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The impact of different nitrogen fertilizer rates on soil characteristics, plant properties, and economic returns in a southeastern Minnesota cornfield

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Ellen Squires

Field Ecology

St. Olaf College

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Abstract

Nitrogen fertilizer is widely used in farming but has recently been implicated for its role in surface and groundwater pollution. Corn is especially dependent on fertilizer inputs, but the amount of fertilizer applied often exceeds optimal levels. Fertilizer inputs can affect the physical and chemical characteristics of the soil, which might carry implications for crop yields and economic returns. Two cornfields in Northfield, Minnesota were partitioned into plots treated with varying amounts of nitrogen fertilizer. The fields were farmed under different tillage methods, either strip tillage or conventional tillage, and were treated according to different nitrogen fertilization schedules. The strip-tilled field was subdivided into six different levels of nitrogen fertilizer, each treatment were analyzed for differences in soil physical and chemical properties, plant properties, yields, and economic returns. While there were few differences by N treatment level within the field, there were significant differences between the two fields under different tillage methods. Soil physical and chemical characteristics, plant properties, yields, and economic returns varied between the two fields. This data can provide valuable information to farmers about optimal levels of fertilizer inputs and can also shed light on the ecological implications of different nitrogen fertilization and tillage practices.

Introduction

Nitrogen fertilizer is a ubiquitous and inevitable part of the modern agricultural system. Because most soils lack a large pool of weatherable nitrogen, the main sources of new nitrogen are atmospheric fixation or synthetic inputs (Robertson and Vitousek 2009). The rate of nitrogen removal by agricultural crops is a large determinant of ecosystem N-balance. When nitrogen is removed through crop harvest, plant residues are lost that would otherwise add more nitrogen to the soil. This can lead to nitrogen depletion in the long term if the rate of removal exceeds the rate of fixation.

Corn (*Zea mays*), a major crop in the Upper Midwest, has one of the highest rates of nitrogen removal and is dependent on continuous inputs of synthetic nitrogen to maintain high yields (Robertson and Vitousek 2009). According the developers of the Iowa State Corn Nitrogen Rate Calculator, when no nitrogen fertilizer is added, corn yields average 55 percent of the optimal level in continuous corn rotation and 70 percent of the optimal level in soybean-corn rotations (Sawyer et al. 2006). While nitrogen fertilizer can increase corn yield and soil organic carbon levels, over-fertilization adds more nitrogen to the soil than can be broken down via natural biogeochemical processing (Kim and Dale 2008). Excess nitrates can then leach into groundwater or enter the surface water as runoff.

Nitrate pollution carries negative ecological consequences that can be dispersed over a wide geographic area. Locally, nitrogen can contaminate the groundwater, threatening aquatic life and lowering the quality of drinking water, which can lead to negative health effects in humans. Agricultural nitrogen pollution has also degraded the quality of surface water Minnesota. According to a recent study by the Minnesota Pollution Control Agency, more than 70 percent of nitrates found in surface water in southern Minnesota, an intensively farmed region, originated from cropland. The same study found that 27 percent of monitored sites had drinking water with nitrate concentrations that exceeded Minnesota's safe drinking water standards, due in large part to groundwater contamination by nitrogenous fertilizers (MPCA 2013).

Nitrate pollution originating in Minnesota agricultural land can also impact ecosystems farther away, as nutrient loads are exported by streams and rivers. The MPCA reports that up to 95% of the nitrate load in the Minnesota, Missouri, and Cedar Rivers are agricultural in origin (MPCA 2013). These rivers feed directly into the Mississippi River, which brings substantial nitrogen loads to the Gulf of Mexico. This high-nitrogen effluent is thought to contribute to the formation of a hypoxic zone in the Gulf. High nutrient inputs from agricultural runoff accumulating along the river's length stimulate algal blooms that eventually decompose and reduce oxygen levels (Howarth 2008).

The negative ecological consequences of nitrate pollution, coupled with the high cost of nitrogen fertilizer, have initiated a debate amongst farmers, policymakers, and environmental advocates about the optimal amount of nitrogen fertilizer. This has led to the development of several methods, including both farming practices and practical guidelines for farmers, that aim to find a fertilization regime that balances economic profit and sustainable stewardship of the land.

Farming practices that have been developed to mitigate the negative effects of nitrate pollution include strip tillage and changes in the schedule of nitrogen fertilization. Under strip tillage, a narrower band of soil is tilled, disturbing no more than 30% of the soil surface while leaving more crop residue intact (Wolkowski et al. 2009). The crop residue remaining at the soil surface between rows acts as a barrier to runoff and also protects against soil erosion, both of which can decrease the amount of nitrogen entering the hydrological system.

Changes in the timing of fertilizer applications can also optimize nutrient uptake while minimizing losses. Because maximum uptake occurs when the plant has reached a rapid-growth phase, applying fertilizer closer to this time can increase uptake by plants (Scharf and Lory 2006). Following a split schedule for fertilizer applications is another way to reduce nitrogen loss by shifting applications towards the spring when the risk of nutrient loss is lower (Cassman et al. 2002).

Tools like the Corn Nitrogen Rate Calculator, developed by scientists from Iowa State and various Midwest universities, have also been developed to provide farmers with suggestions for nitrogen fertilizer rates. The estimated fertilizer rate is calculated based on various characteristics of the production environment like climate, tillage system, and crop rotation (Sawyer et al. 2006).

The environmental and economic effects of different rates of fertilizer application were studied by measuring differences in soil characteristics, plant properties, and economic returns among the treatments. The data was also compared to similar data collected on a field farmed under a different tillage method and a different fertilizer application schedule. This research will help assess the value of tools like Corn Nitrogen Rate Calculator while also providing useful information for a local farmer and other corn farmers seeking to optimize fertilizer inputs.

This study was part of a long-term, on-farm research project that seeks to find an optimal input of nitrogen and to use science to inform farm management practices. The study built on the work of past student researchers in order to make progress towards successful nitrogen management by finding an optimal fertilizer input that balances economics and ecology. This ideal input would provide adequate nitrogen to the crops in order to optimize yields and economic profitability, while also minimizing nitrogen losses to water or the atmosphere.

Methods

Study site

The study took place at a cornfield in Southeastern Minnesota that is leased by farmer David Legvold. The field (Field 1) was under strip tillage, a method that only turns under the strip of soil where seeds will be planted, leaving more plant material on the ground. It was treated according to a split-application fertilization schedule; non-variable inputs (40 lbs of urea) are added just before spring planting, and variable inputs, ranging from 0 lbs to 94 lbs of nitrogen fertilizer were added in June, once the corn has reached a rapid growth phase.

A second study site was added to analyze the impact of tillage method and fertilization schedule on the soil and plant characteristics of interest. This field (Field 2) is privately owned by farmer Mike Ludwig and is tilled at an intermediate level between conventional and "conservation tillage," meaning that 30% of plant residue was left on the field rather than turning it over in the soil. The field was tilled with a John Deere size 5-12 disk stripper and supplemented with a field cultivator with a 4 bar harrow in spring. The field was treated with variable inputs ranging from 80 to 170 lbs of nitrogen fertilizer before spring planting. In June, the fields were treated with constant inputs, which include 30 lbs of N and 75 lbs of ammonium sulfate.

Experimental Design

Field 1 was partitioned into three replicates that each contain six treatments, the Maximum Return to N (MRTN) level recommended by the Iowa State Corn Nitrogen Rate Calculator, and levels set below or above the MRTN level. Specifically, the six treatments were: zero pounds, MRTN-30 lbs, MRTN-15 lbs, MRTN, MRTN+15 lbs, and MRTN+30 lbs (hereafter referred to as 0, -30, -15, MRTN, +15, and +30, respectively). Each treatment plot was approximately 0.9 acres. Soil samples were collected on October 11, 2013 from Field 1 for chemical and physical analysis. Two sampling sites approximately 1 meter apart in each treatment replicate will be selected, for a total of 36 sites.

Field 2 was divided into four different treatment levels, and each treatment was provided with a different variable amount of nitrogen: 80 lbs, 110 lbs, 140 lbs, and 170 lbs. There were two replicates of each treatment level, and three soil samples were collected on October 19, 2013 from each replicate, for a total of 24 samples. Like Field 1, each treatment plot was approximately 0.9 acres.

Soil sampling & processing

Two soil cores were taken at each of 36 sampling sites at Field 1. The first core of a known volume was used to measure bulk density, soil organic matter, and soil moisture. The second core was used for chemical analysis, including pH, nitrates, phosphates, and ammonia.

To measure physical properties, soil samples were weighed immediately after collection. Soils were then dried in a 105° C oven for 48 hours before being weighed again to determine dry weight. Soil moisture and bulk density were then calculated using wet and dry weights according to equations in St. Olaf Field Ecology Procedures. Percent organic matter was determined by sieving the oven-dried soil and combusting it in a muffle furnace set at 500° C for 4 hours. The weight of the ashed sample was used in equations from St. Olaf Field Ecology Procedures to calculate percent organic matter.

Soil was extracted with deionized water and a pH meter was used to measure pH. 2 M KCl extractions were conducted to determine soil nitrate (NO_3^--N) and ammonium (NH_4^+) concentrations. A Lachat Flow Injection Analysis system was used to determine both nitrate and phosphate concentrations. Phosphate (PO_4^{3-}-P) concentrations were determined by extracting soil in a 10% Mehlich 2 solution. Ammonium concentrations were measured using fluorometric analysis as described in St. Olaf College Field Ecology Procedures.

Plant properties

Plant samples were taken for stalk nitrate analysis from Field 1 on October 9, 2013, when the corn kernels had reached their black layer stage, an indication of physiological maturity. One sample was taken in each treatment replicate, for a total of 18 samples, and all samples were sent to the MTVL Lab in New Ulm for analysis. 8 samples were taken from Field 2, two from each treatment level. To obtain the sample, an 8-inch stalk section 10-14 inches above the ground was cut using garden clippers and all husks were removed.

Yield and Economic Returns

Yield data from both fields was obtained upon harvest on October 26 (Field 1) and November 2 (Field 2). Wet weights were obtained using a weigh wagon. At each plot, moisture was calculated and weight was tested for normalization. Yield data, in addition to information from Mr. Legvold (Field 1) and Mr. Ludwig (Field 2) about fertilizer costs and corn prices, were used to calculate economic returns. Flat rate costs for Field 1 were $0.695/lb and variable rate costs were $0.703/lb. Fixed costs for Field 2 were $48.00/acre, and the variable cost of anhydrous ammonia was $0.48/lb. Corn was sold at $5.05/bu.

Data Analysis

One-way ANOVA tests were performed to test for differences in soil characteristics, plant properties and yields between Field 1 treatments. Average values for each variable from Field 1 (regardless of treatment) were then compared to Field 2 average values using two-sample t-tests. An economic analysis was conducted using information on costs and corn prices, and an ANOVA test was performed to test for significant differences in mean yields. All data analysis was performed in R statistical package or Microsoft Excel.

Results

Soil Physical Characteristics

Soil moisture did not vary by treatment in Field 1 soils ($p=0.83$, Figure 1). A two-sample t-test between all Field 1 treatments and all Field 2 treatments found significant differences in means ($p<0.01$). Specifically, soils from Field 1 had a significantly higher moisture content than soils from Field 2 (28.67% and 22.98%, respectively; $p<0.01$). Soil organic matter also did not vary by treatment in Field 1 soils ($p=0.44$, Figure 1). A two-sample t-test for differences between the two fields, however, found significant differences in organic matter. Field 1 had a much higher percent organic matter than Field 2 (7.47% versus 4.80%, respectively). There was no significant difference in bulk density between Field 1 treatments ($p=0.921$, Figure 1), but the two fields had significantly different bulk densities ($p<0.01$). Field 1 soils had a lower mean bulk density than Field 2 (1.698 g/cm^3 and 2.000 g/cm^3, respectively).

Soil Chemical Characteristics

Soil nitrate concentrations ($NO_3^{-}N$) were significantly different between Field 1 treatments ($p<0.01$, Figure 2), and the MRTN rate established by the Iowa Corn Calculator had the highest nitrate concentrations (1.26 mg/kg). 0 lbs, -30 lbs, and +15 lbs treatments all had similarly low nitrate concentrations, while -15 lbs and +30 lbs had intermediate nitrate concentrations. Soil nitrate concentrations differed by Field ($p<0.05$). Specifically, Field 2 had higher nitrate levels than Field 1 (1.12 mg/kg versus 0.871 mg/kg, respectively). Ammonium (NH_4^+) concentrations did not differ significantly by treatment in Field 1 ($p=0.290$ Figure 2). Ammonium concentrations between fields also were not significantly different ($p=0.149$).

Soil phosphate ($PO_4^{3-}P$) concentrations were not significantly different between Field 1 treatments, owing at least in part to the large degree of variability in the samples ($p=0.205$, Figure 2). Field 2 had slightly higher phosphate concentrations than Field 1 (0.77 mg/kg versus 0.48 mg/kg, respectively), although the differences were not significant ($p=0.137$). There were no significant differences in pH between fields or Field 1 N treatments ($p=0.78$, $p=0.36$, respectively).

Plant Properties

All but one stalk sample from Field 1 fell below 250 ppm $NO_3^{-}N$. This value is used as the upper threshold for "low" nitrates by the MTVL. Significant differences were not seen between treatments at Field 1 ($p=0.52$, Figure 4). Stalk nitrate concentrations were considerably higher in Field 2 than Field 1(3,284 ppm versus 143 ppm, $p<0.01$). Half of the stalk samples from Field 2 fell into the 700-2000 ppm range, which is considered optimum, and the other half exceeded 2000 ppm, indicating excessive levels of nitrates. Within Field 2, there was also no relationship between stalk nitrate concentration and nitrogen fertilizer treatment ($p=0.68$).

Yields & Economic Returns

There was a significant difference in yields (measured as total dry weight in bushels) between Field 1 treatments ($p<0.01$, Figure 3). In general, yields increased at higher fertilizer levels, with the exception of the 0 lbs treatment, which was slightly higher than both the -30 lbs and -15 lbs treatments. Field 2 had considerably higher yields than Field 1 when all treatments were combined (142 bu and 235 bu, respectively; $p<0.01$). Economic returns differed slightly between Field 1 treatments (Figure 3). There was a slight upward trend in profit as nitrogen fertilizer increased, with the exception of the 0 lbs treatment. The mean economic profit of all Field 2 treatments was significantly higher than the mean economic profit of all Field 1 treatments ($1,103 and $789, respectively; $p<0.01$).

Discussion

Soil Physical Characteristics

It is not unusual that bulk density did not vary by nitrogen treatment. Bulk density is a measure of soil compaction and porosity, and is calculated as the dry weight of soil divided by its volume (University of Missouri, 2013). Compaction is unlikely to be affected by nutrient inputs, and so it is not surprising that there was no significant difference between Field 1 treatments. It is possible that differences in tillage method contributed to the greater mean bulk density in Field 2 compared to Field 1. Tillage method can sometimes increase bulk density if it enables aggregation of soil particles into a more compact structure (University of Nebraska-Lincoln, 2013). Because Field 2 was under a tillage level between conventional tillage and conservation tillage, and Field 1 was under strip tillage, it is possible that the greater amount of tillage in Field 2 could be driving increases in bulk density.

Soil moisture and soil organic matter did not differ between treatments, suggesting that different nitrogen treatments do not greatly influence these soil physical characteristics. Both of these variables differed considerably by field, however. Soil moisture and organic matter were both significantly higher in Field 1 than Field 2. This trend may also be explained by the differences in tillage method. Because more crop residue, containing high amounts of organic matter, is left on the field in strip tillage, it makes sense that Field 1 would have higher levels of organic matter. This effect can be seen over a longer time scale, as previous research has found that conventional tillage methods are leading to organic matter losses (Burke, et al. 1995). Therefore, maintaining sustainable yields will require proper management of soil organic matter reserves. Organic matter is directly linked to soil moisture (Hudson 1994), and so the similarity in trends between these two variables is not unexpected. Differences in soil moisture between the two fields could be due not only to the relative amount of organic matter, but also to the topography of the two fields. Field 2 was situated on a slight hillslope, which might lead to better drainage and lower soil moisture levels.

Soil Chemical Characteristics

Soil nitrate concentrations generally increased with greater nitrogen inputs in Field 1. This is consistent with previous studies that have found increases in soil NO_3-N with greater fertilizer additions (Ludwick, et al. 1976). Nitrates can accumulate in the soil if addition rates exceed rates of uptake by crops, and our results suggest that this scenario is likely to be occurring in Field 1. Nitrogen fertilization rates in Field 2 (80 lbs-170 lbs) were higher than rates in Field 1 (0 lbs-94 lbs), which might explain the greater nitrate concentration in Field 2 soils (mean concentrations of 1.12 mg/kg in Field 2 versus 0.87 mg/kg in Field 1). Tillage method might also be contributing to differences in nitrate concentrations between fields, since nitrogen accumulation is thought to occur less quickly in strip-tilled fields (Angle, et al. 1993). It is also possible that the large amount of rainfall that occurred during the growing season decreased soil nitrate concentrations at Field 1, as nitrates are easily leached with rainfall. Nitrates' susceptibility to leaching enables them to enter the hydrologic system as runoff, especially with large amounts of rainfall.

Soil ammonium concentrations did not differ by field or treatment. Past research conducted in similar fields in the area has found that ammonium concentrations decrease throughout the growing season (Cornwell, unpublished). Ammonium is converted to nitrate in well-aerated soils, so it is possible that sampling occurred after most of this conversion had taken place. Ammonium concentrations are generally of less importance when evaluating the ecological effects of farming, as they are less mobile and therefore less prone to leaching (College of Tropical Agriculture and Human Resources, 2013).

Soil phosphates from Field 1 were very variable within treatments and did not follow the same trends as nitrates. This could be due to the low ammonium concentrations, since ammonium additions are believed to stimulate phosphatase activity. With low ammonium concentrations, phosphatase may be less active. The lack of differences between N treatments may also be explained by nutrient limitation. It is possible that the soil in the area is less limited by phosphorous, and so phosphate concentrations would not respond to fertilizer enrichment.

Soil pH did not differ significantly either by field or treatment (4.98 for Field 1, 4.92 for Field 2). Most crops are able to tolerate a wide range of pH's, though some agricultural researchers have proscribed enrichment with lime if pH levels fall below 6.0 (Mallarino, et al. 2011). Soil acidity can increase in response to high nitrogen inputs over time, and so acidic pH values can indicate poor soil health, which can lead to lower fertility over time. Because of the late-season sampling time and the high variability in pH levels within treatments, it is difficult to say if the acidic pH values in Fields 1 and 2 warrant further concern.

Plant Properties

Stalk nitrates varied drastically between fields. Field 1 stalks had low nitrate levels, while Field 2 stalks had either excessive or optimum nitrate levels. This can likely be attributed to the greater amount of tillage and nitrogen fertilizer added to Field 2. More fertilizer was used at Field 2, and the more conventional tillage practices likely led to accumulation of nitrates in the soil. With more nitrate available, more was taken up by the plants. The excessive stalk nitrate concentrations found at Field 2 can be an indication of ecological degradation, as excess nitrates are likely to enter the hydrologic system as runoff. It should be noted that Field 1 may have lower stalk nitrate levels than normal due to the high amounts of rainfall discussed earlier. It has been suggested that nitrate levels are susceptible to climatic variation. Specifically, they tend to be higher under drought conditions and lower under conditions of high rainfall (Kaiser & Lamb 2012). According to MTVL, stalk nitrate concentrations can be a reflection of nitrogen fertilizer management. The excessive levels of stalk nitrates found in Field 2 soils are likely to have originated from fertilizer and are an indication of likely pollution via leaching.

Yields and Economic Returns

Yields increased with increasing nitrogen additions at Field 1. If nitrogen levels were already low due to rainfall and subsequent runoff, the effect of nitrogen additions on yields may have been even stronger than normal, since the system was nitrogen-limited. This trend is consistent with those found at a similar field in the area two years ago (Wieme, unpublished); however, another study conducted in the area last year found no trend. The absence of a consistent trend in yields may suggest a large influence of climatic variability. The higher yields observed in Field 2 may be due to the greater concentrations of nitrogen in the soil; with more nitrogen available, the corn was able to incorporate more into biomass, leading to higher productivity and higher yields.

Economic returns only loosely followed yield trends for Field 1 soils. There was a slight upward trend, but there was no significant difference in yields between -15 lbs and MRTN, and +15 lbs and +30 lbs. Profits were considerably higher in Field 2, which reflects the higher yields from Field 2. Because we found no strong relationship between fertilizer additions and economic profits, it is difficult to recommend an optimal amount of fertilizer from an economic and ecological standpoint. Importantly, it should be noted that the social cost and ecological cost of over-fertilization is not reflected in these calculations, only profit accrued by the farmer.

Conclusions

While comparisons between N treatments at Field 1 did not produce many significant trends, between-field analyses provided valuable information about the effects of tillage method on soil properties. Our results suggest that tillage method greatly influences the soil and plant characteristics of a cornfield. Specifically, by leaving more plant residues on the field, strip tillage can increase the amount of organic matter and soil moisture. Depending on external climatic variables, this may have implications for nutrient levels and plant yields. While our data did not produce an optimal recommendation for nitrogen fertilizer input, it does provide information that can be used to inform ecologically sustainable management of farm fields. Excessive levels of nitrate in stalks from Field 2, for example, suggest that much of the field received too much fertilizer, and this excess nitrogen is susceptible to leaching via runoff. The study also highlights the value of on-farm research in providing relevant information to farmers, which can lead toward more scientifically informed management practices.

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Figures and Tables

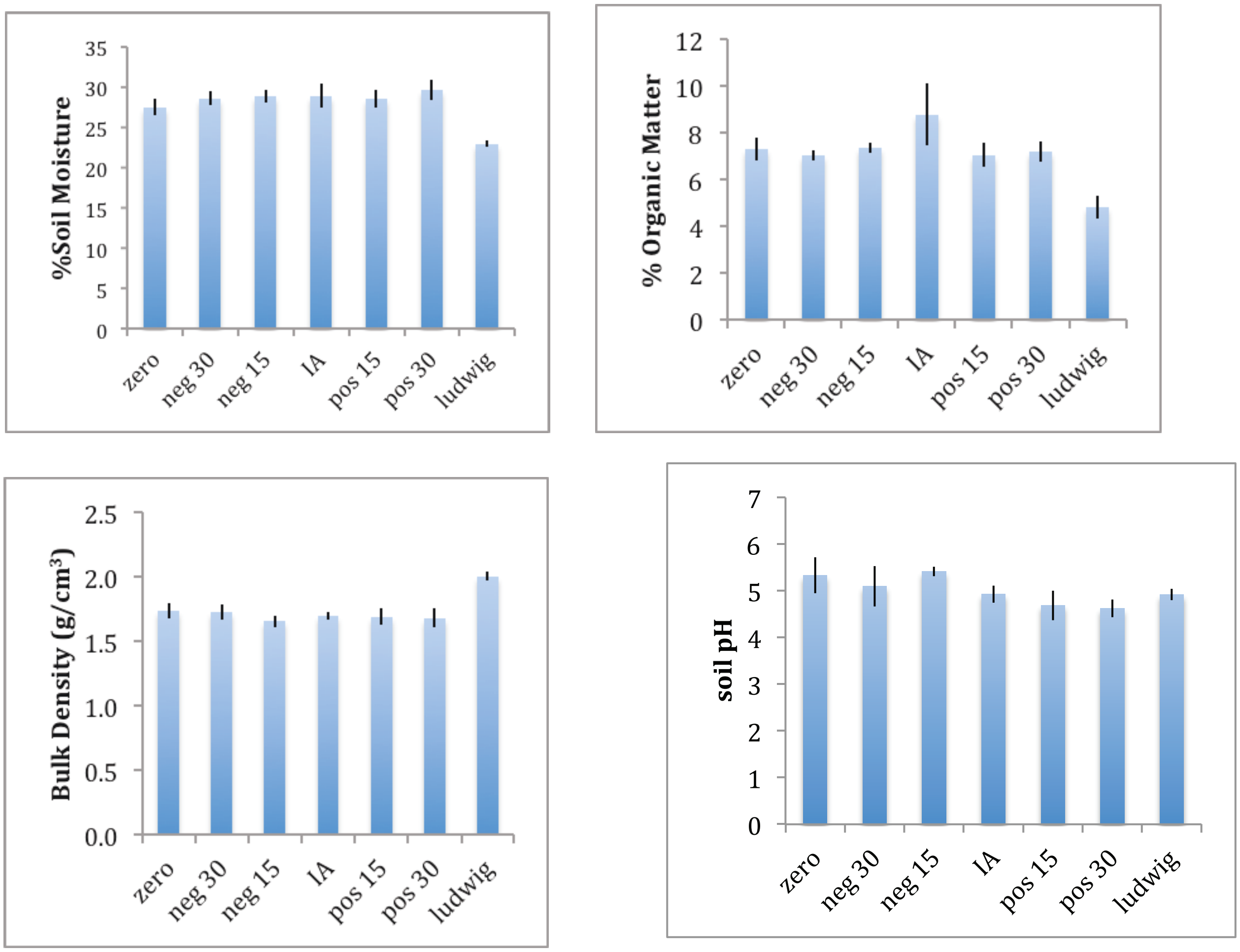


Figure 1. Soil properties by N treatment at Field 1, with Field 2 added for comparison (Field 2="ludwig"). Abbreviations for treatments are as follows: zero=0 lbs; neg 30=-30 lbs; neg 15=-15 lbs; IA=MRTN; pos 15= +15; pos 30=+30 lbs). One-way ANOVA tests found no significant difference in means between Field 1 N treatments. Soils were collected in mid-October and were oven-dried and combusted for %SOM and %OM analysis. Soil bulk density was obtained using a corer of known volume. Soil pH was measured by water extractions and a pH meter.

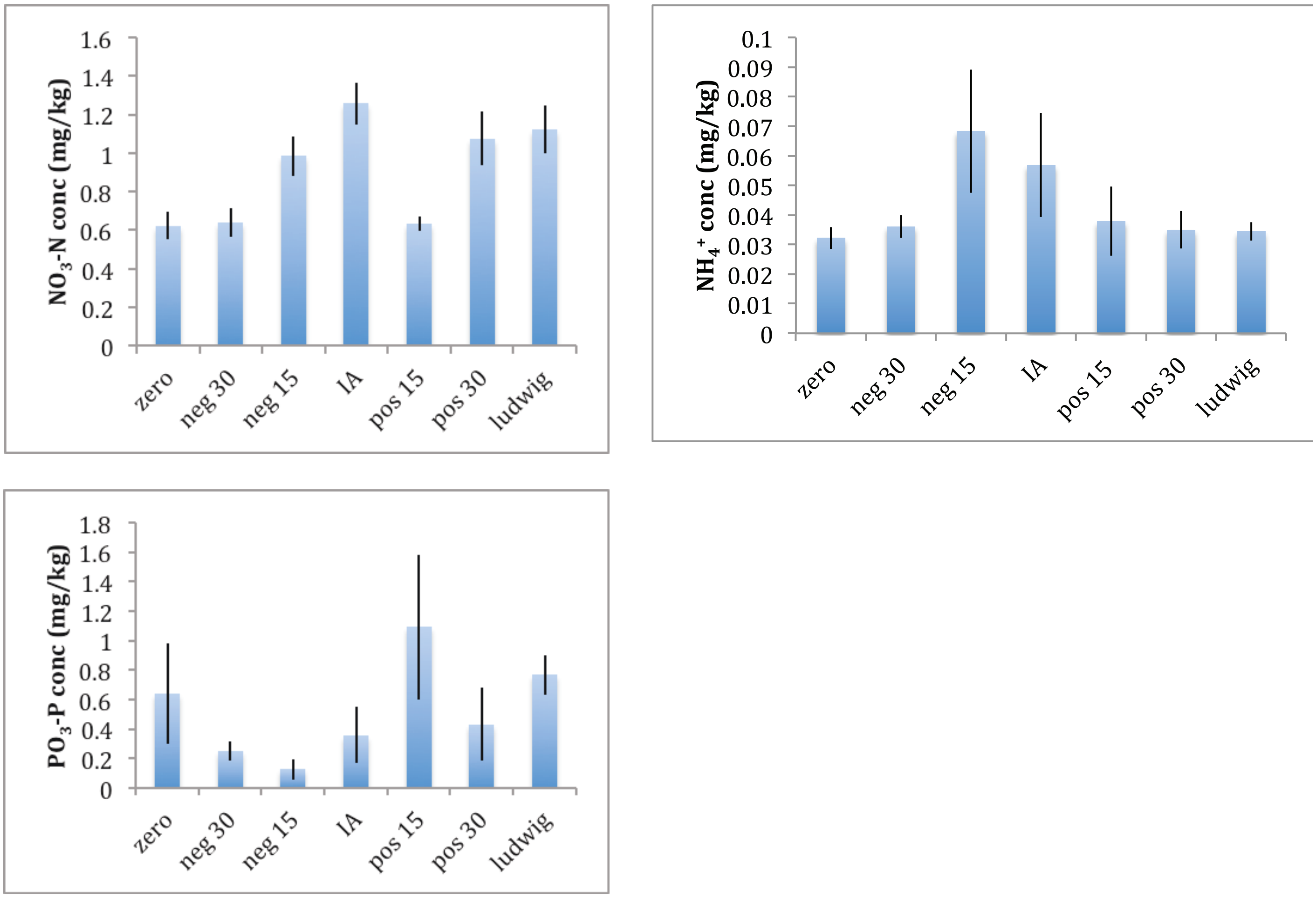
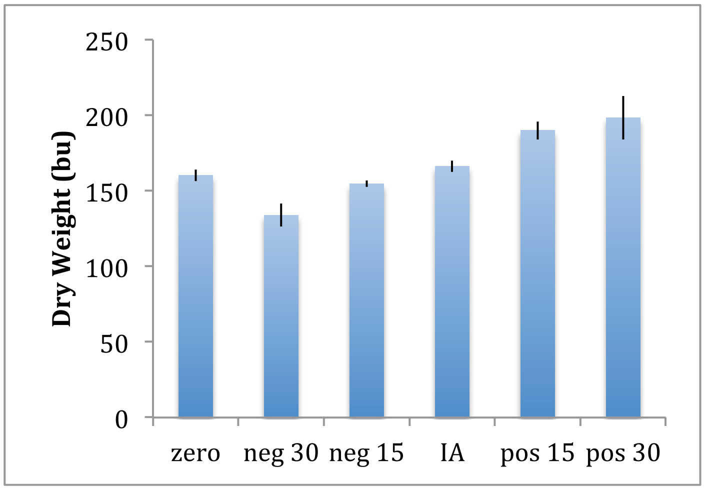


Figure 2. Soil nutrients by N treatment at Field 1, with Field 2 added for comparison (Field 2="Ludwig"). One-way ANOVA tests found no significant difference in means between Field 1 N treatments for PO_4-P and NH_4^+ concentrations (p=0.204, 0.290, respectively). A one-way ANOVA test did find significant differences between NO_3-N concentrations by treatment ($p<0.05$). Soils were collected on October 12 and 19, 2013. 2 M KCl extractions were performed for NO3-N analysis, Mehlich extractions were performed for PO4-P analysis, and florometric analysis was performed to measure NH_4^+ concentrations.



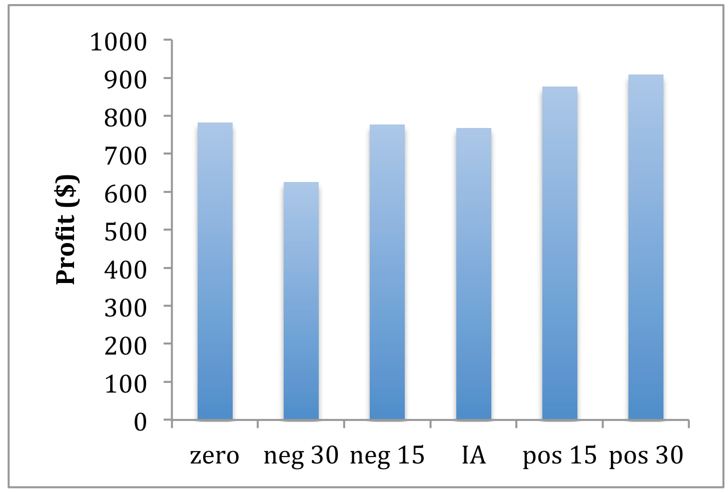


Figure 3. Yields (dry weight in bushels) from Field 1 treatments. Yields were calculated at harvest in late October, and weights were obtained using a weigh wagon. A one-way ANOVA test found significant differences in means ($p<0.01$). Profit was calculated using total and variable fixed costs for each field and the expected price of corn. Profits at each level represent a single point, and so there are no error bars and no opportunity for ANOVA analysis.

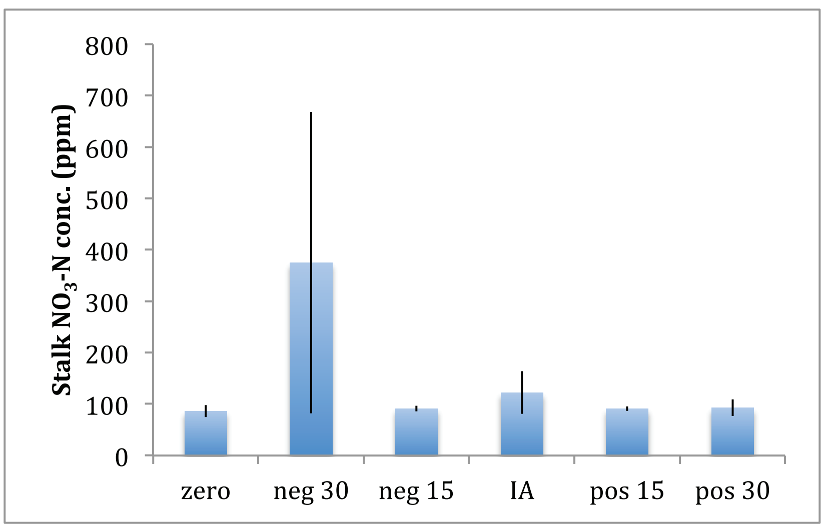


Figure 4. Stalk nitrate concentrations from Field 1 treatments. All except -30 lbs were considered “low” by the MTVL. Stalks were sampled by clipping an 8” piece of stalk 10-14” from the ground. They were sent to MTVL for analysis. The MTVL categorizes nitrate levels as follows: low (0-250 ppm), marginal (250-750 ppm), optimum (700-2000 ppm), and excessive (>2000 ppm). One-way ANOVA tests found no significant differences in means.

Table 1. Field-by-field comparisons for soil properties, plant properties, yields, and economic profit. All variables were measured according to procedures described above. Means and SD are given for each field. Two-sample t-tests were performed to compare means, and the p-value is reported.

	Field 1	**Field 2**	**p-value**
%Soil Moisture	28.67 ± 2.54	22.98 ± 1.90	<0.01
%Organic Matter	7.47 ± 1.60	4.80 ±2.41	<0.01
Bulk Density (g/cm3)	1.70 ± 0.13	2.00 ± 0.16	<0.01
pH	4.98 ± 0.53	4.92 ± 0.33	0.78
NO_3-N (mg/kg)	0.87 ± 0.33	1.12 ± 0.59	<0.05
PO_4-P (mg/kg)	0.48 ± 0.70	0.76 ± 0.58	0.14
NH_4^+ (mg/kg)	0.045 ± 0.005	0.034 ± 0.003	0.15
Stalk NO_3-N (ppm)	143 ± 206	3294 ± 2952	<0.01
Dry Weight (bu)	142.33 ± 18.09	234.75 ± 4.72	<0.01
Profit ($)	788 ± 99	1103 ± 76	<0.01

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MVTL PLANT ANALYSIS REPORT

SUBMITTED BY: 040190
KATHLEEN SHEA
BIOLOGY DEPT - ST OLAF COLLEGE
1520 ST OLAF AVE
NORTHFIELD MN 55057

SUBMITTED FOR: LEGSTO

Date Received: Oct 12 2013
Report Date: Oct 23 2013
Work Order No: 201311-01561

Lab Number	Sample Id	Plant Part	Nitrate (ppm)	Interpretation
13-P2366	1-1-1	Stalk	85	LOW
13-P2367	1-2-1	Stalk	< 50	LOW
13-P2368	1-3-1	Stalk	99	LOW
13-P2369	1-4-1	Stalk	51	LOW
13-P2370	1-5-1	Stalk	99	LOW
13-P2371	1-6-1	Stalk	66	LOW
13-P2372	2-1-2	Stalk	67	LOW
13-P2373	2-2-2	Stalk	961	OPTIMUM
13-P2374	2-3-2	Stalk	81	LOW
13-P2375	2-4-2	Stalk	122	LOW
13-P2376	2-5-2	Stalk	90	LOW
13-P2377	2-6-2	Stalk	90	LOW

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MVTL PLANT ANALYSIS REPORT

SUBMITTED BY: 040190
KATHLEEN SHEA
BIOLOGY DEPT - ST OLAF COLLEGE
1520 ST OLAF AVE
NORTHFIELD MN 55057

SUBMITTED FOR: LEGSTO

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Lab Number	Sample Id	Plant Part	Nitrate (ppm)	Interpretation

Interpretation of NO3-N Concentrations:

Less than 250 ppm -	Low, nitrogen was probably deficient during the growing season.
250 ppm - 700 ppm -	Marginal, it is possible that nitrogen shortage limited yield.
700 ppm - 2000 ppm -	Optimum, yield was not limited by a shortage of nitrogen.
Greater than 2000 ppm-	Excessive, nitrogen rate was too high or some production factor caused a yield reduction.

Excess N may have been derived from fertilizer, manures, plant residues or organic matter

Assessment of the N status of corn at the end of the season is a report card on nitrogen fertilizer management. It can provide crop producers with informationn that can be used to adjust fertilization practices in future years.

Contact an MVTL agronomist if you have any questions.