms in 2009 compared with the distribution of corn acres on all Minnesota farms growing corn in 2007.

Acres of corn grown	**Surveyed farms**	**All MN farms***
	--------------- % of total ----------------	
1-24	5.0	12.5
25-99	20.1	30.1
100-249	30.5	27.1
250-499	24.1	17.0
500-999	14.2	9.5
1000 or more	6.1	4.1

*2007 Census of Agriculture (NASS, 2009). Percentages sum to 100.3% because of rounding.

Table 2. Average N fertilizer rates applied to corn in 2009 by surveyed farmers reporting on an average field, and average yields of previous corn crops grown in that same field, in different BMP regions of Minnesota.

BMP region	**N rate**	**Previous yield***
	lb/acre	bu/acre
Northwestern	131	137
Coarse-textured Soils	129**	127**
Irrigated***	151	160
Non-irrigated	127	124
Southwestern and West Central	139	161
South Central	146	174
Southeastern	140	166
Overall	140	159

*Average yields of the previous 3 corn crops in the surveyed fields.

**Average for all fields in the region.

***8.1% of the fields in the Coarse-textured soils region were irrigated.

Table 3. Nitrogen fertilizer rates on corn following different crops in 2009 by surveyed farmers reporting on an average field.

Previous crop	**N rate** (lb/acre)	**% of fields**
Soybeans	140	74.8
Corn	145	16.8
Corn/alfalfa*	129	2.0
Alfalfa	97	2.0
Other	131	4.4
Overall	140	100

*2009 was the 2nd year of corn following a previous alfalfa crop.

Table 4. Differences in N rate among the three major N sources applied to corn in 2009 by surveyed farmers reporting on an average field.

Major N source	N rate from major source	Total N rate
	---------------- lb/acre ---------------	
Anhydrous ammonia	132	146
Urea	123	136
Liquid N	113	131

Table 5. Anhydrous ammonia application to corn and use of the nitrification inhibitor N-Serve in 2009 by surveyed farmers reporting on an average field.

AA application time	N-Serve used (%)
Fall	28.6
Spring	7.4
Sidedress	8.3
Overall	20.8

Table 6. Incorporation practices following application of urea as the major N source for corn in 2009 by surveyed farmers reporting on an average field.

Urea application time	Incorporation timing (%)		
	< 24 hours	> 24 hours	Not incorporated
Fall	74.3	8.6	17.1
Spring	93.8	1.7	4.5
Sidedress	57.5	2.5	40.0
Overall	89.3	2.6	8.2

Table 7. Incorporation practices following application of liquid N fertilizer as the major N source for corn in 2009 by surveyed farmers reporting on an average field.

Liquid N application time	Incorporation timing (%)		
	< 24 hours	> 24 hours	Not incorporated
Fall	100.0	0.0	0.0
Spring	95.7	4.3	0.0
Sidedress	94.7	5.3	0.0
Overall	95.9	4.1	0.0

Table 8. Differences in the physical form and N rate of starter fertilizer used on corn in different BMP regions of the state in 2009 by surveyed farmers reporting on an average field.

BMP region	**Form**	**% of farmers**	**N rate** (lb/acre)
Northwestern	liquid	84.2	7
	granular	15.8	---
Coarse-textured Soils	liquid	20.5	13
	granular	79.5	25
Southwestern and West Central	liquid	79.5	11
	granular	20.5	20
South Central	liquid	73.1	11
	granular	26.9	15
Southeastern	liquid	35.4	13
	granular	64.6	16

Table 9. Soil sampling methods used in the last five years by surveyed farmers reporting on an average field.

Sampling method	**% of farmers***
Traditional	56.8
Grid	20.1
Zone	10.5
Nitrate	0.9
None	15.9

*Total is greater than 100%, because some farmers used more than one method.

Table 10. Use of the soil nitrate test in the last five years in different BMP regions of the state by surveyed farmers reporting on an average field.

BMP region	**% of farmers**
Northwestern	65.9
Coarse-textured Soils	38.2
Southwestern and West Central	57.7
South Central	41.9
Southeastern	36.6

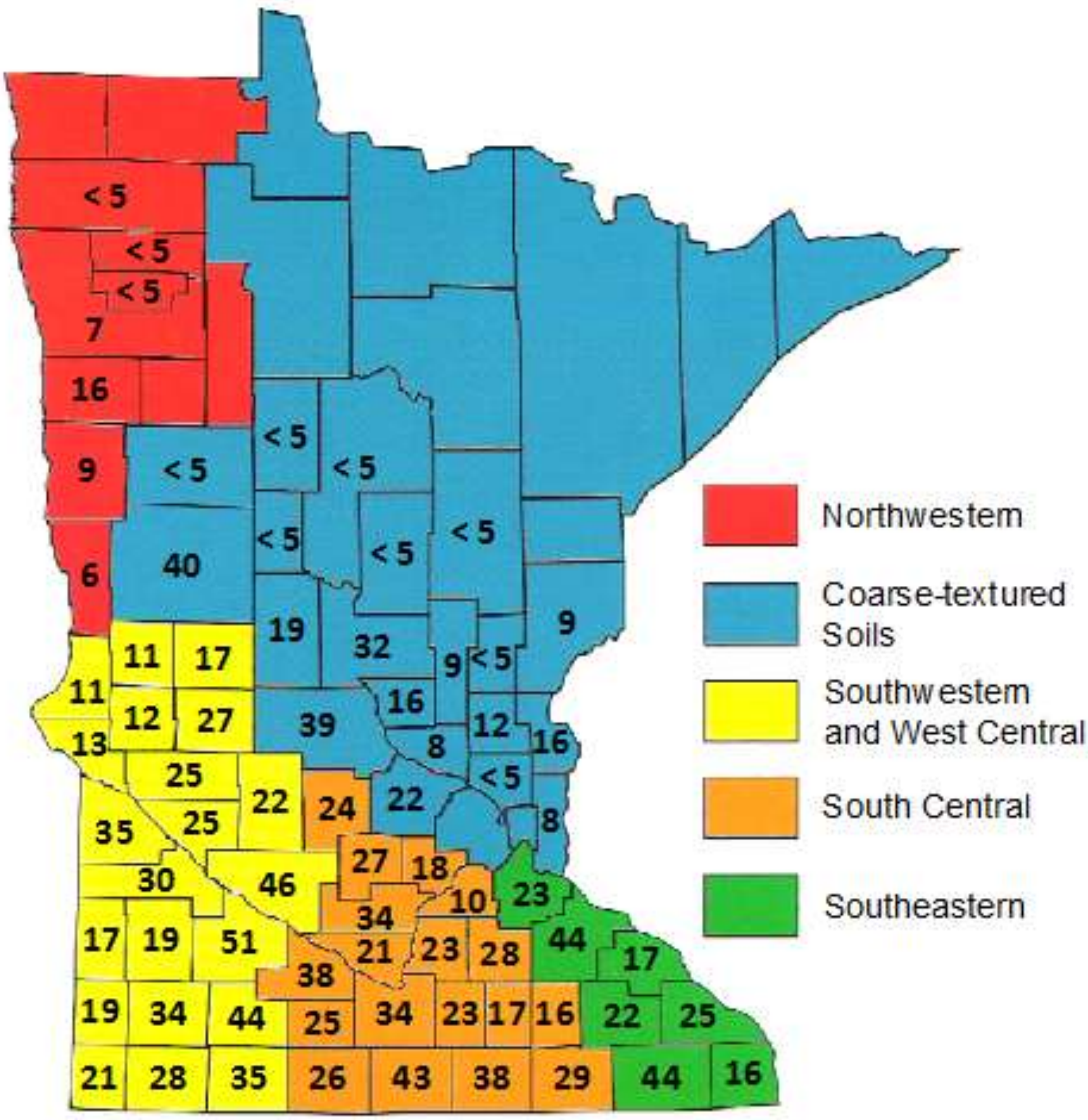

Figure 1. State-wide distribution by county of farmers participating in the survey of nitrogen fertilizer use on corn in the 2009 growing season and division of the state into regions for nitrogen Best Management Practices.

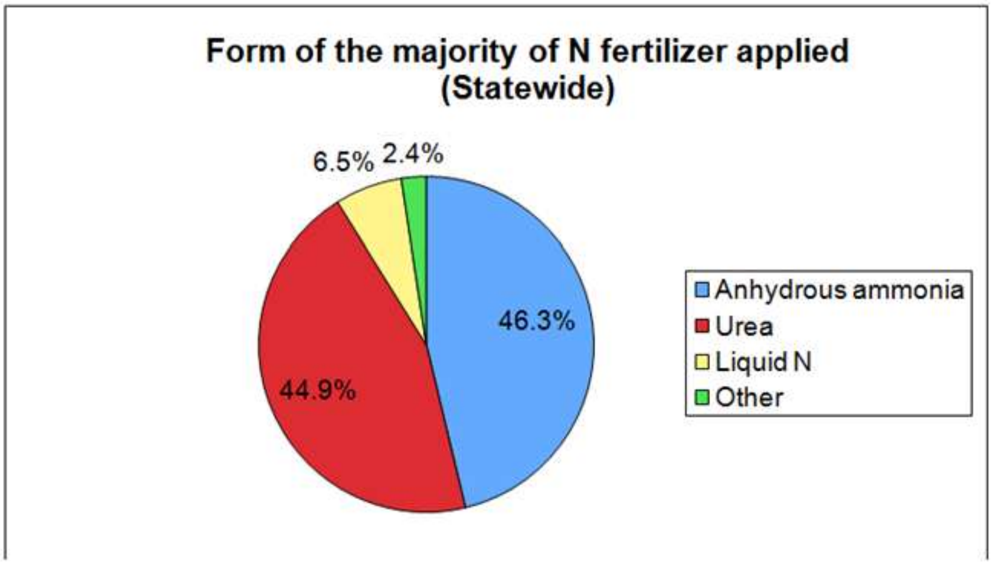

Figure 2. Chemical form of the majority of the N applied to corn in 2009 by surveyed farmers reporting on an average field. Percentages sum to 100.1% because of rounding.

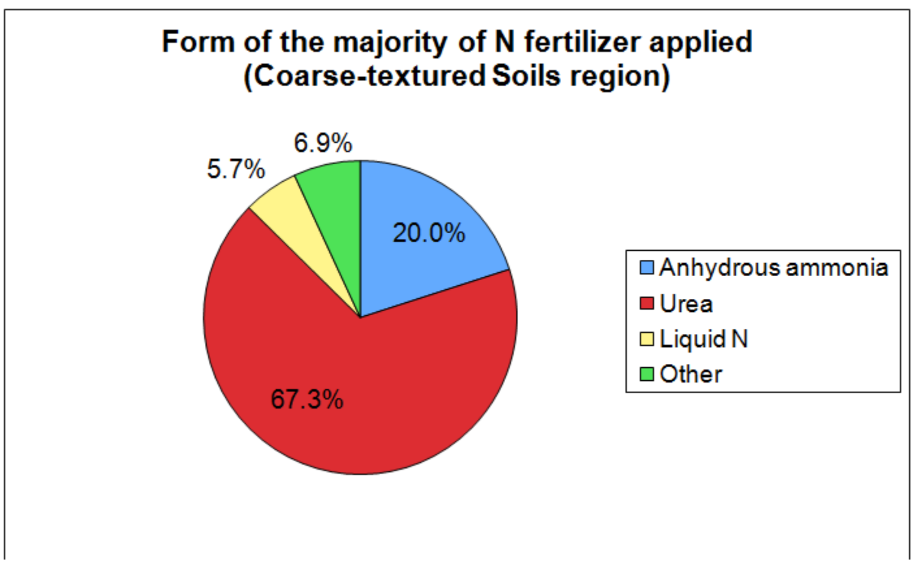

Figure 3. Chemical form of the majority of the N applied to corn in the Coarse-textured Soils region in 2009 by surveyed farmers reporting on an average field. Percentages sum to 99.9% because of rounding.

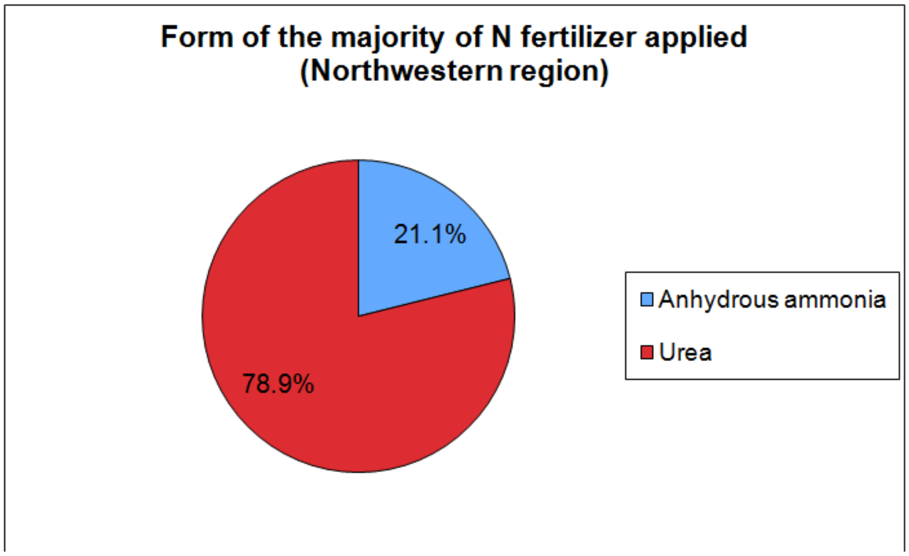

Figure 4. Chemical form of the majority of the N applied to corn in the Northwestern region in 2009 by surveyed farmers reporting on an average field.

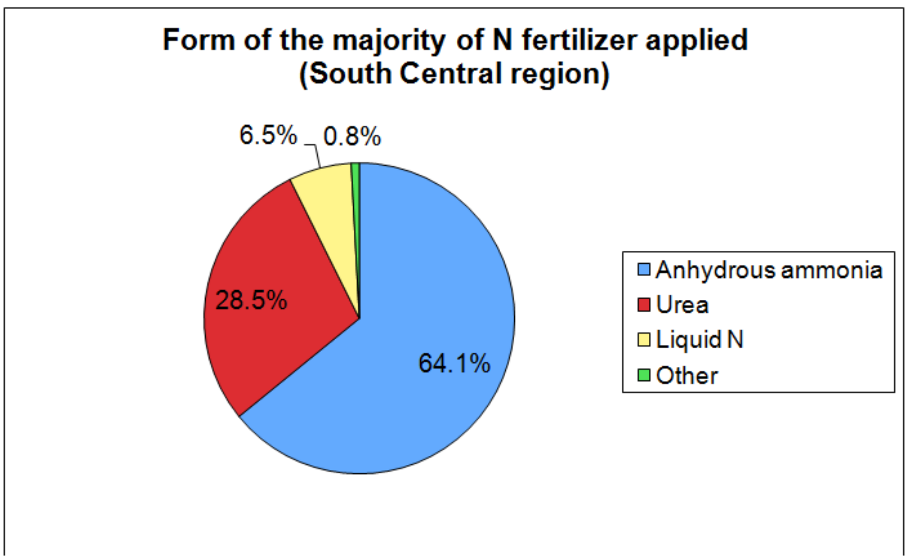

Figure 5. Chemical form of the majority of the N applied to corn in the South Central region in 2009 by surveyed farmers reporting on an average field. Percentages sum to 99.9% because of rounding.

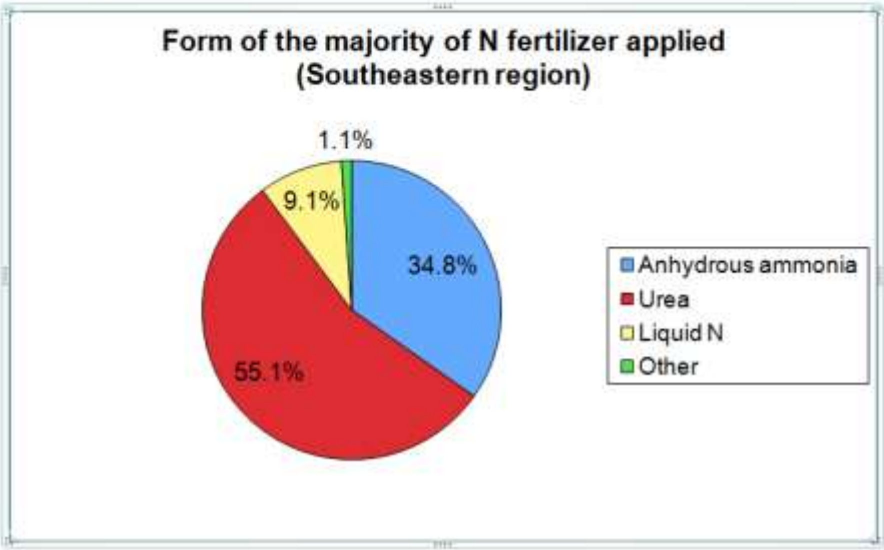

Figure 6. Chemical form of the majority of the N applied to corn in the Southeastern region in 2009 by surveyed farmers reporting on an average field. Percentages sum to 100.1% because of rounding.

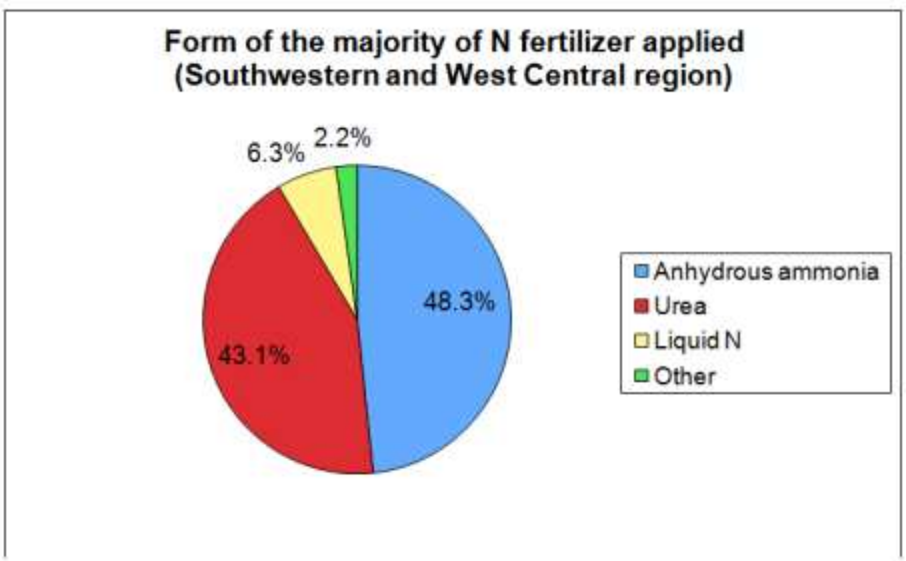

Figure 7. Chemical form of the majority of the N applied to corn in the Southwestern and West Central region in 2009 by surveyed farmers reporting on an average field. Percentages sum to 99.9% because of rounding.

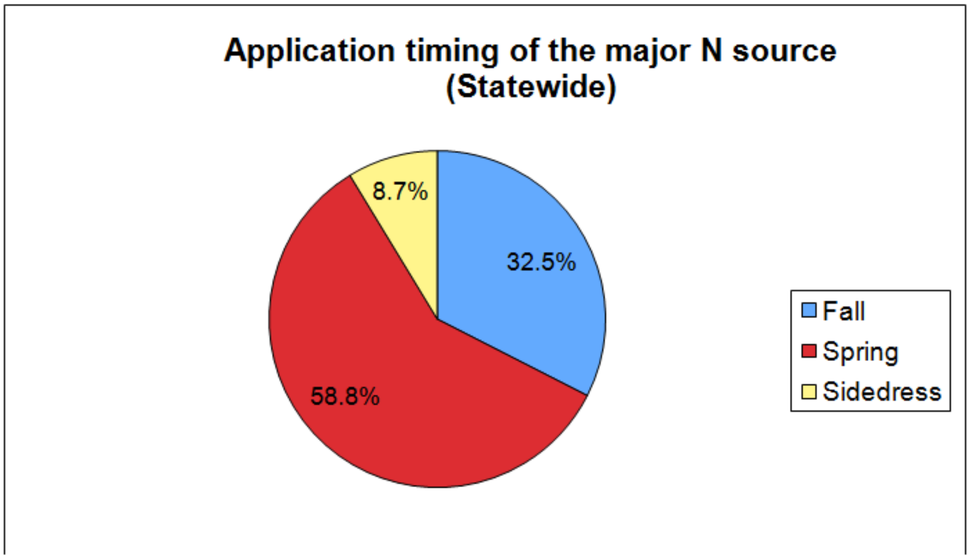

Figure 8. Application timing for the major source of N applied to corn in 2009 by surveyed farmers reporting on an average field.

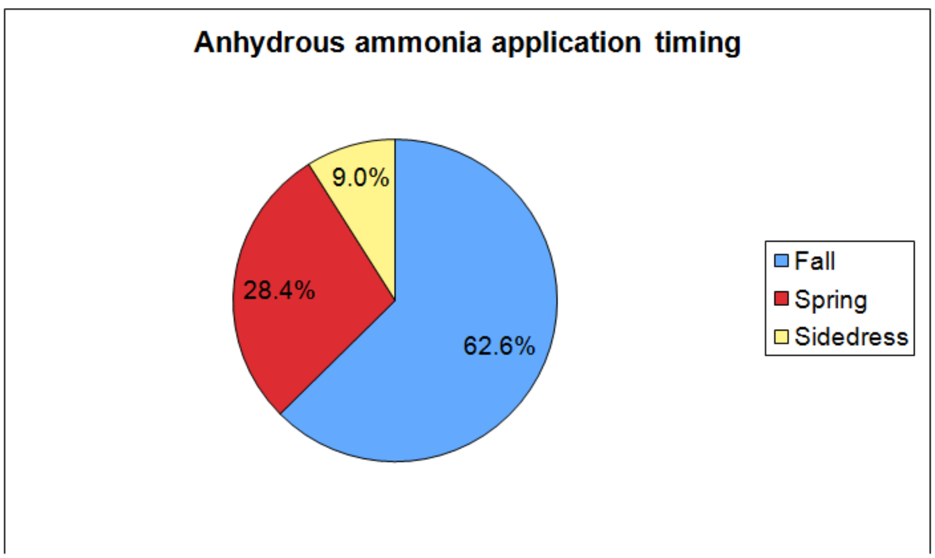

Figure 9. Application timing for anhydrous ammonia used as the major source of N applied to corn in 2009 by surveyed farmers reporting on an average field.

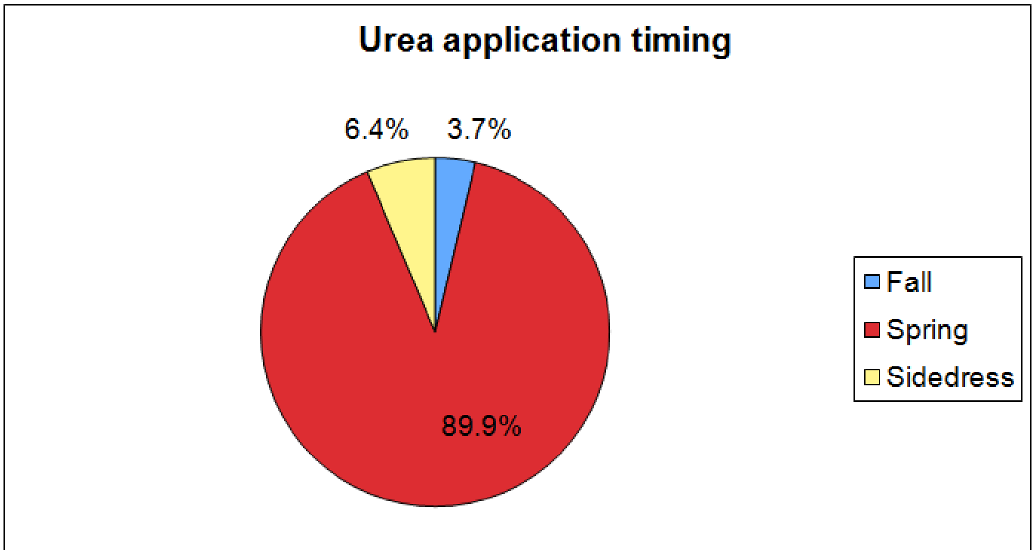

Figure 10. Application timing for urea used as the major source of N applied to corn in 2009 by surveyed farmers reporting on an average field.

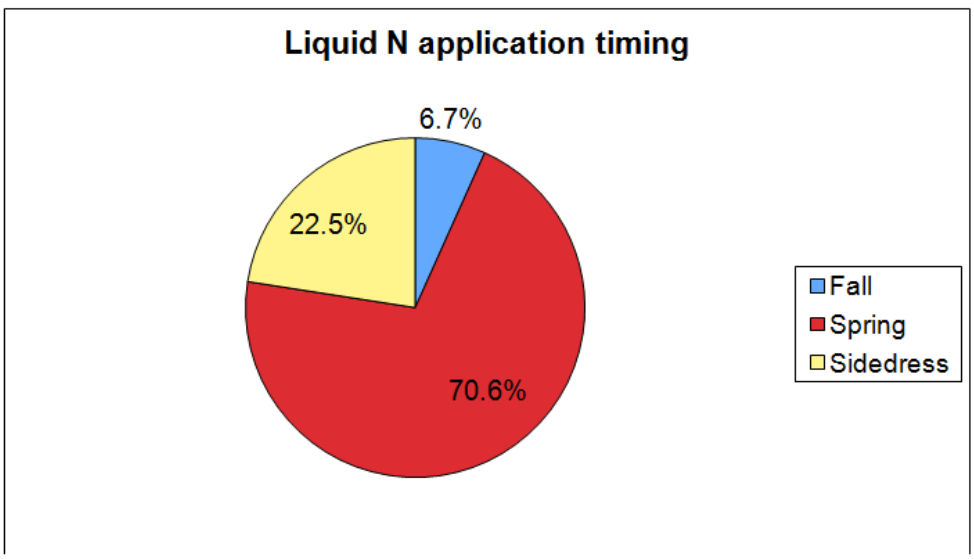

Figure 11. Application timing for liquid N fertilizers used as the major source of N applied to corn in 2009 by surveyed farmers reporting on an average field. Percentages sum to 99.8% because of rounding.

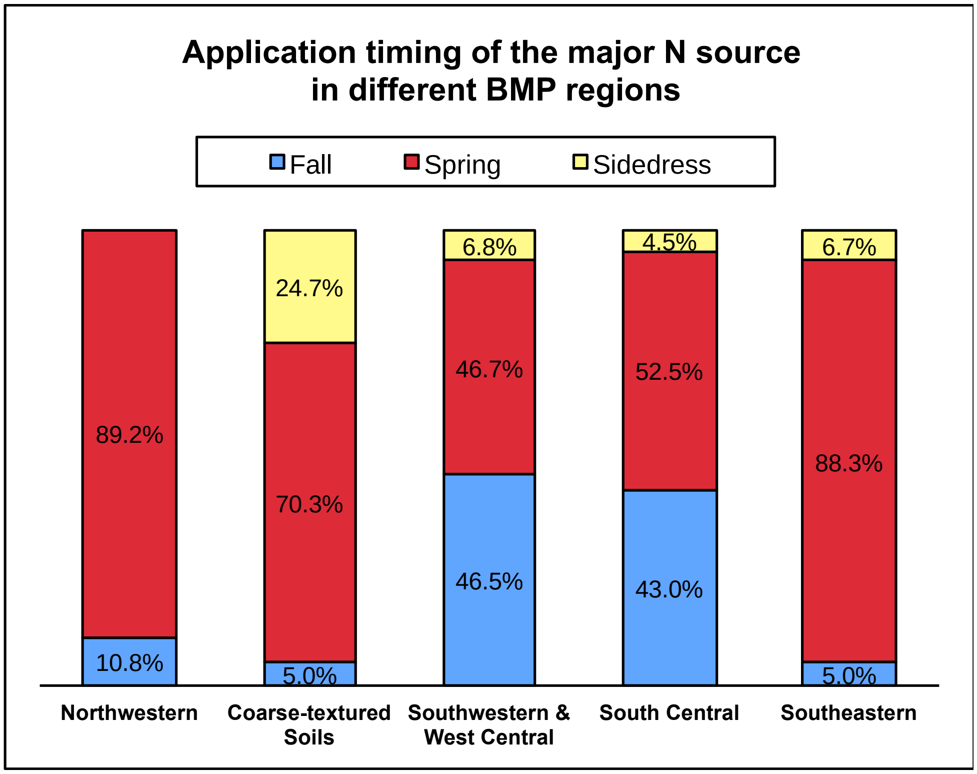

Figure 12. Application timing for the major source of N applied to corn in different BMP regions of the state in 2009 by surveyed farmers reporting on an average field.

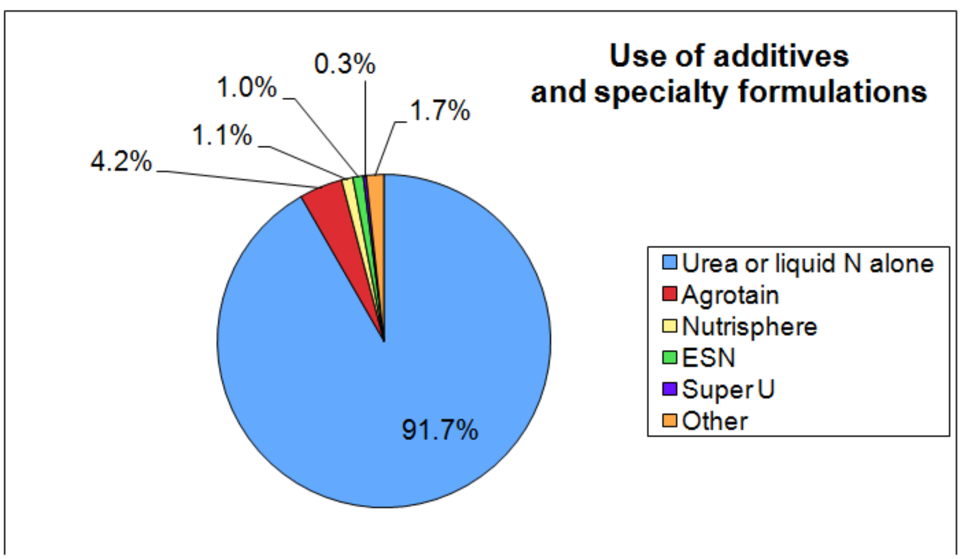

Figure 13. Use of additives and specialty formulations of urea and liquid N fertilizers applied to corn in 2009 by surveyed farmers reporting on an average field.

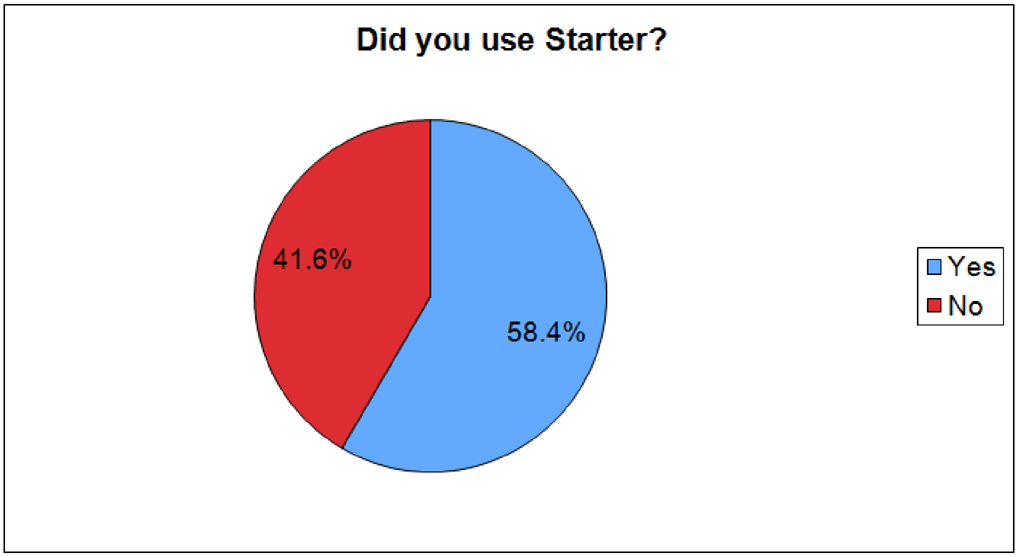

Figure 14. Application of N in starter fertilizer applied to corn in 2009 by surveyed farmers reporting on an average field.

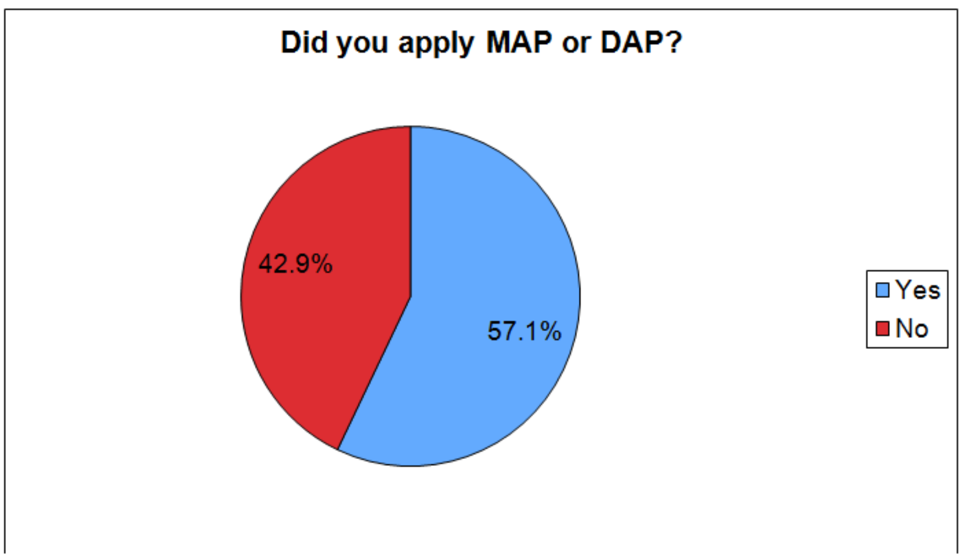

Figure 15. Application of N in MAP (monoammonium phosphate) or DAP (diammonium phosphate) applied to corn in 2009 by surveyed farmers reporting on an average field.

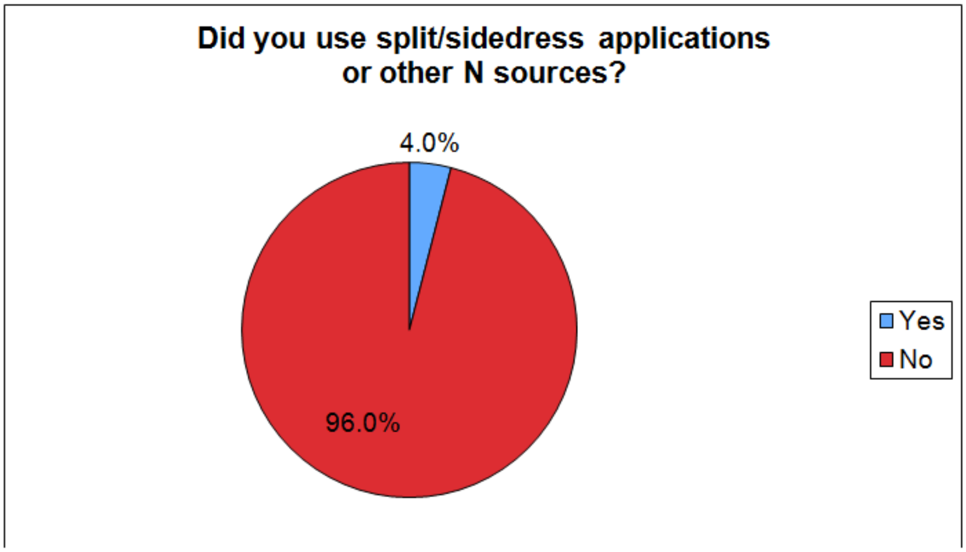

Figure 16. Use of split applications, sidedress applications, or other forms of fertilizer containing N applied to corn in 2009 by surveyed farmers reporting on an average field.

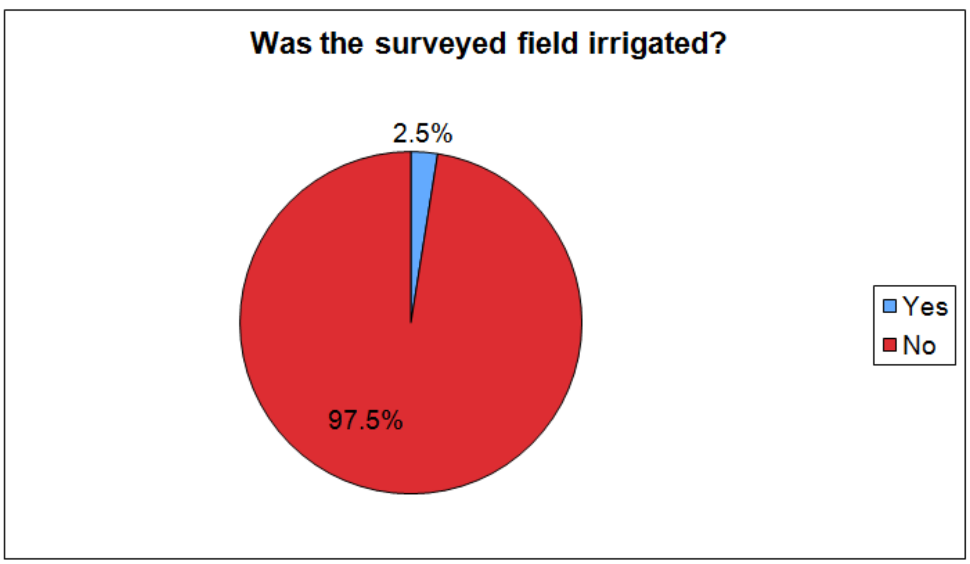

Figure 17. Use of irrigation on corn in 2009 by surveyed farmers reporting on an average field.

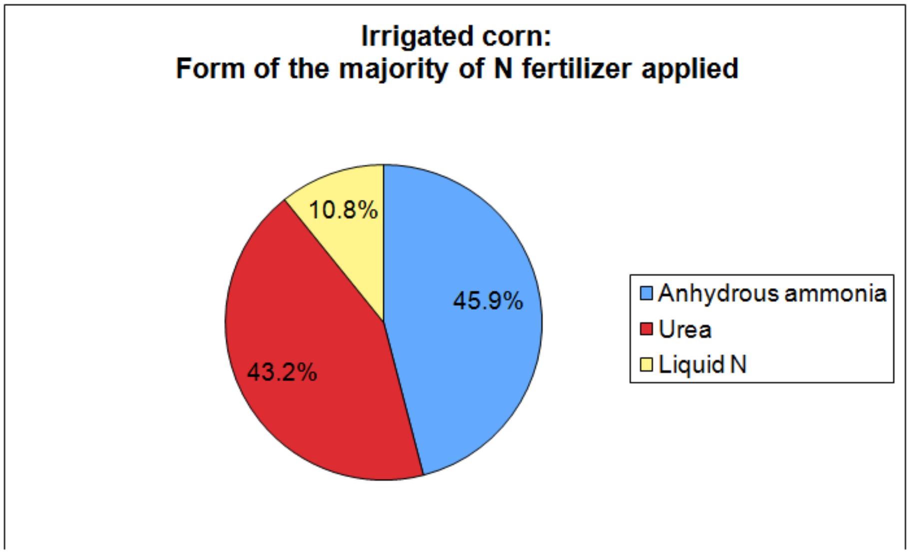

Figure 18. Chemical form of the majority of the N applied to irrigated corn in 2009 by surveyed farmers reporting on an average field. Percentages sum to 99.9% because of rounding.

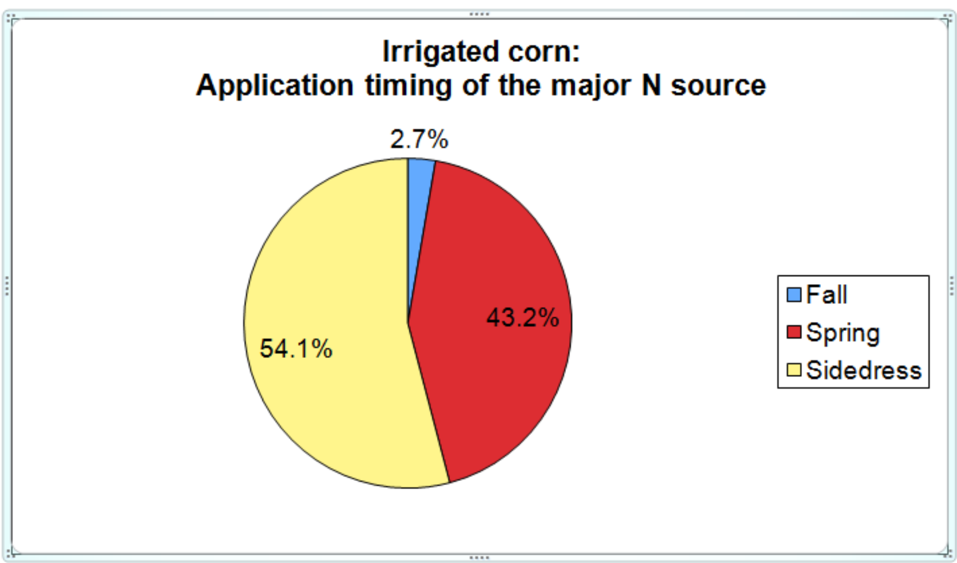

Figure 19. Application timing for the major source of N applied to irrigated corn in 2009 by surveyed farmers reporting on an average field.

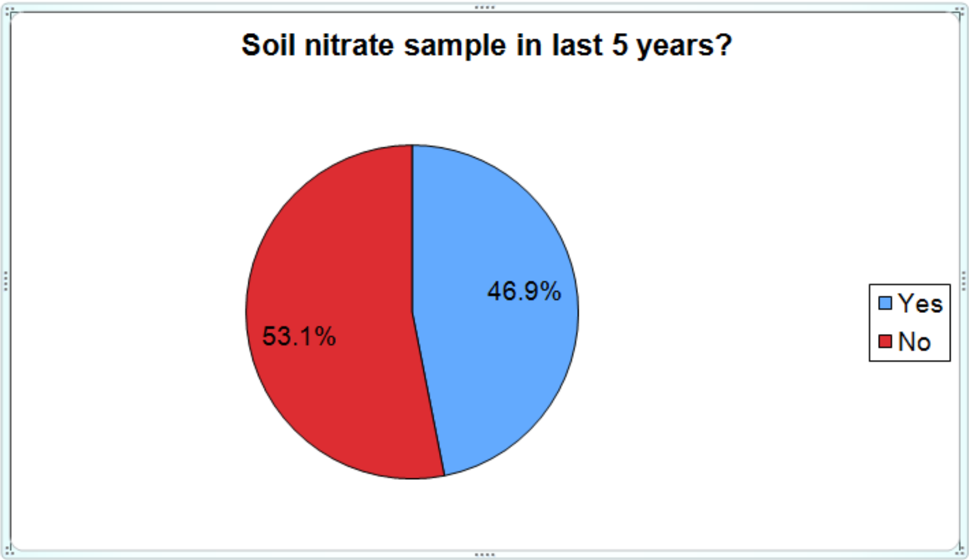

Figure 20. Use of the nitrate-N soil test in the last five years by surveyed farmers reporting on an average field.