DEPARTMENT OF AGRICULTURE

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September 15, 2017

Chris Steller
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RE: PT contract # 109681 MN Department of Agriculture (MDA) and University of Minnesota, Office of Sponsored Projects Final Report

Project: Continuation of an evaluation of variable rate nitrogen technologies for corn in Minnesota

Dear Chris:

Here is complete copy of the final report submitted to the Minnesota Department of Agriculture Pesticide and Management Division. The electronic copy was emailed to you on September 5, 2017.

I am submitting only one print copy. This report was prepared by the contractor and according to the project manager is not mandated by law.

Please note that this agreement started out as a grant but was changed to a PT contract at the direction of the Department of Agriculture's Director of Finance. The final report covers the entire project of the original grant and the converted part to a PT contarct.

Please contact me at (651) 201-6196 if you have questions.

Sincerely,

Kam Carlson

Kam Carlson
Contracts & Grants Coordinator
Pesticide & Fertilizer Management Division
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625 Robert Street N.
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Enclosures: One copy of final report for project listed above

AFREC FINAL REPORT

PROJECT NUMBER: R2013-26 MDA MN DEPT OF AG/64274 PO-3-5-8569

PROJECT TITLE: Evaluation of Variable Rate Nitrogen Technologies for Corn in Minnesota

INVESTIGATORS: Jeffrey Vetsch, Brad Carlson and Ryan Miller.

INTRODUCTION

Improving nitrogen (N) use efficiency in crop production is important for obvious economic and environmental reasons. Nitrogen fertilization of corn usually provides the greatest return on investment of any crop input; therefore, farmers and their agricultural advisors must insure adequate N is available for the crop to maximize yields and economic returns. Soil contains N in organic (soil organic matter and microorganisms) and inorganic (ammonium and nitrate) forms. Nitrate is mobile in the soil and can be lost due to leaching and denitrification both of which have environmental consequences. Minimizing N loss and maximizing crop productivity is critical for increasing nitrogen use efficiency (NUE) in corn.

Crop rotation, N source, N rate, time of N application and the use of N stabilizers are all factors considered when making N recommendations. Generally, N application timing and N rate are the most scrutinized of these management decisions. The ideal time to apply fertilizer N would be just prior to the crops demand for N. Corn uses only 10% of its total N need prior to the V5 growth stage (V5 usually early June in Minnesota). From V5 to R2 the rate of N uptake peaks (Abendroth et al., 2011). At R3, the rate of uptake diminishes but uptake continues through R5. The uptake pattern of corn suggests the ideal time to apply N in corn is early June. However, June is the wettest month in most Minnesota counties and waiting until early June to sidedress all fertilizer N for corn is risky for both farmers and their fertilizer dealers. Therefore, some or all fertilizer N is applied prior to planting when farmers have more time and soil conditions allow, especially on medium and fine textured soils. The desire to increase yields and NUE while minimizing N losses has resulted in a dramatic increase in sidedress applications of N in Minnesota in recent years. For some of the same reasons farmers are also interested in "fine tuning" their N rates.

Minnesota and several other Midwest states use the Maximum Return To Nitrogen (MRTN) approach for making N recommendations (Sawyer et al., 2006). Hundreds of site-years of N rate research plots, where Economic Optimum Nitrogen Rate (EONR) was determined, were included in this recommendation algorithm. The MRTN database has shown optimum N rates are not influenced by yield level and the MRTN approach assumes rates are relatively stable across time and landscape positions within a field. The MRTN rate recommendations are affected or adjusted based on crop rotation, price of N and corn and by soil type (parent material and/or productivity rating) in some states. Research has shown and soil scientists generally agree EONR can vary across landscape and time. However, predicting this variability, which is primarily driven by weather, and incorporating it into N recommendations has been difficult.

The majority of plant available nitrogen comes from two sources, N mineralized from soil organic matter and N additions (commercial fertilizer and manures). Mineralization of N and N losses from leaching and denitrification vary as a result of soil and climatic factors (primarily excessive rainfall), which cannot be predicted. The length of time between N application and N uptake in corn drives these losses. Adjusting N rates in-season with sidedress applications has been proposed as a method to improve N recommendations and N use efficiency (NUE).

The pre-sidedress nitrogen test (PSNT) was first proposed by Magdoff et al. (1984) as a 0-1 ft soil nitrate test taken just prior to sidedress, when corn was about 12-inches tall. The premise of the PSNT was waiting until sidedress time to sample would integrate early spring N mineralization from organic matter and spring weather conditions that drive both the amount of N available for the plant and the loss of N from the soil (Magdoff, 1991). This research showed the PSNT improved N recommendations in the northeast USA and eastern

Midwest. The PSNT was adopted by some growers who regularly applied some or all fertilizer N at sidedress. Fox et al. (1989) found the PSNT was effective at establishing a critical level for when no additional fertilizer N was needed, but it could not be accurately calibrated to base or adjust sidedress N recommendations. In Iowa, Blackmer et al. (1989) found the PSNT had great potential for improving N management in the Corn Belt, however they concluded as did Fox et al., the PSNT was best at predicting when no additional fertilizer N was needed.

In Minnesota, Schmitt and Randall (1994) compared the PSNT to a preplant nitrate test (PPNT) taken to a 0-2 ft depth. They found the PPNT was a sound, accurate and more practical soil N test for Minnesota growers, who were less likely to sidedress N. They developed an algorithm that predicted a soil N credit based on the PPNT result. The best results were obtained and the algorithm was developed from N responsive continuous corn experiments. They proposed a soil N credit, based on the PPNT, would be subtracted from a conventional N rate recommendation (based on yield goal at that time). The Minnesota PPNT should not be used on coarse textured soils and has the greatest potential for success for corn grown after corn and corn grown following a dry growing season (Schmitt and Randall, 1994).

Currently in Minnesota, there is interest in using sidedress N applications to "fine-tune" current N recommendations, primarily for yield enhancement. The objectives of this research project are 1) to demonstrate and evaluate soil-based (PSNT) methods for making in-season N rate adjustments (recommendations); 2) to evaluate the method's ability to integrate climate and landscape based variability at the field scale; 3) to compare this PSNT approach for making N recommendations to a conventional preplant application by measuring grain yield, N removal, residual soil nitrate and economic return; and 4) to determine if the PSNT approach will improve N management for corn in Minnesota.

METHODS

Eight research sites were established in southern Minnesota from 2014 through 2016. Three were corn following soybean and five were corn following corn. A randomized complete block design of field length strips with four replications was used at each location. The width of strips depended on available application equipment and the length of strips depended on field size and plot layout. Three fertilizer N treatments were applied as field length strips either with commercial application equipment or by the farmer. Two of the three treatments consisted of a preplant fixed N rate plus a sidedress rate to be applied around V6. For treatment number 1 "fixed", a fixed rate of N (100 or 105 lb N/ac for corn after soybean and 150 lb N/ac for corn after corn) was applied preplant followed by a fixed sidedress rate of 35-40 lb N/ac for corn after soybean and 50 lb N/ac for corn after corn. For treatment number 2 "variable", a fixed rate of N (similar to treatment # 1) was applied preplant with the intention of applying a variable sidedress rate averaging about 50 lb N/ac. This variable rate would be based on PSNT soil samples collected from these plots. The third treatment was a preplant only application of 120 lb N/ac for corn after soybean and 165 lb N/ac for corn after corn (U of M, MRTN based rate at 0.10 price ratio).

Soil samples [12-15 (0.75-inch diameter) cores to a 6-inch depth] were taken prior to planting on 2.5 ac grids to characterize the research site within the field. These samples were kept cool and moist before being delivered to Solum (Climate Corp.) in Ames, IA where they were analyzed for P, K, Zn (Mehlich III extractant), pH, soil organic matter (SOM), and cation exchange capacity (CEC). At the V1-2 and V4-6 growth stages of corn, PSNT soil samples [8-10 (0.75-inch diameter) cores] were taken from multiple locations (2-4 locations) in each strip-plot at 0-1 and 1-2 ft depths. The variable treatment was sampled by "zones" which were determined by Central Farm Service (CFS); whereas, the fixed and U of M treatments were sampled on regular grids (regular intervals within a strip-plot). These samples were kept cool and moist before being delivered to CFS lab where they were analyzed for nitrate using the No-Wait Rapid Nitrate testing tool (Solum Inc., Mountain View, CA). After being thoroughly mixed and analyzed for nitrate (rapid moist test) the samples were returned to the U of M SROC, dried at 125 degree F, ground and analyzed by a commercial lab for nitrate and ammonium nitrogen. After harvest, soil samples [2 (1.75-inch diameter) cores] were taken from each plot location (2-3 locations per strip-plot) at 0-2 and 2-4 ft depths. These samples were dried at 125 degree F, ground and analyzed by a commercial lab for nitrate and ammonium nitrogen.

Grain yield data were collected using the farmer cooperators combine via yield monitor and weigh wagon. The producer's combine yield monitors were calibrated prior to harvest. A single grain sample was collected from each strip and analyzed for protein via NIR. Yield monitor data were processed using GK Technologies Ag Data Manager software. Partial Factor Productivity (PFP) was calculated by dividing grain yield by the N applied and is reported as bushels per pound of N.

During the growing season remote sensing data (Crop Circle and aerial imagery) were collected at some sites to assist in evaluating the N response of corn to N treatments. The imagery was also used to identify problem areas (primarily plant stand and excess water issues) within the fields. The date each experimental procedure was completed at each location are presented in Table 1.

RESULTS AND DISCUSSION

Weather data

Weather data for each location are summarized monthly in Appendix Tables B–I, weekly in Tables 3a–h; and daily in Figures 1a–h. In-situ weather stations were installed at each location after planting to minimize the inconvenience for the farmer cooperator, which was especially important in a late spring like 2014. Prior to installation, precipitation data were obtained from the local observer network (State Climatology website) and temperature data were taken from Waseca if no local data were available. All climatic data were summarized at 8 am for the previous 24-hour period.

Late April and early May were cool and wet at both locations in 2014. Frequent rainfall events did not allow time for field operations or planting in south-central Minnesota during this period of 2014. Nearly two inches of precipitation was recorded at BP14 (Table 3a) in the first two weeks of May; whereas, NF14 (Table 3b) had 3.68 inches during the same period. Near the end of May, drier and warmer weather allowed for planting to be performed at both sites. Excessive rainfall occurred during a period from June 14–20, 6.6 and 5.7 inches were recorded at BP14 and NF14, respectively. Soils were saturated for several days as evidenced by the spike in soil moisture (Figure 1a and 1b), especially at BP14. These conditions were ideal for denitrification and leaching losses of fertilizer N applied in May. July was cool and drier than normal as was the first three weeks of August at both locations. Soil moisture declined steadily from mid July through the third week of August when much needed precipitation brought some relief to moisture stressed corn plants. Cool temperatures persisted throughout much of the growing season resulting in considerable less than normal growing degree unit accumulation (GDU). GDU's from planting to first frost totaled only 2112 and 2101 at BP14 and NF14, respectively. These totals are about 400 less than normal and resulted in corn that had not fully matured prior to an early frost on September 13. Less than ideal growing conditions – wet spring, late planting, excessively wet June, cool and dry summer and early freeze – resulted in poor corn yields in these studies and throughout south-central Minnesota in 2014.

In 2015, April and the first half of May were dry with near normal temperatures at all locations (Tables 3c, 3d and 3e). These conditions allowed for timely planting and other field operations to be performed. Growing season rainfall was very well distributed throughout the growing season, especially at NF15 and WA15 (Figures 1c and 1d). Rainfall events of two inches or more occurred only once at NF15 and twice at WA15. There were three such events at CG15; moreover, they occurred on June 17–23 and July 24–27. These events had high intensity rainfall and resulted in considerable runoff. This minimized the length of time that soils were saturated for a few days for each event. Saturated conditions are ideal for denitrification and leaching losses of fertilizer N. At all locations the period from late August through early September was unusually wet. This weather was ideal for the development of corn leaf diseases, which were prevalent at the WA15 location. This wet late summer period had minimal impact on N availability to the nearly mature corn crop. Near or slightly cooler-than-normal temperatures persisted throughout much of the growing season. September and October were warmer-than-normal, which resulted in greater than normal GDU. Growing degree units from planting to first frost ranged from 2450 to 2650 among the three 2015 locations.

In 2016, April and May had less than normal precipitation and greater than normal temperatures at all locations (Tables 3f, 3g and 3h). These conditions allowed for timely planting and other field operations to be performed. Precipitation was greater than normal at all locations in July, August, and September, especially at WA16 and CG16 (Appendix Tables G, H, and I). Rainfall events of two inches or more occurred three times at NF16, once at CG16, and five times at WA16. Rainfall was generally well distributed throughout the growing season at Northfield; whereas, soils were saturated for a several days in July, August, and September at WA16 and for several days in September at CG16. Saturated conditions are ideal for denitrification and leaching losses of fertilizer N. At all sites September was unusually wet. The entire growing season had near or greater-than-normal temperatures, which resulted in greater than normal GDU. Growing degree units from planting through September ranged from 2671 to 2752 among the 2016 locations.

Soil test values and soil characteristics

Grid soil samples (0-6 inch depth) were taken to characterize the variability within the experimental area. At BP14 the dominant soil series was a Maxcreek silty clay loam and to a lesser extent Merton silt loam (Table 2.). Soil organic matter ranged from 2.7 – 10.5% and averaged 5.5%. Cation exchange capacity and pH also varied considerably at this location from 13 – 43 meq/100 g for CEC and 5.6 – 7.7 for pH. Nitrate concentration averaged across sampling areas was only 0.7 ppm. These very low surface soil NO_3-N values were likely the result of a winter rye cover crop seeded after soybean in 2013. Soil test P and K (Mehlich III extractant) averaged 54 ppm (range of 21 – 99) and 151 ppm (range of 99 – 218), respectively. About 30% of grid samples tested < 130 ppm K which may have resulted in some potential K deficiency; however, fertilizer K was applied in the fall of 2013.

At NF14 the dominant soil series was a Hayden loam and to a lesser extent Dundas silt loam and Le Sueur loam. Soil organic matter ranged from 1.7 – 4.2% and averaged 2.9%. CEC and pH also varied from 11 – 25 meq/100 g and 5.9 – 7.6, respectively. Nitrate concentration at NF14 averaged 3.6 ppm which is less than normal for corn following soybean. Soil test P and K averaged 48 ppm (range of 22 – 69) and 151 ppm (range of 178 – 335), respectively.

At NF15 the dominant soil series was a Blooming silt loam and to a lesser extent Lester loam. Soil organic matter ranged from 2.1 – 4.7% and averaged 3.6%. CEC and pH also varied from 9 – 22 meq/100 g and 5.8 – 7.4, respectively. Nitrate concentration at NF15 averaged 3.2 ppm and ranged from 0.7 – 9.0 ppm. Soil test P and K averaged 45 ppm (range of 31 – 80) and 136 ppm (range of 92 – 245), respectively.

At CG15 the dominant soil series was a Hamel loam and to a lesser extent Lester loam. Soil organic matter ranged from 2.6 – 7.0% and averaged 4.6%. CEC ranged from 17 – 35 meq/100 g while pH ranged from 5.1 – 7.2. The 2.5 ac grid samples at CG15 were taken after preplant N application; therefore, the nitrate concentration averaged 18.6 ppm. Soil test P and K averaged 38 ppm (range of 17 – 94) and 131 ppm (range of 72 – 241), respectively. Soil test K values < 100 ppm were observed on the western 1/3 of the plot area.

The WA15 location had nearly equal amounts of Webster and Nicollet clay loam soils. Soil organic matter ranged from 4.2 – 8.3% and averaged 5.6%. The CEC ranged from 15 – 36 meq/100 g and pH ranged from 5.7 – 6.9. Nitrate concentration averaged 7.2 ppm but varied from 1.6 – 20.3 ppm. However if the sample at 20.3 ppm was removed from the data set, the range was only 1.6 – 10.5 ppm. Soil test P and K averaged 34 ppm (range of 13 – 58) and 250 ppm (range of 129 – 456), respectively.

At NF16 the dominant soils were Lester loam and Blooming silt loam. Soil organic matter ranged from 2.7 – 4.1% and averaged 3.4%. CEC and pH ranged from 13 – 18 meq/100 g and 5.7 – 7.0, respectively. Nitrate concentration at NF16 averaged 4.8 ppm and ranged from 3.0 – 8.2 ppm. Soil test P and K averaged 35 ppm (range of 21 – 45) and 123 ppm (range of 85 – 170), respectively.

At CG16 the dominant soils were Webster clay loam and Hamel loam. Soil organic matter ranged from 2.6 – 7.9% and averaged 5.0%. CEC ranged from 17 – 39 meq/100 g while pH ranged from 5.2 – 7.7. Nitrate concentration averaged 6.2 ppm and ranged from 0.1 – 18.7 ppm. Soil test P and K averaged 21 ppm (range of 9 – 35) and 80 ppm (range of 57 – 124), respectively. Soil test K values < 100 ppm are concerning; however, a broadcast application of P and K was applied to the entire plot prior to planting corn. This fertilizer K should minimize the potential for K to reduce yields.

The WA16 location had nearly equal amounts of Webster and Nicollet clay loam soils. Soil organic matter ranged from 3.5 – 5.6% and averaged 4.7%. CEC ranged from 21 – 30 meq/100 g and pH ranged from 5.7 – 6.1. Nitrate-N concentration averaged 2.9 ppm (very low) and ranged from 1.2 – 5.3 ppm. Soil test P and K averaged 28 ppm (range of 16 – 53) and 157 ppm (range of 94 – 313), respectively. Only one sample had STK < 100 ppm.

Inorganic Soil N at V2 and V5-6 (PSNT)

Soil samples for nitrate-N (PSNT) were taken from 0-1 and 1-2 ft depths at V2 and V5-6 from multiple locations in each strip-plot. These samples were analyzed for NO_3-N by the rapid nitrate test and for NO_3-N and NH_4-N after being dried and ground. For 2014, only rapid NO_3-N data are presented in this report as the data from dried samples showed extraordinarily low values which were determined to be erroneous by the authors. Following field collection of the moist samples they were stored in a cooler at 40 degree F. in freezer bags (sealed plastic). After being analyzed by CFS using the rapid procedure they were stored at room temperature for a few days prior to being returned to the SROC. It's likely that bacteria in the soil denitrified most of the inorganic nitrogen in these samples in the warm, moist and anaerobic condition created by the plastic bags, prior to SROC staff drying the samples. The sample handling protocol was changed in 2015 to limit this potential error. In 2015 and 2016 soil samples collected in the field were mixed and split into a moist and dry sample.

Soil nitrate data from 2014 research locations (BP14 and NF14) are presented in Tables 4a and 4b. At BP14, NO_3-N was affected by the main effects of sampling time, N treatment (preplant N rates), and the interaction between sampling time and N treatment. When averaged across sampling times (V2 and V6), NO_3-N was greater with the fixed and U of M treatments compared with the variable treatment. The U of M treatment received 120 lb N/ac preplant compared with 105-lb and 100-lb for the fixed and variable treatments, respectively. Greater NO_3-N was found at V2 compared with V6 sampling, when averaged across the main effect of N treatment. These data suggest considerable N loss due to leaching and/or denitrification likely occurred during the exceptionally wet period in mid June. Some N was taken up by corn plants during this period (V2 to V6) but plant uptake alone would not explain the differences in NO_3-N observed in these soil data. A significant interaction between N treatment and sampling date showed at V2 the variable treatment had significantly less NO_3-N compared with the fixed and U of M treatments; whereas, at V6 no significant differences among treatments were observed. This interaction showed that after the excessive wet period in mid June all N treatments had similar NO_3-N left in the soil profile regardless of the preplant N rate. Moreover it suggests N losses were slightly greater with higher rates of preplant applied N. A comparison of sampling depths (0-1 ft vs 0-2 ft) showed numerically less NO_3-N in the 0-2 ft depth (0-2 was an average of 0-1 and 1-2 ft depths) compared with the 0-1 ft depth, especially at the V2 sampling time. Generally, significant differences in soil NO_3-N as a result of treatment main effects (sampling depth and preplant N rates) were similar between the two sampling depths.

At the NF14 location, NO_3-N was affected by the main effects of sampling time and N treatments (Table 4b). When averaged across sampling times (V2 and V6), NO_3-N was greatest with U of M treatment, intermediate with fixed and least with variable. These results correspond exactly with the preplant N rates applied. About twice as much NO_3-N was measured in soil samples at V2 compared with V6 sampling, when averaged across the main effect of N treatment. Similar to the BP14 location, these data suggest considerable N loss due to leaching and/or denitrification likely occurred during the exceptionally wet period in mid June. A significant interaction between N treatment and sampling date was not found at this location. A comparison of sampling depths (0-1 ft vs. 0-2 ft) showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth and differences in soil NO_3-N as a result of treatment main effects (sampling depth and preplant N rates) were similar between the two sampling depths.

Soil inorganic N data from 2015 research locations (NF15, CG15 and WA15) are presented in Tables 4C1-4 (NF15), 4D1-4 (CG15) and 4E1-4 (WA15). At NF15, rapid (moist) NO_3-N was affected by the main effect of sampling time (Table 4C1). Nitrate was considerably greater at the V5 sampling time than at V2 for both the 0-1 and 0-2 ft depths. This suggests significant N mineralization from SOM and very little N loss during this period. Nitrate concentrations in dried samples (Table 4C2) were very similar to moist at this location except at the 0-1 ft depth where significant differences among N treatments were observed. The preplant N rates were similar (150, 150 and 165 lb N/ac for the fixed, variable and U of M treatments, respectively); therefore, we would not expect significant differences due to treatments. In fact, the dry soil NO_3-N concentration was less with the U of M treatment than with the fixed or variable treatments. A comparison of sampling depths (0-1 ft vs 0-2 ft) showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth. Soil NH_4-N (Table 4C3) concentrations were much less than soil NO_3-N concentrations and at the 0-1 ft depth were not affected by treatment main effects. At the 0-2 ft depth NH_4-N was greater at the V5 sampling time, when averaged across N treatments. Ammonium-N was greater with the fixed treatment than with the U of M treatment, when averaged across sampling times. Total inorganic N (TIN = NH_4-N + NO_3-N, Table 4C4) was greater at the V5 sampling time than at V2, when averaged across N treatments. At the 0-1 ft depth, TIN was greater with the fixed and variable treatments than with the U of M treatment which is strange because they received less preplant fertilizer N. The average concentration of nitrate (>30 ppm) and TIN (about 40 ppm) measured at V5 in the 0-1 ft depth likely were adequate for corn production at this location.

Moist NO_3-N was affected by the main effect of sampling time (Table 4D1) at CG15. Nitrate was considerably less at the V5 sampling time than at V2 for both the 0-1 and 0-2 ft depths. This suggests some N loss or movement out the 0-2 ft profile during this period. Nitrate concentrations in dried samples at V2 (Table 4D2) were numerically less than moist samples at this location; whereas, at V5 the opposite was true. A graphical comparison of dry vs. moist samples (Figure 3) showed at V2 some dry samples were near background levels of NO_3-N. Similar to last year, this suggests some denitrification of N during sample storage. However, this doesn't explain why at V5 dry samples were greater than moist samples. Dry NO_3-N concentrations were much greater at the V5 sampling compared with V2 sampling. When averaged across sampling times, the variable treatment had greater dry NO_3-N than the fixed treatment at the 0-1 ft depth. A comparison of sampling depths (0-1 ft vs 0-2 ft) showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth. Soil NH_4-N (Table 4D3) concentrations were much less than soil NO_3-N concentrations. At both depths, soil NH_4-N concentrations were not affected by treatment main effects. Total inorganic N (Table 4D4) was greater at the V6 sampling time than at V2, when averaged across N treatments. At the 0-1 ft depth, TIN was greater with the fixed treatment than with the variable treatment, when averaged across sampling times. At the V2 sampling time, moist NO_3-N concentrations averaged 32.6 ppm in the 0-1 ft depth and 23.9 ppm in the 0-2 ft depth. These levels were likely sufficient for corn production; however, by V5 moist NO_3-N had declined enough to warrant a sidedress N application.

Rapid (moist) NO_3-N concentrations were affected by the main effects of sampling time and nitrogen treatment (Table 4E1) at the WA15 location. Moist NO_3-N concentrations were less at the V6 sampling time than at V2 for the 0-1 ft depth, when averaged across N treatments. At the 0-1 ft depth, moist NO_3-N was numerically less with the variable treatment compared with the fixed and U of M; however, these differences were not statistically significant. At the 0-2 ft depth, NO_3-N with the variable treatment was significantly less than the fixed and U of M treatments, when averaged across sampling times. A significant sampling time × N treatment interaction showed that only the variable treatment at V6 had less NO_3-N and all other treatments were similar. Nitrate-N concentrations in dried samples (Table 4E2) were numerically greater than moist samples at WA15. When averaged across N treatments, dry NO_3-N was less at V6 than at V2 for both sampling depths. Similar to the results from the rapid moist samples, dry NO_3-N was less with the variable N treatments than with the fixed or U of M treatment. Different sample methods and locations were used for the variable treatment (zone method) vs. the other treatments (regular grid method); therefore, sampling method may explain these results. Lower soil NO_3-N concentrations with the variable treatment resulted in a greater sidedress N rate being applied to the variable treatment. A comparison of sampling depths (0-1 ft vs 0-2 ft) at WA15 showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth, which is consistent with other locations. Soil NH_4-N

(Table 4E3) was much less than soil NO_3-N. At both sampling depths, soil NH_4-N concentrations were greater at V2 than at V6, when averaged across N treatments. Soil NH_4-N was not affected by the main effect of N treatments. Total inorganic N (Table 4E4) was greater at the V2 sampling time than at V6, when averaged across N treatments. At both sampling depths TIN concentration was less with the variable treatment than with the fixed and U of M treatments, when averaged across sampling times. The considerable decline in nitrate and TIN concentrations between the V2 and V6 sampling times suggested some N loss had occurred and a response to sidedress N at WA15 was likely, especially with the variable treatment.

In summary the 2015 PSNT data showed rapid NO_3-N concentrations were greater at the V6 stage than at V2 at NF15; whereas, NO_3-N concentrations were greater at V2 than at V6 in CG15 and WA15. These differences may have been related to the N sources used at each location, anhydrous ammonia at NF15 and urea at CG15 and WA15. However, it is more likely that N loss was greater at CG15 and WA15 locations due to greater rainfall and a greater extent of poorly drained soils. The changes in soil nitrate observed over time in this study have major implications for using PSNT values for determining sidedress N rates. Furthermore, developing or calibrating an algorithm (recommendation) for PSNT values appears difficult and it would likely lack precision.

Soil inorganic N data from 2016 research locations (NF16, CG16 and WA16) are presented in Tables 4F1-4 (NF16), 4G1-4 (CG16) and 4H1-4 (WA16). At NF16, rapid (moist) NO_3-N concentrations were not affected by sampling time or N treatment at the 0-1 ft depth (Table 4F1); however, NO_3-N was greater at V5 than at V2 for the 0-2 ft depth. Nitrate-N concentrations in dried samples (Table 4F2) were greater at V5 than at V2 at both sampling depths. Nitrate-N was significantly greater with the U of M treatment at 0-1 ft depth and numerically greater at 0-2 ft depth, when averaged across sampling times. Nitrate-N concentrations in all treatments at 0-1 ft depth (PSNT) were greater than critical levels reported by Mallarino and Sawyer (2013); therefore, no response to additional fertilizer N would have been expected. A comparison of sampling depths (0-1 ft vs 0-2 ft) showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth for both the Rapid and dry tests as expected. Soil NH_4-N (Table 4F3) concentrations were less than NO_3-N concentrations but were greater than typical background levels (4 – 6 ppm). These data suggest a considerable amount of the N from the AA had not yet nitrified even by the V5 sampling time. Ammonium-N concentrations were not affected by sampling time and N treatments at either depth. Total inorganic N (Table 4F4) was greater at the V5 sampling time than at V2, when averaged across N treatments.

At the V2 sampling, moist (rapid) NO_3-N concentrations were erratic across strip plots. Many samples were < 1.0 ppm, which suggests a lab error and/or potential denitrification of samples during handling and prior to analysis. These V2 data are not included in Table 4G1 for CG16. Rapid NO_3-N concentrations at the V5 sampling were not affected by N treatments at either the 0-1 or 0-2 ft depths. Nitrate-N concentrations in dried samples at VV (Table 4G2) were numerically greater than moist samples at this location. Dry NO_3-N concentrations were much greater at the V5 sampling compared with V2 sampling. When averaged across sampling times, N treatments did not affect NO_3-N concentrations at either depth. However, the U of M treatment had greater dry NO_3-N than the fixed treatment at the 0-2 ft depth for the V5 sampling time. A comparison of sampling depths (0-1 ft vs 0-2 ft) showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth. Soil NH_4-N (Table 4G3) concentrations at CG16 were much less than soil NO_3-N concentrations. Soil NH_4-N concentrations were not affected by N treatments, when averaged across sampling times. However, NH_4-N concentrations were greater at V2 than V5, when averaged across N treatments. Total inorganic N (Table 4G4) was greater at the V5 sampling time than at V2, when averaged across N treatments. Nitrogen treatments did not affect TIN concentrations. At V5 sampling, dry NO_3-N concentrations averaged 34.4 ppm in the 0-1 ft depth and 22.2 ppm in the 0-2 ft depth. These levels were likely sufficient for corn production at CG16.

Like CG16, rapid NO_3-N concentrations were erratic across strip plots at the V2 sampling at WA16. Many samples were < 1.0 ppm, which suggests a lab error and/or potential denitrification of samples during handling and prior to analysis. These V2 data are not included in Table 4H1 for WA16. Rapid NO_3-N concentrations were not affected by nitrogen treatments (Table 4H1) at the WA16 location. A significant sampling time × N treatment interaction for dry NO_3-N showed inconsistences in NO_3-N among N treatments and between sampling times; however, no significant differences were found for the main effects (Table 4H2). The variable treatment had the lowest soil NO_3-N concentration at V2 and the highest at V5. A comparison of sampling depths (0-1 ft vs 0-2 ft) at WA16 showed numerically less NO_3-N in the 0-2 ft depth compared with the 0-1 ft depth, which is consistent with other locations and would be expected. Soil NH_4-N (Table 4H3) was much less than NO_3-N. Soil NH_4-N concentrations were not affected by sampling time and N treatments at WA16. The significant interaction between main effects for TIN (Table 4H4) was similar to dry NO_3-N. At V5, dry NO_3-N concentrations averaged 22.4 ppm in the 0-1 ft depth (PSNT) while rapid NO_3-N concentrations averaged only 14.4 ppm. The variable treatment recommendation was made based on the rapid concentration even though the dry concentration was near the critical level of 25 ppm at WA16.

In 2016, rapid NO_3-N concentrations at the V2 sampling were erratic in 2 of 3 sites. Inconsistent or erratic rapid NO_3-N results were observed in at least one location in other years in this study. These results are discerning as these rapid or moist nitrate data were used by CFS to determine sidedress N rates for the variable treatment. Dry NO_3-N concentrations were greater at V5 than at V2 at 2 of 3 sites. This is opposite of what was found in 2015. These results suggest the potential for N loss in the spring of 2016 were generally low and much less than in 2015. Precipitation data from 2016 supports these findings. Considerable NH_4-N was found at NF16, especially with the early (V2) sampling. Anhydrous ammonia was the N source at NF16; whereas, urea was the N source at CG15 and WA15. Spring AA application can greatly affect PSNT values and thereby influence sidedress N recommendations.

Corn production parameters

Corn grain yield and other production parameters for BP14 are presented in Table 5a. The farmer cooperator planted three different corn hybrids within the research plot area; therefore, each production parameter was carefully examined to insure hybrid differences did not mask treatment differences. Fortunately, two of the original five replications (blocks) were planted to a single hybrid. Two reps were split among two hybrids and one (rep 5) contained three hybrids. Data from rep 5 were removed and not used in this analysis. Hybrids did affect results of three parameters: grain moisture (hybrids differed in maturity), grain test weight and NDVI at V8 (data not shown). Because of the influence of hybrid, these parameters are not included in Table 5a. Fortunately, hybrids had only minimal effect on yield, partly because of the large effect of N treatments.

Corn grain yields from weigh wagon measurements were: greatest with the variable sidedress treatment (160 bu/ac) that received 120 lb N/ac (average) at sidedress and 100 lb N/ac preplant (Table 5a), intermediate with the fixed sidedress treatment (150 bu/ac) that received 46 lb N/ac at sidedress and105 lb N/ac preplant and least with the U of M (MRTN based) treatment (136 bu/ac) that did not receive any sidedress N only preplant applied N at 120 lb N/acre. These sidedress N rates were much greater than originally planned because the V6 (PSNT) soil data showed very little nitrate remaining in the soil profile in late June. Nitrate concentrations at the V6 sampling (0-1 ft and 0-2 ft depths) were < 6.0 ppm (Table 4a). Schmitt et al. (2002) gave no N credit when PPNT (0-2 ft depth) soil samples were < 6.0 ppm (Appendix Table I). Therefore, no N credit was given for the preplant applied N in the variable sidedress treatment and the sidedress rate was increased considerably from a proposed 40 lb N/ac up to 120 lb N/ac. The fixed sidedress rate was also increased but only from 35 to 46 lb N/ac. Average strip-plot yields from the combine yield monitor generally agreed closely with weigh wagon yields except for the variable sidedress treatment. Yield monitor yields for the variable treatment were 10 bu/ac greater (170 bu/ac) than weigh wagon yields (160 bu/ac).

Grain N concentration and plant population were not significantly affected by N treatments at BP14 (Table 5a). N removal in corn grain was greater with treatments that received sidedress N (fixed and variable) than with the treatment without sidedress N (U of M). Partial Factor Productivity was greatest with the U of M treatment (1.13 bu/lb), intermediate with the fixed treatment (1.00 bu/lb) that received a modest sidedress N rate of 46 lb/ac and least with the variable treatment (0.73 bu/ac) that received the highest sidedress N rate (120 lb/ac). These PFP values are considerably less than normal and suggest poor NUE at this location.

After careful examination of the sidedress maps [prescription (Appendix B2), as applied (B3) and prescription / as applied overlay (B4)] from the NF14 site, we concluded the applicator was centered on the edges of each plot instead of in the middle of each plot. Therefore, many plots received only half of the correct rate and the other half was incorrect. This application error created treatment overlap in the middle of each plot where the weigh wagon yields and grain samples were collected. We have decided not to include the weigh wagon yields, grain N concentration, N uptake and NUE parameters in this report for the NF14 site.

Average strip-plot yields from the combine yield monitor for NF14 are presented in Figure 2. Due to the application error not every strip was usable (application overlap) and some strips received the incorrect N rate for their respective treatment. Figure 2 shows the relationship between grain yield and total N rate (preplant + sidedress) for combine yield strips where N rates were consistent across the strip (no overlap of rates). Three points (circled) clearly fall outside the other clustered data; therefore, we excluded these values prior to calculating the average yield (written in text near cluster) of each rate/yield cluster. The individual strip yield data are graphed with letters instead of symbols to note the original treatment (UM= U of M preplant only rate, F=Fixed sidedress rate and V=Variable sidedress rate). Strip yields averaged 139, 166 and 177 bu/ac for total N rates that averaged 120, 148 and 218 lb N/ac, respectively. The 120 lb rate was applied preplant; whereas, the other rates were split with 100 or 105 lb N/ac applied preplant and the rest at sidedress.

The poor performance of preplant applied N in 2014, as shown by poor yields in the U of M treatment and PSNT (V6) values similar to background levels in all treatments, is not surprising considering the excessive June rainfall (7.8 and 8.7 inches at BP14 and NF14 sites, respectively). Saturated soil conditions in June obviously resulted in substantial loss of the preplant N. The U of M supplemental N worksheet would have recommended a sidedress application to the U of M treatment at both sites, but we decided to follow the research protocol and not apply supplemental N to the U of M treatment.

Corn grain yields, both weigh wagon and yield monitor, were statistically similar among N treatments at NF15 (Table 5c). Weigh wagon yields ranged from 213 bu/ac with the U of M treatment (165 lb N/ac) to 220 bu/ac with the variable treatment (150 lb N/ac preplant + 64 lb N/ac sidedress). Combine yield monitor yields were somewhat less than weigh wagon yields and were nearly identical among treatments. No significant differences in corn grain moisture or grain test weight were found in these NF15 data. Grain N concentration was less with the U of M treatment (1.23%) than with the fixed (1.27%) and variable (1.26%) treatments. Grain N removal was greater with the variable treatment than with the U of M treatment. Partial factor productivity was greater with the U of M treatment (1.29 bu/lb N) than with the fixed (1.07 bu/lb) and variable (1.04 bu/lb) treatments. Plant populations were quite variable and considerably less than desired. The low populations were most likely a result of improper planter setup. Populations were greater in the fixed treatment (29,200 plants/ac) than in the variable and U of M treatments (25,400 and 25,800 plants/ac, respectively); however, due to considerable variability in stand counts these differences were barely significant (*P* value = 0.091) and were more likely an erroneous difference due to limited measurements in such a large field. Soil NO_3-N concentrations (both rapid and dry) at V5 were greater than the 25-ppm critical level for all N treatments; therefore, a response to additional sidedress N was unlikely and did not occur at this site (NF15).

Grain yields were slightly less with the U of M treatment compared with sidedress treatments at CG15 (Table 5d). Weigh wagon yields ranged from 213 bu/ac with the U of M treatment (165 lb N/ac) to 217 bu/ac with the fixed (150 lb N/ac preplant + 50 lb N/ac sidedress) and variable (150 lb N/ac preplant + 113 lb N/ac sidedress) treatments. Due to very low variability in weigh wagon yield data these small differences were significantly different at CG15; however, combine yield monitor yields were not significantly different among treatments. Corn grain moisture and test weight were not affected by N treatments at CG15. Grain was very dry (13.6%) at the time of harvest. Grain N concentration was greater with the variable treatment (1.20%) than with the U of M (1.13%) and fixed (1.15%) treatments. Grain N removal was greatest with the variable treatment (123 lb/ac), intermediate with fixed treatment (119 lb/ac) and least with the U of M treatment (114 lb/ac). The range in these N removal treatments is quite small, only 9 lb/ac, compared to the range in total N applied among these treatments (98 lb/ac). Therefore, PFP was much greater with the U of M treatment (1.29 bu/lb N) than with the fixed (1.09 bu/lb) and variable (0.79 bu/lb) treatments. Plant populations were less than desired but were not affected by N treatments at CG15. Dry soil NO_3-N concentrations at V5 were greater than 25-ppm (rapid averaged 23.9 ppm) for all N treatments; therefore, a response to additional sidedress N was unlikely and did not occur at this site (CG15).

Grain yields were greater with the variable treatment than with the U of M and fixed treatments at WA15 (Table 5e). Weigh wagon yields were 206, 210 and 221 bu/ac with the U of M (120 lb N/ac), fixed (100 lb N/ac preplant + 40 lb N/ac sidedress) and variable (100 lb N/ac preplant + 101 lb N/ac sidedress) treatments, respectively. The 15 bu/ac range in yields among treatments at WA15 was greater than any other location in 2015. Interestingly, yields with the fixed treatment were not significantly greater than the U of M treatment even though it received 20 lb more N/ac and a split application of N. Yield monitor yields were not calculated because the yield monitor lost signal during harvest and a few yield passes were lost (Appendix Fig. E1). Grain moisture was slightly drier with the U of M treatment compared with the fixed and variable treatments. This may have resulted from early senescence due to late season N deficiency with the U of M treatment. Grain test weights were not affected by N treatments. Grain N concentration and removal was greater with the variable treatment than with the U of M treatment. Similar to CG15, the range in N removals between these treatments was quite small compared to the range in total N applied; therefore, PFP was much greater with the U of M treatment (1.71 bu/lb N) than with fixed (1.50 bu/lb) and variable (1.10 bu/lb) treatments. Plant populations were not affected by N treatments at WA15. Soil NO_3-N concentrations (both rapid and dry) at V5 were less than 25-ppm for all N treatments; therefore, a response to sidedress N was likely and did occur at WA15 but only with the variable treatment that received a significantly greater total N rate.

Corn grain yields, both weigh wagon and yield monitor, were not affected by N treatments at NF16 (Table 5f). Weigh wagon yields ranged from 191 bu/ac with the U of M treatment (165 lb N/ac) to 193 bu/ac with the variable treatment (150 lb N/ac preplant + 54 lb N/ac sidedress). Combine yield monitor yields were slightly less than weigh wagon yields and were nearly identical among treatments. Corn grain moisture and grain N concentration were slightly less with the U of M treatment compared with other treatments. Grain test weight, N removal and plant populations were not affected by N treatments at NF16. Partial factor productivity was greater with the U of M treatment (1.16 bu/lb N) than with the fixed (0.96 bu/lb) and variable (0.97 bu/lb) treatments. Soil NO_3-N (rapid and dry) concentrations at V5 were greater than 25-ppm for all N treatments; therefore, a response to additional sidedress N was unlikely and did not occur at this site (NF16).

Weigh wagon yields were not affected by N treatments at CG16 (Table 5g); whereas, combine monitor yields were greater with the U of M (209 bu/ac with 165 lb N/ac) treatment than with the fixed (206 bu/ac with 150 lb N/ac preplant + 50 lb N/ac sidedress) and variable (206 bu/ac with 150 lb N/ac preplant + 66 lb N/ac sidedress). Partial factor productivity was greatest with U of M (1.24 bu/lb N), intermediate with fixed (1.01 bu/lb) and least with variable (0.93 bu/lb). Corn grain moisture, test weight, N concentration, N removal, and plant populations were not affected by N treatments. Dry soil NO_3-N concentrations at V5 were greater than 25-ppm for all N treatments and rapid NO_3-N averaged 21.9 ppm across treatments; therefore, a response to additional sidedress N was not expected and did not occur at this site (CG16).

Grain yields, both weigh wagon and yield monitor, were greater with the variable and fixed treatments than with the U of M at WA16 (Table 5h). Weigh wagon yields were 188, 205 and 210 bu/ac with the U of M (165 lb N/ac), fixed (150 lb N/ac preplant + 50 lb N/ac sidedress) and variable (150 lb N/ac preplant + 76 lb N/ac sidedress) treatments, respectively. The U of M treatment had considerably lower yields on the east half of the field (Appendix Fig. H1). Weigh wagon yields for U of M treatment averaged 177 bu/ac on the east side and 199 bu/ac on the west side. Soil NO_3-N concentrations at V5 were also less on the east side of the field (20 ppm, data not shown) than on the west side of the field (25 ppm). These soil data successfully predicted the east side would need additional N to optimize yield. Grain moisture was slightly drier with the U of M treatment compared with the fixed and variable treatments. This may have resulted from early senescence due late season N deficiency with the U of M treatment. Grain test weight was not affected by N treatments. Grain N concentration was greater with the variable treatment than with the fixed and U of M treatments. Nitrogen removal was less with the U of M treatment than with the variable and fixed treatments. At WA16, PFP was greatest with the U of M treatment (1.14 bu/lb N), intermediate with fixed (1.02 bu/lb) and least with variable

(0.93 bu/lb). These PFP values were lower than other sites, likely a result of the excessive rainfall in July, August, and September which led to significant N loss due to leaching and denitrification. Plant populations were not affected by N treatments. Soil NO_3-N concentrations (both rapid and dry) at V5 were less than 25-ppm when averaged across reps and N treatments. As stated earlier NO_3-N concentrations were lower on the east half of the field than on the west half and the yield response to sidedress N was greater on the east side of the field.

To calculate the economics of sidedress N treatments, based on PSNT, used in this study a few assumptions and input costs are required. The following costs were provided by CFS or U of M Extension: PSNT soil sampling on 4.5 ac grids/zones = \$6.50/ac; sidedress application of urea with a high clearance applicator = \$9.00/ac for fixed rate or \$9.50/ac for variable rate; preplant N = \$0.45/lb; sidedress N (urea with NBPT) = \$0.50/lb; grain handling (field to farm) = \$0.10/bu; grain drying = \$0.025/point/bu and corn = \$4.00/bu. Calculated net returns from N treatments at BP14 ranged from \$471 to \$500 and ranked fixed ≈ variable > U of M. At NF15, net returns ranged from \$734 to \$752 and ranked U of M > variable ≈ fixed. At CG15, net returns ranged from \$706 to \$756 and ranked U of M > fixed > variable. At WA15, net returns ranged from \$737 to \$744 and ranked U of M ≈ variable, variable ≈ fixed, and U of M > fixed. At NF16, net returns ranged from \$642 to \$670 and ranked U of M > fixed ≈ variable. At CG16, net returns ranged from \$669 to \$722 and ranked U of M > fixed > variable. At WA16, net returns ranged from \$649 to \$683 and ranked fixed ≈ variable > U of M. These economic return calculations show: 1) the value of applying sidedress (split) N applications when precipitation is greater than normal (BP14 and WA16 sites); 2) the cost vs. benefit relationship of applying high sidedress N rates, even though PSNT levels showed less than ideal amounts of soil nitrate in the 0-1 ft soil profile; and 3) the U of M treatment, MRTN rate applied preplant, had numerically the greatest net returns at 5 of 7 site-years.

Inorganic soil N after harvest

Residual soil N levels [nitrate, ammonium (NH_4-N) and total inorganic-N (TIN) = nitrate + ammonium] from soil samples taken after harvest were very low at both locations in 2014 (Table 7a, NF14 site not shown due to sidedress application error). These low levels suggest soil N from mineralization and fertilizer N were utilized by the corn crop. At BP14, NO_3-N was affected by the main effects of sampling depth, N treatment (N rates), and the interaction between sampling depth and N treatment. When averaged across sampling depths (0-2 and 2-4 ft), NO_3-N was greatest with the variable treatment, intermediate with the fixed treatment and least with the U of M treatment. Greater NO_3-N, NH_4-N and TIN were found at 0-2 depth than 2-4 ft depth, when averaged across the main effect of N treatment.

Mean soil N concentrations from each strip length plot for samples taken after harvest at all 2015 locations are found in Tables 7C, 7D and 7E. When averaged across sampling depths (0-2 and 2-4 ft), soil NO_3-N, NH_4-N and TIN were not significantly different among the three N treatments. However, at NF15 and CG15 locations NO_3-N and TIN concentrations were numerically greater with the variable treatment, which received the highest total N rate of all treatments. Finding no significant differences in residual soil nitrate (RSN) among treatments is somewhat surprising when considering the sidedress N rates that were applied to the variable treatment. Only small differences in N removal were found among these treatments; therefore, this suggests that some fertilizer N from the variable treatment was either lost to leaching or denitrification or was immobilized in the soil and corn residue at sampling time. When averaged across N treatments, NO_3-N, NH_4-N and TIN concentrations were greater at the 0-2 depth than at 2-4 ft depth. Ammonium-N concentrations were quite low, especially at NF15 and CG15 locations. Nitrate-N concentrations in the 0-2 ft depth averaged 7.3, 6.2 and 4.3 ppm at NF15, CG15 and WA15, respectively. If we assume a six-inch furrow slice of soil weighs approximately 2,000,000 lbs, then the location average RSN remaining after harvest was 94, 78, and 54 lb/ac of NO_3-N at NF15, CG15, and WA15, respectively.

Inorganic soil N concentrations from samples taken after harvest in 2016 are found in Tables 7F, 7G, and 7H. When averaged across sampling depths (0-2 and 2-4 ft), NO_3-N, NH_4-N and TIN concentrations were generally not affected by N treatments. The significant difference in NO_3-N found at WA16 was numerically very small and not agronomically important. Inorganic N concentrations at all sites were greater at 0-2 ft depth than at 2-4 ft depth, when averaged across N treatments. Like 2015, in 2016 we found no significant differences in RSN among treatments. RSN values were quite low at all sites, likely due to excessive rainfall in September. It's likely at CG16 and WA16 any leftover N had already been leached or denitrified prior to post harvest sampling.

SUMMARY AND CONCLUSIONS

This research study compared split (preplant plus at sidedress) N applications to a single preplant application based on U of M (MRTN) guidelines. A variable rate treatment (split application) was based on inorganic soil N data collected prior to application. In 4 of 7 site-years corn grain yields were greater with split N applications than with a single preplant application; however, in only 2 of 7 site-years did the added input costs (application, soil sampling, and extra fertilizer N) associated with these split application treatments result in greater economic return than the U of M treatment. For the 2 of 7 sites-years with greater net returns split applications had $65 more combined net profit than the U of M treatment; whereas, for the other 5 site-years the U of M treatment had $123 more net profit than the average of the split applications. Generally, grain N concentrations and removals were greater with split applications which received higher N rates than the U of M treatment. The U of M treatment had greater PFP, a measure of fertilizer use efficiency, than split applications.

This research found positives and negatives for using a soil-based (PSNT) method for making in-season N rate recommendations. Generally, PSNT values were correlated with yield responses observed at sites. Research sites that had large yield responses to split N application had the lowest soil NO_3-N concentrations at V5-6. Using the 25 ppm NO_3-N critical value for dry soil analysis (0-1 ft depth), reported by Mallarino and Sawyer (2013), would have correctly predicted the yield response to sidedress N in 6 of 7 site-years. A 0-1 ft sampling depth was as effective as the 0-2 ft depth in predicting yield responses to sidedress N applications in this study. Split applications which received greater total N rates rarely increased residual soil nitrate remaining in the soil profile after harvest. On the negative side, the CFS algorithm (recommendation) used to determine the N rate for the variable treatment in this study regularly recommended sidedress N when none was needed and recommended high sidedress N rates (>100 lb N/ac) at three sites where PSNT values were less than optimum. Partly due to these recommendations, the variable treatment never ranked better than second in economic return among site-years. Inconsistent and very low NO_3 results with the rapid (moist) soil test was concerning and not completely understood. It was likely due to sample handling and storage prior to and after lab analyses. The logistics of getting timely and quality samples in wet springs was also challenging.

This research showed a soil-based approach to in-season N recommendations could increase corn yields in Minnesota, especially in wet springs. However, without proper rate calibration this approach likely would not increase economic return.

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TABLES and FIGURES

Table 1a. Experimental procedures and their completion dates for 2014 locations.

Procedure	BP14	NF14
Apply P, K, S and Zn as needed to optimize corn production.	Oct 2013,	Oct 2013,
Collect 0-6" grid (2.5 ac) soil samples	May 16	May 21
Apply preplant N treatments	May 25, UAN w/herbicide	May 26, urea
Incorporate preplant fertilizer with tillage	None, No-till	May 26, field cult.
Plant corn	May 21, Spectrum 4660, 4130 & 5045	May 26, DKC 49-29RIB
Install weather station	May 24	Jun 3
At V2, collect PSNT soil samples (0-1' and 1-2')	Jun 6, V2	Jun 10, V2
Take stand counts	Oct 14	Jun 10
At V4-6, collect PSNT soil samples (0-1' and 1-2')	Jun 25, V5-6	Jun 25, V6
At V6, apply sidedress N treatments	Jul 7, V8-10	Jul 2, V8
Collect imagery of plot area	Jul 3, Jul 10, Aug 7	Jul 3, Jul 9, Aug 7
Take plot notes (crop color, N deficiency)	Jul 3	Jul 3 and 31
Combine harvest corn grain, collect grain sample	Oct 28	Nov 6
Take post harvest soil nitrate samples (0-2' and 2-4')	Oct 30	Nov 6

Table 1b. Experimental procedures and their completion dates for 2015 locations.

Procedure	NF15	CG15	WA15
Apply P, K, S and Zn as needed to optimize corn production.	Oct 2014,	Apr 29 0-45-74-10(S)	Apr 17, 0-0-0-10(S)
Collect 0-6" grid (2.5 ac) soil samples	Apr 15	May 1	Apr 17
Apply preplant N treatments†	Apr 17 AA	Apr 29, urea	Apr 17, urea
Incorporate preplant fertilizer with tillage	Apr 30, field cult.	Apr 29, field cult.	Apr 17, field cult.
Plant corn	May 1, Latham 4099 SS RIB	Apr 29, Gold Country 102-88	Apr 18, LG 5499
Install weather station	May 4	May 1	Apr 21
At V2, collect PSNT soil samples (0-1' and 1-2')	May 28, V2	Jun 1, V3	May 22, V2
Take stand counts	May 28	Jun 1	Jun 2
At V4-6, collect PSNT soil samples (0-1' and 1-2')	Jun 9, V5	Jun 9, V5	Jun 10, V6
At V6, apply sidedress N treatments	Jun 18, V7	Jun 25, V7-8	Jun 16, V7
Collect imagery of plot area	Jun 18, Aug 5	Jun 25, Aug 5	Jun 19, Aug 5
Take plot notes (crop color, N deficiency)	Jun 18	Jun 25	Jun 25
Combine harvest corn grain, collect grain sample	Nov 2	Oct 21	Oct 7
Take post harvest soil samples (0-2' and 2-4')	Nov 3	Oct 22	Oct 14

† At NF15 and CG15 a base rate of 150 lb N/ac was applied to the entire plot area on the date shown. Then an additional 15-lb N/ac was applied to the U of M treatment ASAP to bring it up to a total of 165 lb N/ac.

Table 1c. Experimental procedures and their completion dates for 2016 locations.

Procedure	NF16	CG16	WA16
Apply P, K, S and Zn as needed to optimize corn production.	Nov 2015	May 4, 0-45-74-10(S)	Apr 19, 0-0-0-15(S)
Collect 0-6" grid (2.5 ac) soil samples	Apr 14	Apr 15	Apr 18
Apply preplant N treatments†	Apr 24, AA	May 4, urea	Apr 19, urea
Incorporate preplant fertilizer with tillage	Apr 22, field cult.	May 5, field cult.	Apr 19, field cult.
Plant corn	Apr 22, DKC 53-56	May 5, Wyffels W2270	Apr 20, DKC 53-56
Install weather station	Apr 26	May 12	Apr 25
At V2, collect PSNT soil samples (0-1' and 1-2')	May 24, V2	May 26, V2	May 23, V2
Take stand counts	Jun 6	Jun 8	Jun 7
At V4-6, collect PSNT soil samples (0-1' and 1-2')	Jun 6, V4-5	Jun 8, V5	Jun 6, V5
At V6, apply sidedress N treatments	Jun 20, V8	Jun 27, V10	Jun 17, V7
Collect imagery of plot area	Jun 17, Aug 6 (R4)	Jun 17, Aug 6	Jun 17, Aug 6
Take plot notes (crop color, N deficiency)	Jun 17	Jun 17	Jun 23
Combine harvest corn grain, collect grain sample	Nov 8	Oct 22	Oct 18
Take post harvest soil samples (0-2' and 2-4')	Nov 11	Nov 4	Oct 20

† At NF15 and CG15 a base rate of 150 lb N/ac was applied to the entire plot area on the date shown. Then an additional 15-lb N/ac was applied to the U of M treatment ASAP to bring it up to a total of 165 lb N/ac.

Table 2. Soil properties from grid soil samples at each of the experimental locations.

Year	Location, abbrev.	Soil series	SOM	CEC	pH	NO_3-N	Solum Mehlich III P	Solum Mehlich III K
			%	meq/100		----------- ppm -----------		
2014	Blooming Prairie,	Maxcreek sicl	5.5†	27	6.6	0.7	54	151
	BP14	Merton sil	2.7-10.5‡	13-43	5.6-7.7	0.1-2.5	21-99	99-218
2014	Northfield,	Hayden l	2.9	16	6.7	3.6	48	255
	NF14	Dundas sil	1.7-4.2	11-25	5.9-7.6	0.3-7.8	22-69	178-335
2015	Northfield,	Blooming sil	3.6	17.8	6.2	3.2	45.2	136
	NF15	Lester l	2.1-4.7	9.2-22.4	5.8-7.4	0.7-9.0	30.9-79.5	92-245
2015	Clarks Grove	Hamel l	4.6	25.4	5.8	18.6	38	131
	CG15	Lester l	2.6-7.0	17.1-35.0	5.1-7.2	7.7-47.6	17-94	72-241
2015	Waseca	Webster cl	5.6	25.6	6.1	7.2	33.7	250
	WA15	Nicollet cl	4.2-8.3	14.8-36.1	5.7-6.9	1.6-20.3	13.2-57.9	129-456
2016	Northfield,	Lester l	3.4	16.4	6.4	4.8	35	123
	NF16	Blooming sil	2.7-4.1	13.4-18.3	5.7-7.0	3.0-8.2	21-45	85-170
2016	Clarks Grove	Webster cl	5.0	26.6	6.3	6.2	21	80
	CG16	Hamel l	2.6-7.9	16.6-39.3	5.2-7.7	0.1-18.7	9-35	57-124
2016	Waseca	Webster cl	4.7	25.9	5.9	2.9	28	157
	WA16	Nicollet cl	3.5-5.6	21.3-29.6	5.7-6.1	1.2-5.3	16-53	94-313

† Mean value.
‡ Range in values.

Table 3a. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Blooming Prairie in 2014.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	---------	°F	---------	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
5/7	--	47	39	56	28	0.48	--	--	--	--
5/14	--	54	44	65	54	1.54	--	--	--	--
5/21	--	51	41	62	43	0.15	--	--	--	--
5/28	74	64	55	77	116	0.09	0.30	61	0.40	55
6/4	66	70	61	81	145	0.57	0.30	66	0.41	59
6/11	66	66	57	76	113	0.01	0.29	66	0.42	61
6/18	71	67	58	75	115	5.12	0.32	65	0.44	62
6/25	85	71	63	80	153	1.51	0.36	69	0.46	65
7/2	85	69	62	77	140	0.80	0.29	69	0.44	66
7/9	75	67	56	78	123	0.05	0.28	67	0.43	64
7/16	79	65	56	75	110	0.40	0.24	67	0.42	65
7/23	75	71	62	80	148	0.00	0.23	67	0.37	64
7/30	80	68	56	79	124	0.50	0.22	68	0.33	66
8/6	80	69	54	84	133	0.57	0.21	67	0.32	65
8/13	82	68	58	80	131	0.42	0.21	67	0.31	65
8/20	83	71	60	84	153	0.36	0.21	68	0.31	65
8/27	87	72	64	84	166	1.39	0.21	70	0.38	67
9/3	89	67	59	78	127	2.68	0.29	67	0.39	66
9/10	83	65	54	76	112	1.14	0.28	65	0.38	65
9/17	81	49	40	61	8	0.54	0.30	56	0.37	59
9/24	78	61	49	75	frost	1.31	0.31	58	0.41	58
10/1	78	62	51	74		0.29	0.30	60	0.43	59
10/8	81	46	37	55		0.41	0.31	52	0.42	55
10/15	76	46	34	57		0.51	0.30	48	0.41	51

Table 3b. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Northfield location in 2014.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	---------	°F	---------	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
5/7	--	47	39	56	28	0.08	--	--	--	--
5/14	--	54	44	65	54	3.60	--	--	--	--
5/21	--	51	41	62	43	0.72	--	--	--	--
5/28	--	66	55	76	112	0.06	--	--	--	--
6/4	82	70	60	80	139	1.66	0.37	66	0.44	63
6/11	73	65	55	74	103	0.66	0.37	65	0.44	62
6/18	70	67	59	74	115	3.06	0.37	65	0.44	62
6/25	81	72	64	80	155	2.65	0.38	72	0.45	67
7/2	82	70	63	78	145	0.76	0.36	71	0.44	68
7/9	72	69	59	80	136	0.17	0.35	71	0.42	68
7/16	79	67	58	76	118	1.03	0.34	70	0.40	68
7/23	74	72	63	81	155	0.00	0.32	70	0.37	67
7/30	79	69	58	81	137	0.55	0.29	69	0.32	68
8/6	81	71	57	85	143	0.04	0.28	69	0.29	67
8/13	80	69	58	83	142	0.12	0.27	68	0.28	67
8/20	83	72	61	86	160	1.15	0.29	69	0.29	67
8/27	86	73	63	84	161	0.76	0.32	71	0.29	69
9/3	87	68	59	79	136	2.03	0.33	67	0.31	67
9/10	83	66	53	79	113	0.35	0.33	65	0.33	65
9/17	80	50	40	62	6	0.21	0.32	56	0.32	59
9/24	80	62	49	77	frost	0.50	0.32	59	0.31	59
10/1	82	61	50	74		0.14	0.32	60	0.31	60
10/8	80	47	38	56		1.25	0.34	51	0.35	55
10/15	77	45	33	60		0.20	0.34	47	0.35	50

Table 3c. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Northfield location in 2015.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	---------	°F	---------	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
5/7	70.5	60.2	49.0	73.3	20	0.31	0.36	55.6	0.31	52.2
5/14	76.2	53.9	45.1	61.9	42	1.48	0.37	54.8	0.31	52.9
5/21	78.5	54.0	46.2	61.2	48	0.80	0.37	54.8	0.31	53.1
5/28	71.7	62.6	53.7	71.7	95	1.38	0.37	58.7	0.31	55.5
6/4	69.4	61.9	53.0	70.2	90	1.41	0.37	61.4	0.31	58.6
6/11	69.3	70.3	60.3	79.6	136	0.46	0.37	66.2	0.30	61.8
6/18	77.6	66.8	58.9	74.1	116	0.91	0.37	67.8	0.31	64.6
6/25	72.5	70.8	60.1	80.2	141	1.24	0.36	70.7	0.30	67.4
7/2	81.2	67.2	57.0	78.0	122	2.86	0.37	69.6	0.31	67.4
7/9	78.5	67.1	56.7	76.7	117	0.35	0.37	67.5	0.32	66.2
7/16	83.0	73.7	62.6	83.5	160	0.02	0.37	68.9	0.31	66.4
7/23	80.2	71.8	59.9	83.1	147	0.13	0.36	69.4	0.31	67.5
7/30	83.3	74.7	64.9	85.7	175	0.27	0.36	70.3	0.31	68.0
8/6	--	70.1	58.6	81.6	141	0.00	0.34	68.5	0.30	67.3
8/13	--	70.6	62.4	78.9	145	0.68	0.32	67.9	0.28	66.4
8/20	--	69.6	61.9	77.3	135	1.84	0.31	68.9	0.27	67.3
8/27	--	61.6	50.4	72.9	87	1.25	0.36	63.6	0.30	63.9
9/3	--	68.1	58.4	77.7	127	0.31	0.35	64.8	0.29	63.4
9/10	--	70.4	60.1	80.7	142	1.20	0.34	69.5	0.29	67.4
9/17	--	64.1	53.0	75.1	106	0.25	0.36	62.8	0.30	63.2
9/24	--	62.6	53.3	72.0	93	1.77	0.36	62.7	0.30	62.7
10/1	--	61.4	51.0	71.7	84	0.06	0.37	62.4	0.30	62.5

Table 3d. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Clarks Grove (CG) in 2015.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	---------- °F --------- -			50/86	inch	m^3/m^3	°F	m^3/m^3	°F
4/21	--	55	44	66	60	0.88	--	--	--	--
4/28	--	44	34	54	20	0.54	--	--	--	--
5/5	--	60	48	73	84	0.07	--	--	--	--
5/12	--	55	47	63	50	0.11	--	--	--	--
5/19	--	55	47	64	59	0.88	--	--	--	--
5/26	--	58	50	66	73	1.40	--	--	--	--
6/2	--	62	53	70	87	0.88	--	--	--	--
6/9	--	68	59	77	126	0.24	--	--	--	--
6/16	--	69	60	77	127	1.28	--	--	--	--
6/23	--	70	60	80	140	4.86	--	--	--	--
6/30	77	69	61	78	136	0.41	0.35	69	0.34	67
7/7	76	67	57	76	116	0.47	0.33	67	0.33	66
7/14	76	71	62	80	146	0.06	0.30	68	0.33	66
7/21	84	73	64	83	164	0.65	0.29	70	0.33	68
7/28	--	73	63	82	159	6.03	--	--	--	--
8/4	80	71	61	82	150	0.00	0.31	68	0.32	67
8/11	80	71	61	83	154	0.39	0.30	68	0.32	67
8/18	81	72	63	84	163	2.98	0.29	69	0.31	67
8/25	81	62	52	72	89	1.14	0.35	64	0.34	64
9/1	84	65	56	77	119	1.03	0.34	62	0.33	62
9/8	84	76	67	88	184	2.71	0.35	69	0.34	67
9/15	79	60	50	72	90	0.06	0.35	63	0.33	64
9/22	76	65	54	77	115	0.69	0.35	63	0.33	63
9/29	75	67	57	80	131	0.76	0.36	63	0.33	63
10/6	65	51	37	67	26	0.00	0.35	58	0.33	60

Table 3e. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Waseca location in 2015.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	---------	°F	---------	50/86	inch	m³/m³	°F	m³/m³	°F
4/30	54	50	39	59	35	0.43	0.4	47.6	0.4	44.9
5/7	58	61	51	72	85	0.39	0.4	55.3	0.4	49.9
5/14	--	55	43	64	43	0.30	--	--	--	--
5/21	--	54	45	62	49	1.45	--	--	--	--
5/28	--	63	52	72	94	1.03	--	--	--	--
6/4	69	61	53	70	87	0.95	0.40	64	0.43	60
6/11	71	70	60	79	133	1.68	0.41	69	0.43	63
6/18	80	67	60	74	118	2.04	0.41	69	0.43	65
6/25	76	70	59	79	134	1.51	0.41	70	0.44	66
7/2	79	68	58	77	125	0.58	0.35	69	0.43	66
7/9	77	67	56	76	115	1.78	0.33	66	0.42	65
7/16	80	75	65	85	171	0.06	0.31	69	0.40	66
7/23	79	72	59	86	152	0.53	0.30	69	0.37	67
7/30	83	74	62	86	166	4.13	0.39	70	0.42	67
8/6	76	70	55	85	142	0.03	0.37	68	0.41	67
8/13	83	72	62	84	160	2.09	0.39	69	0.42	67
8/20	87	69	61	78	134	2.10	0.38	69	0.41	67
8/27	78	62	51	76	103	0.94	0.40	64	0.42	64
9/3	88	69	62	80	142	1.15	0.41	65	0.41	63
9/10	85	72	64	83	160	3.49	0.44	70	0.44	68
9/17	75	65	53	77	117	0.65	0.42	64	0.42	64
9/24	84	63	54	73	100	0.60	0.42	64	0.42	64
10/1	69	63	51	77	111	0.00	0.42	64	0.42	63

Table 3f. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Northfield location in 2016.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	--------	°F	---------	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
5/7	50	59	45	69	68	0.05	0.40	54	0.28	50
5/14	73	53	44	60	37	1.33	0.40	56	0.28	54
5/21	49	56	43	66	56	0.00	0.40	55	0.28	52
5/28	65	70	61	79	141	0.60	0.40	66	0.27	60
6/4	77	65	58	74	112	0.68	0.39	66	0.28	62
6/11	69	68	58	78	124	2.32	0.38	67	0.28	62
6/18	79	72	64	80	151	1.96	0.37	72	0.30	66
6/25	70	72	62	81	149	0.00	0.36	74	0.29	69
7/2	70	69	57	80	125	0.15	0.34	74	0.28	70
7/9	78	70	59	81	140	1.57	0.34	73	0.28	69
7/16	78	72	64	81	156	1.09	0.36	72	0.27	69
7/23	81	77	66	87	177	0.81	0.35	74	0.27	69
7/30	82	73	65	81	163	1.22	0.35	74	0.27	71
8/6	83	74	65	83	167	0.34	0.35	73	0.26	70
8/13	84	73	64	84	164	3.69	0.35	72	0.26	69
8/20	84	71	61	83	152	0.87	0.36	71	0.28	69
8/27	81	67	59	77	125	1.21	0.37	68	0.27	67
9/3	83	67	55	79	121	0.77	0.38	67	0.27	66
9/10	85	69	61	77	134	2.03	0.38	67	0.28	66
9/17	77	64	54	76	107	1.31	0.38	64	0.28	64
9/24	80	67	58	78	126	2.58	0.38	65	0.32	64
10/1	76	58	49	69	74	0.19	0.39	60	0.37	62
10/8	73	61	48	75	68	0.53	0.39	60	0.34	60

Table 3g. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Clarks Grove (CG) in 2016.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	---------- °F --------- -			50/86	inch	m^3/m^3	°F	m^3/m^3	°F
5/7		54	43	66	59	0.00			--	--
5/14	82	52	44	59	35	1.00	0.40	51	0.34	52
5/21	54	54	42	65	53	0.07	0.40	54	0.34	51
5/28	67	68	61	78	136	1.06	0.41	64	0.34	58
6/4	72	65	57	75	112	1.39	0.44	66	0.36	62
6/11	68	68	58	79	126	1.10	0.43	67	0.36	63
6/18	79	73	66	83	169	2.00	0.44	72	0.39	68
6/25	72	71	60	80	140	0.24	0.32	72	0.39	69
7/2	73	68	56	79	121	1.18	0.25	70	0.38	68
7/9	79	69	58	79	130	1.81	0.25	68	0.37	66
7/16	79	71	61	80	145	1.43	0.30	69	0.41	67
7/23	81	76	67	86	180	1.32	0.36	70	0.40	67
7/30	81	72	62	81	151	1.43	0.39	71	0.41	69
8/6	82	73	64	82	161	1.13	0.39	70	0.40	68
8/13	81	72	62	83	156	0.80	0.31	70	0.37	68
8/20	81	70	59	82	145	2.47	0.30	69	0.36	68
8/27	80	65	57	76	114	1.84	0.41	66	0.43	66
9/3	81	66	56	77	118	0.05	0.39	66	0.40	66
9/10	80	69	62	78	138	3.03	0.42	67	0.42	66
9/17	76	63	54	75	103	2.30	0.43	64	0.43	65
9/24	78	67	59	77	126	6.48	0.43	64	0.44	64
10/1	72	58	50	68	73	0.38	0.43	60	0.43	62
10/8	73	60	50	73	63	0.37	0.40	60	0.40	61

Table 3h. Weekly relative humidity, air temperature, GDU, precipitation, 6- and 18-inch soil volumetric water content and temperature at Waseca location in 2016.

Week		Air Temperature					6-inch Soil		18-inch Soil	
Ending	RH	Mean	Min	Max	GDU	Precip.	VWC	Temp.	VWC	Temp.
	%	--------- °F ---------			50/86	inch	m^3/m^3	°F	m^3/m^3	°F
4/23		60	50	71	84	0.27				
4/30	87	50	42	57	36	0.96	0.44	50	0.32	50
5/7	57	57	44	68	64	0.40	0.46	53	0.33	50
5/14	76	52	44	60	38	1.37	0.46	56	0.33	55
5/21	54	55	42	65	54	0.02	0.46	55	0.33	53
5/28	67	69	61	78	138	1.05	0.47	65	0.34	61
6/4	77	64	57	72	102	1.03	0.48	65	0.35	63
6/11	68	68	59	79	128	0.57	0.48	68	0.35	64
6/18	78	73	65	83	166	2.60	0.49	74	0.38	69
6/25	71	72	60	82	146	0.33	0.46	74	0.37	71
7/2	71	69	57	80	126	0.49	0.40	74	0.36	71
7/9	79	69	59	80	137	3.27	0.40	72	0.36	70
7/16	81	71	62	80	145	1.26	0.44	71	0.37	69
7/23	82	77	68	87	183	1.75	0.44	72	0.37	69
7/30	84	72	63	81	154	1.02	0.45	73	0.36	72
8/6	83	73	64	83	164	0.59	0.42	73	0.35	71
8/13	84	72	63	83	159	4.95	0.42	71	0.37	70
8/20	83	70	61	82	150	2.36	0.46	71	0.37	70
8/27	82	66	57	76	116	2.13	0.47	68	0.37	68
9/3	82	67	57	79	127	0.47	0.47	68	0.36	67
9/10	82	69	61	77	135	2.85	0.47	68	0.37	67
9/17	78	63	54	75	102	0.87	0.47	64	0.36	65
9/24	79	67	59	78	128	8.93	0.48	65	0.39	65
10/1	75	58	50	69	76	0.22	0.47	61	0.36	63

Table 4A. Soil nitrate-N (PSNT) as affected by sampling time and depth and preplant N rate at BP-14.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V6		Average	
	lb/ac	------------ ppm ------------					
Soil nitrate 0-1 ft depth							
Fixed	105	10.2		4.1		7.2	a†
Variable	100	6.7		3.7		5.2	b
UM	120	11.1		4.7		7.9	a
	Average:	9.3	A	4.2	B		
Soil nitrate 0-2 ft depth							
Fixed	105	6.6		3.5		5.0	a
Variable	100	3.7		3.8		3.7	b
UM	120	7.2		4.1		5.6	a
	Average:	5.8	A	3.8	B		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4B. Soil nitrate-N (PSNT) as affected by sampling time and depth and preplant N rate at NF-14.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V6		Average	
	lb/ac	------------ ppm ------------					
Soil nitrate 0-1 ft depth							
Fixed	105	14.9		6.4		10.6	b†
Variable	100	13.6		5.4		9.5	c
UM	120	16.9		7.8		12.4	a
	Average:	15.2	A	6.5	B		
Soil nitrate 0-2 ft depth							
Fixed	105	10.5		5.5		8.0	b
Variable	100	10.0		4.3		7.1	c
UM	120	11.6		6.6		9.1	a
	Average:	10.7	A	5.5	B		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4C1. Rapid soil nitrate-N as affected by sampling time, preplant N rate and depth of sampling at NF-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	150	18.5		29.0		23.7	a†
Variable	150	22.1		31.7		26.9	a
UM	165	19.8		31.3		25.5	a
	Average:	20.1	B	30.7	A		
Soil nitrate 0-2 ft depth							
Fixed	150	11.0		20.0		15.5	a
Variable	150	13.5		21.0		17.2	a
UM	165	15.3		22.7		19.0	a
	Average:	13.3	B	21.2	A		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4C2. Soil nitrate-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at NF-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	150	17.6		32.7		25.1	a†
Variable	150	17.8		34.9		26.3	a
UM	165	11.3		31.8		21.5	b
	Average:	15.5	B	33.1	A		
Soil nitrate 0-2 ft depth							
Fixed	150	9.6		22.4		16.0	a
Variable	150	9.9		22.9		16.4	a
UM	165	9.6		23.2		16.4	a
	Average:	9.7	B	22.8	A		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4C3. Soil ammonium-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at NF-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	ppm					
Soil nitrate 0-1 ft depth							
Fixed	150	5.6		8.0		6.8	a†
Variable	150	5.4		5.8		5.6	a
UM	165	3.8		5.0		4.4	a
	Average:	4.9	A	6.3	A		
Soil nitrate 0-2 ft depth							
Fixed	150	3.8		5.4		4.6	a
Variable	150	3.7		4.1		3.9	ab
UM	165	2.2		3.4		2.8	b
	Average:	3.2	B	4.3	A		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4C4. Soil total inorganic-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at NF-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	ppm					
Soil nitrate 0-1 ft depth							
Fixed	150	23.2		40.7		31.9	a†
Variable	150	23.2		41.4		32.3	a
UM	165	13.2		36.8		25.0	b
	Average:	19.8	B	39.6	A		
Soil nitrate 0-2 ft depth							
Fixed	150	13.3		27.7		20.5	a
Variable	150	13.5		27.9		20.7	a
UM	165	11.8		26.6		19.2	a
	Average:	12.9	B	27.4	A		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4D1. Rapid soil nitrate-N as affected by sampling time, preplant N rate and depth of sampling at CG-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	150	28.3		20.9		24.6	a†
Variable	150	37.0		23.7		30.3	a
UM	165	32.5		27.0		29.7	a
	Average:	32.6	A	23.9	B		
Soil nitrate 0-2 ft depth							
Fixed	150	21.3		14.9		18.1	a
Variable	150	26.1		15.9		21.0	a
UM	165	25.4		18.9		22.1	a
	Average:	24.3	A	16.6	B		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4D2. Soil nitrate-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at CG-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	150	17.9		32.5		25.2	b†
Variable	150	26.4		43.4		34.9	a
UM	165	25.2		36.9		31.0	ab
	Average:	23.1	B	37.6	A		
Soil nitrate 0-2 ft depth							
Fixed	150	13.4		22.9		18.2	a
Variable	150	16.8		28.1		22.4	a
UM	165	17.6		25.1		21.4	a
	Average:	15.9	B	25.4	A		

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4D3. Soil ammonium-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at CG-15.

Nitrogen Treatment		Sampling Time				
Method	Rate	V2		V5		Average
	lb/ac	------------ ppm -------------				
Soil nitrate 0-1 ft depth						
Fixed	150	4.1		4.1		4.1 a†
Variable	150	4.8		4.4		4.6 a
UM	165	4.6		5.4		5.0 a
	Average:	4.5	A	4.6	A	
Soil nitrate 0-2 ft depth						
Fixed	150	3.5		3.2		3.4 a
Variable	150	3.8		3.2		3.5 a
UM	165	3.4		3.7		3.6 a
	Average:	3.6	A	3.4	A	

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4D4. Soil total inorganic-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at CG-15.

Nitrogen Treatment		Sampling Time				
Method	Rate	V2		V5		Average
	lb/ac	------------ ppm -------------				
Soil nitrate 0-1 ft depth						
Fixed	150	22.3		36.7		29.5 b†
Variable	150	31.4		47.8		39.6 a
UM	165	30.0		42.3		36.1 ab
	Average:	27.9	B	42.3	A	
Soil nitrate 0-2 ft depth						
Fixed	150	17.1		26.1		21.6 a
Variable	150	20.6		31.2		25.9 a
UM	165	21.1		28.9		25.0 a
	Average:	19.6	B	28.7	A	

† Numbers within a column followed by the same lower case letter and numbers within a row followed by the same upper case letter are not significantly different at ($P \leq 0.10$).

Table 4E1. Rapid soil nitrate-N as affected by sampling time, preplant N rate and depth of sampling at WA-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	25.3		18.1		21.7	A†
Variable	100	18.5		15.2		16.8	A
UM	125	25.7		19.5		22.6	A
	Average:	23.1	A	17.6	B		
Soil nitrate 0-2 ft depth							
Fixed	100	17.3	a	16.8	a	17.1	A
Variable	100	16.0	a	11.8	b	13.9	B
UM	125	17.7	a	18.8	a	18.2	A
	Average:	17.0	A	15.8	A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4E2. Soil nitrate-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at WA-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	36.5		22.2		29.4	A†
Variable	100	26.7		14.4		20.6	B
UM	125	38.3		24.6		31.4	A
	Average:	33.9	A	20.4	B		
Soil nitrate 0-2 ft depth							
Fixed	100	24.3		19.3		21.8	A
Variable	100	19.0		14.9		16.9	B
UM	125	25.2		21.6		23.4	A
	Average:	22.8	A	18.6	B		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4E3. Soil ammonium-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at WA-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	6.0		4.8		5.4	A†
Variable	100	6.5		4.2		5.4	A
UM	125	6.4		4.9		5.6	A
	Average:	6.3	A	4.6	B		
Soil nitrate 0-2 ft depth							
Fixed	100	4.2		3.4		3.8	A
Variable	100	4.8		2.9		3.8	A
UM	125	4.8		3.4		4.1	A
	Average:	4.6	A	3.2	B		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4E4. Soil total inorganic-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at WA-15.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	42.5		27.0		34.8	A†
Variable	100	33.2		18.0		25.6	B
UM	125	44.7		29.4		37.1	A
	Average:	40.1	A	24.8	B		
Soil nitrate 0-2 ft depth							
Fixed	100	28.6		22.7		25.6	A
Variable	100	23.7		17.4		20.6	B
UM	125	30.0		25.0		27.5	A
	Average:	27.4	A	21.7	B		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4F1. Rapid soil nitrate-N as affected by sampling time, preplant N rate and depth of sampling at NF-16.

Nitrogen Treatment		Sampling Time				
Method	Rate	V2		V5		Average
	lb/ac	------------ ppm -------------				
Soil nitrate 0-1 ft depth						
Fixed	150	27.6		29.7		28.6 A†
Variable	150	25.8		32.6		29.2 A
UM	165	32.5		36.8		34.7 A
	Average:	28.6	A	33.0	A	
Soil nitrate 0-2 ft depth						
Fixed	150	14.0		18.2		16.1 A
Variable	150	12.8		20.2		16.5 A
UM	165	17.2		22.6		19.9 A
	Average:	14.7	B	20.4	A	

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4F2. Soil nitrate-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at NF-16.

Nitrogen Treatment		Sampling Time				
Method	Rate	V2		V5		Average
	lb/ac	------------ ppm -------------				
Soil nitrate 0-1 ft depth						
Fixed	150	31.0		38.2		34.6 B†
Variable	150	31.0		41.6		36.3 B
UM	165	36.8		44.2		40.5 A
	Average:	32.9	B	41.3	A	
Soil nitrate 0-2 ft depth						
Fixed	150	19.6		23.4		21.5 A
Variable	150	19.4		25.4		22.4 A
UM	165	24.0		26.9		25.4 A
	Average:	21.0	B	25.2	A	

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4F3. Soil ammonium-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at NF-16.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm ------------					
Soil nitrate 0-1 ft depth							
Fixed	150	12.3		14.4		13.4	A†
Variable	150	14.1		14.3		14.2	A
UM	165	16.8		13.6		15.2	A
	Average:	14.4	A	14.1	A		
Soil nitrate 0-2 ft depth							
Fixed	150	8.1		10.1		9.1	A
Variable	150	9.6		9.9		9.7	A
UM	165	11.3		9.6		10.4	A
	Average:	9.7	A	9.9	A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4F4. Soil total inorganic-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at NF-16.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm ------------					
Soil nitrate 0-1 ft depth							
Fixed	150	43.4		52.7		48.0	A†
Variable	150	45.6		55.8		50.7	A
UM	165	53.7		57.8		55.8	A
	Average:	47.6	B	55.4	A		
Soil nitrate 0-2 ft depth							
Fixed	150	27.8		33.8		30.8	A
Variable	150	29.3		35.4		32.3	A
UM	165	35.2		36.5		35.9	A
	Average:	30.8	B	35.2	A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4G1. Rapid soil nitrate-N as affected by sampling time, preplant N rate and depth of sampling at CG-16.

Nitrogen Treatment		Sampling Time		
Method	Rate	V2	V5	Average
	lb/ac	------------ ppm -------------		
Soil nitrate 0-1 ft depth				
Fixed	150	---	19.2	19.2 A†
Variable	150	---	22.1	22.1 A
UM	165	---	24.3	24.3 A
	Average:		21.9	
Soil nitrate 0-2 ft depth				
Fixed	150	---	13.1	13.1 A
Variable	150	---	15.0	15.0 A
UM	165	---	16.2	16.2 A
	Average:		14.8	

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4G2. Soil nitrate-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at CG-16.

Nitrogen Treatment		Sampling Time		
Method	Rate	V2	V5	Average
	lb/ac	------------ ppm -------------		
Soil nitrate 0-1 ft depth				
Fixed	150	21.3	31.2	26.2 A†
Variable	150	27.7	33.9	30.8 A
UM	165	22.5	38.2	30.4 A
	Average:	23.8 B	34.4 A	
Soil nitrate 0-2 ft depth				
Fixed	150	13.2 c	20.0 b	16.6 A
Variable	150	15.8 c	22.1 ab	19.0 A
UM	165	13.8 c	24.4 a	19.1 A
	Average:	14.3 B	22.2 A	

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4G3. Soil ammonium-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at CG-16.

Nitrogen Treatment		Sampling Time			
Method	Rate	V2	V5	Average	
	lb/ac	----------- ppm -----------			
Soil nitrate 0-1 ft depth					
Fixed	150	8.1	6.2	7.1	A†
Variable	150	9.0	6.4	7.7	A
UM	165	10.9	7.1	9.0	A
	Average:	9.3 A	6.6 B		
Soil nitrate 0-2 ft depth					
Fixed	150	5.5	3.9	4.7	A
Variable	150	5.8	4.0	4.9	A
UM	165	7.0	4.4	5.7	A
	Average:	6.1 A	4.1 B		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4G4. Soil total inorganic-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at CG-16.

Nitrogen Treatment		Sampling Time			
Method	Rate	V2	V5	Average	
	lb/ac	----------- ppm -----------			
Soil nitrate 0-1 ft depth					
Fixed	150	29.4	37.4	33.4	A†
Variable	150	36.7	40.3	38.5	A
UM	165	33.4	45.3	39.4	A
	Average:	33.2 B	41.0 A		
Soil nitrate 0-2 ft depth					
Fixed	150	18.6	24.0	21.3	A
Variable	150	21.6	26.0	23.8	A
UM	165	20.8	28.9	24.8	A
	Average:	20.4 B	26.3 A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4H1. Rapid soil nitrate-N as affected by sampling time, preplant N rate and depth of sampling at WA-16.

Nitrogen Treatment		Sampling Time			
Method	Rate	V2	V5	Average	
	lb/ac	------------ ppm -------------			
Soil nitrate 0-1 ft depth					
Fixed	150	---	13.7	13.7	A†
Variable	150	---	14.6	14.6	A
UM	165	---	15.1	15.1	A
	Average:		14.4		
Soil nitrate 0-2 ft depth					
Fixed	150	---	10.9	10.9	A
Variable	150	---	12.0	12.0	A
UM	165	---	12.2	12.2	A
	Average:		11.7		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4H2. Soil nitrate-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at WA-16.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	23.8	ac	19.6	bd	21.7	A†
Variable	100	19.9	cd	24.7	ab	22.3	A
UM	125	23.9	abc	22.8	abc	23.4	A
	Average:	22.5	A	22.4	A		
Soil nitrate 0-2 ft depth							
Fixed	100	16.5	ab	14.1	c	15.2	A
Variable	100	14.4	bc	17.3	a	15.8	A
UM	125	15.9	abc	16.6	abc	16.2	A
	Average:	15.6	A	16.0	A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4H3. Soil ammonium-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at WA-16.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	6.1		5.8		6.0	A†
Variable	100	6.6		7.0		6.8	A
UM	125	6.8		5.2		6.0	A
	Average:	6.5	A	6.0	A		
Soil nitrate 0-2 ft depth							
Fixed	100	4.1		3.9		4.0	A
Variable	100	4.4		4.4		4.4	A
UM	125	4.2		3.5		3.8	A
	Average:	4.2	A	3.9	A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 4H4. Soil total inorganic-N (Dry) as affected by sampling time, preplant N rate and depth of sampling at WA-16.

Nitrogen Treatment		Sampling Time					
Method	Rate	V2		V5		Average	
	lb/ac	------------ ppm -------------					
Soil nitrate 0-1 ft depth							
Fixed	100	29.8	ab	25.4	ab	27.6	A†
Variable	100	26.4	b	31.7	a	29.1	A
UM	125	30.6	ab	28.0	ab	29.3	A
	Average:	29.0	A	28.4	A		
Soil nitrate 0-2 ft depth							
Fixed	100	20.5	ab	18.0	b	19.2	A
Variable	100	18.7	ab	21.8	a	20.2	A
UM	125	20.0	ab	20.1	ab	20.0	A
	Average:	19.8	A	19.9	A		

† Numbers within a column or row followed by an upper case letters indicate significance of main effects. Numbers followed by lower case letters indicate significance of interactions between main effects at $P \leq 0.10$.

Table 5a. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at BP14.

	Nitrogen Treatments					Weigh	Yield		N		
		N Rates		Grain	Grain	Wagon	Monitor	Grain	Removal		Plant
Trt	Method	PP	SD	Moist.	Test wt.	Yield	Yield	N conc.	Grain	PFP_N	Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	pl*10^3/ac
1	Fixed	105	46	ND†	ND	150 b	153 b	1.32	94 a	1.00 b	31.0
2	Variable	100	120	ND	ND	160 a	170 a	1.37	103 a	0.73 c	31.9
3	UM‡	120	0	ND	ND	136 c	132 c	1.23	79 b	1.13 a	30.6
Prob. > F:						0.002	<0.001	0.195	0.017	<0.001	0.130
Average LSD (0.10):						8	7	NS	11	0.05	NS

† ND = no data for this location. ‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 5c. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at NF15.

	Nitrogen Treatments					Weigh	Yield		N		
		N Rates		Grain	Grain	Wagon	Monitor	Grain	Removal		Plant
Trt	Method	PP	SD	Moist.	Test wt.	Yield	Yield	N conc.	Grain	PFP_N	Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	pl*10^3/ac
1	Fixed	150	50	16.2	56.3	215	203	1.27 a	128 ab	1.07 b	29.2 a
2	Variable	150	64	16.5	56.5	220	202	1.26 a	131 a	1.04 b	25.4 b
3	UM‡	165	0	16.3	56.5	213	202	1.23 b	124 b	1.29 a	25.8 b
Prob. > F:				0.472	0.700	0.339	0.906	0.050	0.093	0.002	0.091
Average LSD (0.10):				NS	NS	NS	NS	0.02	5	0.09	3.0

‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 5d. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at CG15

	Nitrogen Treatments					Weigh	Yield		N		
		N Rates		Grain	Grain	Wagon	Monitor	Grain	Removal		Plant
Trt.	Method	PP	SD	Moist.	Test wt.	Yield	Yield	N conc.	Grain	PFP_N	Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	pl*10^3/ac
1	Fixed	150	50	13.6	57.1	217 a	210	1.15 b	119 b	1.09 b	29.6
2	Variable	150	113	13.6	57.1	217 a	211	1.20 a	123 a	0.79 c	29.1
3	UM‡	165	0	13.4	57.0	213 b	208	1.13 b	114 c	1.29 a	29.3
Prob. > F:				0.320	0.894	0.049	0.792	0.037	0.013	0.006	0.861
Average LSD (0.10):				NS	NS	2	NS	0.03	3	0.15	NS

‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 5e. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at WA15

Trt.	Nitrogen Treatments Method	N Rates PP	N Rates SD	Grain Moist.	Grain Test wt.	Weigh Wagon Yield	Yield Monitor Yield	Grain N conc.	N Removal Grain	PFP_N	Plant Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	pl*10^3/ac
1	Fixed	100	40	17.1 a	55.7	210 b	ND†	1.14 ab	113 ab	1.50 b	31.6
2	Variable	100	101	17.3 a	55.9	221 a	ND	1.16 a	122 a	1.10 c	31.5
3	UM‡	120	0	16.6 b	55.7	206 b	ND	1.10 b	107 b	1.71 a	31.6
Prob. > F:				0.018	0.390	0.025		0.077	0.052	<0.001	0.954
Average LSD (0.10):				0.3	NS	8		0.04	9	0.09	NS

† ND = no data for this location. ‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 5f. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at NF16.

Trt	Nitrogen Treatments Method	N Rates PP	N Rates SD	Grain Moist.	Grain Test wt.	Weigh Wagon Yield	Yield Monitor Yield	Grain N conc.	N Removal Grain	PFP_N	Plant Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	pl*10^3/ac
1	Fixed	150	50	15.6 a	59.3	192	186	1.11 a	101	0.96 b	29.1
2	Variable	150	54	15.6 a	59.3	193	187	1.13 a	104	0.97 b	30.0
3	UM‡	165	0	15.3 b	59.4	191	186	1.09 b	98	1.16 a	29.2
Prob. > F:				0.002	0.990	0.882	0.970	0.014	0.258	0.052	0.365
Average LSD (0.10):				0.1	NS	NS	NS	0.02	NS	0.14	NS

‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 5g. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at CG16.

Trt.	Nitrogen Treatments Method	N Rates PP	N Rates SD	Grain Moist.	Grain Test wt.	Weigh Wagon Yield	Yield Monitor Yield	Grain N conc.	N Removal Grain	PFP_N	Plant Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	pl*10^3/ac
1	Fixed	150	50	15.5	57.8	202	206 b	1.13	108	1.01 b	30.2
2	Variable	150	66	15.4	57.8	201	206 b	1.13	107	0.93 c	30.4
3	UM‡	165	0	15.5	57.8	204	209 a	1.10	106	1.24 a	29.8
Prob. > F:				0.348	0.964	0.138	0.037	0.571	0.813	<0.001	0.320
Average LSD (0.10):				NS	NS	NS	2	NS	NS	0.03	NS

‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 5h. Corn grain moisture, test weight, yield, N concentration, N removal and Partial Factor Productivity, and plant population as affected by N treatments at WA16.

	Nitrogen Treatments					Weigh	Yield		N		
		N Rates		Grain	Grain	Wagon	Monitor	Grain	Removal		Plant
Trt.	Method	PP	SD	Moist.	Test wt.	Yield	Yield	N conc.	Grain	PFP_N	Pop.
		lb N/ac		%	lb/bu	------- bu/ac	-------	%	lb/ac	bu/lb	$pl*10^3/ac$
1	Fixed	150	50	18.3 a	55.5	205 a	218 a	1.16 b	112 a	1.02 b	31.2
2	Variable	150	76	18.3 a	55.4	210 a	228 a	1.20 a	119 a	0.93 c	30.9
3	UM‡	165	0	17.7 b	55.4	188 b	198 b	1.16 b	103 b	1.14 a	30.5
Prob. > F:				0.020	0.993	0.046	0.030	0.072	0.016	0.006	0.276
Average LSD (0.10):				0.4	NS	14	16	0.03	7	0.08	NS

‡ UM=Univ. of MN rate based on MRTN (N rate calculator).

Table 6. Economic return as affected by nitrogen treatments by location.

Location	Treatment	Soil sampling	Preplant N Fertilizer	Preplant N Rate	Sidedress N Fertilizer	Sidedress N Rate	Sidedress N applic.	Grain yield	Grain moisture	Grain handling	Grain drying	Input costs	Gross Income	Net Return	Rank
			$0.45/lb	lb/ac	$0.50/lb	lb/ac		bu/ac	%	$0.10/bu	$0.025/bu	$/ac	$4.00/bu	$/ac	
BP14	Fixed	$ -	$ 47.25	105	$ 23.00	46	$ 9.00	150	17.0	$ 15.00	$ 5.63	$ 99.88	$600.00	$500.13	1
BP14	Variable	$ 6.50	$ 45.00	100	$ 60.00	120	$ 9.50	160	17.0	$ 16.00	$ 6.00	$143.00	$640.00	$497.00	2
BP14	U of M	$ -	$ 54.00	120	$ -	0	$ -	136	17.0	$ 13.60	$ 5.10	$ 72.70	$544.00	$471.30	3
NF15	Fixed	$ -	$ 67.50	150	$ 25.00	50	$ 9.00	215	16.2	$ 21.50	$ 3.49	$126.49	$860.00	$733.51	3
NF15	Variable	$ 6.50	$ 67.50	150	$ 32.00	64	$ 9.50	220	16.5	$ 22.00	$ 5.64	$143.14	$880.00	$736.86	2
NF15	U of M	$ -	$ 74.25	165	$ -	0	$ -	213	16.3	$ 21.30	$ 4.39	$ 99.94	$852.00	$752.06	1
CG15	Fixed	$ -	$ 67.50	150	$ 25.00	50	$ 9.00	217	15.5	$ 21.70	$ -	$123.20	$868.00	$744.80	2
CG15	Variable	$ 6.50	$ 67.50	150	$ 56.50	113	$ 9.50	217	15.5	$ 21.70	$ -	$161.70	$868.00	$706.30	3
CG15	U of M	$ -	$ 74.25	165	$ -	0	$ -	213	15.5	$ 21.30	$ -	$ 95.55	$852.00	$756.45	1
WA15	Fixed	$ -	$ 45.00	100	$ 20.00	40	$ 9.00	210	17.1	$ 21.00	$ 8.14	$103.14	$840.00	$736.86	3
WA15	Variable	$ 6.50	$ 45.00	100	$ 50.50	101	$ 9.50	221	17.3	$ 22.10	$ 9.88	$143.48	$884.00	$740.52	2
WA15	U of M	$ -	$ 54.00	120	$ -	0	$ -	206	16.6	$ 20.60	$ 5.86	$ 80.46	$824.00	$743.54	1
NF16	Fixed	$ -	$ 67.50	150	$ 25.00	50	$ 9.00	192	15.6	$ 19.18	$ 0.60	$121.28	$767.28	$646.00	2
NF16	Variable	$ 6.50	$ 67.50	150	$ 27.00	54	$ 9.50	193	15.6	$ 19.31	$ 0.24	$130.05	$772.28	$642.23	3
NF16	U of M	$ -	$ 74.25	165	$ -	0	$ -	191	15.3	$ 19.08	$ -	$ 93.33	$763.28	$669.95	1
CG16	Fixed	$ -	$ 67.50	150	$ 25.00	50	$ 9.00	202	15.5	$ 20.19		$121.69	$807.76	$686.06	2
CG16	Variable	$ 6.50	$ 67.50	150	$ 33.00	66	$ 9.50	201	15.4	$ 20.14		$136.64	$805.44	$668.81	3
CG16	U of M	$ -	$ 74.25	165	$ -	0	$ -	204	15.5	$ 20.41	$ 0.13	$ 94.79	$816.37	$721.59	1
WA16	Fixed	$ -	$ 67.50	150	$ 25.00	50	$ 9.00	205	18.3	$ 20.48	$ 14.08	$136.05	$819.01	$682.95	1
WA16	Variable	$ 6.50	$ 67.50	150	$ 38.00	76	$ 9.50	210	18.3	$ 20.97	$ 14.68	$157.14	$838.63	$681.48	2
WA16	U of M	$ -	$ 74.25	165	$ -	0	$ -	188	17.7	$ 18.79	$ 10.10	$103.15	$751.77	$648.63	3

Table 7A. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at BP14.

Nitrogen Treatment			Sampling Depth					
Method	PP Rate	SD Rate	0-2 ft		2-4 ft		Avg.	
	lb/ac	lb/ac	ppm					
Soil nitrate-N								
Fixed	105	46	3.9		0.6		2.3	AB†
Variable	100	120	4.9		0.8		2.8	A
UM	120	0	2.6		0.5		1.5	B
		Average:	3.8	A	0.6	B		
Soil ammonium-N								
Fixed	105	46	3.6		2.5		3.1	A
Variable	100	120	3.4		2.5		2.9	A
UM	120	0	3.8		2.6		3.2	A
		Average:	3.6	A	2.5	B		
Soil nitrate + ammonium-N								
Fixed	105	45	7.6		3.1		5.3	A
Variable	100	100	8.2		3.3		5.7	A
UM	120	0	6.3		3.1		4.7	A
		Average:	7.3	A	3.2	B		

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

Table 7C. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at NF15.

Nitrogen Treatment			Sampling Depth					
Method	PP Rate	SD Rate	0 - 2 ft		2 - 4 ft		Avg.	
	lb/ac	lb/ac	ppm					
Soil nitrate-N								
Fixed	150	50	7.4		3.9		5.7	A†
Variable	150	64	8.7		4.9		6.8	A
UM	165	0	5.8		4.7		5.2	A
		Average:	7.3	A	4.5	B		
Soil ammonium-N								
Fixed	150	50	2.7		1.1		1.9	A
Variable	150	64	2.3		1.4		1.8	A
UM	165	0	2.2		1.0		1.6	A
		Average:	2.4	A	1.1	B		
Soil nitrate + ammonium-N								
Fixed	150	50	10.1		5.0		7.5	A
Variable	150	64	11.0		6.2		8.6	A
UM	165	0	8.0		5.7		6.8	A
		Average:	9.7	A	5.6	B		

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

Table 7D. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at CG15.

Nitrogen Treatment			Sampling Depth		
Method	PP Rate	SD Rate	0 - 2 ft	2 - 4 ft	Avg.
	lb/ac	lb/ac	------------ ppm -------------		
Soil nitrate-N					
Fixed	150	50	5.4	3.9	4.7 A†
Variable	150	113	9.8	4.3	7.0 A
UM	165	0	3.3	2.4	2.9 A
		Average:	6.2 A	3.5 B	
Soil ammonium-N					
Fixed	150	50	2.6	1.7	2.2 A
Variable	150	113	2.4	1.7	2.1 A
UM	165	0	2.5	1.6	2.1 A
		Average:	2.5 A	1.7 B	
Soil nitrate + ammonium-N					
Fixed	150	50	8.0	5.6	6.8 A
Variable	150	113	12.2	6.0	9.1 A
UM	165	0	5.6	3.8	4.7 A
		Average:	8.6 A	5.1 B	

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

Table 7E. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at WA15.

Nitrogen Treatment			Sampling Depth		
Method	PP Rate	SD Rate	0 - 2 ft	2 - 4 ft	Avg.
	lb/ac	lb/ac	------------ ppm -------------		
Soil nitrate-N					
Fixed	100	40	4.5	2.9	3.7 A†
Variable	100	101	4.0	2.4	3.2 A
UM	120	0	4.4	1.9	3.2 A
		Average:	4.3 A	2.4 B	
Soil ammonium-N					
Fixed	100	40	4.9	2.1	3.5 A
Variable	100	101	5.2	2.6	3.9 A
UM	120	0	5.0	2.3	3.6 A
		Average:	5.0 A	2.3 B	
Soil nitrate + ammonium-N					
Fixed	100	40	9.4	5.0	7.2 A
Variable	100	101	9.1	4.9	7.0 A
UM	120	0	9.4	4.1	6.8 A
		Average:	9.3 A	4.7 B	

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

Table 6F. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at NF16.

Nitrogen Treatment			Sampling Depth					
Method	PP Rate	SD Rate	0 - 2 ft		2 - 4 ft		Avg.	
	lb/ac	lb/ac	------------ ppm -------------					
Soil nitrate-N								
Fixed	150	50	4.7		3.8		4.2	A†
Variable	150	60	4.3		3.1		3.7	A
UM	165	0	4.1		2.4		3.2	A
		Average:	4.4	A	3.1	B		
Soil ammonium-N								
Fixed	150	50	6.6		3.5		5.0	A
Variable	150	60	6.2		4.0		5.1	A
UM	165	0	6.0		3.2		4.6	A
		Average:	6.3	A	3.6	B		
Soil nitrate + ammonium-N								
Fixed	150	50	11.3		7.3		9.3	A
Variable	150	60	10.5		7.0		8.7	A
UM	165	0	10.2		5.6		7.9	A
		Average:	10.6	A	6.6	B		

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

Table 6G. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at CG16.

Nitrogen Treatment			Sampling Depth					
Method	PP Rate	SD Rate	0 - 2 ft		2 - 4 ft		Average	
	lb/ac	lb/ac	------------ ppm -------------					
Soil nitrate-N								
Fixed	150	50	4.2		3.2		3.7	A†
Variable	150	66	4.3		3.8		4.1	A
UM	165	0	4.2		3.4		3.8	A
		Average:	4.2	A	3.4	B		
Soil ammonium-N								
Fixed	150	50	4.6		3.6		4.1	A
Variable	150	66	5.0		3.5		4.3	A
UM	165	0	5.4		4.2		4.8	A
		Average:	5.0	A	3.8	B		
Soil nitrate + ammonium-N								
Fixed	150	50	8.8		6.7		7.8	A
Variable	150	66	9.4		7.3		8.3	A
UM	165	0	9.6		7.6		8.6	A
		Average:	9.3	A	7.2	B		

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

Table 7H. Residual soil N after harvest as affected by sampling depth and N treatment (rate) at WA16.

Nitrogen Treatment			Sampling Depth					
Method	PP Rate	SD Rate	0 - 2 ft		2 - 4 ft		Avg.	
	lb/ac	lb/ac	------------ ppm -------------					
Soil nitrate-N								
Fixed	150	50	2.1		1.3		1.7	AB†
Variable	150	76	2.1		1.7		1.9	A
UM	165	0	1.6		1.1		1.4	B
		Average:	1.9	A	1.4	B		
Soil ammonium-N								
Fixed	100	40	3.9		2.7		3.3	A
Variable	100	76	3.4		2.6		3.0	A
UM	120	0	2.8		2.6		2.7	A
		Average:	3.4	A	2.6	B		
Soil nitrate + ammonium-N								
Fixed	100	40	6.0		4.0		5.0	A
Variable	100	76	5.5		4.2		4.9	A
UM	120	0	4.4		3.7		4.0	A
		Average:	5.3	A	4.0	B		

† Numbers within a column or row followed by the same letter are not significantly different at ($P \leq 0.10$).

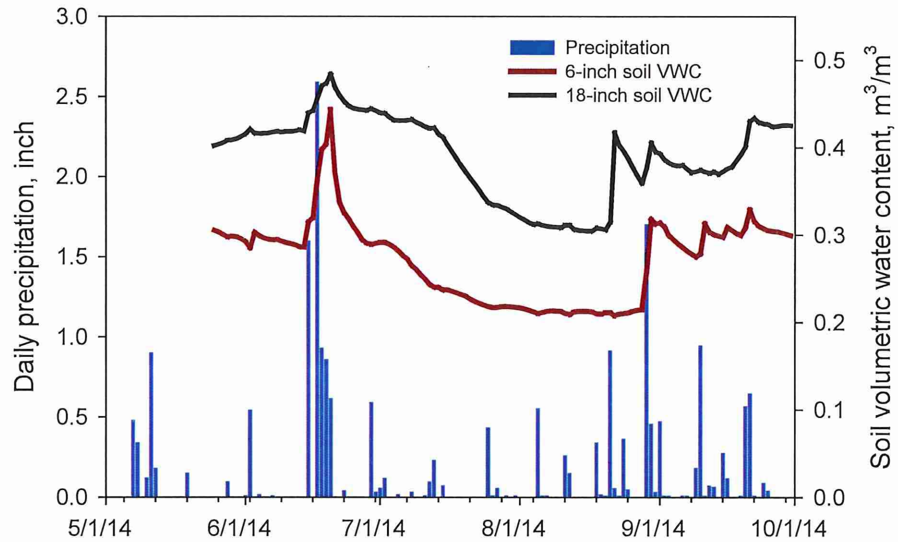


Figure 1a. Daily precipitation and soil volumetric water content at Blooming Prairie in 2014.

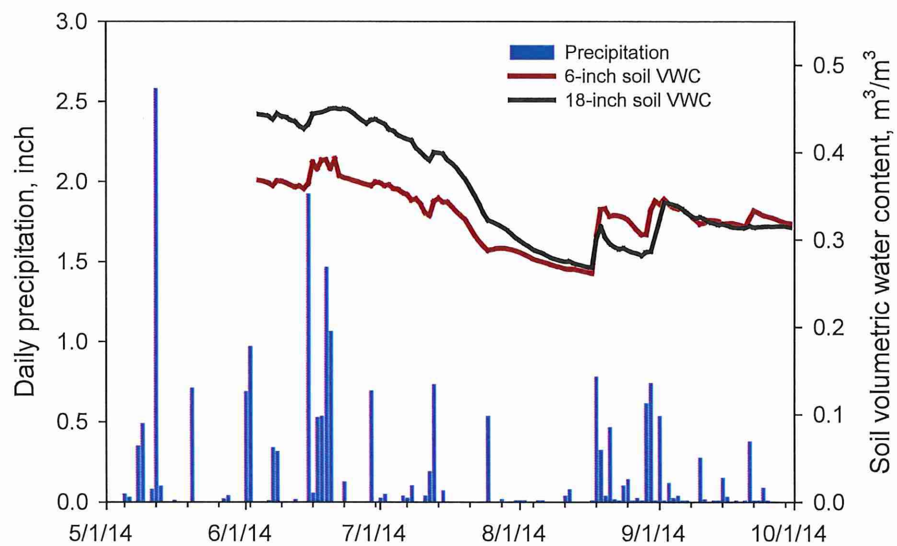


Figure 1b. Daily precipitation and soil volumetric water content at Northfield in 2014

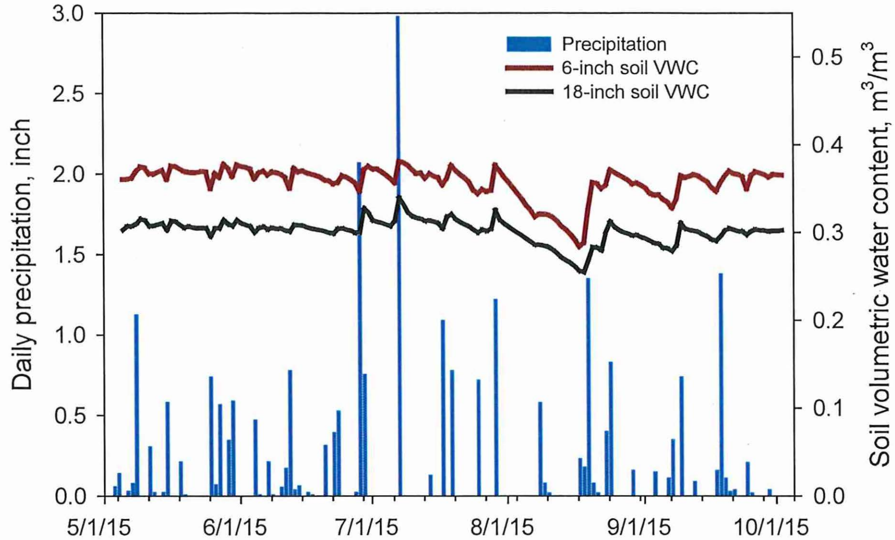


Figure 1c. Daily precipitation and soil volumetric water content at Northfield in 2015.

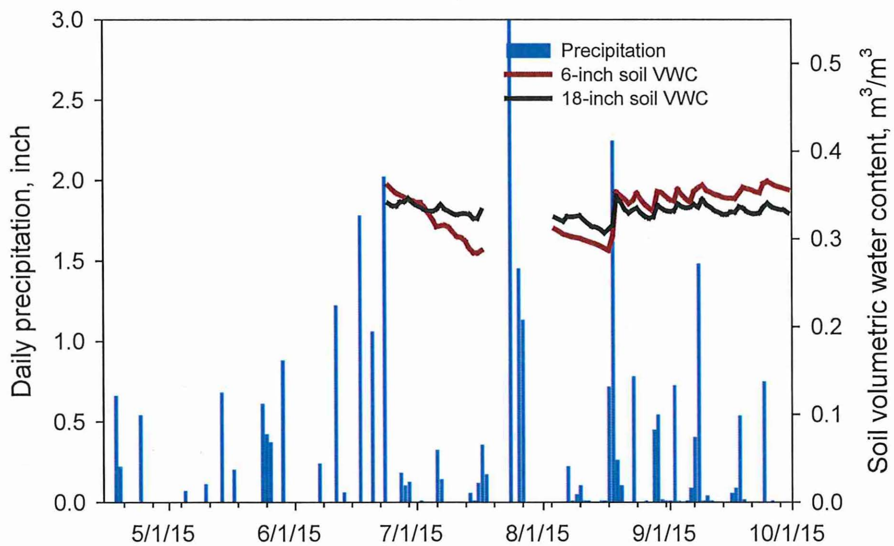


Figure 1d. Daily precipitation and soil volumetric water content at Clarks Grove in 2015.

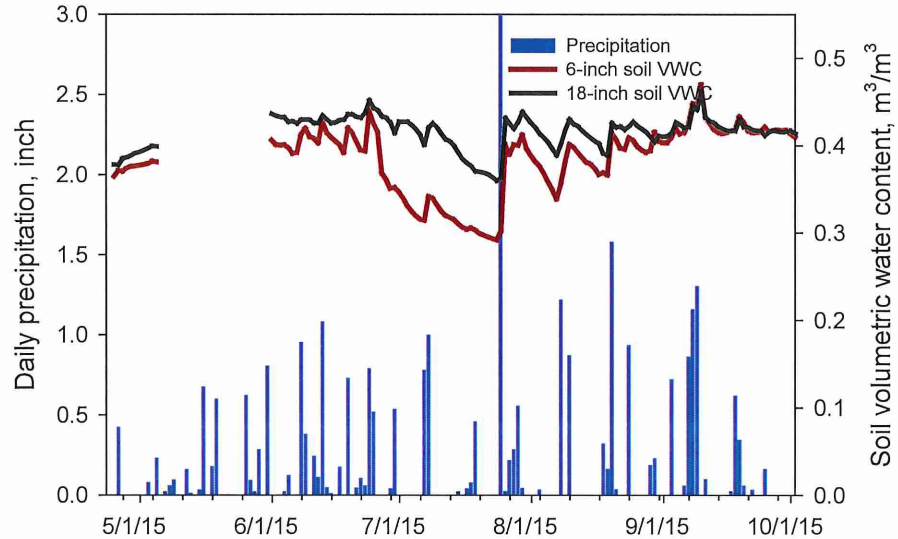


Figure 1e. Daily precipitation and soil volumetric water content at Waseca in 2015.

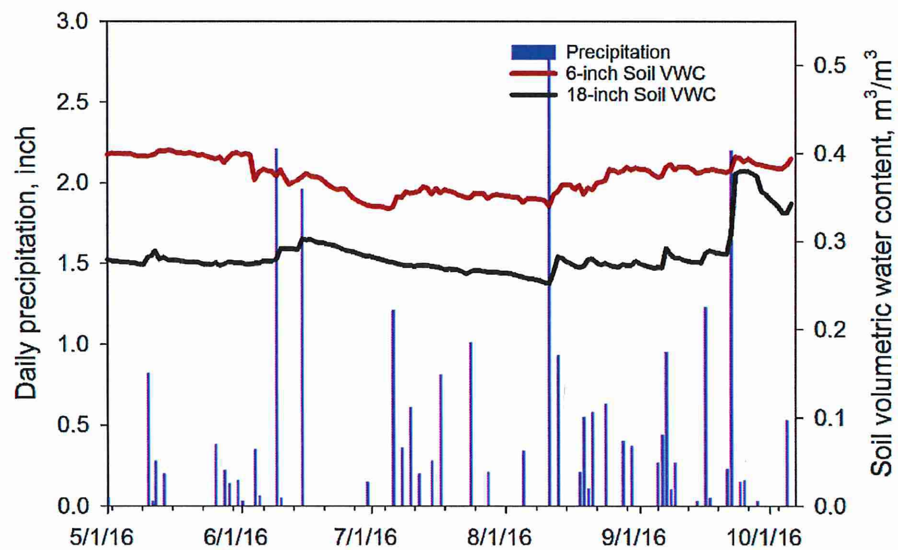


Figure 1f. Daily precipitation and soil volumetric water content at Northfield in 2016.

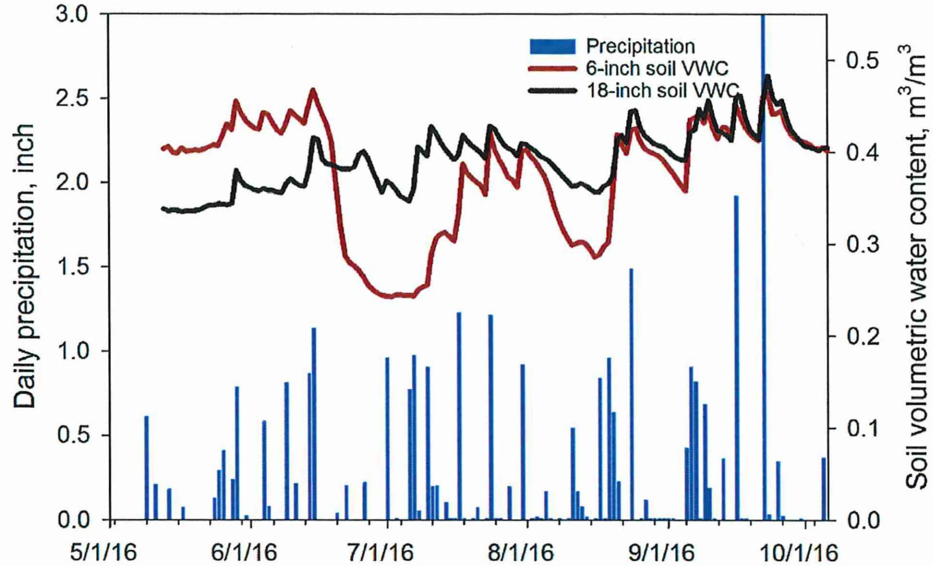


Figure 1g. Daily precipitation and soil volumetric water content at Clarks Grove in 2016.

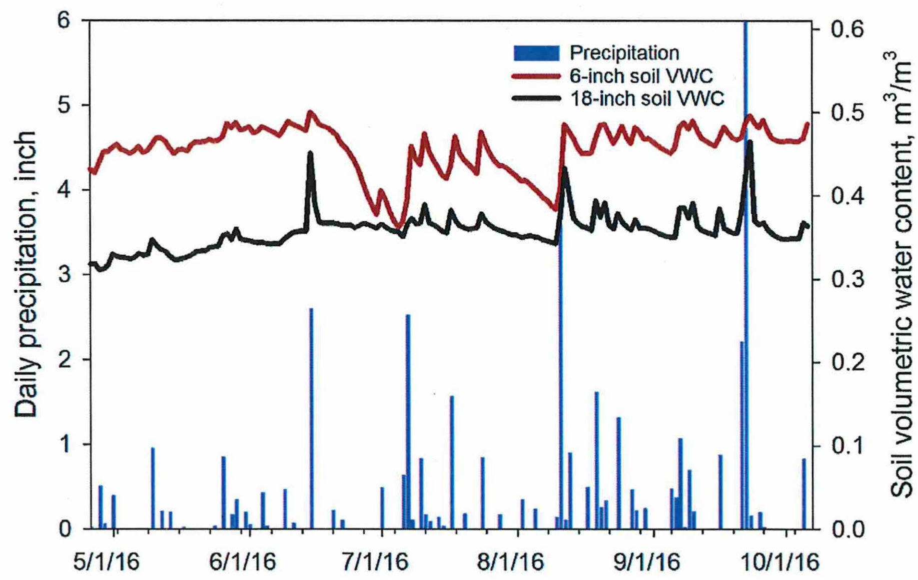


Figure 1h. Daily precipitation and soil volumetric water content at Waseca in 2016.

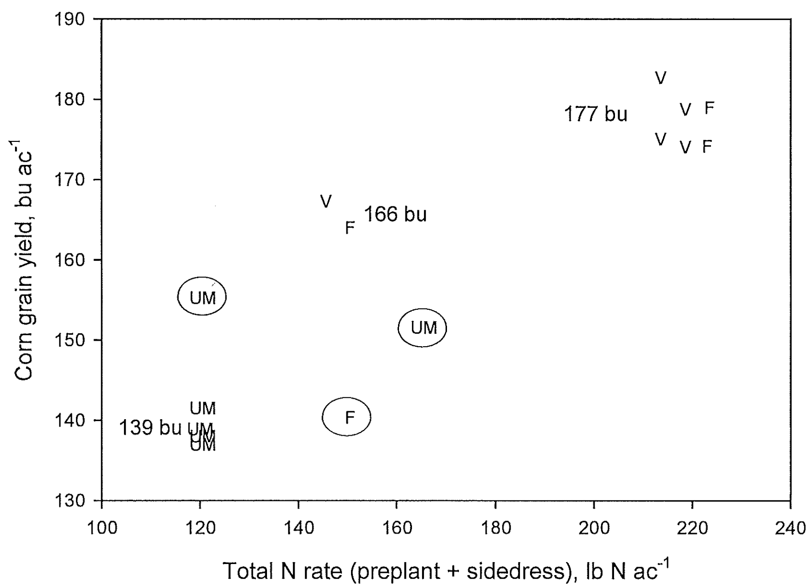


Figure 2. Corn grain yields as affected by the total N rate (preplant + sidedress) at NF14. Potential outliers are circled and not included in mean calculations. Abbreviations: UM= UM preplant only rate (120 lb N/ac), F=Fixed sidedress rate (105 lb N/ac preplant plus sidedress) and V=Variable sidedress rate (100 lb N/ac preplant = sidedress).

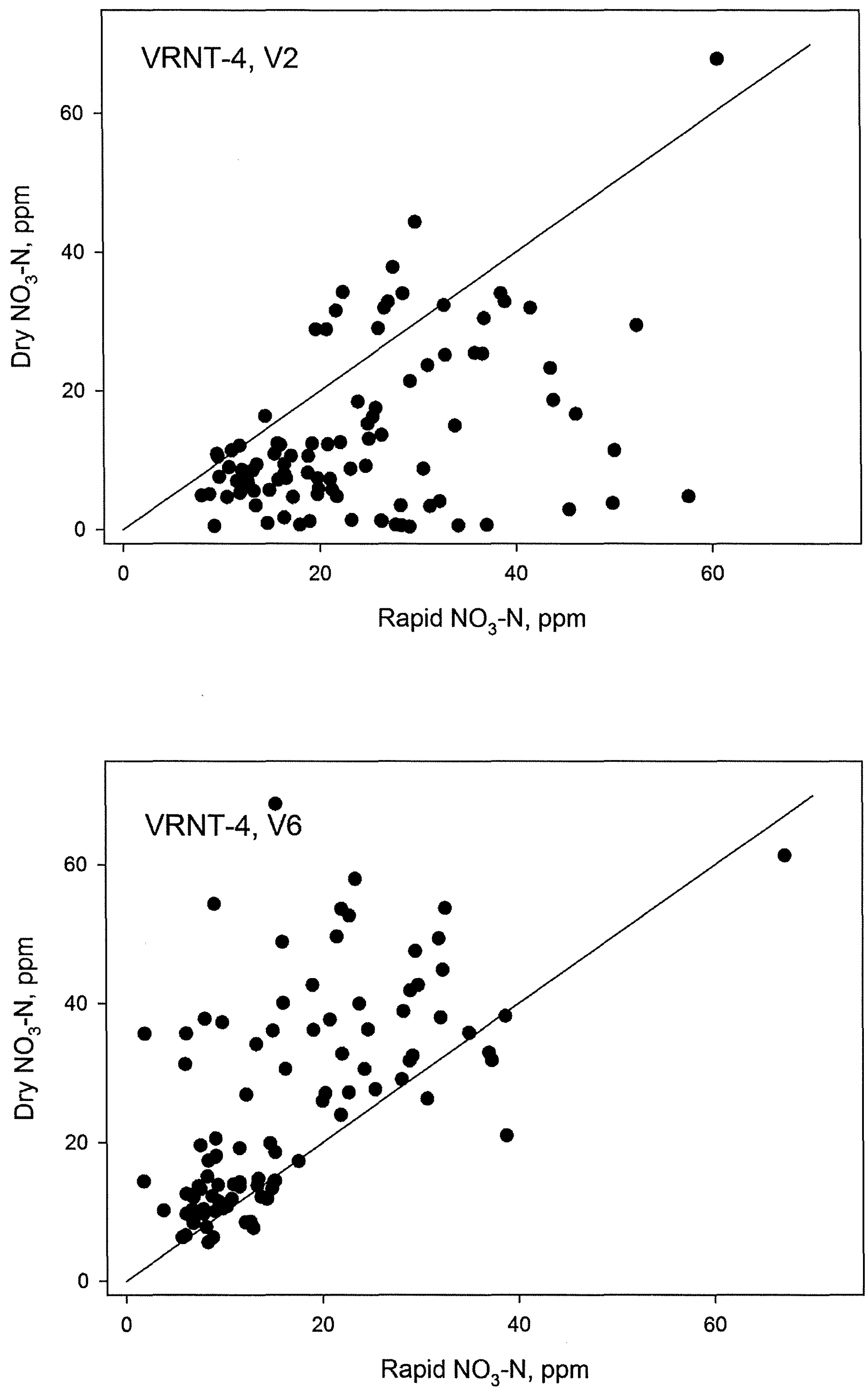


Figure 3. Comparison of dry and moist soil nitrate-N at CG15.

APPENDIX Tables and Figures

Table A. Residual N credit values based on the concentration of NO_3-N measured before planting in the spring from the top two feet of soil (adapted from Schmitt et al., 2002).

Soil NO_3-N	Residual N Credit
ppm	lb N per acre
0.0-6.0	0
6.1-9.0	35
9.1-12.0	65
12.1-15.0	95
15.1-18.0	125
>18.1	155

Table B. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetric soil water content and soil temperature at Blooming Prairie in 2014.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	**RH**	**Mean**	**Min**	**Max**	**GDU**	**Precip**	**VWC**	**Temp**	**VWC**	**Temp**
	%	**°F**	**°F**	**°F**	**50/86**	**inch**	**m³/m³**	**°F**	**m³/m³**	**°F**
May-14		56.2	46.3	66.9	307	2.26				
Jun-14	76.0	68.6	60.2	77.5	570	7.83	0.32	67.1	0.44	62.9
Jul-14	78.0	67.5	57.2	77.7	547	1.13	0.24	67.2	0.39	65.0
Aug-14	84.2	69.7	59.4	82.1	638	4.91	0.22	67.8	0.34	65.8
Sep-14	80.4	60.2	49.6	72.6	175	3.52	0.30	60.5	0.40	60.9
May-Sep Avg/Sum:		64.4	54.6	75.4	2236	19.66	0.27	65.7	0.39	63.7

Table C. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetric soil water content and soil temperature at Northfield in 2014.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	**RH**	**Mean**	**Min**	**Max**	**GDU**	**Precip**	**VWC**	**Temp**	**VWC**	**Temp**
	%	**°F**	**°F**	**°F**	**50/86**	**inch**	**m³/m³**	**°F**	**m³/m³**	**°F**
May-14		56.6	46.3	66.8	306	4.46				
Jun-14	76.4	68.4	60.3	76.5	555	8.72	0.37	68.0	0.44	64.6
Jul-14	76.3	69.0	59.4	79.0	595	1.83	0.33	69.6	0.38	67.7
Aug-14	83.3	70.8	59.9	83.7	663	3.43	0.29	68.9	0.29	67.3
Sep-14	81.6	60.8	49.5	74.2	179	1.73	0.33	60.8	0.32	61.3
May-Sep Avg/Sum:		65.1	55.1	76.1	2296	20.18	0.33	66.8	0.36	65.2

Table D. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetric soil water content and soil temperature at Northfield in 2015.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	**RH**	**Mean**	**Min**	**Max**	**GDU**	**Precip**	**VWC**	**Temp**	**VWC**	**Temp**
	%	**°F**	**°F**	**°F**	**50/86**	**inch**	**m^3/m^3**	**°F**	**m^3/m^3**	**°F**
May-15	74.7	58.1	48.7	67.4	243	4.91	0.37	56.7	0.31	54.2
Jun-15	73.4	68.3	59.0	77.3	543	5.93	0.37	67.5	0.31	64.3
Jul-15	81.3	71.2	60.4	81.7	644	6.92	0.36	69.0	0.31	67.1
Aug-15		67.6	58.1	77.1	548	3.93	0.33	66.6	0.29	65.7
Sep-15		65.7	55.4	75.9	487	3.43	0.36	64.9	0.30	64.1
May-Sep Avg/Sum:		66.2	56.3	75.9	2464	25.12	0.36	64.9	0.30	63.1

Table E. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetirc soil water content and soil temperature at Clarks Grove (CG15) in 2015.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	**RH**	**Mean**	**Min**	**Max**	**GDU**	**Precip**	**VWC**	**Temp**	**VWC**	**Temp**
	%	**°F**	**°F**	**°F**	**50/86**	**inch**	**m^3/m^3**	**°F**	**m^3/m^3**	**°F**
May-15	--	58.2	49.1	67.4	316	3.34	--	--	--	--
Jun-15	77.1	68.2	59.4	77.1	546	6.79	0.35	69.4	0.34	67.3
Jul-15	77.4	71.1	61.5	80.6	651	7.21	0.31	68.0	0.33	66.4
Aug-15	81.5	67.5	58.1	79.2	582	5.54	0.32	65.6	0.33	65.3
Sep-15	77.9	66.6	56.8	79.0	553	4.22	0.35	64.5	0.33	64.1
May-Sep Avg./Sum:		66.3	57.0	76.7	2648	27.09	0.33	66.9	0.33	65.8

Table F. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetric soil water content and soil temperature at Waseca in 2015.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	**RH**	**Mean**	**Min**	**Max**	**GDU**	**Precip**	**VWC**	**Temp**	**VWC**	**Temp**
	%	**°F**	**°F**	**°F**	**50/86**	**inch**	**m^3/m^3**	**°F**	**m^3/m^3**	**°F**
May-15		58.4	48.2	67.8	308	3.97				
Jun-15	75.0	67.9	59.2	76.7	535	5.95	0.40	68.5	0.43	64.4
Jul-15	79.8	71.1	59.9	82.7	648	6.50	0.33	68.5	0.40	66.1
Aug-15	82.3	67.6	57.5	79.9	584	5.59	0.39	66.8	0.41	65.6
Sep-15	79.4	67.2	57.3	78.9	556	5.46	0.42	66.0	0.42	64.8
May-Sep Avg./Sum:		66.4	56.4	77.2	2629	27.47	0.39	67.4	0.42	65.2

Table G. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetric soil water content and soil temperature at Northfield in 2016.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	RH	Mean	Min	Max	GDU	Precip	VWC	Temp	VWC	Temp
	%	°F	°F	°F	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
May-16	61	60	49	69	356	2.28	0.40	59	0.28	55
Jun-16	72	70	60	79	579	4.81	0.37	71	0.29	66
Jul-16	80	72	63	82	684	4.69	0.35	73	0.27	69
Aug-16	83	71	62	81	663	6.88	0.36	71	0.27	68
Sep-16	80	64	55	75	471	6.11	0.38	64	0.31	64
May-Sep:		67	58	77	2752	24.77	0.37	68	0.28	65

Table H. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetirc soil water content and soil temperature at Clarks Grove (CG15) in 2016.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	RH	Mean	Min	Max	GDU	Precip	VWC	Temp	VWC	Temp
	%	°F	°F	°F	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
May-16	65	58	49	68	333	2.95	0.41	59	0.34	56
Jun-16	72	70	60	80	589	4.15	0.38	70	0.38	66
Jul-16	80	71	62	81	653	7.87	0.32	69	0.40	67
Aug-16	81	70	60	81	632	5.35	0.36	69	0.39	67
Sep-16	77	64	56	74	465	12.20	0.42	64	0.43	65
May-Sep Avg./Sum:		67	57	77	2671	32.52	0.38	66	0.39	64

Table I. Relative humidity, air temperature, GDU, precipitation, 6- and 18-inch volumetric soil water content and soil temperature at Waseca in 2016.

		Air Temperature					6-inch Soil		18-inch Soil	
Month	RH	Mean	Min	Max	GDU	Precip	VWC	Temp	VWC	Temp
	%	°F	°F	°F	50/86	inch	m^3/m^3	°F	m^3/m^3	°F
May-16	65	59	49	69	344	3.39	0.46	58	0.33	56
Jun-16	72	70	60	80	586	3.98	0.46	71	0.36	68
Jul-16	81	72	63	81	670	7.78	0.43	72	0.36	70
Aug-16	83	70	61	81	647	10.50	0.45	70	0.37	69
Sep-16	79	64	56	75	473	12.87	0.47	65	0.37	65
May-Sep Avg./Sum:		67	58	77	2718	38.53	0.46	67	0.36	66

APPENDIX FIGURES

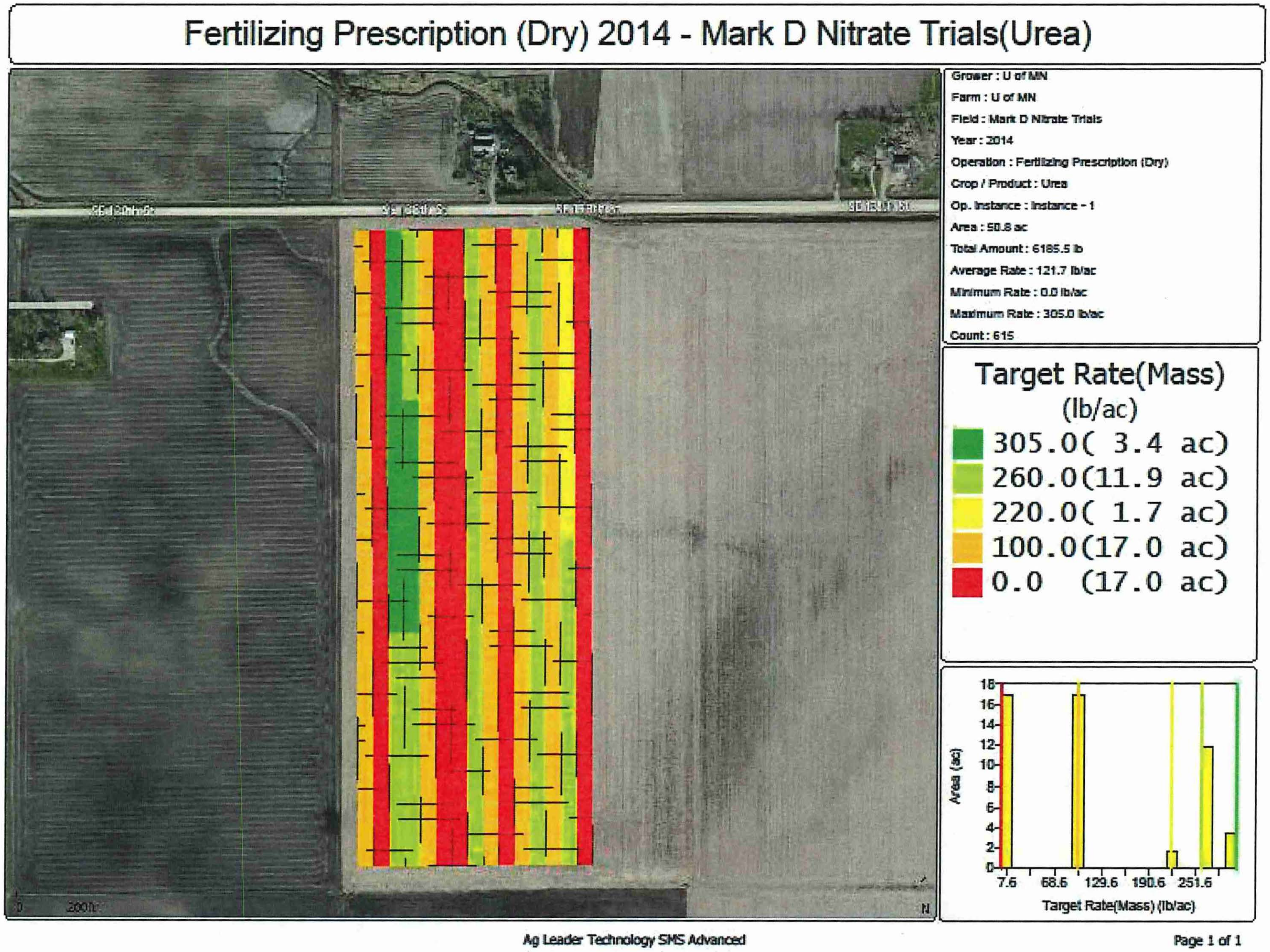


Figure A1. Sidedress prescription map for BP14. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

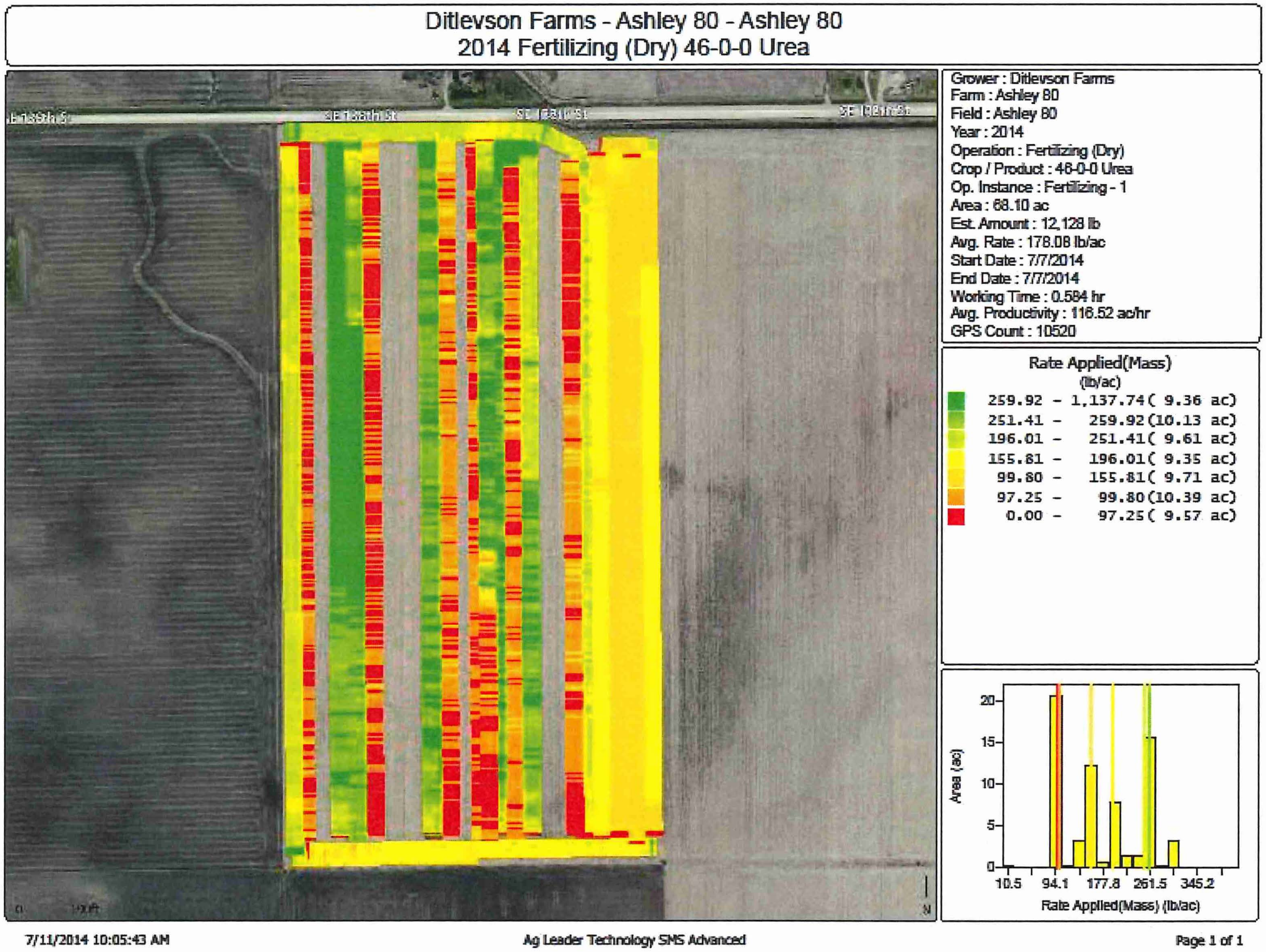


Figure A2. Sidedress N as applied application map for BP14. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

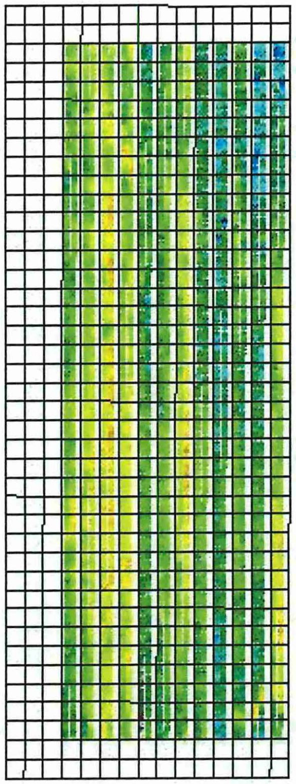


Figure A3. Combine yield map for BP14.

Figure B1. Northfield (NF14) preplant treatment map. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

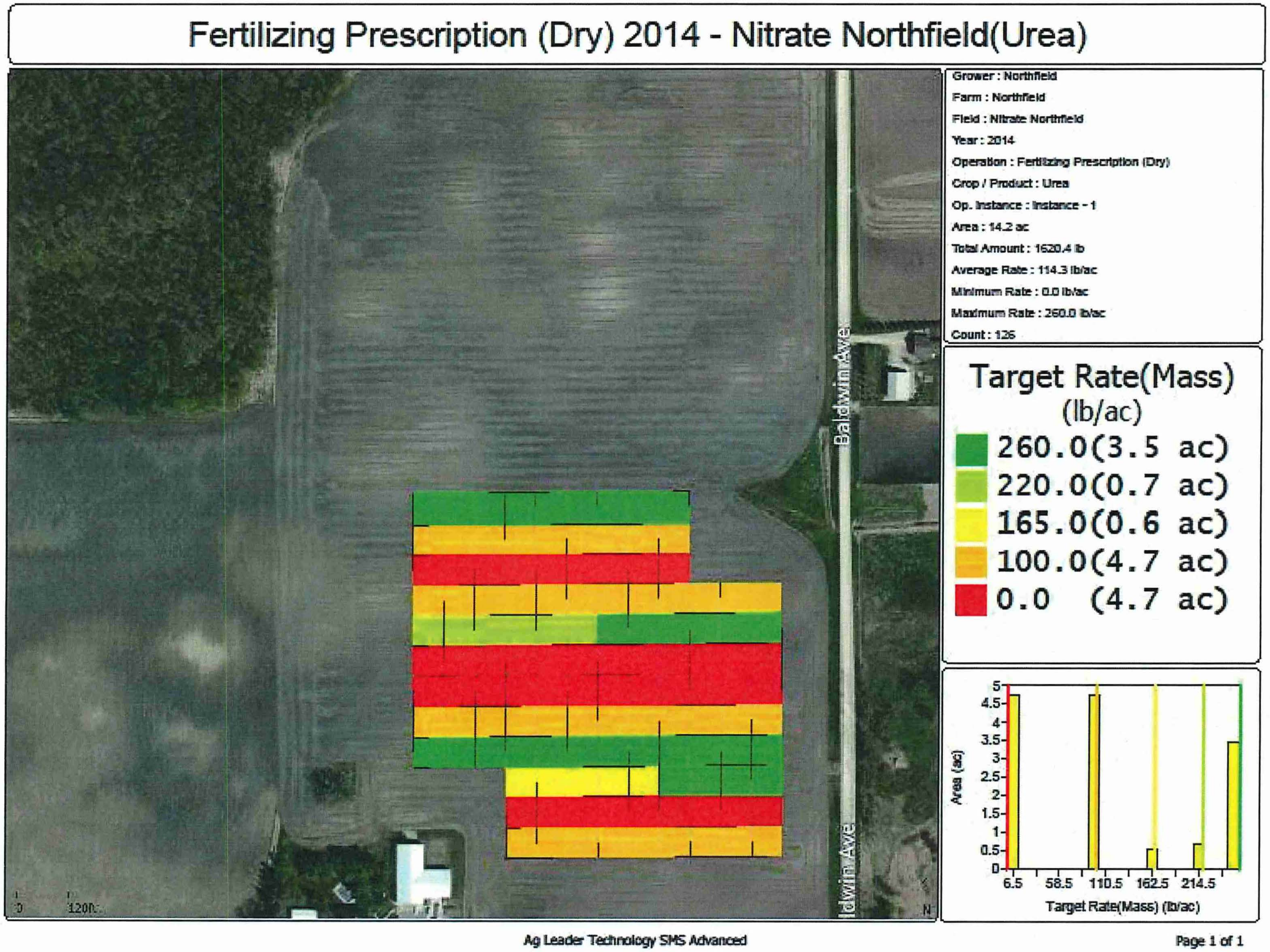


Figure B2. Sidedress prescription map for NF14. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

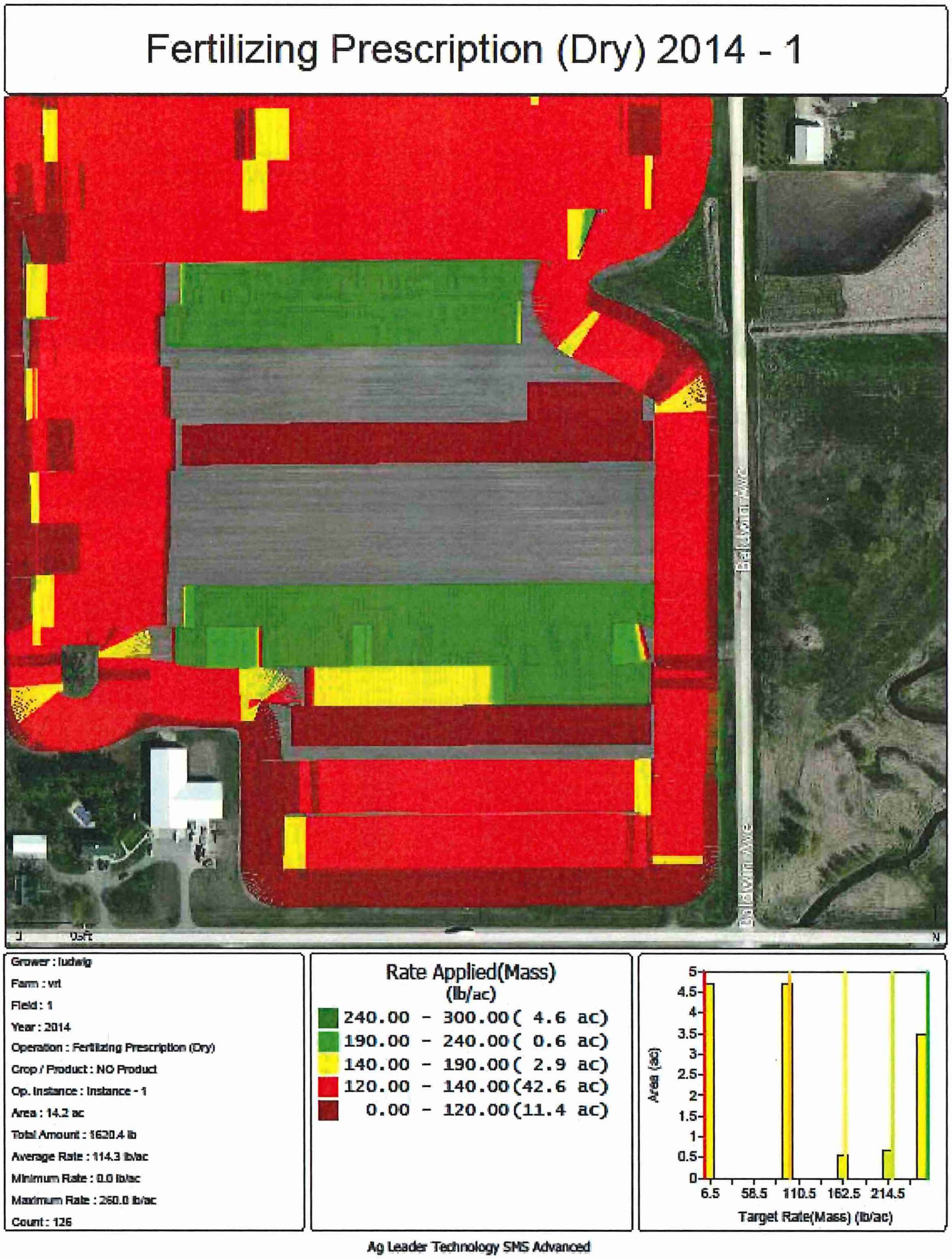


Figure B3. Sidedress N as applied application map for NF14. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

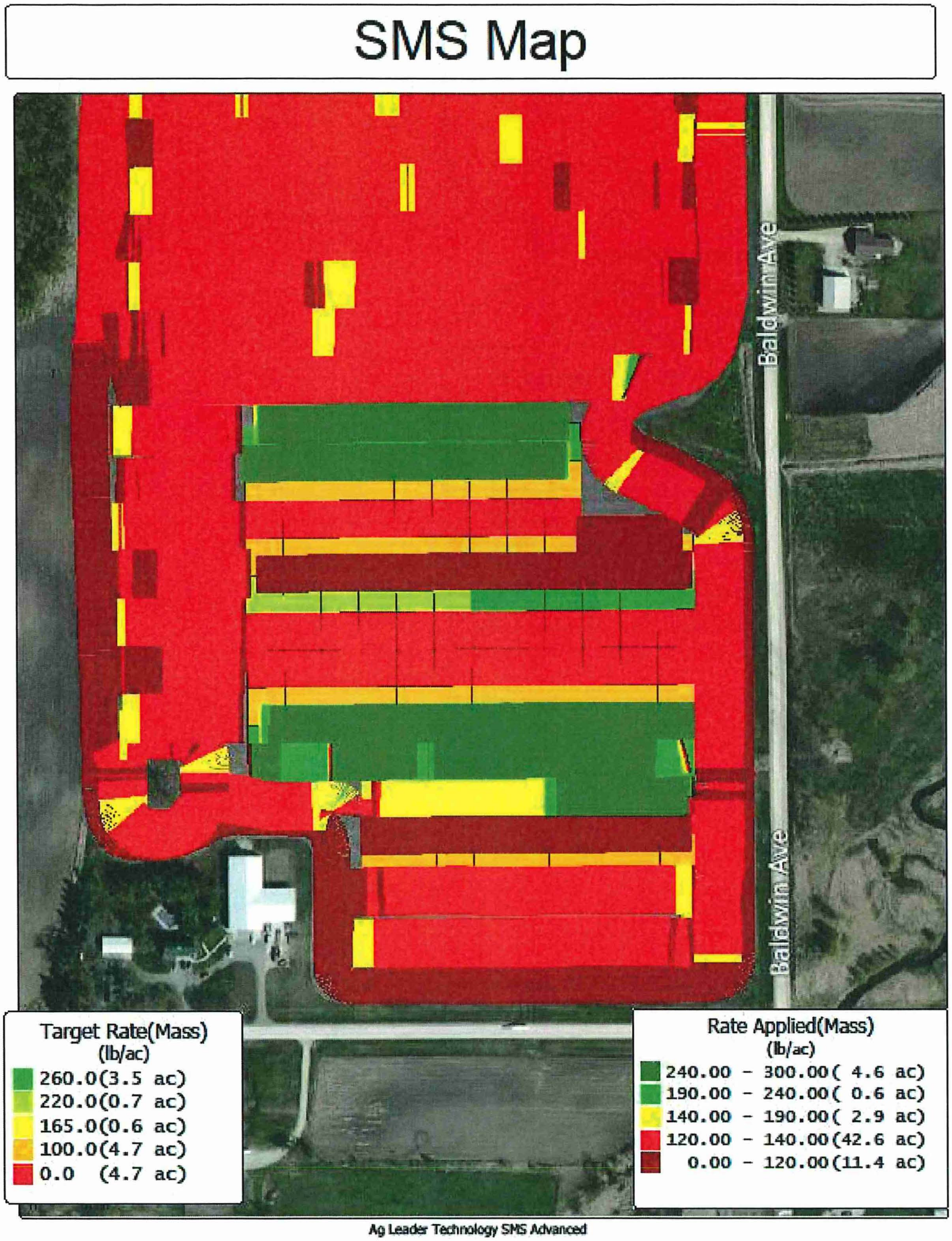


Figure B4. Overlay map of sidedress N prescription and as applied for NF14. This map clearly shows improper alignment of sidedress application. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

Figure B5. Combine yield map at NF14 site.

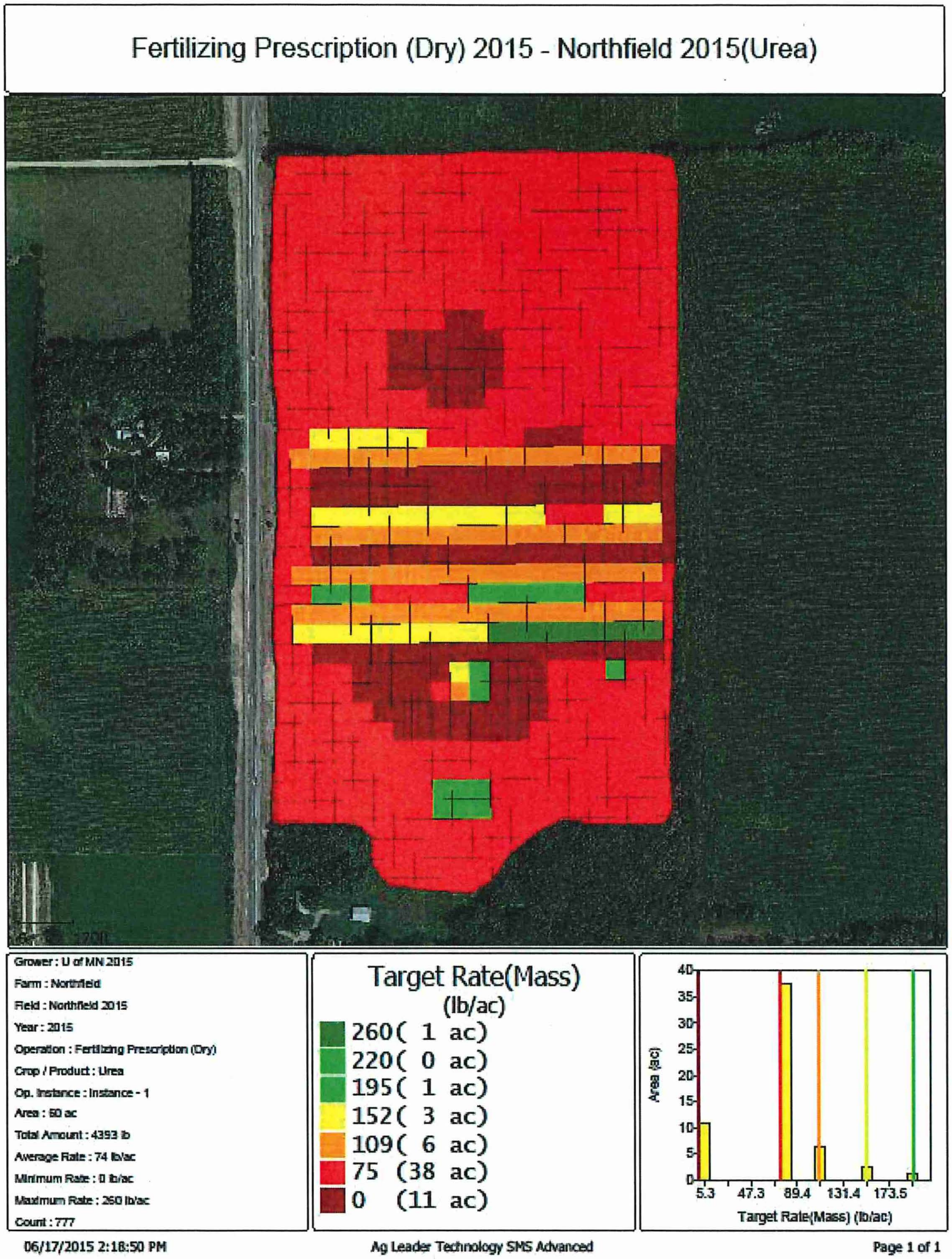


Figure C1. Sidedress prescription map for NF15. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.

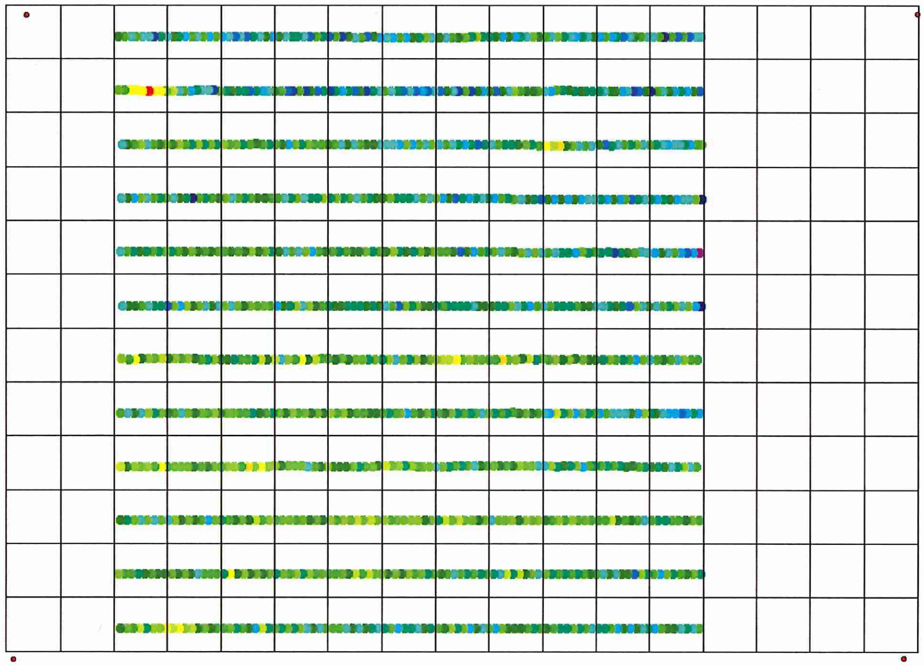


Figure C2. Combine yield map at NF15 site.

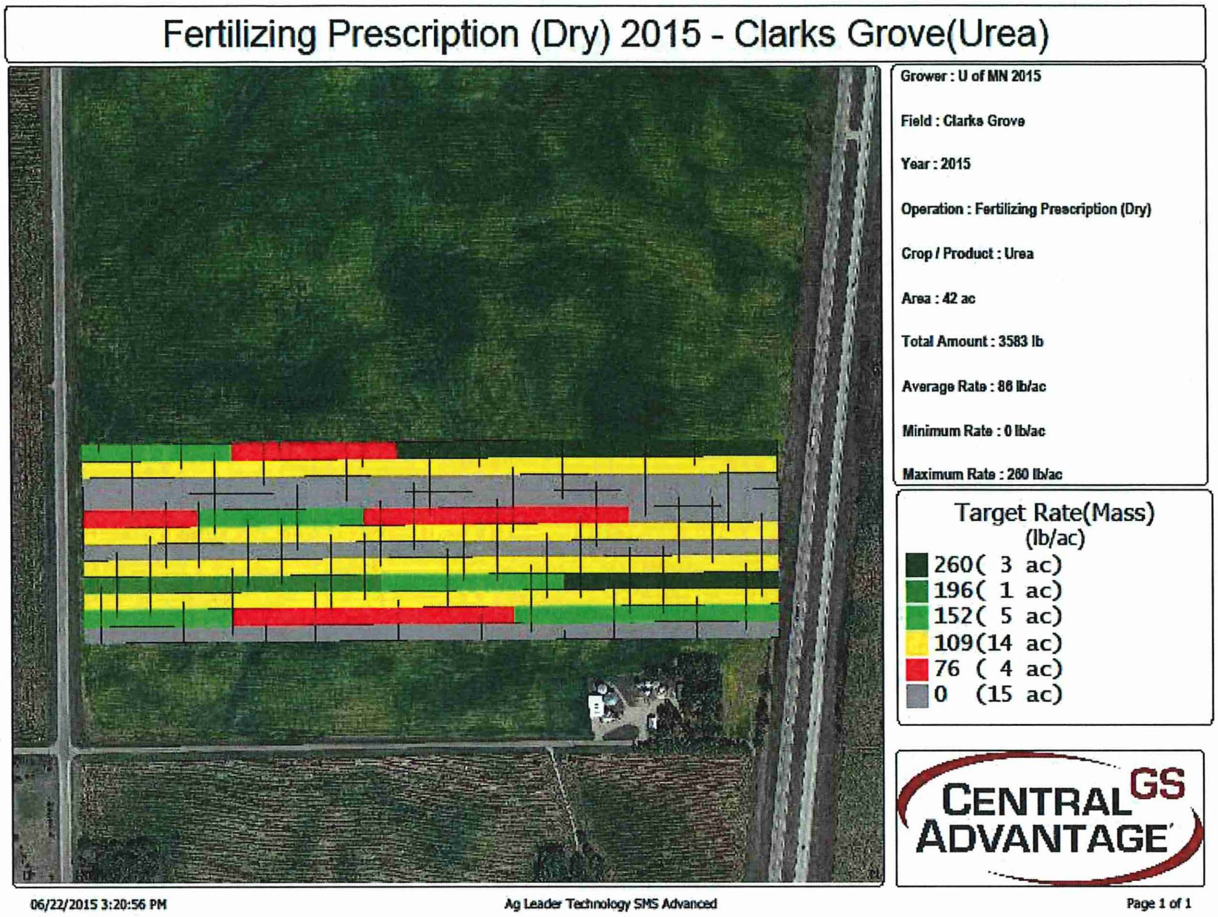
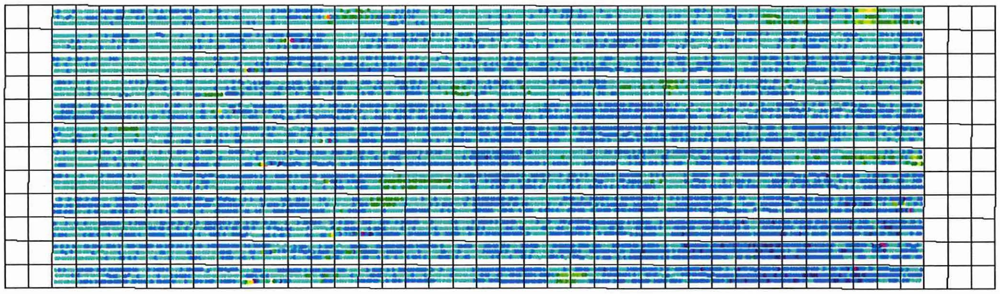


Figure D1. Sidedress prescription map for CG15. Colors represent N treatments applied in pounds of urea (46-0-0) per acre.



Color	Min	Max
	59.33	83.1
	83.1	106.87
	106.87	130.64
	130.64	154.42
	154.42	178.19
	178.19	201.96
	201.96	225.73
	225.73	249.51
	249.51	273.28
	273.28	297.05

Figure D2. Combine yield map at CG15 site.

Figure E1. Corn yield map for WA15.

Fertilizing (Dry) 2016 - 1925(blend)

CENTRAL GS ADVANTAGE

Rate (Mass)
(lb/ac)
145.76 - 290.41 (5.570 ac)
104.14 - 145.76 (4.982 ac)
74.58 - 104.14 (5.819 ac)
73.59 - 74.58 (7.132 ac)
72.70 - 73.59 (7.047 ac)
71.10 - 72.70 (6.051 ac)
0.00 - 71.10 (5.146 ac)

As-Applied Summary

estrem farms | silkey | 1925
2016 | Fertilizing (Dry) | blend | Fertilizing - 1

Dataset	Area ac	Est. Amount lb	Avg. Rate lb/ac	Start Date	End Date
R0:Dry Fert	41.73	3,889.1	93.21	6/20/2016	6/20/2016
Totals	41.73	3,889.1	93.21 Average	6/20/2016 Minimum	6/20/2016 Maximum

Operation Summary

Grower : estrem farms
Farm : silkey
Field : 1925
Year : 2016
Operation : Fertilizing (Dry)
Crop / Product : blend
Op. Instance : Fertilizing - 1
Area : 41.73 ac

Est. Amount : 3,889.1 lb
Avg. Rate : 93.21 lb/ac
Start Date : 6/20/2016
End Date : 6/20/2016
Working Time : 0.303 h
Avg. Productivity : 137.63 ac/h
GPS Count : 5457

Notes/Comments

Operator Signature and Date

Figure F1. Sidedress prescription map for NF16. Colors represent N applied in pounds of urea (46-0-0) per acre.

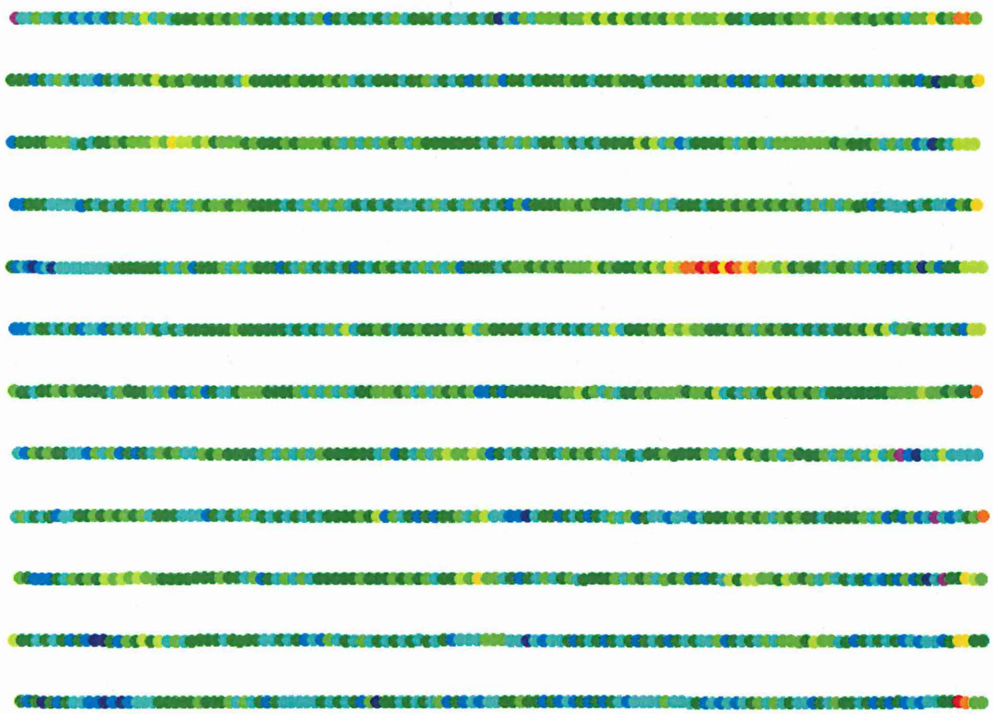


Figure F2. Yield map for NF16 site.

Color	Min	Max	Value
	129.86	140.06	129.86 - 140.06
	140.06	150.26	140.06 - 150.26
	150.26	160.46	150.26 - 160.46
	160.46	170.66	160.46 - 170.66
	170.66	180.86	170.66 - 180.86
	180.86	191.05	180.86 - 191.05
	191.05	201.25	191.05 - 201.25
	201.25	211.45	201.25 - 211.45
	211.45	221.65	211.45 - 221.65
	221.65	231.85	221.65 - 231.85

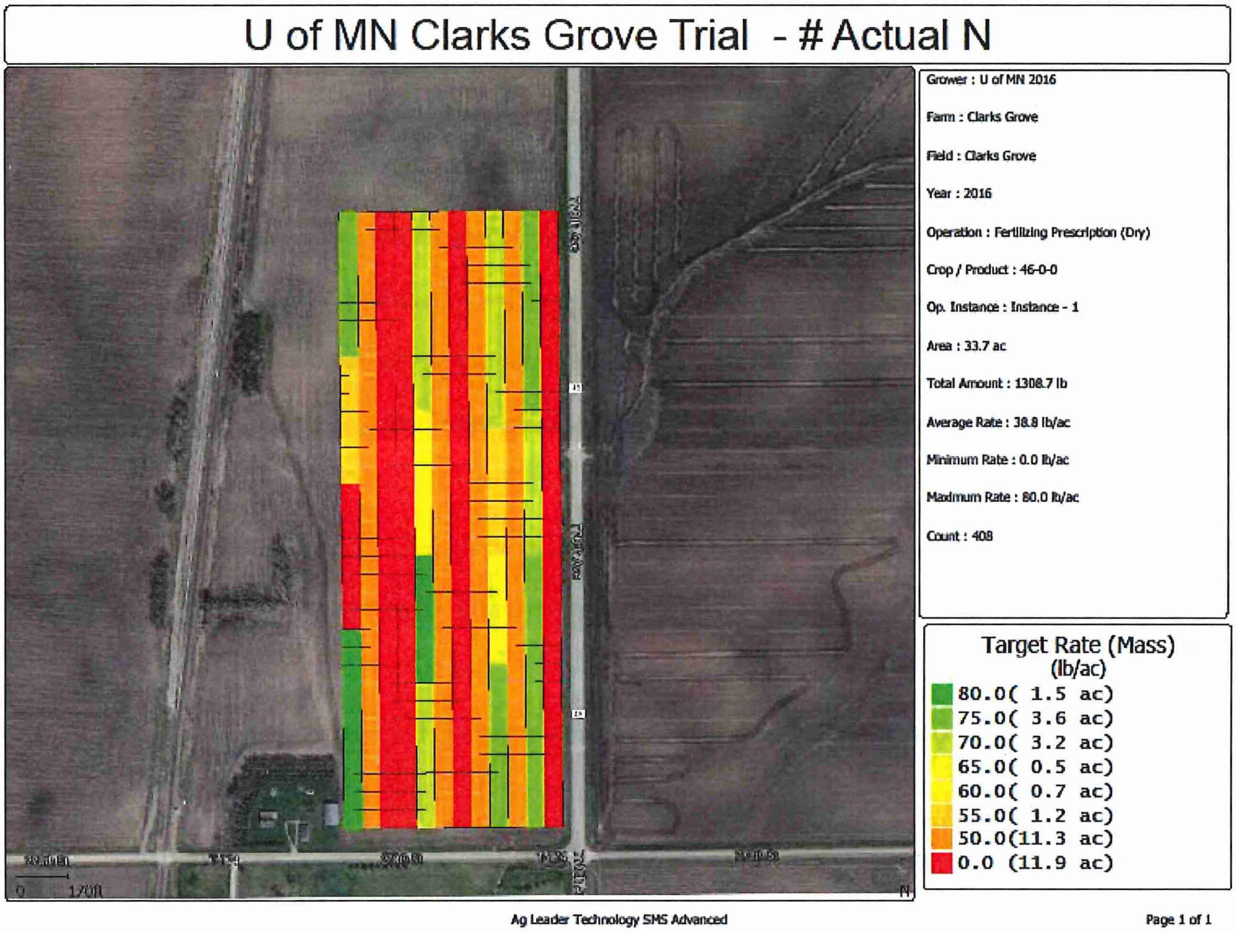


Figure G1. Sidedress prescription map for CG16. Colors represent N applied in pounds of urea (46-0-0) per acre.

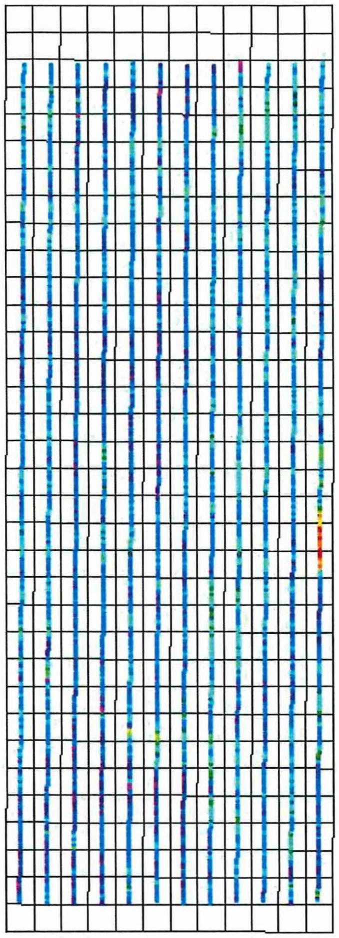


Figure G2. Yield map for CG16 site.

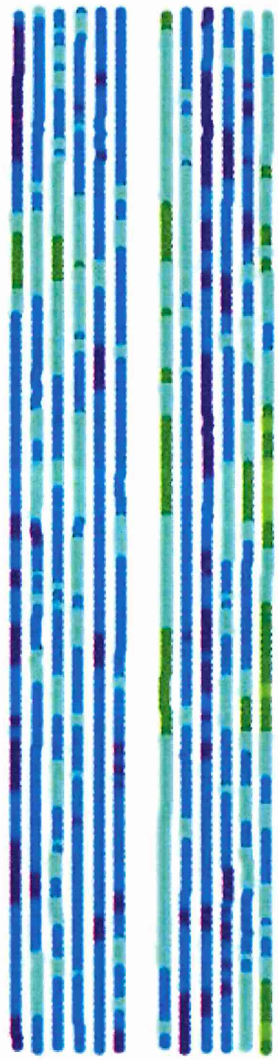


Figure H1. Yield map for WA16 site.