RAISED BEDS, TILE DRAINAGE, AND NITROGEN FERTILIZER MANAGEMENT ON CORN YIELD IN EASTERN NORTH DAKOTA

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MASTER OF SCIENCE

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ABSTRACT

Surface drainage, tillage, and different nitrogen fertilizer rates and management practices can influence corn (*Zea mays* L.) grain yield. The objective of this research was to evaluate the effect of subsurface drainage, raised bed tillage, and nitrogen fertilizer treatments (rates and managements practices) on corn grain yield in the Red River Valley. The effect of subsurface drainage was evaluated at one location in 2012 and 2013. The effect of raised bed tillage and nitrogen fertilizer treatments were evaluated at three and four locations in 2012 and 2013. The drainage x tillage interaction was significant for yield in 2012. Averaged over all environments, conventional tillage had significantly greater corn stand and yield than raised beds. The significance difference in yield between the N fertilizer management practices and rates varied between years. There were no NH_4^+ and total N soil test differences between urea alone, nitrapyrin, and PCU treatments at V6 stage.

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INTRODUCTION

Corn is currently one of the most important crops in the Red River Valley (RRV) of the north. Corn production in North Dakota has increased from 500,000 hectares in 2002 to 1.4 million hectares in 2012 (NASS, 2012). Corn requires a high level of nitrogen fertilization in order to maximize its yield potential. Nitrogen use efficiency is becoming increasingly important in the RRV. Nitrogen fertilizers have risen in price over the past few years for the grower. Furthermore, there is growing concern about nitrate leaching into waterways and ground water due in part to the abnormally wet conditions in the RRV since the early 1990’s. Nitrogen (N) can be lost from the soil in many ways including denitrification (nitrate “NO_3^-” being converted to gaseous N_2O), volatilization (converting ammonium “NH_4^+” to gaseous ammonia “NH_3”), and leaching (NO_3^- moving out of the root zone). Using N more efficiently in corn would be very beneficial to the grower. For example, it would benefit growers if lower rates of N could be applied yearly to their corn crop while maintaining or increasing grain yield. This would reduce the total cost of inputs enabling them to be more profitable. Furthermore, environmental concerns pertaining to N could be reduced within the farming region.

Subsurface (tile) drainage is becoming more important in the RRV in the last few years because this area has been in a wet cycle since the early 1990’s (NDAWN, 2013). This has caused localized seasonal soil waterlogging which inhibits crop yield potential in the clay soils of this region which are slow to drain. Moreover, tile drainage, a relatively new technology for the region, has increasingly been considered by growers to help reduce salinity, and drain excess water out of the crop root zone in their fields (Cihacek et al., 2012). By draining the excess water, growers hope to do field operations earlier, and reduce waterlogging so plants will grow better and produce higher yields. One environmental concern is that subsurface drainage will increase the concentration of nitrates in the waterways (Drury et al., 1993).

Like tile drainage, a raised bed tillage system could have a benefit in the RRV during an excessively wet growing season. With raised beds, the water could flow between the raised beds and therefore part of the plant's root system will not be subjected to excess soil moisture. The soil forming a ridge in a raised bed system could be aerated, while in a conventionally tilled field the soil might be at or near saturation. In a conventional tillage system when a field is completely saturated (waterlogged) the plant's roots will not be able to get oxygen because all of the soil pores will be filled with water. A plant will eventually die after a certain period of time under saturated, low oxygen conditions (Vitorino et al., 2001). Moreover, N losses through denitrification and leaching have the potential to be higher in a waterlogged soil.

The use of split applications, slow release compounds and nitrification inhibitors could possibly reduce N loss, lower rates of N needed for a corn crop, and maintain or increase grain yield. Limited research has been conducted in the RRV dealing with split application of N, polymer coated urea, nitrapyrin, and dicyandiamide plus N-(n-butyl) thiophosphoric triamide under a raised bed tillage system. The research reported here will address the following main questions: Can corn grain yield be improved using a raised bed tillage system? Can subsurface (tile) drainage enhance corn grain yield in the heavy, slowly drained soils of the RRV of the north? Can corn grain yield be increased in the RRV with the use of split applications of N, slow release compounds ((polymer coated urea (PCU)), urease inhibitors ((dicyandiamide (DCD)) and nitrification inhibitors ((nitrapyrin and N-(n-butyl) thiophosphoric triamide (NBPT)), and might these practices interact with tillage systems or/and tile drainage?

OBJECTIVE

The objective of this research was to evaluate the effect of tile drainage, raised beds, and N rates and management practices on corn grain yield. This research was conducted in an area where the soils are poorly drained, N loss through volatilization and denitrification is a concern, and conventional tillage is the main tillage system used.

LITERATURE REVIEW

This section contains a literature review dealing with the impact of subsurface drainage, raised bed tillage system, urease inhibitors, nitrification inhibitors, polymer coated urea, and split applications of N fertilizers on N loss and uptake in corn and their influence on corn yield.

Saturated soil conditions

Raised bed tillage and subsurface (tile) drainage may be adapted to the RRV, since this area has been in a wet cycle since the early 1990's. Over the past 23 years (1990 to 2013) Fargo, Langdon, and Prosper received an average annual precipitation of 57 cm, 49 cm, and 59 cm, respectively (NDAWN, 2013). In Fargo during those years, the minimum annual precipitation was 24 cm and the maximum annual precipitation was 80 cm (NDAWN, 2013). In several of these seasons, crop grain yield was reduced due to excessive soil moisture. Because of slow infiltration rates, the clay soils in the Fargo area and the clay loam soils in Langdon area have a tendency to become waterlogged resulting in frequent yield losses. Some North Dakota growers have not been able to plant or harvest their fields due to excess moisture and saturated soil conditions in the spring or fall, or both in the spring and the fall. From 2002 to 2011 there has been on average of 108300 hectares not harvested yearly in North Dakota, often due to excessive moisture (NASS, 2012).

Saturated soil conditions, also called "water saturated or waterlogged", occur when all or nearly all of the soil pores are filled with water (Brady and Weil, 2010, p. 202). Due to the swelling property of montmorrillonitic clays, as moisture levels reach maximum water-holding capacity, permeability is obstructed (Boru et al., 2003). Saturation leads to numerous changes within the soil. Early effects include reduced oxygen concentrations and gas exchange. Water fills soil pores previously filled with air, and oxygen does not diffuse as readily through water as through air filled pores. The resulting environment becomes hypoxic and carbon dioxide levels rise (Boru et al., 2003). Anaerobic soil conditions lead to changes in soil chemistry. Due to anoxic conditions, facultative anaerobes may convert nitrate to N gas through denitrification (Ponnamperuma, 1972). Nitrate can function as an alternative electron acceptor to oxygen (Bacanamwo and Purcell, 1999). As the reducing intensity of the soil increases, oxides of manganese and iron are also reduced to highly soluble cations which can enter roots, interfering with enzyme function and damaging membranes (Laanbroek, 1990). Sulfate may also be reduced to a form which is toxic to respiratory enzymes (Ponnamperuma, 1972).

Flooding occurs due to excessive rainfall or irrigation and compromises crop growth. Lowland flooding can occur due to inadequate surface drainage and slow permeability of soils in depression areas (Sullivan et al., 2001). Unnatural flooding can be caused by excessive irrigation or irrigation followed by rainfall. Flooding can refer to complete submergence of the plants or waterlogging where only the roots of the crop are submerged in water.

Subsurface drainage

Subsurface drainage is the practice of placing perforated pipes at a specified grade (slope) at some depth below the soil surface in order to lower the water table (Sands, 2001). Excess water from the crop root zone can enter the pipe through the perforations and flow away from the field to a ditch or other outlet (Sands, 2001). The presence of salts in soils with a high water table in North Dakota has stimulated interest in the installation of tile drainage systems due to the recent extended climatic wet cycle (Cihacek et al., 2012). Subsurface drainage lowers the water table and encourages the leaching and removal of salts from the soil above the tile lines. This improves soil productivity, culminating in improved yields. Other advantages of subsurface drainage include lower crop production risks, reduced seasonal wetness and improved timeliness of field operations. On the other hand, the cost of installation and maintenance, wetland issues, outflow management, the need for water in dry seasons, and strained relationships with neighbors may be disadvantages associated with tile drainage. Zucker and Brown (1998) reported that subsurface tile drainage systems enhance crop yields on poorly drained but highly productive soils, and helped to reduce year-to-year variability in yields. Subsurface tile drainage also improves aeration, increases the availability of nutrients, and enhances crop productivity (Lal and Taylor, 1970; Cannell, 1979). Fausey et al. (1986) found that subsurface drainage reduces crop diseases, soil erosion, and surface runoff.

Although soil drainage is usually successful, instances may occur in which the tile functions properly when first installed, but within a few growing seasons, the efficacy or performance may appear to decrease and areas in fields may not appear to be draining as expected (Cihacek et al., 2012). This may be from changes in soil chemistry due to the removal of salts, and soil swelling associated with aggregate dispersion rather than improper installation of the tile drains.

Many research studies have shown that the presence of subsurface tile drainage systems can increase NO_3-N losses from fields (Baker and Johnson, 1981; Baker and Melvin, 1994; Logan et al., 1994; Skaggs et al., 1994; Soenksen, 1996), even when no additional fertilizer is applied (Randall and Iragavarapu, 1995). However, Davis et al. (2000) found that a decrease in the N application rate from 225 to 175 kg ha^{-1} decreased NO_3-N loss by 48%. Critical factors affecting nitrate loss from tile-drained agricultural fields include the amount and timing of precipitation, soil moisture content, time of year (growing season versus non-cropping period), and tile depth and spacing (Drury et al., 2009). In humid temperate regions, for example, 88 to 95% of nitrate loss through tile drainage can occur during the non-cropping period (fall-winterspring), and nitrate concentrations in this drainage water can often exceed the drinking water guideline of 10 mg N L^{-1} (Drury et al., 1996).

In a study conducted by Drury et al. (1993), which looked at the influence of tillage on nitrate loss in surface runoff and subsurface drainage, they found that the concentrations of NO_3^- in subsurface drainage water from conventional, ridge, and no-tillage treatments exceeded the maximum recommended safe limit for drinking water (10 mg N L^{-1}) in 79% of the leaching events, with flow-weighted concentrations between 12 and 17 mg N L^{-1} in 1989 and 1990.

One of the main reasons growers consider installing subsurface drainage in their fields is to increase its yield potential. Research conducted by Kladivko et al. (2005) showed that over ten years, the non-drained control treatment, on average, had a six percent lower corn yield than the subsurface drainage treatment. The non-drained plot had the lowest corn yield of all plots in seven of the ten years, but was significantly lower in only three. Only two of the ten years were wet enough at planting time to have substantial planting date delays between the subsurface drainage treatment (5 meter spacing) and the non-drained control. Zucker and Brown (1998) reported that corn yield increased annually by 0.9 to 1.4 Mg ha^{-1} and 1.3 to 1.9 Mg ha^{-1} in Indiana and Ohio, respectively, for crops grown with subsurface drainage versus those without subsurface drainage.

Chieng et al. (1987) reported in British Columbia, that subsurface drainage not only increased crop yield; it also advanced soil trafficability and workability. Kandel et al. (2013) found that the drained soil was capable of a higher load carrying capacity compared to the undrained soil, based on penetrometer readings. They also found that the average depth to the water table was greater on drained soil compared to the undrained soil both early and late in the growing season.

Hundal et al. (1976) observed that total hay yields and percentage of alfalfa (*Medicago sativa* L.) cover were higher in the subsurface drainage treatment than the undrained treatment (no subsurface or surface drainage). From a 12-state area, Sutton (1943) found that corn yields increased 1132 kg ha^{-1} with drainage (from 1760 to 2890 kg ha^{-1} or 64%). In a survey of 67 farms in Maryland, Uhland (1944) reported that corn yields were more than doubled by drainage. Additionally, Triplett and Van Doren (1963) found that corn yield in Ohio increased from 4500 to 6900 kg ha^{-1} with tile drainage.

Several studies, however, found that subsurface drainage did not significantly increase yield when compared to no subsurface drainage. Fausey et al. (1986) reported in northwestern Ohio, that low crop yields and delays in tillage operations due to wet soil indicated that drainage was still inadequate with all treatments. However, they also noted that the Hoytville silty clay loam soil at the experimental site had a compacted, impaired permeability layer in the profile that impeded water movement through the subsoil and to the subsurface drains. Kandel et al. (2013) concluded in Fargo, North Dakota, that wheat (*Triticum aestivum* L.) and soybean (*Glycine max* L.) yields were not statistically significantly different when comparing drained and undrained treatments in 2009 and 2010. When combined across both years, soybean yields were greater for drained than undrained treatment by and 50 kg ha^{-1} (2%), and wheat yields were 77 kg ha^{-1} (2%) lower for drained compared to the undrained treatment. Wiersma et al. (2010) also found that the grain yield of both wheat and soybean did not statistically significantly improve with subsurface drainage. Walker et al. (1982) reported the five year average corn yield on plots with no drainage and no irrigation was 5000 kg ha^{-1} compared to 6000 kg ha^{-1} for plots with surface and subsurface drainage with no irrigation. However, this was not a statistically significant increase.

Raised bed tillage system

Raised beds is a tillage system that refers to ridging the soil or raising the seedbed above the area of peak water accumulation or above the mean water elevation of the field (Blessitt, 2008). Bedding systems vary by the height of the bed, the width of the bed, and the number of rows each bed supports (Blessitt, 2008). A raised bed tillage system is similar to ridge tillage. The difference between the two tillage systems is that ridge tillage is a conservation tillage system that leaves the soil undisturbed as much as possible, and crops are planted on the same ridge year after year. The only time the soil is disturbed in a ridge tillage system is for re-ridging. A raised bed in the context of the RRV is not a conservation tillage system; its main goal is to keep most of the crop's roots out of saturated soil conditions. A raised bed system can be switched to a conventional system from year to year, depending on growers preferences and needs.

Research has shown that crop plants can have an increased flood tolerance when planting on a bed (Spooner, 1961). Soybean in one study was planted on raised beds and showed injury seven days after flooding (Griffin and Saxton, 1988). In a different study, where soybean was planted under a conventional tillage system, plant injury was seen two days after flooding (Heatherly and Pringle, 1991). One would expect raised beds to show less plant injury under flooded conditions than conventional tillage. Takahashi et al., (2006) evaluated raised beds as a means of alleviating flood stress in rice (*Oryza sativa*) paddy fields. In this research, locations that have been used as paddy fields were converted to upland fields and planted to soybeans. Ridging was an attempt to raise the root system of the growing soybean out of the saturated zone in clayey fields. Oxygen concentrations were measured and reached 13% in the raised beds compared to the conventional tillage system where concentrations were 3%. Soybean planted on raised beds showed increased leaf N concentration in all growth stages except the early vegetative stages relative to conventional tillage. In similar studies, soybean yield was 110 to 120% higher in elevated beds relative to conventional tillage (Hosokawa et al. 2005). Takahashi et al. (2006) observed yield increases of 7 to 20% over flat planting in another trial evaluating raised bed tillage as a means of alleviating water stress.

In a study looking at the effect of raised beds on soil structure, waterlogging, and productivity on duplex soils in Western Australia, Bakker et al. (2005) reported that the incidence of waterlogging in raised beds was reduced and this was accompanied by an increase in runoff from the raised beds. In the same study the perched water table level and bulk density was lower in the raised beds than the control. The hydraulic conductivity and runoff was higher in the raised beds than the control. The crop yield (wheat "*Triticum aestivum*", oat "*Avena sativa*" and canola "*Brassica napus*") from the raised beds was always higher than the control; however, occasionally problems with the establishment of the crop or harvest affected the final yield on the raised beds.

In a study looking at the productivity and profitability of raised seedbeds for soybean production on clayey soils in the Mississippi Delta, Blessitt (2008) reported that soybeans grown on raised beds in 2006 were 14 cm taller, had a leaf area index (LAI) 52% greater, and yielded 620 kg ha^{-1} more compared to soybean planted on the flat. In 2007, soybean planted on raised beds were nine cm taller, had 107% greater LAI, and yielded 730 kg ha^{-1} more than soybean planted on the flat. Averaged across years, net returns above input costs were \$237 ha^{-1} higher for soybean grown on raised beds. The raised bed in this study was 100 cm wide, planted with 4 rows spaced 25 cm apart.

In a different study conducted in 2006, Blessit (2008) found that soybean yields were highest for 100 cm-wide raised beds, but also were higher on 200 cm-wide raised beds compared to flat plantings. Averaged across two years, only the 100 cm-wide raised beds offered yields significantly higher than flat plantings. A four-row planter (four planter units) with planter units spaced 100 cm apart was used in this study.

Since there is limited research comparing conventional tillage versus raised beds, ridge till research will also be discussed. Ridge till is similar to the raised beds tillage system with only a couple differences that were stated previously. Data from South Dakota have shown that ridge till could be a viable alternative to conventional tillage (Archer et al, 2002). Averaged across ten years (1990-1999), yields, fertilizer costs, and operating costs were not significantly different between tillage systems. Net returns for ridge tillage, however, were significantly higher than for conventional tillage in three out of the ten years. Net returns for conventional tillage were significantly higher in one out of the ten years. Fuel and labor costs were lower in ridge till than conventional till, but pesticide use was higher in the ridge till system.

Pikul et al. (2001) in a study in the northern corn belt of the United States concluded that corn grain yield was significantly greater on conventional tillage than with ridge till. Averaged across 11 years and three fertilizer N rates, corn yield was 6267 kg ha^{-1} with ridge till and 6500 kg ha^{-1} with conventional tillage. Soybean grain yield was not different between ridge till and conventional tillage. Bundy et al. (1992) reported that yields in ridge till were lower than mold board plow only in 1987 when dry soil conditions at ridging contributed to mechanical damage of the root systems and above-ground portions of plants.

Nitrogen management practices

Environmental and economic issues combined have increased the need to better understand the role and fate of N in crop production systems (O'Leary et al., 1994). Nitrogen is the nutrient most often deficient for crop production and its proper use can result in substantial economic return for growers. However, when N inputs to the soil system exceed crop needs at any given time and ammonium (NH_4^+) is converted to nitrate (NO_3^-), there is a possibility that any unused NO_3^- may be lost from the soil and be unavailable for crop uptake.

Volatilization (converting NH_4^+ to gaseous ammonia NH_3) and denitrification (NO_3^- being converted to gaseous N_2O and N_2) are two other important ways N can be lost from the soil (O'Leary et al., 1994). Nitrification is the process of converting NH_4^+ to NO_3^-. For denitrification to occur, NO_3^- must be present in the soil (Brady and Weil, 2010). The more NO_3^- in the soil, the greater the chances for denitrification to occur. Denitrification is a process that converts NO_3^- to N_2O. This compound may be further broken down to dinitrogen gas (N_2). Nitrous oxide gas is a potent greenhouse gas that can also damage the ozone layer (Brady and Weil, 2010). Managing N inputs to achieve a balance between profitable crop production and environmentally tolerable levels of NO_3^- in water supplies and lowering greenhouse gas emissions from N loss to nitrous oxide gas should be every grower's goal.

Products like environmentally smart urea (ESN) (Agrium U.S. Inc., Denver, CO) a type of polymer coated urea (PCU), nitrapyrin (Instinct) (Dow Agro Sciences LLC, Indianapolis, IN), and dicyandiamide and N-(n-butyl) thiophosphoric triamide (Agrotain Plus) (IMC Phosphates Company, St. Louis, MO) could have potential to reduce N loss and increase N availability for corn uptake. There is little information available on the effect of split application of N, PCU, nitrapyrin, and DCD+NBPT in corn production under a raised bed tillage system and subsurface drainage, particularly in the RRV.

Urease and nitrification inhibitor

Dicyandiamide plus N-(n-butyl) thiophosphoric triamide (Agrotain Plus) is an additive specifically designed for use with UAN (urea ammonium nitrate) solutions (IMC Phosphates Company, 2012). Agrotain Plus contains both N-(n-butyl) thiophosphoric triamide (NBPT), a urease inhibitor that prevents N loss by ammonia (NH_3) volatilization from synthetic or organic urea; and dicyandiamide (DCD), a nitrification inhibitor that may slow the conversion of NH_4^+ to NO_3^- . Thus, this product acts against both the volatilization and nitrification processes that lead to N losses from urea. The NO_3^- portion of the UAN solution, however, is not protected.

Urease inhibitors block an enzyme called urease which breaks down urea to NH_3. If urea is converted to NH_3 below the soil's surface, then the NH_3 is almost instantaneously converted to NH_4^+ (Schwab and Murdock, 2009). Ammonium binds to soil particles and is resistant to loss. If urea fertilizers are converted to NH_3 on the soil surface or on surface residues, there is potential for the NH_3 gas to escape back into the atmosphere by a process called NH_3 volatilization (Schwab and Murdock, 2009). According to the product label, DCD+NBPT at a rate of 7.5 g kg^{-1} will be effective in 28%, 30%, or 32% UAN (IMC Phosphates Company, 2012). Research conducted in Kentucky showed that corn grain yield was not significantly improved when DCD+NBPT was added to UAN when compared to urea alone and UAN alone treatments in side-dressed no-till corn (Schwab and Murdock, 2009). Yield was 9934 kg ha^{-1} for urea alone, 9431 kg ha^{-1} UAN alone, and 11003 kg ha^{-1} for UAN plus DCD+NBPT treatments (Schwab and Murdock, 2009).

A study looking at urea hydrolysis response to NBPT in corn under a ridge tillage system, found that the yield response of corn to urea or a UAN solution containing NBPT was highly variable, dependent mainly on the climatic conditions following fertilization (Murphy and Ferguson, 1997). The first two years of the Murphy and Ferguson (1997) study showed no differences in grain yield as influenced by N source, N rate, or inhibitor. The grain yields in the third year, however, were significantly influenced by N source, inhibitor, and N rate. Limited precipitation and low humidity for an extended period following fertilization in 1992 (third year) resulted in a 3660 kg ha^{-1} increase in yield when NBPT was applied with urea (averaged over rates and application methods), but no yield increase when NBPT was applied with UAN. The authors concluded that the major difference between the first two years and the third year was that the third year had lower relative humidity during the two days after fertilization. Therefore, a microclimate conducive to rapid hydrolysis and volatilization from urea was present. No differences in yield were observed between broadcast and soil banded application methods. The authors also concluded that it was probable that in some years in south-central Nebraska the use of a urease inhibitor will help protect surface-applied urea from volatile NH_3 loss.

Nitrification inhibitor

Instinct is a new encapsulated formulation of the chemical nitrapyrin (2-chloro-6-(trichloromethyl) pyridine) (Dow Agro Sciences, 2012). This product is a nitrification inhibitor that acts against the *Nitrosomonas* bacteria responsible for nitrification, thus slowing the conversion from NH_4^+ to NO_3^-. Nitrate is more susceptible to loss in the soil than NH_4^+. According to the manufacturer, this new formulation of nitrapyrin is intended for preplant, preemergence, at-plant row or band injection applications of UAN or granular NH_4^+ containing fertilizers and urea. Nitrapyrin can be applied in the spring with liquid fertilizer or tank-mixed with herbicides or insecticides prior to or at planting. It can also be tank-mixed with compatible fungicides, according to the manufacturer.

Wolt (2004) in his review of many studies in different parts of the United States found that an application of nitrapyrin increased crop grain yield by 7% and soil N retention by 28%; and reduced N leaching by 16% and greenhouse gas emissions by 51%. In more than 75% of the individual comparisons, use of a nitrification inhibitor increased soil N retention and crop yield, and decreased N leaching and volatilization (Wolt, 2004). Factors such as N fertilization practices (rate, timing, source, placement), soil factors (texture, organic matter content, pH), and environmental conditions (soil cover, temperature, moisture) combine to influence the overall performance of a nitrification inhibitor.

In approximately 25% of the studies considered, use of a nitrification inhibitor did not positively affect agronomic or environmental performance (Wolt, 2004). These instances may represent situations where environmental conditions were not conducive to N losses from the agroecosystem (Blackmer and Sanchez, 1988), or they may represent situations where a nitrification inhibitor used in conjunction with a fertilization practice results in N loss through NH_3 volatilization (Thompson et al., 1987).

Slow release urea

Polymer-coated urea (PCU) is another type of N stabilization (Schwab and Murdock, 2009). One type of PCU that is widely available for use on crops is called ESN. The amount and rate of N release of ESN is controlled by the thickness and other characteristics of its polymer coating (Schwab and Murdock 2009). Nitrogen in PCU is encapsulated with a patented polymer membrane that releases the N as the soil warms. Polymer-coated urea can be applied in advance of the crop's demand because cool soil temperatures in early spring slow N release. Schwab and

Murdock (2009) in 2007 at Princeton, KY showed that corn yield was significantly greater with PCU when compared to urea alone, Nutrisphere N (maleic itaconic copolymer "MIC"), and the experimental control. A regular urea granule will dissolve immediately, even in cool conditions when moisture is present in the soil. The PCU takes more moisture and warmer temperatures before the urea will dissolve in the capsule and be released for crop uptake.

A study in north central Kansas reported that in the 2006 and 2007 growing seasons, grain yield of irrigated corn plots receiving untreated urea were lower yielding than plots receiving urea treated with NBPT, PCU, or MIC at all levels of applied N (Gordon, 2008). In the same study, Gordon (2008) reported that yields with UAN (28%) alone were lower than yields with UAN treated with NBPT, PCU, DCD+NBPT, or MIC. Averaged over three different N rates, grain yields achieved with all treated N products were greater than yields with untreated UAN or urea alone. There were no significant differences in corn grain yields among NBPT, DCD+NBPT, PCU, or MIC. The lower grain yields with urea and UAN alone indicated that volatilization of N may have been a significant problem.

Split application of nitrogen

Splitting the application of N in corn is another option that may decrease N loss because the N is being applied closer to the time of the crops greatest N demand. Split fertilizer applications can reduce NO_3^- loss through subsurface drains (Kanwar et al., 1988), lower residual soil NO_3^- (Varshney et al., 1993) and increase N use efficiency by corn (Fox et al., 1986). Gerwing et al. (1979) demonstrated that four smaller N fertilizer applications throughout the growing season on a sandy soil resulted in lower NO_3^- concentrations in a shallow aquifer than a single spring application. Bjorneberg et al. (1998) concluded that combining no-tillage practices with a split N fertilizer management strategy based on the pre-side dressed soil NO_3^- test can have positive environmental benefits without reducing corn grain yield when corn was rotated with soybean. Randall et al. (1997) reported that in a ridge tillage system, a split application consisting of 34 to 45 kg ha^{-1} of N applied preemergence as a band and a sidedress application of 67 to 79 kg N ha^{-1} as either anhydrous NH_3 or UAN at the V7 and V16 corn growth stages did not produce greater yields, N uptake, or profit than the single preemergence applications of injected N. They also found that whether 30, 40, or 50% of the total N was applied at pre-plant, N losses through volatilization, leaching, or denitrification could still be reduced (Randall et al., 1997). A Split application of N does have its shortcomings (Randall et al., 1997). Applying some of the N after planting can be problematic because it requires an extra field operation which will raise yearly expenses in labor and fuel. Timeliness of the split application could be an issue if rain prevents machinery from entering the field. Any N that is applied that is retained by the corn leaves could injure the plant. The grower should have resources available to band or dribble the N source on or in the soil to protect the plant from the N being applied. Nitrogen (N) applied on the soil surface with a split application is still susceptible to volatilization and denitrification if the weather is favorable for those reactions to occur.

MATERIALS AND METHODS

Field studies were conducted in 2012 and 2013 to determine the effect of N fertilizer treatments, tillage systems, and drainage systems on corn grain yield and N efficiency. Experiments were located at four locations: Fargo (46°55'55.63"N and 96°51'32.08"W), Hitterdal (47°0'26.44"N and 96°24'6.73"W), Prosper (47°0'11.59"N and 97°6'29.63"W), and Langdon (48°45'17.36"N and 98°19'31.93"W) in 2012 and five locations: Fargo, Hitterdal, Casselton (46°52'42.83"N and 97°15'4.38"W), Barnesville (46°31'28.65"N and 96°30'35.30"W), and Langdon in 2013. The soil type at Langdon was a Cresbard (Fine smetitic, frigid Glossic Natrudolls); at Casselton and Prosper a Kindred-Bearden clay loam (Fine-silty, mixed, superactive, frigid Typic Endoaquolls); at Fargo a Fargo-Ryan silty clay (Fine, smectitic, frigid Typic Epiaquerts); at Barnesville a Hamerly clay loam (Fine-loamy, mixed, superactive, frigid Aeric calciaqoulls); and at Hitterdal a Hamerly loam (Fine-loamy, mixed superactive, frigid Aeric calciaqoulls).

Experiments at all locations were replicated four times. Experiments in all but the Langdon and Fargo locations consisted of three factors: tillage, N rate, and N management practices. These experiments were laid out in a randomized complete block design (RCBD) with a split-plot arrangement with tillage as the main plot and a factorial combination of N fertilizer rates and N management practices as the subplots. Included with these treatments was a non-N fertilizer check treatment at all locations except Fargo. The two tillage treatments were conventional and raise beds. The five N management practices were: urea alone, urea plus nitrapyrin, urea and PCU (70:30 ratio), urea and UAN (split application), and urea and UAN plus DCD+NBPT (split application). The three N fertilizer rates were 135, 180, and 225 kg ha^{-1} (low, medium, and high) in 2012 and 45, 90, and 135 kg ha^{-1} in 2013. Nitrogen (N) fertilizer treatments are described below in Table 1. The rate of DCD+NBPT applied with the UAN was 7.5 g kg^{-1} (labeled rate). The rate of nitrapyrin applied with urea was the labeled rate of 2.6 L ha^{-1}. Nitrapyrin was sprayed on the soil surface after the urea was broadcasted and before it was incorporated in the soil. The UAN and UAN + (DCD+NBPT) treatments were applied on the soil surface (no incorporation) 10 to 15 cm away from the corn plant at the V6 stage (Abendroth et al., 2011). In the conventional tillage treatments, in the urea containing treatments urea was broadcasted by hand and incorporated with a three m wide cultivator before planting. In the raised bed treatments, in the urea containing treatments urea was broadcasted by hand and incorporated with a two row HR6 Hipper Roller (Pitonyak Machinery Corporation, Carlisle, AR) spaced at 76 cm with a 41 cm diameter drum to flatten the tops of the raised beds.

The Fargo experiment layout was an RCBD with a split-split plot arrangement with drainage as the main plot, tillage as the subplot, and a factorial combination of three N fertilizer rates and five N fertilizer management practices as the sub-subplots. The drainage treatments were subsurface (tile) drainage and no subsurface drainage (no-tile). The Fargo location contains eight units that have tile line inserted 1 meter deep, 7.6 meters apart. The tile lines on four units were closed using a control box soon after they were first inserted to simulate an un-tiled soil. The other four units have been open and closed to manage the water table which simulated a tiled-drained soil. Tillage and N fertilizer treatments were as described above minus the non-N fertilizer check treatment.

The Langdon location experiment layout was an RCBD with only the factorial combination of three N fertilizer rates and five N fertilizer management practices described above and summarized in Table 1 below. The tillage treatments were not included at this location. Nitrogen (N) fertilizer rates at Langdon were 67, 112, and 157 kg ha^{-1} in 2012, with a zero N rate treatment (check/control) included. The lower N rates were used due to the shorter growing season, and lower yield potential at this site requiring less N. At Langdon, Pioneer 39D97, a 79 day relative maturity hybrid was planted using a four row John Deere (model 71) planter (John Deere, Moline IL), with rows spaced 76 cm apart. At all of the other locations, Pioneer 8640, an 86 day relative maturity hybrid was planted, using a two row John Deere (model 7100) planter (John Deere, Moline IL), with rows spaced 76 cm apart. Both hybrids were glyphosate resistant.

Table 1. List of N fertilizer treatments at Prosper 2012, Hitterdal 2012, Barnesville 2013, Casselton 2013, Hitterdal 2013, and Langdon 2013.

N source	2012 N rate	2013 N rate	Additive
	----------kg ha^{-1} of N----------		
Urea†	135	45	
Urea	180	90	
Urea	225	135	
Urea	135	45	Nitrapyrin‡
Urea	180	90	Nitrapyrin
Urea	225	135	Nitrapyrin
Urea + PCU¶	94 + 41	31.5 + 13.5	
Urea + PCU	126 + 54	63 + 27	
Urea + PCU	157 + 68	94.5 + 40.5	
Urea and UAN††	67.5 + 67.5	22.5 + 22.5	
Urea and UAN	90 + 90	45 +45	
Urea and UAN	112.5 + 112.5	67.5 + 67.5	
Urea and UAN	67.5 + 67.5	22.5 + 22.5	DCD + NBPT‡‡
Urea and UAN	90 + 90	45 +45	DCD + NBPT
Urea and UAN	112.5 + 112.5	67.5 + 67.5	DCD +NBPT
None	none	none	none

† Urea and PCU was broadcasted and incorporated pre-plant
‡ Nitrapyrin: Trade Name Instinct applied as a surface spray at the labeled rate of 2.6 l ha^{-1}
¶ PCU (Polymer Coated Urea): Trade Name ESN (Environmentally Smart Urea)
†† UAN was all side dressed on the soil surface at the V6 stage
‡‡ DCD+NBPT (Dicyandiamide + N-(n-butyl) thiophosphoric triamide): Trade Name Agrotain Plus applied at the labeled rate of 7.5 g kg^{-1} of N.

The three N rates were lowered to 45, 90, and 135 kg ha^{-1} at all locations in 2013, with a zero N rate treatment (check/control) included. The N rates were lowered because the fall soil test results, soybean N credits, and corn N requirements to reach the yield goal at each location indicated that only 135 kg ha^{-1} of N would be needed to provide adequate fertility (Table 3). That led to 135 kg ha^{-1} being the highest N rate. The other two rates were set to be lower so a response curve to additional N fertilizer could be developed. The previous crop at all locations besides Langdon was soybeans. At Langdon, the previous crop was hard red spring wheat both years.

Soil tests were taken in the fall before the experiments were planted to determine soil organic matter, pH, EC, Zn, N, P, and K levels. Phosphorus, Zn, and K were broadcasted and incorporated 10 cm into the soil at each site if soil test levels were considered low. Raised beds were made in the fall and re-formed in the spring to incorporate the fertilizer since we had no way to band the fertilizer in the raised beds. With the appropriate equipment, banding N in the raised bed tillage system could be possible if the producer thought reforming the bed in the spring was unnecessary. The seeding rate was 86500 seeds ha^{-1} at all locations. The all the corn seed was planted had 95% germination so the pure live seed seeding rate was 82175 seeds ha^{-1}. Plots consisted of four rows spaced at 76 cm, 7.6 m in length, giving a plot area of 22.8 m^2. Alleys 1.8 m wide were cut between ranges using a mower at every location so the effective plot length at harvest was 5.8 m. The middle two rows of each plot were harvested. Glyphosate, tank mixed with a broadleaf herbicide was applied twice at recommended rates when needed during the growing season to kill all the weeds present at the time of application. Ammonium sulfate or non-ionic surfactant were also in the herbicide tank mix to increase weed control depending on the herbicides used. The first herbicide application consisted of: glyphosate at 1.54 L ha^{-1}

(Monsanto, St. Louis, MO) + Status (dicamba and diflufenzopyr and isoxadifen safener) (BASF, Research Triangle Park, NC) at 13.14 g of ai ha^{-1} + NIS at 0.25% v/v at the three collar leaf stage (V3) (Abendroth et al., 2011). The second herbicide application consisted of glyphosate (1.54 L ha^{-1}) + luadis (atrazine tembotrione and isoxadifen safener) (Bayer, Research Triangle Park, NC) at 96 ml of ai ha^{-1} + AMS at 3.86 kg per 378.5 L at the seven collar leaf stage (V7) (Abendroth et al., 2011).

Table 2. Application dates for all environments.

Trial Appl. Dates	Fargo 2012	Pros 2012†	Hitt 2012	Lang 2012	Fargo 2013	Cass 2013	Hitt 2013	Barnes 2013	Lang 2013
Fertilizer applied	4/25	4/26	4/30	5/10	5/15	5/10	5/08	5/09	5/16
Fertilizer incorporated	4/27	4/26	4/30	5/10	5/15	5/10	5/08	5/09	5/16
Instinct applied	4/27	4/26	4/30	5/10	5/15	5/10	5/08	5/09	5/16
Instinct incorporated	4/27	4/26	4/30	5/10	5/15	5/10	5/08	5/09	5/16
Date planted	4/30	4/30	4/30	5/11	5/15	5/13	5/13	5/13	5/16
First herbicide	5/24	5/31	5/14	6/01	6/12	6/07	6/13	6/07	6/19
Second herbicide	7/02	6/27	6/25	7/10	6/30	6/30	6/30	6/30	
First N soil test	6/11	6/06	6/08	6/22	6/25	7/01	6/25	6/24	7/02
Split applications	6/11	6/06	6/08	6/22	6/28	7/01	6/25	6/24	7/02
Second N soil test	8/01	7/30	7/30	8/15	8/13	8/13	8/12	8/12	
Greenseeker reading	7/11	7/03	7/03	7/27	7/09	7/09	7/08	7/08	
Harvest date	10/9	10/5	10/3	10/21	10/22	10/28	10/25	10/25	

† Pros = Prosper, Hitt = Hitterdal, Lang = Langdon, Cass = Casselton, Barnes = Barnesville.

Soil tests in 2012 and 2013 were taken for NO_3^- and NH_4^+ levels at the 0-31 cm depth on the five high N rate treatments and check (no N applied) at the six collar leaf stage (V6) (35 to 45 days after planting) and milk stage (R3) (85 to 95 days after planting) (Abendroth et al., 2011). Three soil cores $plot^{-1}$, 2 cm in diameter, were obtained and mixed together as one sample to be analyzed in 2012. In 2013, five soil cores $plot^{-1}$, 2 cm in diameter, were obtained and mixed together as one sample to be analyzed. More samples per plot were taken in 2013 in order to get more precise results. Nitrate and NH_4^+ levels were analyzed by the North Dakota State University Soil Testing Lab (Fargo, ND) in 2012 and Agvise laboratories in 2013. Soil samples taken at the V6 stage in 2012 and 2013 were placed into cold temperatures (~4.4°C) for four to six weeks before they were analyzed for NO_3^- and NH_4^+ levels. Soil samples taken at the R3 stage in 2012 and 2013 were analyzed for NO_3^- and NH_4^+ within a week after sampling.

Table 3. Nitrate fall soil test results for each location.

Location	----------------------------soil depth (cm)---------------------------		
	0-15	15-61	0-61
Fargo 2012	15	20	35
Hitterdal 2012	33	61	94
Prosper 2012	39	47	86
Langdon 2012	28	79	107
Fargo 2013	28	29	57
Casselton 2013	27	13	40
Hitterdal 2013	8	74	82
Barnesville 2013	25	74	99
Langdon 2013	24	47	71

Stand counts (plant population) were taken on the two harvest rows at the V4 to V6 stage (Abendroth et al., 2011). Plants were counted in a 5.3 m length of each harvest row. The stand counts for each row were averaged together and converted to plants ha^{-1}. Plant greenness (normalized difference vegetative index “NDVI”) was measured on one of the two harvest rows the entire length of the plot on each plot using the Greenseeker Model 505 optical Sensor unit (Ntech industries, INC Ukiah, CA). NDVI values were measured at V8 stage (Abendroth et al., 2011) in 2012 and 2013. Corn heights were measured after plants ceased elongation. The height of the corn plant was measured from the ground up to the first collar leaf below the tassel. Plot lengths and number of harvestable ears in each harvested row in every plot was obtained just before corn harvest. The corn was harvested using a Wintersteiger Classic plot combine (Wintersteiger Ag, Ried, Austria) with a two row Geringhoff corn header (Geringhoff, Minot, ND). Yield, percent moisture, and test weight for each plot was recorded using the Harvest Master (Juniper Systems, Logan, UT) on the combine. Yield weights were converted from kg $plot^{-1}$ to kg ha^{-1} and expressed at 15.5% grain moisture.

A grain sub-sample from each plot was taken from the field to measure protein percentage and thousand kernel weight in the lab. Grain protein was measured using a 0.5 kg sub-sample of seed from each plot using a Diode Array 7200 NIR analyzer (Perten Instruments, Springfield, IL). To obtain the thousand kernel weight of each sample, five hundred seeds were counted with a seed counter (Model 850-3, International Marketing and Design Corp., San Antonio, TX). The weight of the five hundred seeds was measured using a RS-232 Scientech scale, and these weights were multiplied by two and expressed at 15.5% moisture.

Data were subject to an ANOVA using Proc Mixed in SAS (2013 SAS Institute, Cary, NC). Means for drainage treatments, tillage treatments, N fertilizer rates, and N management practices were separated using a protected least significance difference (LSD) at the 0.10 level of confidence. Drainage, tillage, N fertilizer rates, and N management practices were considered fixed effects. Replicates, and environments (years and locations) were considered random effects. The no N fertilizer check was not used in any analysis, because the N treatments were analyzed as a factorial arrangement of N fertilizer management practices and N rates. This allowed us to see whether the N rates, N fertilizer management practice, or their interaction is causing the significant differences in N treatments. The no N fertilizer mean was calculated separately, to show the yield response from adding N fertilizer.

Locations and years were identified as environments in the combined statistical analysis when analyzing the data for significant tillage, N rate, and N management practice main effects and interactions within those three factors. The Langdon 2012 and 2013 locations were not used in any combined analysis because the experiment did not include the tillage factor. The Langdon data was analyzed and reported separately. In the combined analysis for the tillage and nitrogen treatments, the Fargo 2012 and 2013 locations were considered as four separate environments; Fargo-tiled 2012, Fargo-untiled 2012, Fargo-tiled 2013, and Fargo-untiled 2013.

The SAS calculated means for the three N rates and the arithmetic calculated check (no N applied) treatment were graphed using the regression analysis on excel. The R-value was calculated using a polynomial trendline. The polynomial trendline was used because it was a better fit than a linear trendline.

RESULTS AND DISCUSSION

Precipitation timing and amount during the growing season can significantly impact N loss, the plant's ability to uptake and utilize N and produce corn grain yield.

Table 4. Monthly precipitation during the 2012 growing season at four locations in ND and MN.

Month	Langdon†		Prosper†		Fargo†		Hitterdal†	
	2012	Normal‡	2012	Normal	2012	Normal	2012	Normal
	------------------------------------- mm -------------------------------							
April	18	26	30	37	29	35	15	36
May	37	68	46	78	43	71	38	82
June	109	99	67	100	57	99	56	114
July	87	82	16	88	30	71	16	93
August	42	65	23	67	21	65	36	70
September	2	46	15	66	1	65	3	67
October	80	38	45	62	62	55	50	57
Total	375	424	242	498	243	461	214	519

†Weather data from the closest NDAWN weather station: Langdon=Langdon, Prosper=Prosper, Fargo=Fargo, and Hitterdal=Perley.
‡Normal = the average monthly precipitation at each location from 1990 to 2011.

For the 2012 season as a whole, significantly less precipitation than normal occurred at all locations (Table 4). The Prosper, Fargo, and Hitterdal locations had less than normal rainfall in June, July, and August, respectively. This caused visible drought stress symptoms to occur, especially later in the season at all locations except Langdon. The Langdon location received normal June and July rainfall, and therefore did not show any drought symptoms. During the growing season, no prolonged waterlogging occurred in any location except Langdon in June and July.

The 2013 growing season had very sporadic precipitation. In the early spring the soils were saturated/waterlogged repeatedly at all locations in the months of May and June (Table 5). On the 29th of May a heavy precipitation event caused standing water to occur in parts of the experimental area at the Casselton, Fargo, and Hitterdal locations. Corn was planted on the 13th of May at Casselton, Barnesville, and Hitterdal; and on the 15th of May in Fargo. Therefore, the heavy late May and June rains stressed the small corn plants and presented ideal conditions for N loss through denitrification, and leaching. The wet conditions in May and June were followed by dry conditions in July and August (Table 5). Drought symptoms were evident at the Casselton and Fargo locations, which resulted in lower grain yield than the Hitterdal and Barnesville locations.

Table 5. Monthly precipitation during the 2013 growing season and monthly normal precipitation at all four locations.

Month	Barnesville		Casselton		Fargo		Hitterdal	
	2013	Normal	2013	Normal	2013	Normal	2013	Normal
	------------------------------------ mm ----------------------------							
April	47	40	3	37	43	35	6	36
May	69	80	105	78	141	71	86	82
June	195	105	193	100	199	99	109	114
July	38	82	20	88	26	71	26	93
August	36	68	51	67	12	65	15	70
September	135	75	93	66	106	65	90	67
October	107	66	84	62	112	55	89	57
Total	627	516	549	498	639	461	421	519

†Weather data from the closest NDAWN weather station: Barnesville=Sabin, Casselton=Prosper.
‡Normal = the average monthly precipitation at each location from 1990 to 2012.

Corn response

Subsurface drainage results

Since the two growing seasons were very different at the Fargo location, data from each season will be discussed separately. When analyzed separately, all four replicates were used in 2013 and two replicates in 2012. Two of the replicates at Fargo in 2012 were not harvested because of the poor stand establishment, and no other data was recorded on these two replicates. Corn grain yield did not differ significantly between the two drainage treatments in 2012 and 2013 (Table 5). In 2012, no main effects and interactions were significant except for drainage (D) x tillage (T) interaction (Table 6). This experiment was designed to test the effect of saturated/waterlogging conditions which didn't occur in 2012. Therefore, the lack of difference between treatments in 2012 was not surprising. Under tile drainage the conventional tillage system had greater yield then with raised bed tillage (Table 7). While without tiled drainage there was no significant difference between the two tillage systems. In 2013, no main effects and interactions for drainage were significant. In 2013 even though there was no significant D x T interaction for corn grain yield (Table 6); under tiled drainage, conventional tillage grain yield was 608 kg ha^{-1} more than raised bed tillage. In 2013, however, the yields on raised beds was 7474 kg ha^{-1} and compared to 7395 kg ha^{-1} under no tile drainage.

Table 6. ANOVA for corn grain yield in 2012, and 2013 at Fargo.

SOV		2012	2013
	df	Probability	Probability
Drainage (D)	1	0.93	0.77
D x N fertilizer management practices (M)	4	0.50	0.28
D x N fertilizer rates (R)	2	0.72	0.44
D x M x R	8	0.86	0.97
D x T	1	0.04	0.36
D x T x M	4	0.27	0.37
D x T x R	2	0.25	0.91
D x T x M x R	8	0.11	0.44

Table 7. Effect of the D x T interaction on corn grain yield averaged across N fertilizer management practices and N rates at the Fargo location in 2012.

Drainage	Tillage	2012	2013
		----------------kg ha^{-1}	----------------
Tiled	Raised beds	6295	7362
Tiled	Conventional	6719	7970
Untiled	Raised beds	6742	7474
Untiled	Conventional	6442	7395
	LSD ($P \leq 0.1$)†	302	ns

†LSD ($P \leq 0.1$) is a Fisher's Protected LSD

Tillage results

Locations and years were identified as environments in the combined statistical analysis. The locations/years used in the analysis for yield were: Hitterdal 2012, Hitterdal 2013, Prosper

2012, Casselton 2013, Barnesville 2013, Fargo 2012, and Fargo 2013. The Langdon 2012 and 2013 locations were not used in this analysis because the experiment did not include the tillage factor. In the combined analysis for tillage and N treatments, the Fargo 2012 and 2013 locations were considered as four separate environments; the tiled soil was considered one environment and the untiled soil was considered as another environment.

Table 8. ANOVA for corn grain yield averaged over all environments 2012, 2013, and 2012 and 2013.

SOV	2012†		2013‡		2012 and 2013¶	
	df	Probability	df	Probability	df	Probability
Tillage (T)	1	0.25	1	0.23	1	0.07
Management Practices (M)	4	0.46	4	0.03	4	0.78
Fertilizer Rate (R)	2	0.98	2	0.00	2	0.01
T x M	4	0.69	4	0.47	4	0.64
T x R	2	0.55	2	0.20	2	0.20
M x R	8	0.85	8	0.40	8	0.48
T x M x R	8	0.86	8	0.83	8	0.83
Environment (E)	3	0.00	4	0.00	8	0.00
E x T	3	0.41	4	0.15	8	0.24
E x M	12	0.31	16	0.28	32	0.05
E x R	6	0.32	8	0.44	16	0.03
E x M x R	24	0.27	32	0.62	64	0.34
E x T x M	12	0.38	16	0.81	32	0.61
E x T x R	6	0.51	8	0.95	16	0.87
E x T x M x R	24	0.76	32	0.11	64	0.50

†Environments in the 2012 analysis: Fargo-tiled, Fargo-untiled, Hitterdal, and Prosper.
‡Environments in the 2013 analysis: Fargo-tiled, Fargo-untiled, Barnesville, Casselton, and Hitterdal.
¶Environments in the 2012 and 2013 analysis: Fargo-tiled, Fargo-untiled, Hitterdal, Prosper, Fargo-tiled, Fargo-untiled, Barnesville, Casselton, and Hitterdal.

When combined across all environments (locations and years) tillage significantly impacted corn grain yield (Table 8). Conventional tillage had 358 kg ha^{-1} more grain yield than the raised bed tillage system (Table 12). This difference in yield was probably due to the significant difference in the corn stand between tillage systems (Table 9). Conventional tillage had 4392 more plants ha^{-1} than the raised bed tillage system (Table 12). When running co-variance, considering yield equals plant stand for both tillage systems was 79040 plants ha^{-1}, grain yield was not significantly different, and conventional tillage had 125 kg ha^{-1} more grain yield than the raised bed tillage system.

Variability in planting depth on the raised beds probably caused the significant difference in corn stand and yield between the two tillage systems because, getting a uniform planting depth on the raised beds was difficult, due to the planter sliding to the side of the ridge from time to time and not planting the seed on the top of the ridge.

Table 9. ANOVA for corn stand averaged over all environments in 2012, 2013, and 2012 and 2013 combined.

SOV	2012†		2013‡		2012 and 2013¶	
	df	Probability	df	Probability	df	Probability
Tillage (T)	1	0.20	1	0.22	1	0.05
Management Practices (M)	4	0.02	4	0.76	4	0.03
Fertilizer Rate (R)	2	0.18	2	0.59	2	0.58
T x M	4	0.21	4	0.88	4	0.27
T x R	2	0.20	2	0.58	2	0.13
M x R	8	0.02	8	0.98	8	0.31
T x M x R	8	0.27	8	0.62	8	0.48
Environment (E)	3	0.19	4	0.09	8	0.00
E x T	3	0.01	4	0.02	8	0.00
E x M	12	0.15	16	0.54	32	0.08
E x R	6	0.46	8	0.61	16	0.40
E x M x R	24	0.54	32	0.38	64	0.37
E x T x M	12	0.07	16	0.16	32	0.03
E x T x R	6	0.15	8	0.37	16	0.17
E x T x M x R	24	0.92	32	0.48	64	0.82

† Environments in the 2012 analysis: Fargo-tiled, Fargo-untiled, Hitterdal, and Prosper.
‡ Environments in the 2013 analysis: Fargo-tiled, Fargo-untiled, Barnesville, Casselton, and Hitterdal.
¶ Environments in the 2012 and 2013 analysis: Fargo-tiled, Fargo-untiled, Hitterdal, Prosper, Fargo-tiled, Fargo-untiled, Barnesville, Casselton, and Hitterdal.

The significance of the various factors included in this experiment varied across environments (locations and years) (Table 8 and 9). The environment by tillage interaction for corn stand was significant for both the combined and single year analysis (Table 9). Tillage systems differed significantly for corn stands at the Fargo-tiled 2012, Hitterdal 2012, Prosper 2012, and Casselton 2013 locations (Table 11 and 12). Only the Hitterdal 2012 location resulted in a significantly greater corn stand on raised beds than the conventional tillage system (Table 12). Tillage systems did not differ significantly for yield at the Hitterdal 2012, Prosper 2012 and Fargo-tiled 2012 locations (Table 10 and 12).

Table 10. ANOVA for corn grain yield for all locations in 2012 (Fargo-untiled, Fargo-tiled, Hitterdal “Hitt”, and Prosper), and all location in 2013 (Barnesville “Barnes”, Casselton “Cass”, Fargo-untiled, Fargo-tiled, and Hitterdal).

SOV	Fargo-untiled	Fargo-tiled	Hitt	Prosper	Fargo-untiled	Fargo-tiled	Hitt	Barnes	Cass
	------------2012----------				----------------2013--------------				
	----------------------------------Probability---------------------------								
Tillage (T)	0.02	0.21	0.39	0.22	0.90	0.19	0.56	0.11	0.09
Management (M)	0.16	0.15	0.11	0.04	0.02	0.60	0.83	0.00	0.01
Rates (R)	0.76	0.92	0.21	0.15	0.00	0.00	0.01	0.00	0.00
T x M	0.99	0.10	0.59	0.29	0.34	0.38	0.92	0.20	0.46
T x R	0.62	0.39	0.41	0.34	0.82	1.00	0.34	0.67	0.59
M x R	0.73	0.79	0.19	0.31	0.59	0.73	0.30	0.47	0.04
T x M x R	0.80	0.03	0.65	0.92	0.88	0.60	0.14	0.15	0.22

Table 11. ANOVA for corn stand for all locations in 2012 (Fargo-untiled, Fargo-tiled, Hitterdal, and Prosper), and all location in 2013 (Barnesville "Barnes", Casselton “Cass”, Fargo-untiled, Fargo-tiled, and Hitterdal).

SOV	Fargo-untiled	Fargo-tiled	Hitterdal (Hitt)	Prosper	Fargo-untiled	Fargo-tiled	Hitt	Barnes	Cass
	----------------2012----------------				---------------2013----------------				
	------------------------------Probability-----------------------------								
T	0.25	0.02	0.02	0.02	0.70	0.13	0.13	0.68	0.05
M	0.27	0.01	0.03	0.00	0.86	0.02	0.62	0.12	0.54
R	0.73	0.29	0.58	0.04	0.40	0.13	0.43	0.59	0.90
T x M	0.58	0.52	0.04	0.10	0.69	0.09	0.33	0.39	0.32
T x R	0.72	0.24	0.09	0.14	0.23	0.35	0.58	0.45	0.32
M x R	0.94	0.64	0.34	0.61	0.96	0.62	0.61	0.04	0.31
T x M x R	0.90	0.88	0.19	0.92	0.53	0.96	0.15	0.28	0.44

At the Prosper 2012 and Fargo-tiled 2012 locations, raised bed tillage had lower corn grain yield than conventional tillage by 8.5 and 6.3%, respectively (Table 12). At Casselton in 2013, raised bed tillage had significantly lower corn grain yield and stand than conventional tillage by 11.7 and 13.1%. When running co-variance, considering yield equals plant stand for both tillage systems was 79040 plants ha^{-1}, grain yield at Prosper and Casselton was not significantly different, and conventional tillage had lower grain yield than the raised bed tillage system by 1 and 1.5% (133 and 134 kg ha^{-1}), respectively. At Fargo-untiled in 2012, raised bed tillage had significantly higher corn grain yield than conventional tillage by 4.5% (300 kg ha^{-1}). Corn stand did not differ significantly between the two tillage systems at the Fargo-untiled environment in 2012.

Table 12. Effect of tillage systems on corn stand and grain yield averaged over all N fertilizer rates and management practices, and all environments in 2012, 2013, and 2012 and 2013 combined.

	Raised bed	Conventional	Probability	Raised bed	Conventional	Probability
	------Plants ha^{-1}------			------kg ha^{-1}------		
Fargo-untiled 12	58086	65743^{ns}	0.25	6742	6442*	0.02
Fargo-tiled 2012	58127	66731*	0.02	6295	6719^{ns}	0.21
Hitterdal 2012	72453	69469*	0.02	10182	10521^{ns}	0.39
Prosper 2012	51973	63603*	0.02	10785	11788^{ns}	0.22
Fargo-untiled 13	86862	85709^{ns}	0.70	7474	7396^{ns}	0.90
Fargo-tiled 2013	83342	86059^{ns}	0.13	7363	7970^{ns}	0.19
Hitterdal 2013	72536	76158^{ns}	0.13	11855	11666^{ns}	0.56
Barnesville 2013	81881	81407^{ns}	0.68	9181	9363^{ns}	0.11
Casselton 2013	71836	82704*	0.05	8023	9087*	0.09
2012	60194	66363^{ns}†	0.20	8494	8920^{ns}	0.25
2013	79291	82407^{ns}	0.22	8772	9091^{ns}	0.23
2012 and 2013	70873	75265*‡	0.05	8657	9015*	0.07

†ns = non-significant at P≤0.1.
‡* = significant at P≤0.1.

Four locations in 2013 showed no significant difference in corn stand between tillage systems (Table 11 and 12). Interestingly, at these locations, tillage systems did not significantly differ in corn grain yield. When stands are similar between tillage systems, similar corn grain yield were obtained. Though we hypothesized, that raised bed tillage could increase corn grain yield in untiled (no subsurface drainage) soil in some years, it appears that is not the case even when plant stands do not differ. Based on these data, the purchase of equipment to form raised beds and the conversion from conventional to raised beds does not seem beneficial to a grower that grows corn and is looking to increase yield, atleast within the environments sampled by this research.

Raised beds had significantly lower corn stands than conventional tillage at the Prosper 2012, Casselton 2013, and Fargo-tiled 2012 locations (Table 11). These soils have higher clay content then the Barnesville and Hitterdal locations. The lower stand was probably due to poor seed/soil/moisture contact which resulted in poor absorption of moisture by the seed. Furthermore, getting a uniform planting depth on the raised beds was difficult, due to the planter sliding to the side of the ridge from time to time and not planting the seed on the top of the ridge. This resulted in a shallower planting depth then desired. This problem could probably have been prevented by making a shorter and wider raised beds for the planter to plant on, or using a machine that digs a groove on the top of the ridge before planting. This will cause the raised bed to be wider and allow the planter to follow that groove and not slide off the raised beds. Shorter and wider raised beds were formed at the Fargo-untiled 2013, and Fargo-tiled 2013 locations. These locations had good emergence and no significant difference in corn stand (Table 12).

Nitrogen fertilizer management practices results

Nitrogen fertilizer management practices did not differ significantly for corn grain yield when combined over all environments (Table 8 and 14). Nitrogen fertilizer management practices, however, differed for corn stand in the combined analysis (Table 9 and 15).When combined across all environments, there was a significant E X M interaction for corn grain yield (Table 8). This means that N fertilizer management practices differed in their relative response between environments. Therefore, the N management practices will be discussed for each environment individually.

In 2012, there was no significant difference in corn grain yield for the N fertilizer management practices tested (Table 8 and 14), though plant stands differed (Table 9 and 15). Even though the corn yield was not significantly different between the N fertilizer management practices, the two N split applications had greater corn grain yield than the urea alone treatment by 6.3 and 6.7 % (562 and 602 kg ha^{-1}) (Table 14). The two N split application treatments also had significantly greater corn stand than the urea alone and urea plus nitrapyrin treatments (Table 15). The higher grain yield in these treatments was probably due to the higher plant populations.

Table 13. Amount of precipitation (mm) after the split application of N fertilizer treatments were applied.

Days after split application	Fargo 2012	Prosper 2012	Hitterdal 2012	Langdon 2012	Fargo 2013	Casselton 2013	Hitterdal 2013	Barnesville 2013
	----------------------------------mm--------------------------------							
1	0	0	0	0	0	0	11.2	0
2	0	18	0	0	0	0	27.7	38.6
3	0	0	18.8	0	0	0	0	18.8
4	22.1	0	0	0	0	0	0	0
5	0	13.2	0	0	0	0	0	0
6	1.3	0	0	0	0	3.6	0	0
7	0	0	7.9	0	0	0	0	0
8	0	0	0	0	0	0	0	0
9	7.6	9.4	1.5	0	5.8	2.5	0	0
10	20	0	0	0	0	0	0	0
11	0	0	0	0.3	0	0	0	0
12	0	0	1.3	0	2.3	0	2.5	0
13	0.5	0	7.4	39.1	0	0	0	4.6
14	0	3	0	0.3	0	0	0	0
15	0	22.9	0	12.2	0	1	3.3	0
16	0	0	0	0	0	0	0.3	13.5
17	0	0	0	0	0	6.4	0	0
18	0	0.8	0	0	4.6	0	0	0
19	0	0	0	0	0	3.6	0	0
20	0	0	0	0	0	0	0	0
21	0	0	0	20.1	0	0	0	0
Total	51.5	64.3	36.9	72	12.7	17.1	45	75.5

Table 14. Effect of N fertilizer management practices on corn grain yield averaged over all N fertilizer rates and tillage systems at all ten individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	MP1†	MP2‡	MP3¶	MP4††	MP5‡‡	Probability	LSD¶¶	Check†††
			----------------kg ha^{-1}----------------					
Fargo-untiled 12	6482	6637	6541	6175	7125	0.16		
Fargo-tiled 2012	6559	6102	6274	6539	7062	0.15		
Hitterdal 2012	9599	11046	10339	10681	10092	0.11		9237
Prosper 2012	10840	10871	11289	11854	11578	0.04	649 *	10755
Langdon 2012	8575	8759	8975	9101	9106	0.18		7639
Fargo-untiled 13	7916	7646	7411	7073	7129	0.02	477 *	
Fargo-tiled 2013	7930	7469	7609	7592	7732	0.60		
Hitterdal 2013	11692	11963	11704	11572	11872	0.83		9206
Barnesville 2013	9616	9404	9697	8822	8819	0.00	474 *	7392
Casselton 2013	8798	9205	8267	7880	8626	0.01	568 *	6090
2012	8325	8708	8688	8887	8927	0.46		
2013	9182	9107	8932	8591	8842	0.03	299 *	
2012 and 2013	8834	8942	8820	8705	8877	0.78		

† MP1=urea alone.
‡ MP2=urea plus nitrapyrin.
¶ MP3=urea plus PCU.
†† MP4=urea plus UAN.
‡‡ MP5=urea plus UAN with DCD plus NBPT.
¶¶LSD = LSD (P≤0.1) which is a Fisher's Protected LSD.
††† Check = was not included in the SAS analysis, it is just an calculated arithmetic mean averaged over two tillage systems and replicated four times in each tillage system.
‡‡‡*=significant at P≤0.1.
¶¶¶ ns=not significant at P≤0.1.

The N fertilizer management practices did not significantly affect plant stand and grain yield at Langdon in 2012 (Table 10, 12, 14, and 15). The two split application management practices had 526 and 531 kg ha^{-1} greater yield than the urea alone (Table 14). The split application treatments were applied on June 22nd. On July 4th Langdon received 39 mm of rainfall which should have been sufficient to incorporate the surface applied UAN (Table 13). No rainfall occurred from June 22nd to July 4th. In the months of June and July, Langdon received 109 and 87 mm of rainfall, respectively (NDAWN, 2013). Timely application of UAN and normal heavy June and July rainfalls probably caused the two split application treatments to have more grain yield then the urea alone treatment.

At the Prosper 2012 environment, grain yield was significantly impacted by N fertilizer management practices (Table 10 and 14). The two split application treatments yielded significantly more than the urea alone and urea plus nitrapyrin treatments, but did not differ significantly from the urea plus PCU treatment (Table 14). The urea alone, urea plus nitrapyrin, and urea plus PCU treatments did not significantly differ in yield. Corn stand differed significantly between management practices (Table 11). The highest yielding management practice had the highest plant stand and the lowest yielding management practice has the lowest plant stand (Table 14 and 15). The two split application treatments have significantly higher corn stands than the urea alone, urea plus nitrapyrin, and urea plus PCU treatments (Table 15). The split application treatments were applied on June 6th. On June 7th Prosper received 18 mm of rainfall which should have been sufficient to incorporate the surface applied UAN (Table 13). Given the low rainfall, low N loss potential, and high N soil tests at the six collar leaf and milk stage at the Prosper environment in 2012, it was most likely the high plant populations associated with the splits application treatments than N availability perse in this environment. Coulter, et al. (2011) reported that yield declined when corn stands were lower than 74100 plants ha^{-1}. Asim et al. (2013) reported that corn grain yield was not significantly different between 53000 and 67000 plants ha^{-1}. Plant populations of 53000 and 67000 plants ha^{-1} had significantly more grain yield then 43000 plants ha^{-1} by 12 and 13% when averaged over all nitrogen rates.

Corn yield was not significantly influenced by N fertilizer management practices at Hitterdal in 2012 (Table 10 and 14). The N fertilizer management practices did significantly affect plant stand at this location in 2012 (Table 11 and 15). In 2012, the urea plus nitrapyrin had greater yield than the urea alone and urea plus UAN with DCD plus NBPT treatments by 13 and 9% respectively (Table 14). The urea plus UAN treatment yielded higher than the urea alone treatment by 10%. The N fertilizer management practices plant stands in 2012 in order from highest to lowest were: urea plus UAN, urea plus PCU, urea plus nitrapyrin, urea plus UAN with DCD plus NBPT, and urea alone (Table 15). The split application treatments were applied on June 8th and on June 10th. Hitterdal received 19 mm of rainfall which should have been efficient to incorporate the surface applied UAN (Table 13). The low rainfall, low N loss potential, and high N soil tests at the six collar leaf and milk stage, contributed to the fact that no significant differences between management practices occurred at the Hitterdal environment in 2012.

Table 15. Effect of N fertilizer management practices on corn stand averaged over all N fertilizer rates and tillage systems at all ten individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	MP1†	MP2‡	MP3¶	MP4††	MP5‡‡	Probability	LSD¶¶
	------------------------plants ha^{-1}				-----------------------		- kg ha^{-1}-
Fargo-untiled 12	60206	59898	59176	62676	67616	0.27	
Fargo-tiled 2012	61133	53310	64941	66176	66586	0.01	6251 *
Hitterdal 2012	68388	71681	71836	72299	70601	0.03	2154 *
Prosper 2012	54700	55318	56553	61287	61081	0.00	3534 *
Langdon 2012	78217	78628	79040	79658	78731	0.90	
Fargo-untiled 13	85729	86450	87171	86554	85524	0.86	
Fargo-tiled 2013	86346	82950	85215	87532	81458	0.02	3232 *
Hitterdal 2013	74564	72712	74718	74204	75540	0.62	
Barnesville 2013	83568	80739	81562	81098	81253	0.12	
Casselton 2013	75488	77958	77393	76570	78936	0.54	
2012	61016	60392	63126	65625	66231	0.02	3412 *
2013	81140	80161	81211	81191	80542	0.76	
2012 and 2013	72312	71489	73221	74233	74090	0.03	1817 *

† MP1=urea alone.
‡ MP2=urea plus nitrapyrin.
¶ MP3=urea plus PCU.
†† MP4=urea plus UAN.
‡‡ MP5=urea plus UAN with DCD plus NBPT.
¶¶LSD = LSD (P≤0.1) which is a Fisher's Protected LSD.
†††*=significant at P≤0.1.
‡‡‡ns=not significant at P≤0.1.

This is one location in 2012 where nitrapyrin seemed to have been effective. The soils are coarser at Hitterdal than the other locations. In a study looking at the effect of nitrapyrin on N response of corn on sandy soils, Chancy and Kamprath (1981) found that 112 kg ha^{-1} of N as urea with nitrapyrin had significantly greater corn grain yield than 112 kg ha^{-1} of N as urea alone treatment in one of three environments. At the one environment where significant differences occurred, the 112 kg ha^{-1} of N treatment as urea with nitrapyrin and the 112 kg ha^{-1} of N treatment as urea alone yielded 6088 and 2974 kg ha^{-1}, respectively. In a study conducted on a clay loam soil, Randall and Vetsch (2005) reported that averaged over six years the spring prepalnt without nitrapyrin and spring pre-plant with nitrapyrin treatments yielded 10820 and 11030 kg ha^{-1}, respectively.

At the Fargo-untiled and Fargo-tiled environments in 2012, N fertilizer management practices did not significantly impact corn grain yield (Table 10 and 14). The urea plus UAN with DCD plus NBPT treatment had the highest corn grain yield in both environments (Table 14). The split application treatments where applied June 11th at the six collar leaf stage in corn and a rainfall event of 22 mm occurred on June 14th (Table 13). That rainfall should have been enough to incorporate the N into the soil with minimal N loss, as only 7.6 to 12.7 mm is required to facilitate this process. With less rainfall the NH_4^+ form of N is susceptible to losses through volatilization. The low rainfall, low N loss potential, and high N soil tests at the V6 and R3, were probably why there were no significant differences between N management practices at the Fargo environments in 2012. Plant stands differed significantly in the Fargo-tiled environments, which could also be contributing to the lack of significance in corn grain yield between the NFMP (Table 11 and 15). Plant stands did not differ significantly at the Fargo-untiled location, but there was still some variability between N fertilizer management practices for stand (Table 16).

When all environments were combined in 2013, N fertilizer management practices significantly impacted grain yield but not plant stand (Table 14 and 15). Grain yield did not differ significantly between the urea alone, urea plus nitrapyrin, and urea plus PCU treatments ($P \leq 0.1$) (Table 14). Urea alone applied before planting had significantly greater grain yield than the two split application treatments by 6% and 4%, respectively. The urea alone, urea plus nitrapyrin, and urea plus PCU treatments had significantly greater grain yield than the urea plus UAN treatment by 6%, 6%, and 4%, respectively. The urea plus nitrapyrin, urea plus PCU, and the urea plus UAN with DCD plus NBPT treatments were not significantly different from each other.

Nitrogen fertilizer management practices did not significantly differ for corn grain yield at the Fargo-tiled environment in 2013, but they differed at Fargo-untiled (Table 10 and 14). The N fertilizer management practices did significantly differ in corn stand at the Fargo-tiled environment in 2013, but there was no significant difference in corn stand at the Fargo-untiled environment (Table 11 and 15). When averaged over all tillage and rate treatments, the urea alone and urea plus nitrapyrin management practices had significantly greater yield than the two split application management practices (Table 14). The urea alone treatment had significantly greater yield than the urea plus PCU treatment. The urea alone did not have significantly greater yield than the urea plus nitrapyrin treatment, and the urea plus nitrapyrin did not significantly differ from urea plus PCU for grain yield.

Given the high precipitation events in the first month after planting, it was expected that the urea plus nitrapyrin and urea plus PCU should have yielded as much or better than the urea alone treatment since these treatments are intended to protect N from loss. It is not clear why these treatments did not perform up to expectation. The NH_4^+ and total N (NO_3+NH_4^+) soil test results at the six leaf stage did not show significance between the N fertilizer management practices (Table 21, 22, 23, and 24).

On May 15th, the pre-planting N fertilizer treatments were broadcasted and incorporated at Fargo in 2013. The trial was also planted on May 15th. Three, four, and five days after the N fertilizer was incorporated, rainfall events of 6.4, 17.5, and 15 mm occurred (NDAWN, 2013). The rainfall should have been sufficient to dissolve the urea and facilitate its reaction to NH_4^+ with minimal NH_3 loss. Ammonium is attracted to soil particles. It be speculated that if the urea was coated with nitrapyrin and then broadcasted, instead of just being sprayed on the soil surface after the urea had already been broadcasted, then the nitrapyrin might have worked better. In the case of PCU some of the granules were observed to still be on the soil surface after cultivation. Since PCU releases urea slowly, these granules would not have released their N after a single high rainfall event. Therefore, PCU sitting on the soil's surface might be susceptible to loss through volatilization once it releases. PCU banded into the soil might help all of the granules get incorporated into the soil and help minimize this problem.

In 2013, the two split application management practices were lower yielding than the urea alone treatment. The UAN was applied on June 28th on the soil's surface and precipitation did not occur tell July 6th (NDAWN, 2013). On July 6th the location received only 5.8 mm, probably not enough precipitation to incorporate the N into the soil. On July 9th and July 15th the Fargo location received another 2.3 and 4.6 mm, which again probably wasn't sufficient precipitation to incorporate the N in the soil (Table 13). Only after 21 days was there rainfall sufficient to ensure good incorporation. By that point it is probable that N loss through volatilization had occurred. There is also the issue of N not being moved into the zone of active root uptake, with dry top soil then N would have essentially been stranded. Therefore, the lower yield could have reasonably been associated with less available N in these treatments when compared to the urea alone treatment. Incorporating the UAN into the soil during side dressing at the V6 corn stage instead of dribbling it on the surface could lower the risk of N loss through volatilization. Palma et al. (2014) reported higher losses of NH_3 through volatilization occurred when the N fertilizer was surface applied when compared to being incorporated. Sanz-Cobena et al. (2012) reported that DCD and NBPT reduced surface applied N losses to N_2O by 24 and 43% in 2009 and 2010, respectively, when compared to the surface applied urea alone treatment. The DCD and NBPT treatment also reduced NO_3^- losses by 22.7%.

Plant emergence in 2013 at Langdon was really poor across the whole trial, due to imbibitional chilling injury (Kruger, 2013). The corn was fertilized and planted on May 16, 2013. After planting, Langdon received 95 mm of rainfall over the next five days (NDAWN, 2013). During planting, there was still snow along tree lines in the area. The soil was just getting dry and warm enough on the top to plant right before the 95 mm of rainfall. The minimum air temperature the next ten days after planting averaged 7.4°C (NDAWN, 2013).

Corn yield and stand was not significantly influenced by N fertilizer management practices at Hitterdal in 2013 (Table 10, 11, 14, and 15). The treatment with nitrapyrin had the highest yield in 2013 (Table 14).

At Barnesville in 2013, there were significant differences between N fertilizer management practices for grain yield, but not for plant stand (Table 10, 11, 14, and 15). The urea alone, urea plus nitrapyrin, and urea plus PCU did not differ and had significantly greater corn grain yield then the two split application treatments (Table 14). The two split application treatments did not significantly differ from each other. The split application treatments probably should have had better yield because there should have been enough precipitation at that location to incorporate the surface applied UAN into the soil before significant losses could occur. The UAN at the Barnesville location was applied on June 24th, and the location received 13 and 17 mm of precipitation according to the nearest NDAWN station, which is about 37 km away from the research trial, on June 25th and 26th (NDAWN, 2013 and Table 13). In July and August, this location only received 38 and 36 mm of rainfall, so there might not have been enough rainfall to move the N down to the corn root zone to be taken up by the plant (Table 5).

In a study looking at plant nutrient uptake under full and limited irrigation, Djamin et al. (2013) reported that N uptake increased with water supply. Total N uptake ranged from 154 kg ha^{-1} for rainfed to 253 kg ha^{-1} for the fully irrigated treatment (FIT) in 2009 and 182 kg ha^{-1} for rainfed to 270 kg ha^{-1} for FIT in 2010. Ferguson et al. (2002) stated that there is a close relationship between soil water status and plant nutrient availability, and it is generally believed that irrigation conditions improve fertilizer use efficiency where water supply is one of the dominant limiting factors to crop production. Marschner (1995), and Kumar and Dey (2011) also reported that water supply affects N uptake. This supports the fact that the lack of rainfall after the split application treatments at Barnesville could have caused less N uptake and resulted in lower yield than the other treatments.

At Casselton in 2013, N fertilizer management practices significantly differed for corn grain yield but not stand (Table 10, 11, 14, and 15). When averaged over both tillage systems and all three N rates, the urea alone, urea plus nitrapyrin, and urea plus UAN with DCD plus NBPT had significantly greater yield than the urea plus UAN management practice (Table 14). The urea plus nitrapyrin management practice had significantly greater yield then the urea plus PCU, urea plus UAN, and urea plus UAN with DCD plus NBPT management practice. The urea plus UAN with DCD plus NBPT had significantly greater yield the urea plus UAN management practice. The urea plus nitrapyrin, urea plus PCU, and urea plus UAN with DCD plus NBPT management practices are not significantly different from urea alone.

Generally the split application treatments had the highest yield at every location in 2012 except for Hitterdal, mainly due to better plant stands (Table 14 and 15). In 2013, the split application treatments (especially the UAN alone split) generally had the lowest yields due to the dry conditions in July and August.

Nitrogen fertilizer rate results

In the 2012 and 2013 combined analysis, N fertilizer rates significantly differed for corn grain yield, but not for plant stand (Table 8 and 9). The medium and high rates had significantly higher corn grain yield than the low rates by 4.5 and 6.4 % (400 and 583 kg ha^{-1}), respectively (Table 16). The medium and high rates did not differ significantly for corn grain yield (Table 16). The chance of significantly increasing corn grain yield by applying additional N above the medium N rate was minimal, suggesting that the N requirement was met at the medium rate and that any additional N would not be economical to the grower.

Based on these yield data, if a grower used the high N rate instead of the medium rate, 45 kg ha^{-1} more N fertilizer would be applied. If the N fertilizer price was \$1.28 kg^{-1}, the selling price for their corn to the elevator was \$0.2 kg^{-1}, the grower would obtain 183 kg ha^{-1} additional yield increase going from medium to high N rate (Table 16). They would be spending \$58 more ha^{-1} on N fertilizer while receiving \$37 more ha^{-1} from the increased yield. Therefore, the additional yield would not pay for the additional N applied, at this higher rate. Nitrogen fertilizer cost, corn grain price, and the expected yield increase or yield decrease should be considered when a grower determines the rate of N to apply.

Table 16. Effect of N fertilizer rates on corn grain yield averaged over all N fertilizer management practices and tillage systems at all ten individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Low†	Medium	High	Probability	LSD (P≤0.1)‡	Check¶
	----------kg ha^{-1}----------				------kg ha^{-1}------	
Fargo-untiled 12	6711	6553	6511	0.76		
Fargo-tiled 2012	6447	6508	6567	0.92		
Hitterdal 2012	9916	10543	10595	0.21		9237
Prosper 2012	11620	11051	11189	0.15		10755
Langdon 2012	8585	9120	9005	0.02	332 *	7639
Fargo-untiled 13	6916	7490	7898	0.00	369 *	
Fargo-tiled 2013	7103	7945	7952	0.00	383 *	
Hitterdal 2013	11239	12004	12039	0.01	470 *	9206
Barnesville 2013	8537	9541	9737	0.00	367 *	7392
Casselton 2013	8133	8349	9183	0.00	439 *	6090
2012	8678	8714	8729	0.98		
2013	8386	9060	9346	0.00	228 *	
2012 and 2013	8508	8908	9091	0.01	279 *	

†Nitrogen fertilizer rates (low, medium, high) at locations besides Langdon in 2012 were 135, 180, 225 kg ha^{-1} of N. Langdon 2012 N rates were 67, 112, and 157 kg ha^{-1} of N. Nitrogen fertilizer rates at all locations in 2013 were 45, 90, and 135 kg ha^{-1} of N.
‡ LSD (P≤0.1) is a Fisher's Protected LSD.
¶ Check = was not included in the SAS analysis, it is just a calculated arithmetic mean averaged over two tillage systems and replicated four times in each tillage system.
††*=significant at P≤0.1.
‡‡ns=not significant at P≤0.1.

In the 2012 combined analysis, rates did not significantly differ in grain yield or plant stand (Table 8 and 9). Furthermore, in none of the individual environments in 2012 did rates differ significantly for grain yield (Table 10 and 16). The lack of yield differences among N rates in 2012 was due to lower than normal precipitation resulting in low N loss, and good mineralization. The only environment that significantly differed in plant stand between N rates was Prosper in 2012 (Table 11 and 16), where the low rate had significantly higher corn stand than the medium and high rates (Table 17). The low rate had 569 and 431 kg ha^{-1} more grain yield than the medium and high rates, respectively (Table 16). However, in a study looking at the effect of irrigation, N fertilizer rate, and plant population, Bakelana (1981) and Asim et al.

(2013) concluded that the N fertilizer rate and plant population interaction did not significantly influence corn grain yield.

Table 17. Effect of N fertilizer rates on corn stand averaged over all N fertilizer management practices and tillage systems at all ten individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Low†	Medium	High	Probability	LSD (P≤0.1)‡
	----------------plants ha^{-1}----------------				--kg ha^{-1}--
Fargo-untiled 12	63294	61750	60700	0.73	
Fargo-tiled 2012	61627	65023	60639	0.29	
Hitterdal 2012	71477	70983	70427	0.58	
Prosper 2012	60268	56779	56316	0.04	2737 *
Langdon 2012	79164	77249	80152	0.05	1934 *
Fargo-untiled 13	85306	86912	86635	0.40	
Fargo-tiled 2013	85124	82992	85986	0.13	
Hitterdal 2013	73297	74997	74750	0.43	
Barnesville 2013	82157	81293	81480	0.59	
Casselton 2013	77649	76911	77249	0.90	
2012	64341	63397	62096	0.18	
2013	80707	80621	81221	0.59	
2012 and 2013	73389	72986	72830	0.58	

†Nitrogen fertilizer rates (low, medium, high) at locations besides Langdon in 2012 were 135, 180, 225 kg ha^{-1} of N. Langdon 2012 N rates were 67, 112, and 157 kg ha^{-1} of N. Nitrogen fertilizer rates at all locations in 2013 were 45, 90, and 135 kg ha^{-1} of N.
‡ LSD (P≤0.1) is a Fisher's Protected LSD.
¶*=significant at P≤0.1 †† ns=not significant at P≤0.1.

Due to low rainfall, low N loss, and the high N V6 and R3 corn stage soil tests results at Prosper in 2012, it probably would not have been economical to the grower to apply more than 135 kg ha^{-1} of N except at the Hitterdal environment. At Hitterdal, the medium rate had 627 kg ha^{-1} more grain yield than the low rate (Table 15). Based on a fertilizer cost of $1.28 kg^{-1}, corn grain price of $0.2 kg^{-1}, and the expected yield increase between the low and medium rate of 627 kg ha^{-1}, the grower would make $58 ha^{-1} more by applying the medium N rate.

The Langdon environment in 2012 was not in the 2012 combined analysis because it did not contain the tillage factor. At Langdon in 2012, N rates differed significantly for corn grain yield (Table 16 and Figure 1). The medium and high rates had significantly greater yield than the lower rate by 5.9 and 4.7% (535 and 420 kg ha^{-1}), respectively. Plant stand was significantly affected by N rates, but even at the lowest stand, the stand was high enough that yield was not impacted by the significantly different stands between rates (Table 17). Coulter, et al. (2011) reported that yield declined when corn stands were lower than 74100 plants ha^{-1}.

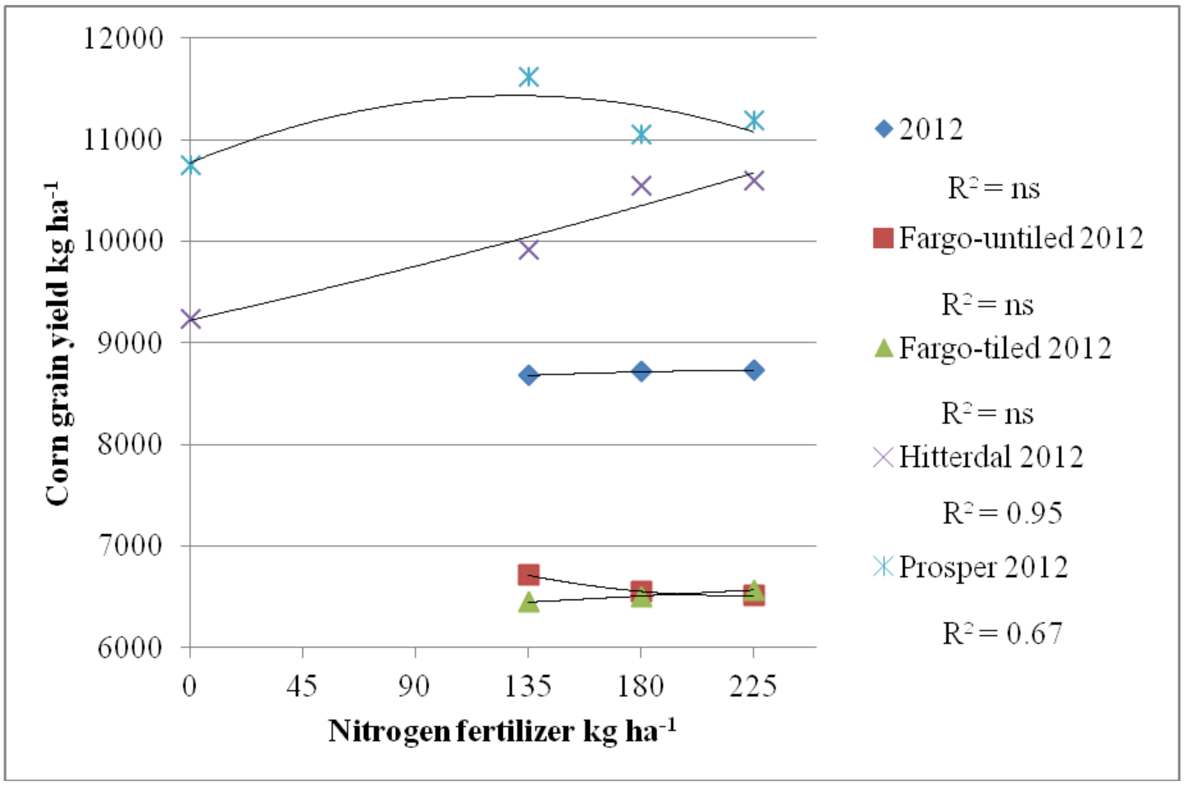

Figure 1. Effect of N fertilizer rates on corn grain yield averaged over all N fertilizer management practices and tillage systems at all four individual locations, all locations in 2012 combined not including Langdon 2012.

In the 2013 combined analysis, N rates did significantly impact grain yield but not corn stand (Table 8 and 9). In 2013, the high (135 kg ha^{-1}) N fertilizer rate yield was significantly greater than the low (45 kg ha^{-1}) and medium (90 kg ha^{-1}) N fertilizer rates by 10% and 3%, respectively (Table 16). The medium N fertilizer rate corn yield was significantly greater than the low N fertilizer rate by 7%. There was a significant polynomial relationship between grain yield and N rates (Figure 3).

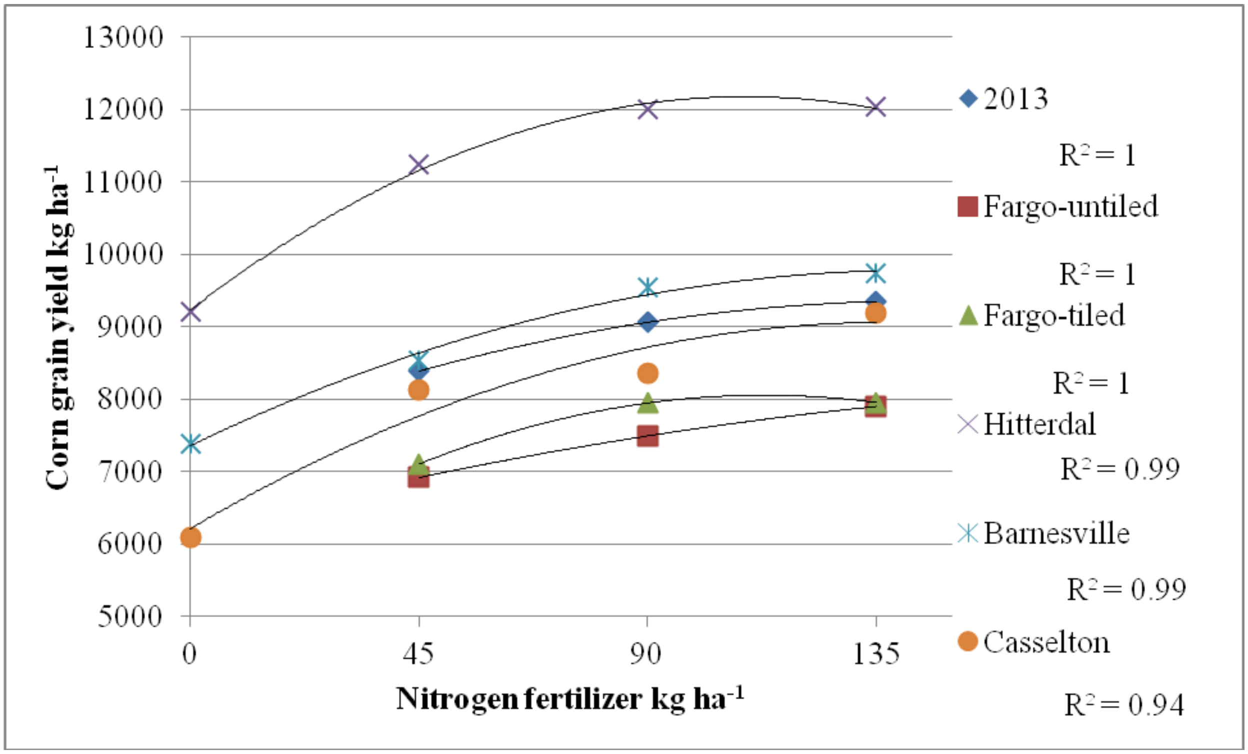

Figure 2. Effect of N fertilizer rates on corn grain yield averaged over all N fertilizer management practices and tillage systems at all five individual environments in 2013, and all five environments in 2013 combined.

If the N rates would have been increased above 135 kg ha^{-1} in 2013, the yield increase probably would have been smaller and smaller as more N was added, becoming uneconomical to the grower. If a grower was deciding on whether to apply 90 or 135 kg ha^{-1} of N to their corn crop, based on current fertilizer prices, market prices and expected yield gain (Table 16), going from 90 to 135 kg ha^{-1} of N, the grower would spend $58 more ha^{-1} on N fertilizer while receiving $57 more ha^{-1} from the increased yield. Therefore, it would not pay to increase the N fertilizer rate above 90 kg ha^{-1} in environments similar to those experienced in 2013. If the price of corn grain increased or the cost of N fertilizer decreased, only then it would pay to increase the N fertilizer rate above 90 kg ha^{-1}.

Looking at the economics of applying 45 versus 90 kg ha^{-1} of N, using current fertilizer and market prices, the most profitable rate would be the 90 kg ha^{-1} rate by $77 ha^{-1}.

In all five individual environments in 2013 there was a significant rate response for yield, but not for plant populations (Table 10 and 11). The medium and high rates had significantly greater corn grain yield than the low rate at the Fargo-tiled, Hitterdal, and Barnesville environments (Table 16 and Figure 2). The medium and high rates did not differ significantly in corn grain yield at these three environments. At the Fargo-untiled 2013 and Casselton environments, the medium and high rate had significantly greater corn grain yield than the low rate, and the high rate had significantly greater yield than the medium rate.

At the Fargo-untiled and Casselton environments in 2013, it probably would have been economical for a grower to apply 135 instead of 90 kg ha^{-1}. At the Fargo-tiled, Barnesville, and Hitterdal environments in 2013, it probably would have been more economical for a grower to apply the 90 kg ha^{-1} rate instead of 135 kg ha^{-1} rate.

At Casselton in 2013, there was a significant N fertilizer management practice (M) X N fertilizer rate (R) interaction for grain yield (Table 10). All of the management practices except the urea plus PCU and urea plus UAN management practices show an increase in yield as the N rates increase from the low N rate to medium N rate to the high N rate (Figure 3). For the urea plus PCU management practice, the highest yield is obtained with the low N rate and the lowest yield is obtained with the medium N rate. For the urea plus UAN management practice, the highest yield is obtained with the highest N rate and lowest yield is obtained with the medium rate. The urea plus PCU and urea plus UAN management practice is causing the M X R interaction.

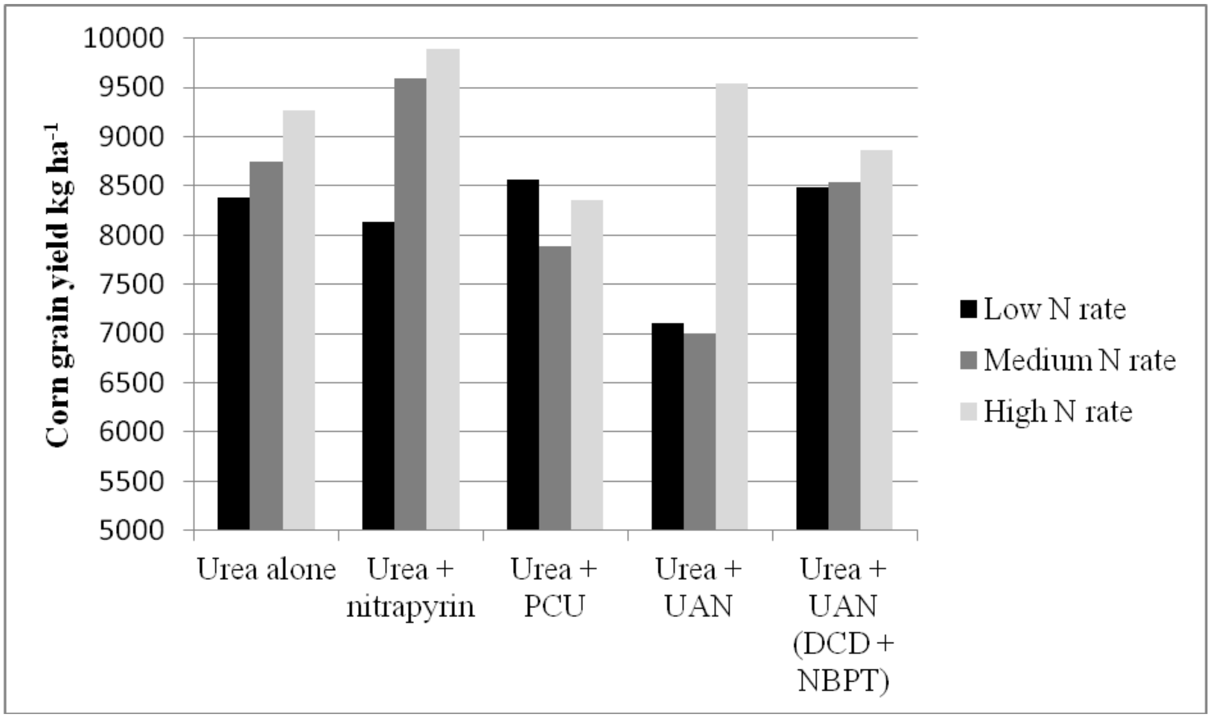

Figure 3. Effect of the M x R interaction on corn grain yield averaged over both tillage systems at Casselton in 2013.
†LSD (0.1): is used for comparing the three rates within a management practice, and for comparing across management practices within one rate.

Nitrogen in the soil

For the 2012 and 2013 combined analysis, there were significant differences in NH_4^+ and total N levels at the V6 and R3 stage for the environment (E) main effect; there were significant differences in NH_4^+ and total N between years or locations. In the 2012 combined analysis, there were significant differences in NH_4 and total N levels at the R3 stage for the environment (E) main effect. That meant that there were significant differences in NH_4 and total N levels across environments within a year at the R3 stage. In the 2013 combined analysis, there were significant differences in NH_4^+ and total N levels at the V6 stage for the environment (E) main effect.

Tillage system main effect and the E x T interaction did not significantly differ for NH_4^+ or total N sampled at the 0-31 cm depth at the V6 or R3 stage in corn for the 2012 combined, 2013 combined, and 2012 and 2013 combined analysis. Tillage systems did not cause significant differences in NH_4^+ or total N at the milk stage at any individual environment (Table 19).

Table 18. Tillage systems differences in NH_4^+, and total N soil test results taken at the 0-31 cm depth, at the V6 stage at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	NH_4^+			Total N		
	Beds†	Conv	Probability	Beds	Conv	Probability
	-----kg ha^{-1}------			-----kg ha^{-1}------		
Fargo-untiled 12	40.3^{ns}‡	57.1	0.37	115.2^{ns}	138.3	0.54
Fargo-tiled 2012	55.7^{ns}	34.8	0.30	121.5^{ns}	115.4	0.78
Hitterdal 2012	21.0^{ns}	20.6	0.89	245.4^{ns}	278.0	0.15
Prosper 2012	28.2*	36.6	0.08	188.7*	223.8	0.04
Fargo-untiled 13	14.0^{ns}	14.8	0.42	41.1^{ns}	35.7	0.47
Fargo-tiled 2013	14.1^{ns}	15.3	0.43	29.2^{ns}	35.1	0.17
Hitterdal 2013	5.0^{ns}	4.9	0.98	24.5*	33.1	0.10
Barnesville 2013	8.9^{ns}	8.5	0.51	51.7^{ns}	43.0	0.31
Casselton 2013	13.7^{ns}	12.2	0.25	46.8^{ns}	49.6	0.61
2012	35.5^{ns}	37.7	0.81	173.7^{ns}	201.1	0.12
2013	11.2^{ns}	11.2	0.87	40.9^{ns}	41.4	0.87
2012 and 2013	22.0^{ns}	23.0	0.78	99.9^{ns}	112.4	0.12

†Beds = raised bed tillage, Conv = conventional tillage.
‡ ns = not significant at $P \leq 0.1$. * = significant at $P \leq 0.1$.

Tillage system was only significantly different for NH_4^+ and total N at the V6 stage in corn at the Prosper environment in 2012 (Table 18). At Prosper in 2012, conventional tillage had significantly greater NH_4^+ levels at the 0-31 cm soil depth than the raised beds by 8.4 and 26.6 kg ha^{-1} (23 and 14%) (Table 22). Tillage systems did not result in significant differences in corn grain yield at Prosper in 2012 but corn grain yield was 1003 kg ha^{-1} more for conventional tillage than raised beds (Table 12). Higher corn stands and N levels at the V6 stage for conventional tillage could have resulted conventional tillage having greater grain yield than the raised beds.

Table 19. Tillage systems differences in NH_4^+, and total N soil test results taken at the 0-31 cm depth, at the R3 stage at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	NH_4^+			Total N		
	Beds†	Conv	Probability	Beds	Conv	Probability
	----kg ha^{-1}----			----kg ha^{-1}----		
Fargo-untiled 12	7.1^{ns}‡	2.3	0.36	66.3^{ns}	46.5	0.36
Fargo-tiled 2012	5.5^{ns}	9.5	0.64	48.3^{ns}	78.7	0.22
Hitterdal 2012	35.1^{ns}	34.3	0.82	149.4^{ns}	147.2	0.88
Prosper 2012	57.9^{ns}	61.6	0.56	123.4^{ns}	137.3	0.30
Fargo-untiled 13	13.3^{ns}	12.0	0.73	22.3^{ns}	20.3	0.76
Fargo-tiled 2013	12.9^{ns}	11.5	0.49	18.8^{ns}	18.0	0.60
Hitterdal 2013	7.3^{ns}	7.0	0.48	12.9^{ns}	15.7	0.19
Barnesville 2013	7.0^{ns}	7.1	0.83	20.6^{ns}	19.4	0.57
Casselton 2013	11.0^{ns}	10.3	0.22	20.0^{ns}	19.4	0.77
2012	26.3^{ns}	27.8	0.58	103.6^{ns}	110.9	0.55
2013	10.3^{ns}	10.3	0.13	19.5^{ns}	19.4	0.94
2012 and 2013	17.4^{ns}	17.7	0.77	56.9^{ns}	60.1	0.51

†Beds = raised bed tillage, Conv = conventional tillage.
‡ ns = not significant at P≤0.1. * = significant at P≤0.1.

The environment (E) X N fertilizer management practices (M) interaction was not significant for NH_4^+ or total N in the 2012, 2013, and 2012 and 2013 combined analysis. In the 2012 and 2013, and 2013 combined analysis, N fertilizer management practices main effect differed significantly in total N at the V6 stage (Table 20). The urea alone, urea plus nitrapyrin, and urea plus PCU had significantly more total N than the two split application treatments (Table 22). The UAN in the split application treatments was not applied until after the soil tests for NH_4^+, and total plant available N (NO_3 and NH_4^+) were taken at the V6 stage in corn. It should be expected that the urea alone, urea plus nitrapyrin, and urea plus PCU N fertilizer management practices would have significantly more total N than the two split applications, and no N fertilizer management practices at the V6 stage.

Table 20. Nitrogen fertilizer management practices probability for NH_4^+, and total N (NO_3 + NH_4^+) soil test results 0-31 cm deep at the V6 and R3 growth stage in corn at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Six collar leaf stage		Milk stage	
	NH_4^+	Total N	NH_4^+	Total N
Fargo-untiled 12	0.61	0.81	0.50	0.29
Fargo-tiled 2012	0.51	0.33	0.64	0.27
Hitterdal 2012	0.70	0.00	0.68	0.00
Prosper 2012	0.20	0.00	0.00	0.00
Langdon 2012	0.08	0.01	0.48	0.02
Fargo-untiled 13	0.92	0.16	0.73	0.86
Fargo-tiled 2013	0.43	0.00	0.4	0.0
Hitterdal 2013	0.05	0.00	0.75	0.03
Barnesville 2013	0.09	0.03	0.34	0.10
Casselton 2013	0.26	0.00	0.43	0.00
2012	0.27	0.18	0.45	0.98
2013	0.09	0.00	0.82	0.89
2012 and 2013	0.24	0.00	0.45	0.98

Table 21. Nitrogen fertilizer management practices differences in NH_4^+ soil test results taken at the 0-31 cm depth, at the V6 stage at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Urea alone	Urea + nitrapyrin	Urea + PCU	Urea + UAN	Urea + UAN (DCD+NBPT)	No N	LSD‡
	---------------------------kg ha^{-1}--------------------------						
Fargo-untiled 12	67.8	51.7	46.6	39.9	37.6^{ns}†	¶	
Fargo-tiled 2012	37.9	57.1	33.5	63.0	35.0^{ns}		
Hitterdal 2012	22.3	20.1	22.1	19.0	17.5	23.8^{ns}	
Prosper 2012	36.8	41.1	31.3	26.9	25.7	32.6^{ns}	
Langdon 2012	2.1	47.2	19.9	2.4	0.9	0.7*	29.7
Fargo-untiled 13	14.5	14.7	14.2	14.6	13.9^{ns}		
Fargo-tiled 2013	14.1	15.7	15.2	13.3	15.2^{ns}		
Hitterdal 2013	4.0	4.9	6.1	4.6	5.4	4.6*	1.1
Barnesville 2013	8.1	10.2	9.7	8.3	7.6	8.3*	1.7
Casselton 2013	13.5	12.5	14.5	13.2	11.5	12.5^{ns}	
2012	41.2	42.5	33.3	37.2	28.9^{ns}		
2013	10.8	11.6	12.0	10.8	10.7*		1.3
2012 and 2013	24.3	25.3	21.5	22.5	18.8^{ns}		

†ns = not significant at P≤0.1. * = significant at P≤0.1.

‡LSD (P≤0.1): Fisher protected LSD (P≤0.1).

¶The No N treatment was not included at all of the Fargo environments, and in the 2012, 2013, and 2012 and 2013 combined analysis.

Table 22. Nitrogen fertilizer management practices differences in total N soil test results taken at the 0-31 cm depth, at the V6 stage at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Urea alone	Urea + nitrapyrin	Urea + PCU	Urea + UAN	Urea + UAN (DCD+NBPT)	No N	LSD‡
	----------------------------			kg ha^{-1}	-------------------------		
Fargo-untiled 12	148.3	131.7	125.9	121.6	106.1^{ns}†	¶	
Fargo-tiled 2012	118.2	125.9	94.3	154.8	99.0^{ns}		
Hitterdal 2012	285.5	327.2	305.3	227.0	266.7	158.5*	54.5
Prosper 2012	244.2	247.9	225.5	192.4	200.3	127.2*	33.9
Langdon 2012	98.3	180.2	135.0	71.5	54.5	30.3*	63.5
Fargo-untiled 13	46.3	45.4	44.2	28.5	27.5^{ns}		
Fargo-tiled 2013	28.3	45.0	45.2	20.2	21.9*		11.8
Hitterdal 2013	41.8	28.9	41.1	24.0	20.8	16.4*	10.1
Barnesville 2013	51.4	64.8	49.4	45.8	48.6	24.3*	18.7
Casselton 2013	65.4	61.5	55.2	38.2	38.3	30.7*	14.3
2012	199.1	208.2	187.7	174.0	168.0^{ns}		
2013	46.6	49.1	47.2	31.3	31.4*		10.0
2012 and 2013	114.4	119.8	109.6	94.7	92.1*		13.1

†ns = not significant at P≤0.1. * = significant at P≤0.1.
‡LSD (P≤0.1): Fisher protected LSD (P≤0.1).
¶The No N treatment was not included at all of the Fargo environments, and in the 2012, 2013, and 2012 and 2013 combined analysis.

In the 2013 combined analysis, N fertilizer management practices significantly differed in NH_4^+ at the V6 stage (Table 19). The urea plus PCU treatment had significantly more NH_4^+ than the urea plus UAN with DCD plus NBPT treatment, every other N fertilizer management practice comparison for NH_4^+ was not significantly different (Table 21). Nitrogen fertilizer management practices were significantly different for NH_4^+ at the V6 stage at the Langdon 2012, Hitterdal 2013, and Barnesville 2013 environments (Table 20). At Langdon in 2012 and Barnesville in 2013, urea plus nitrapyrin had significantly more NH_4^+ than the urea alone, two split applications, and the no N NFMP (Table 21). At Hitterdal in 2013, urea plus PCU had significantly more NH_4^+ at the V6 stage than all of the other N fertilizer management practices besides the urea plus UAN with DCD plus NBPT.

Table 23. Nitrogen fertilizer management practices differences in NH_4^+ soil test results taken at the 0-31 cm depth, at the R3 stage at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Urea alone	Urea + nitrapyrin	Urea + PCU	Urea + UAN	Urea + UAN (DCD+NBPT)	No N	LSD‡
	---------------------------kg ha^{-1}---------------------------						
Fargo-untiled 12	4.2	3.4	2.0	1.1	12.8^{ns}†	¶	
Fargo-tiled 2012	2.0	1.9	17.2	7.2	9.3^{ns}		
Hitterdal 2012	33.6	38.6	32.6	33.0	35.9	34.5^{ns}	6.8
Prosper 2012	56.4	74.6	65.8	53.3	57.9	50.5*	9.9
Langdon 2012	2.0	2.7	1.5	1.5	2.4	1.3^{ns}	
Fargo-untiled 13	11.6	11.8	12.0	14.5	13.4^{ns}		
Fargo-tiled 2013	10.9	12.0	12.8	13.3	12.1^{ns}		
Hitterdal 2013	7.2	7.5	7.3	6.6	7.4	6.7^{ns}	
Barnesville 2013	7.1	7.9	6.9	6.7	6.4	7.2^{ns}	
Casselton 2013	11.5	10.1	11.4	10.3	10.2	10.5^{ns}	
2012	24.1	29.6	29.4	23.6	28.6^{ns}		
2013	9.7	9.8	10.1	10.3	9.9^{ns}		
2012 and 2013	16.1	18.6	18.7	16.2	18.2^{ns}		

†ns = not significant at P≤0.1. * = significant at P≤0.1.

‡LSD (P≤0.1): Fisher protected LSD (P≤0.1).

¶The No N treatment was not included at all of the Fargo environments, and in the 2012, 2013, and 2012 and 2013 combined analysis.

At the Hitterdal 2012, Prosper 2012, Langdon 2012, Casselton, Barnesville, Hitterdal 2013, and Fargo-tiled 2013; N fertilizer management practices main effects differed significantly for total N at the V6 stage (Table 22). The urea alone, urea plus nitrapyrin, and urea plus PCU N fertilizer management practices had significantly more total N than the two split applications, and no N treatments at the V6 stage for the Prosper 2012, and Casselton environments. The urea plus nitrapyrin, and urea plus PCU N fertilizer management practices had significantly more total N than the two split application, and no N at the V6 stage for the Hitterdal 2012, Langdon, and Fargo-tiled 2013 environments.

Nitrogen fertilizer management practices did not differ significantly for NH_4^+, and total N at the R3 stage in corn looking at the 2012, 2013, and 2012 & 2013 combined analysis (Table

20). Nitrogen fertilizer management practices were significantly different for NH_4 at the R3 stage at Prosper in 2012 (Table 23). At this environment, urea plus nitrapyrin had significantly more NH_4^+ at the R3 stage than any of the other NFMP besides the urea plus PCU (Table 23). The significant NFMP main effects for total N at the individual environments largely result from the no N (zero N applied) having significantly less total N than all of the other treatments at the R3 stage (Table 24).

Table 24. Nitrogen fertilizer management practices differences in total N soil test results taken at the 0-31 cm depth, at the R3 stage at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Urea alone	Urea + nitrapyrin	Urea + PCU	Urea + UAN	Urea + UAN (DCD+NBPT)	No N	LSD‡
	----------------------------			kg ha^{-1}	----------------------------		
Fargo-untiled 12	64.5	54.0	55.4	32.2	76.0^{ns}†	¶	
Fargo-tiled 2012	60.9	41.2	61.6	93.8	60.0^{ns}		
Hitterdal 2012	157.6	168.2	168.0	149.2	187.2	59.8^{ns}	32.1
Prosper 2012	138.9	161.9	135.7	152.1	123.6	69.8*	29.0
Langdon 2012	28.7	25.0	15.1	19.8	25.5	4.6*	10.9
Fargo-untiled 13	19.2	19.8	21.1	25.1	21.5^{ns}		
Fargo-tiled 2013	15.4	18.4	20.8	19.5	18.1*		2.8
Hitterdal 2013	17.4	12.5	16.1	12.1	17.5	10.0*	4.4
Barnesville 2013	19.7	26.3	20.0	21.7	21.7	10.8^{ns}	
Casselton 2013	22.5	20.9	24.6	17.3	17.0	16.1*	3.8
2012	105.5	106.3	105.2	106.8	112.6^{ns}		
2013	18.8	19.6	20.5	19.1	19.2^{ns}		
2012 and 2013	57.4	58.1	58.1	58.1	60.7^{ns}		

†ns = not significant at P≤0.1. * = significant at P≤0.1.
‡LSD (P≤0.1): Fisher protected LSD (P≤0.1).
¶The No N treatment was not included at all of the Fargo environments, and in the 2012, 2013, and 2012 and 2013 combined analysis.

The T x M interaction was significantly different for NH_4^+ at the R3 stage, and total N at the V6 stage in corn for the 2012 and 2012 and 2013 combined analysis (Table 25). Conventional tillage had more NH_4^+ than the raised beds for the urea plus nitrapyrin and urea plus PCU NFMP (Figure 4). Raised bed tillage had more NH_4^+ than conventional tillage for the urea plus UAN with DCD plus NBPT NFMP. Conventional tillage had more total N than raised beds for the urea alone and urea plus PCU (Figure 5).

Table 25. T x M interaction probability for NO_3^-, NH_4^+, and total N (NO_3 + NH_4) soil test results 0-31 cm deep at the V6 and R3 growth stage in corn at all ten individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	V6 stage			R3 stage		
	NO_3	NH_4	Total N	NO_3	NH_4	Total N
Fargo-untiled 12	0.31	0.15	0.16	0.83	0.48	0.70
Fargo-tiled 2012	0.09	0.08	0.02	0.71	0.34	0.66
Hitterdal 2012	0.22	0.64	0.20	0.33	0.24	0.36
Prosper 2012	0.18	0.18	0.09	0.15	0.01	0.05
Fargo-untiled 13	0.80	0.54	0.81	0.84	0.20	0.57
Fargo-tiled 2013	0.84	0.45	0.80	0.24	0.38	0.06
Hitterdal 2013	0.01	0.12	0.02	0.44	0.88	0.51
Barnesville 2013	0.09	0.51	0.11	0.04	0.42	0.03
Casselton 2013	0.43	0.28	0.30	0.45	0.64	0.36
2012	0.52	0.13	0.19	0.84	0.04	0.46
2013	0.13	0.83	0.11	0.64	0.45	0.74
2012 and 2013	0.23	0.14	0.08	0.69	0.06	0.28

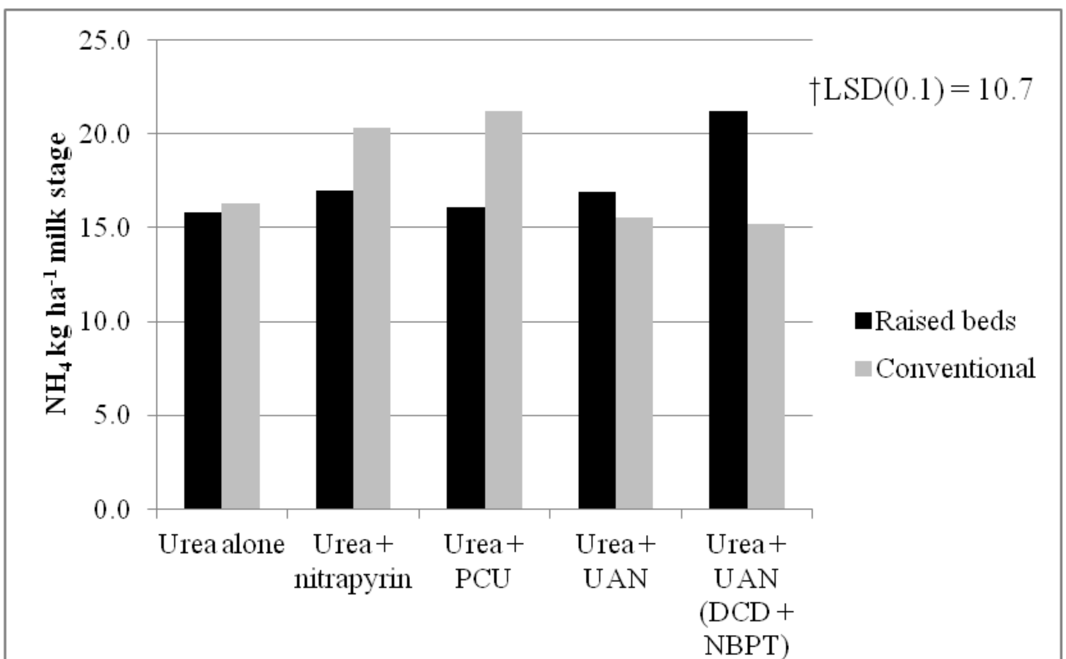

Figure 4. Effect of the T x M interaction on NH_4 in the 0-31 cm soil depth at the R3 stage in corn for the 2012 and 2013 combined analysis.

†LSD (0.1): is used for comparing the two tillage systems within a management practice, and for comparing across management practices within one tillage system.

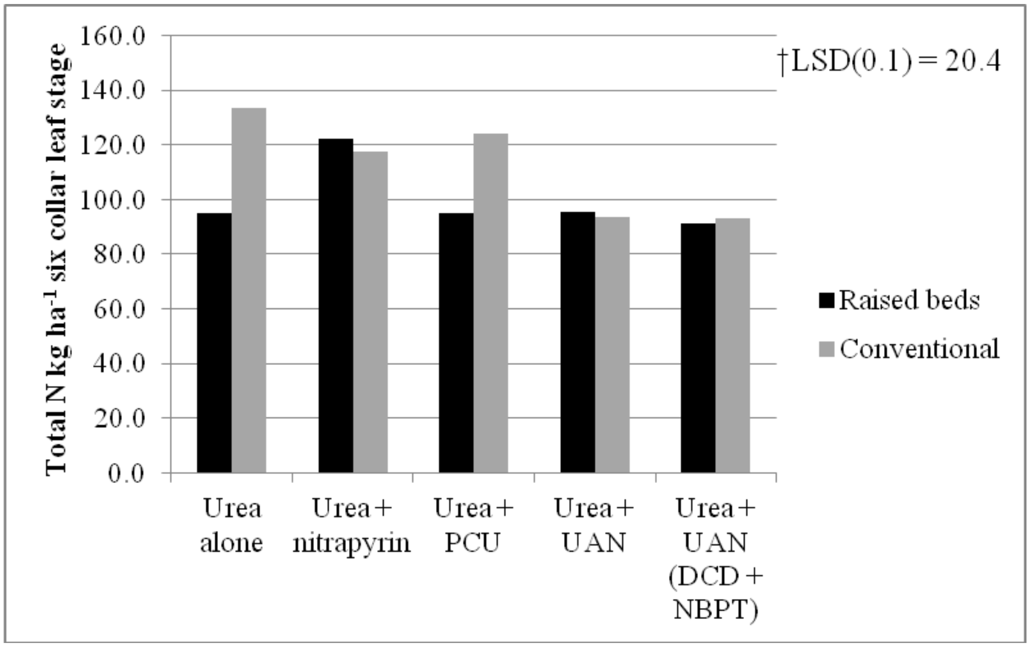

Figure 5. Effect of the T x M interaction on total N in the 0-31 cm soil depth at the V6 collar leaf stage in corn for the 2012 and 2013 combined analysis.

†LSD (0.1): is used for comparing the two tillage systems within a management practice, and for comparing across management practices within one tillage system.

CONCLUSION

In the high clay content soils at the Fargo location, under subsurface drainage grain yield was greater under conventional than raised bed tillage. With no subsurface drainage, grain yield was greater for raised bed than conventional tillage. Furthermore, there was no evidence that this practice interacted with N rates, or N fertilizer management practices. Within the scope of the two seasons, when this research was conducted, the installation of subsurface drainage resulted in little yield differences between subsurface and no subsurface drainage. This was probably due to the fact the tile pipe with subsurface drainage did not pump any water out in 2012 and in 2013 the tile pipe only pumped water out early in the growing season. Corn showed drought symptoms in 2012 and 2013 at the subsurface drainage site in Fargo. Conventional tillage had significantly greater corn yield than the raised bed tillage system when averaged over all nine environments. This was largely due to the lower corn stands in the raised bed tillage system at the Prosper and Casselton locations, which resulted in lower yield. Establishment of uniform stands can be problematic in raised beds because of the extra tillage required to incorporate fertilizer after application and the planting method used. If adequate and uniform seeding depth can be maintained on the raised beds then the stand and yield between the two tillage systems will not be significantly different.

The significance in yield between the N fertilizer management practices and N fertilizer rates varied between years and locations within a year. Generally the split application treatments had the highest yield at every location in 2012 except for Hitterdal, mainly due to better plant stands. In 2013, the split application treatments generally had the lowest yields due to the dry conditions in July and August. Overall, the urea alone management practice seems to be the best, but the split application management practice could produce the highest yields depending on the year and application method.

Nitrogen rates did not significantly differ in yield in 2012. In 2013, the medium and high rates had significantly more yield then the low N rate. Applying around 135 kg ha^{-1} (±30 kg ha^{-1}) of N should produce maximum yields if there are no other factors limiting grain yield.

There were significant differences in NH_4^+ and total N at the V6 stage and R3 stage between environments (years and locations). Tillage systems did not result in significant differences in NH_4^+ or total N at the V6 stage or R3 stage at any individual environment in 2012, 2013, and 2012 plus 2013 combined analysis. In the 2012 and 2013, and 2013 combined analysis, N fertilizer management practices differed significantly in total N at the V6 stage, because the urea alone, urea plus nitrapyrin, and urea plus PCU had more total than the two split application treatments. The V6 stage soil tests were taken right before the split application of UAN was applied. In the 2013 combined analysis, N fertilizer management practices significantly differed in NH_4^+ at the V6 stage, which resulted in urea alone having more NH_4^+ than the urea plus UAN (DCD + NBPT) treatment.

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APPENDIX

Table A 1. ANOVA for corn grain yield averaged over both Fargo environments (2012 and 2013).

SOV		2012	2013
	df	------------Probability------------	
Tillage (T)	1	0.48	0.23
Management Practices (M)	4	0.03	0.03
Fertilizer Rate (R)	2	0.97	0.00
T x M	4	0.41	0.47
T x R	2	0.95	0.20
M x R	8	0.66	0.40
T x M x R	8	0.20	0.83
Drainage (D)	1	0.93	0.00
D x M	4	0.50	0.15
D x R	2	0.72	0.28
D x M x R	8	0.86	0.44
D x T	1	0.04	0.62
D x T x M	4	0.27	0.81
D x T x R	4	0.25	0.95
D x T x M x R	8	0.11	0.11

Table A 2. Effect of drainage on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

Drainage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled	13.5	62429	25.3	6507	163	0.67
Untiled	13.7	61915	25.4	6592	162	0.68
Probability	0.07	0.17	0.14	0.93	0.96	0.84
LSD ($P \leq 0.1$)	0.2					

Table A3. Effect of drainage on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

Drainage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled	17.7	84700	23.3	7666	182	0.64
Untiled	17.2	86285	23.2	7435	183	0.62
Probability	0.54	0.06	0.58	0.77	0.71	0.49
LSD ($P \leq 0.1$)		1226				

Table A4. Effect of drainage (D) x N fertilizer management practices (M) interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D X M	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled x MP1†	13.5	61133	25.3	6559	163	0.64
Tiled x MP2‡	13.6	53310	25.3	6102	165	0.69
Tiled x MP3¶	13.5	64941	25.2	6274	157	0.63
Tiled x MP4††	13.4	66176	25.4	6539	161	0.69
Tiled x MP5‡‡	13.4	66586	25.3	7062	167	0.68
Untiled x MP1	13.8	60206	25.3	6482	164	0.67
Untiled x MP2	13.8	59898	25.5	6637	163	0.70
Untilled x MP3	13.8	59176	25.4	6541	164	0.66
Untiled x MP4	13.7	62676	25.4	6175	158	0.68
Untiled x MP5	13.6	67616	25.4	7125	163	0.70
Probability	0.83	0.23	0.73	0.50	0.36	0.96

†MP1=urea alone.
‡MP2=urea plus nitrapyrin.
¶MP3=urea plus PCU.
††MP4=urea plus UAN.
‡‡MP5=urea plus UAN with DCD plus NBPT.

Table A5. Effect of drainage (D) x N fertilizer management practices (M) interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D X M	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled x MP1†	17.5	86346	23.4	7930	183	0.60
Tiled x MP2‡	17.2	82950	23.2	7469	181	0.66
Tiled x MP3¶	17.4	85215	23.2	7608	183	0.63
Tiled x MP4††	18.5	87532	23.2	7591	180	0.62
Tiled x MP5‡‡	18.1	81458	23.3	7732	181	0.67
Untiled x MP1	17.2	85729	23.3	7916	186	0.64
Untiled x MP2	16.9	86450	23.2	7646	185	0.61
Untilled x MP3	17.2	87171	23.1	7411	183	0.65
Untiled x MP4	17.0	86554	23.2	7073	181	0.59
Untiled x MP5	17.4	85524	23.2	7129	181	0.62
Probability	0.03	0.16	0.71	0.28	0.76	0.04

†MP1=urea alone.
‡MP2=urea plus nitrapyrin.
¶MP3=urea plus PCU.
††MP4=urea plus UAN.
‡‡MP5=urea plus UAN with DCD plus NBPT.

Table A6. Effect of D x N fertilizer rates (R) interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D x R	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled x R1†	13.5	61627	25.3	6447	164	0.67
Tiled x R2‡	13.4	65023	25.2	6508	162	0.67
Tiled x R3¶	13.5	60639	25.4	6567	162	0.66
Untiled x R1	13.6	63294	25.3	6711	163	0.69
Untiled x R2	13.7	61750	25.4	6553	161	0.68
Untiled x R3	13.8	60700	25.4	6511	163	0.68
Probability	0.31	0.51	0.02	0.72	0.82	0.98

†R1=low N rate (135 kg ha^{-1}).
‡R2=medium N rate (180 kg ha^{-1}).
¶R3=high N rate (225 kg ha^{-1})

Table A7. Effect of D x N fertilizer rates (R) interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D x R	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled x R1†	18.1	85124	23.2	7102	177	0.61
Tiled x R2‡	17.4	82992	23.4	7945	184	0.66
Tiled x R3¶	17.7	85988	23.2	7952	184	0.64
Untiled x R1	17.7	85306	23.1	6916	178	0.61
Untiled x R2	17.0	86912	23.3	7490	185	0.62
Untiled x R3	16.7	86635	23.2	7898	186	0.64
Probability	0.16	0.12	0.59	0.44	0.67	0.22

†R1=low N rate (45 kg ha^{-1}).
‡R2=medium N rate (90 kg ha^{-1}).
¶R3=high N rate (135 kg ha^{-1}).

Table A8. Effect of drainage (D) x Tillage (T) interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D x T	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled x T1†	13.5	58127	25.0	6295	167	0.59
Tiled x T2‡	13.4	66732	25.6	6719	158	0.75
Untiled x T1	13.9	58087	25.1	6742	171	0.62
Untiled x T2	13.6	65744	25.7	6442	154	0.74
Probability	0.41	0.80	0.93	0.04	0.33	0.73

†T1=Raised bed tillage.
‡T2=Conventional tillage.

Table A9. Effect of drainage (D) x Tillage (T) interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D x T	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Tiled x T1†	17.6	83343	23.35	7362		0.65
Tiled x T2‡	17.9	86060	23.22	7970		0.62
Untiled x T1	16.9	86862	23.30	7474		0.65
Untiled x T2	17.4	85709	23.08	7395		0.59
Probability	0.75	0.24	0.73	0.36	0.18	0.37

Table A10. Effect of the D x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D x M x R	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	- kg bu^{-1}-	--kg ha^{-1}--	--cm--	--NDVI--
TiledxM1xR1	13.6	61441	25.4	6502	162	0.59
TiledxM1xR2	13.4	62676	25.2	6665	161	0.66
TiledxM1xR3	13.4	59280	25.4	6510	167	0.68
TiledxM2xR1	13.6	48783	25.2	5937	167	0.68
TiledxM2xR2	13.5	55266	25.2	6313	168	0.67
TiledxM2xR3	13.7	55884	25.5	6056	160	0.71
TiledxM3xR1	13.5	68543	25.4	6210	157	0.64
TiledxM3xR2	13.4	69778	25.0	6331	159	0.63
TiledxM3xR3	13.5	56501	25.3	6283	157	0.64
TiledxM4xR1	13.5	62368	25.2	6346	164	0.70
TiledxM4xR2	13.4	69778	25.2	6036	156	0.69
TiledxM4xR3	13.3	66381	25.6	7236	162	0.67
TiledxM5xR1	13.3	66999	25.4	7242	172	0.75
TiledxM5xR2	13.3	67616	25.3	7195	165	0.69
TiledxM5xR3	13.4	65146	25.4	6749	163	0.61
UntiledxM1xR1	13.9	62676	25.3	6372	169	0.64
UntiledxM1xR2	13.9	57428	25.3	6609	163	0.66
UntiledxM1xR3	13.7	60515	25.4	6463	161	0.72
UntiledxM2xR1	13.6	61441	25.4	7284	167	0.72
UntiledxM2xR2	13.9	59589	25.6	6450	159	0.70
UntiledxM2xR3	13.8	58663	25.4	6176	164	0.67
UntiledxM3xR1	13.6	64838	25.2	6497	163	0.70
UntiledxM3xR2	13.8	58971	25.4	6838	165	0.67
UntiledxM3xR3	14.1	53723	25.5	6288	163	0.61
UntiledxM4xR1	13.5	60206	25.3	6014	156	0.67
UntiledxM4xR2	13.7	64220	25.4	6088	154	0.65
UntiledxM4xR3	13.8	63603	25.5	6423	163	0.71
UntiledxM5xR1	13.5	67308	25.2	7388	161	0.73
UntiledxM5xR2	13.6	68543	25.4	6781	163	0.70
UntiledxM5xR3	13.6	66999	25.5	7205	164	0.68

Table A 10. Effect of the D x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012 (continued).

D x M x R	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	- kg bu^{-1}-	--kg ha^{-1}--	--cm--	--NDVI--
Probability	0.98	0.99	0.53	0.86	0.59	0.88

Table A 11. Effect of the D x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D x M x R	Moisture	Stand	Test weight	Yield	Plant height	Greenness
	--%--	plants ha^{-1}	- kg bu^{-1}-	--kg ha^{-1}--	--cm--	--NDVI--
TiledxM1xR1	17.6	87068	23.4	7075	177	0.58
TiledxM1xR2	17.2	85679	23.5	8481	188	0.64
TiledxM1xR3	17.8	86297	23.3	8234	185	0.58
TiledxM2xR1	17.2	82745	23.2	6973	176	0.64
TiledxM2xR2	17.1	79966	23.3	7337	183	0.68
TiledxM2xR3	17.2	86141	23.2	8095	186	0.66
TiledxM3xR1	18.2	86914	23.2	7145	177	0.61
TiledxM3xR2	16.8	81357	23.4	8092	187	0.66
TiledxM3xR3	17.2	87376	23.1	7587	186	0.64
TiledxM4xR1	18.6	89229	23.2	6996	176	0.57
TiledxM4xR2	18.1	87376	23.3	7764	181	0.66
TiledxM4xR3	18.6	85988	23.2	8014	182	0.65
TiledxM5xR1	18.8	79658	23.3	7322	180	0.67
TiledxM5xR2	17.8	80584	23.3	8049	182	0.67
TiledxM5xR3	17.6	84133	23.4	7826	180	0.66
UntiledxM1xR1	17.9	84444	23.2	7095	175	0.59
UntiledxM1xR2	16.8	85215	23.3	7841	189	0.63
UntiledxM1xR3	16.9	87532	23.3	8810	194	0.68
UntiledxM2xR1	17.7	85524	23.2	7076	179	0.56
UntiledxM2xR2	16.6	88458	23.2	7609	188	0.63
UntiledxM2xR3	16.5	85371	23.3	8251	187	0.63
UntiledxM3xR1	17.5	86450	23.0	6888	179	0.63
UntiledxM3xR2	17.5	88458	23.3	7806	184	0.65
UntiledxM3xR3	16.7	86606	23.1	7538	185	0.67
UntiledxM4xR1	17.7	85833	23.1	6583	179	0.59
UntiledxM4xR2	16.9	86450	23.3	6999	179	0.56
UntiledxM4xR3	16.5	87376	23.2	7635	185	0.61
UntiledxM5xR1	18.1	84289	23.1	6938	181	0.65
UntiledxM5xR2	17.2	85986	23.3	7193	182	0.60
UntiledxM5xR3	17.1	86297	23.2	7256	181	0.60
Probability	0.35	0.55	0.88	0.97	0.61	0.68

Table A12. Effect of D x T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D x T x M	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	- kg bu^{-1}-	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT1xM1	13.6	55370	25.2	5946	166	0.54
TiledxT1xM2	13.8	45695	25.0	5927	169	0.62
TiledxT1xM3	13.5	63190	24.9	6530	165	0.57
TiledxT1xM4	13.5	62985	25.0	6617	169	0.61
TiledxT1xM5	13.4	63397	25.1	6455	167	0.60
TiledxT2xM1	13.4	66895	25.5	7172	161	0.74
TiledxT2xM2	13.5	60927	25.6	6277	161	0.76
TiledxT2xM3	13.5	66690	25.6	6019	150	0.69
TiledxT2xM4	13.3	69365	25.7	6461	152	0.76
TiledxT2xM5	13.3	69778	25.6	7669	167	0.76
UntiledxT1xM1	13.9	57633	25.1	6681	175	0.63
UntiledxT1xM2	14.1	55370	25.2	6848	171	0.60
UntiledxT1xM3	14.1	51253	25.0	6574	174	0.58
UntiledxT1xM4	13.8	60310	25.2	6369	169	0.64
UntiledxT1xM5	13.6	65867	25.1	7237	167	0.67
UntiledxT2xM1	13.7	62780	25.6	6282	154	0.71
UntiledxT2xM2	13.5	64425	25.7	6426	155	0.79
UntiledxT2xM3	13.6	67102	25.8	6509	153	0.74
UntiledxT2xM4	13.5	65043	25.6	5981	147	0.71
UntiledxT2xM5	13.5	69365	25.6	7012	159	0.74
Probability	0.28	0.44	0.39	0.27	0.85	0.51

Table A13. Effect of D x T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D X T X M	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	- kg bu^{-1}-	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT1xM1	17.5	87685	23.4	7935	182	0.59
TiledxT1xM2	17.0	80171	23.2	6903	179	0.67
TiledxT1xM3	17.1	83363	23.3	7392	181	0.65
TiledxT1xM4	18.3	87480	23.4	7284	176	0.65
TiledxT1xM5	18.1	78010	23.5	7297	176	0.69
TiledxT2xM1	17.6	85010	23.4	7926	185	0.62
TiledxT2xM2	17.3	85729	23.2	8034	184	0.65
TiledxT2xM3	17.7	87068	23.2	7825	185	0.62
TiledxT2xM4	18.7	87581	23.1	7899	184	0.59
TiledxT2xM5	18.1	84906	23.2	8167	185	0.64
UntiledxT1xM1	17.0	86038	23.4	7910	187	0.66
UntiledxT1xM2	16.7	87994	23.2	7481	183	0.64
UntiledxT1xM3	17.1	88303	23.3	7266	183	0.66
UntiledxT1xM4	17.1	85833	23.3	7416	180	0.65
UntiledxT1xM5	16.7	86141	23.3	7298	179	0.64
UntiledxT2xM1	17.3	85420	23.1	7921	185	0.61
UntiledxT2xM2	17.2	84906	23.2	7810	187	0.58
UntiledxT2xM3	17.3	86038	23.0	7557	183	0.64
UntiledxT2xM4	17.0	87273	23.0	6729	182	0.53
UntiledxT2xM5	18.2	84906	23.0	6960	183	0.60
Probability	0.15	0.09	0.85	0.37	0.91	0.70

Table A14. Effect of D x T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D X T X R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT1xR1	13.6	56563	25.0	6161	169	0.58
TiledxT1xR2	13.4	63479	24.9	6526	169	0.60
TiledxT1xR3	13.6	54340	25.1	6199	163	0.59
TiledxT2xR1	13.4	66690	25.6	6733	160	0.77
TiledxT2xR2	13.4	66566.5	25.5	6490	154	0.73
TiledxT2xR3	13.4	66937	25.7	6935	161	0.74
UntiledxT1xR1	13.7	60762	25.0	6917	172	0.65
UntiledxT1xR2	14.0	56563	25.1	6544	169	0.60
UntiledxT1xR3	14.0	56933.5	25.2	6764	172	0.62
UntiledxT2xR1	13.5	65825.5	25.6	6505	155	0.73
UntiledxT2xR2	13.5	66937	25.7	6563	153	0.76
UntiledxT2xR3	13.7	64467	25.7	6258	154	0.73
Probability	0.28	0.26	0.93	0.25	0.22	0.27

Table A15. Effect of D x T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D x T x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT1xR1	18.2	83795	23.3	6801	172	0.62
TiledxT1xR2	17.1	80522	23.4	7645	183	0.68
TiledxT1xR3	17.4	85709	23.3	7640	181	0.65
TiledxT2xR1	18.0	86450	23.2	7404	182	0.61
TiledxT2xR2	17.7	85462	23.3	8243	185	0.64
TiledxT2xR3	17.9	86265	23.1	8263	186	0.62
UntiledxT1xR1	17.2	87129	23.2	7030	178	0.65
UntiledxT1xR2	16.9	87068	23.5	7468	183	0.64
UntiledxT1xR3	16.6	86388	23.3	7924	186	0.65
UntiledxT2xR1	18.3	83486	23.1	6802	179	0.56
UntiledxT2xR2	17.0	86759	23.1	7512	186	0.59
UntiledxT2xR3	16.9	86882	23.1	7872	187	0.63
Probability	0.02	0.24	0.13	0.91	0.23	0.20

Table A16. Effect of D x T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012.

D x T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT1xM1xR1	13.7	50018	25.3	5958	166	0.47
TiledxT1xM1xR2	13.3	62368	24.9	6500	161	0.59
TiledxT1xM1xR3	13.7	53723	25.3	5380	169	0.57
TiledxT1xM2xR1	14.1	39520	24.7	5425	173	0.55
TiledxT1xM2xR2	13.6	51253	24.9	5860	174	0.60
TiledxT1xM2xR3	13.6	46313	25.2	6495	160	0.70
TiledxT1xM3xR1	13.4	67925	25.0	7072	164	0.55
TiledxT1xM3xR2	13.5	70395	24.7	6148	168	0.57
TiledxT1xM3xR3	13.5	51253	24.8	6370	162	0.60
TiledxT1xM4xR1	13.9	62368	24.9	5386	167	0.59
TiledxT1xM4xR2	13.3	67925	24.7	6911	173	0.65
TiledxT1xM4xR3	13.3	58663	25.4	7555	168	0.59
TiledxT1xM5xR1	13.2	62985	25.1	6964	176	0.71
TiledxT1xM5xR2	13.3	65455	25.2	7207	170	0.60
TiledxT1xM5xR3	13.6	61750	25.0	5193	154	0.48
TiledxT2xM1xR1	13.5	72865	25.4	7046	159	0.72
TiledxT2xM1xR2	13.5	62985	25.5	6830	161	0.72
TiledxT2xM1xR3	13.1	64838	25.6	7640	165	0.79
TiledxT2xM2xR1	13.2	58045	25.6	6448	162	0.81
TiledxT2xM2xR2	13.5	59280	25.5	6766	163	0.74
TiledxT2xM2xR3	13.9	65455	25.7	5617	159	0.73

Table A16. Effect of D x T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2012 (continued).

D x T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT2xM3xR1	13.7	69160	25.7	5348	149	0.72
TiledxT2xM3xR2	13.2	69160	25.3	6512	149	0.69
TiledxT2xM3xR3	13.5	61750	25.8	6196	152	0.67
TiledxT2xM4xR1	13.2	62368	25.6	7305	162	0.80
TiledxT2xM4xR2	13.5	71630	25.8	5160	139	0.74
TiledxT2xM4xR3	13.3	74100	25.9	6916	155	0.75
TiledxT2xM5xR1	13.4	71013	25.7	7520	168	0.78
TiledxT2xM5xR2	13.4	69778	25.4	7183	160	0.78
TiledT2xM5xR3	13.3	68543	25.7	8305	172	0.73
UntiledxT1xM1xR1	13.9	58663	25.1	6642	181	0.58
UntiledxT1xM1xR2	14.3	50018	24.9	6151	175	0.58
UntiledxT1xM1xR3	13.5	64220	25.2	7250	168	0.73
UntiledxT1xM2xR1	13.8	60515	25.0	7803	178	0.63
UntiledxT1xM2xR2	14.1	52488	25.4	6527	162	0.62
UntiledxT1xM2xR3	14.3	53105	25.1	6214	173	0.54
UntiledxT1xM3xR1	13.6	58663	24.8	6553	171	0.64
UntiledxT1xM3xR2	14.2	51870	24.9	6684	175	0.51
UntiledxT1xM3xR3	14.4	43225	25.2	6485	177	0.60
UntiledxT1xM4xR1	13.7	58663	25.1	6103	169	0.71
UntiledxT1xM4xR2	14.0	61133	25.1	6514	164	0.56
UntiledxT1xM4xR3	13.9	61133	25.3	6491	174	0.66
UntiledxT1xM5xR1	13.6	67308	25.1	7482	162	0.69
UntiledxT1xM5xR2	13.6	67308	25.3	6847	168	0.71
UntiledxT1xM5xR3	13.6	62985	25.1	7383	169	0.60
UntiledxT2xM1xR1	13.8	66690	25.5	6103	158	0.70
UntiledxT2xM1xR2	13.5	64838	25.6	7068	151	0.74
UntiledxT2xM1xR3	13.9	56810	25.7	5676	154	0.71
UntiledxT2xM2xR1	13.3	62368	25.7	6766	155	0.81
UntiledxT2xM2xR2	13.7	66690	25.8	6373	155	0.79
UntiledxT2xM2xR3	13.4	64220	25.6	6139	155	0.79
UntiledxT2xM3xR1	13.6	71013	25.7	6441	156	0.75
UntiledxT2xM3xR2	13.3	66073	26.0	6993	155	0.83
UntiledxT2xM3xR3	13.8	64220	25.7	6091	149	0.62
UntiledxT2xM4xR1	13.4	61750	25.5	5924	144	0.63
UntiledxT2xM4xR2	13.4	67308	25.7	5662	145	0.74
UntiledxT2xM4xR3	13.6	66073	25.6	6356	152	0.76
UntiledxT2xM5xR1	13.4	67308	25.4	7293	160	0.76
UntiledxT2xM5xR2	13.6	69778	25.6	6716	158	0.69
UntiledxT2xM5xR3	13.6	71013	25.9	7027	159	0.77
Probability	0.27	0.92	0.64	0.11	0.54	0.45

Table A 17. Effect of D x T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013.

D x T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
TiledxT1xM1xR1	17.5	88920	23.5	7246	174	0.53
TiledxT1xM1xR2	17.3	85215	23.5	8480	187	0.66
TiledxT1xM1xR3	17.7	88920	23.2	8078	184	0.57
TiledxT1xM2xR1	16.9	78423	23.2	6243	172	0.67
TiledxT1xM2xR2	16.9	77496	23.2	6927	182	0.70
TiledxT1xM2xR3	17.1	84598	23.3	7540	184	0.65
TiledxT1xM3xR1	18.5	84906	23.3	7319	175	0.59
TiledxT1xM3xR2	16.5	77805	23.4	7571	185	0.67
TiledxT1xM3xR3	16.4	87376	23.2	7286	185	0.68
TiledxT1xM4xR1	18.2	91081	23.1	6208	170	0.60
TiledxT1xM4xR2	17.8	84906	23.6	7509	181	0.67
TiledxT1xM4xR3	18.8	86450	23.4	8135	176	0.69
TiledxT1xM5xR1	19.9	75644	23.5	6988	171	0.69
TiledxT1xM5xR2	17.2	77188	23.4	7740	180	0.71
TiledxT1xM5xR3	17.0	81201	23.6	7163	178	0.66
TiledxT2xM1xR1	17.6	85215	23.2	6904	180	0.64
TiledxT2xM1xR2	17.1	86141	23.5	8482	189	0.62
TiledxT2xM1xR3	18.0	83671	23.3	8391	187	0.59
TiledxT2xM2xR1	17.5	87068	23.1	7703	180	0.61
TiledxT2xM2xR2	17.2	82436	23.4	7747	184	0.65
TiledxT2xM2xR3	17.2	87685	23.2	8652	188	0.68
TiledxT2xM3xR1	18.0	88920	23.1	6972	180	0.62
TiledxT2xM3xR2	17.2	84906	23.3	8612	189	0.64
TiledxT2xM3xR3	18.0	87376	23.1	7889	187	0.59
TiledxT2xM4xR1	19.1	87376	23.3	7785	182	0.54
TiledxT2xM4xR2	18.4	89846	23.1	8018	181	0.64
TiledxT2xM4xR3	18.5	85524	22.9	7894	188	0.60
TiledxT2xM5xR1	17.7	83671	23.1	7655	189	0.65
TiledxT2xM5xR2	18.5	83980	23.3	8357	184	0.63
TiledT2xM5xR3	18.1	87068	23.2	8490	183	0.65
UntiledxT1xM1xR1	17.9	86141	23.3	7228	172	0.65
UntiledxT1xM1xR2	16.3	85524	23.4	7735	193	0.63
UntiledxT1xM1xR3	16.7	86450	23.5	8766	195	0.70
UntiledxT1xM2xR1	17.2	87685	23.1	7120	179	0.59
UntiledxT1xM2xR2	16.7	89846	23.3	7535	185	0.66

Table A 17. Effect of D x T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all environments in Fargo 2013 (continued).

D x T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
UntiledxT1xM2xR3	16.2	86450	23.3	7789	184	0.66
UntiledxT1xM3xR1	17.1	85833	23.1	6591	179	0.64
UntiledxT1xM3xR2	17.6	90773	23.5	7578	182	0.67
UntiledxT1xM3xR3	16.5	88303	23.1	7627	188	0.68
UntiledxT1xM4xR1	17.2	87685	23.1	7267	183	0.67
UntiledxT1xM4xR2	17.5	83363	23.6	7178	175	0.64
UntiledxT1xM4xR3	16.7	86450	23.2	7805	183	0.64
UntiledxT1xM5xR1	16.7	88303	23.1	6945	177	0.71
UntiledxT1xM5xR2	16.6	85833	23.4	7313	182	0.62
UntiledxT1xM5xR3	16.8	84289	23.4	7637	179	0.57
UntiledxT2xM1xR1	17.8	82745	23.1	6961	177	0.54
UntiledxT2xM1xR2	17.2	84906	23.1	7947	185	0.64
UntiledxT2xM1xR3	17.0	88611	23.1	8856	194	0.67
UntiledxT2xM2xR1	18.2	83363	23.4	7032	179	0.54
UntiledxT2xM2xR2	16.4	87068	23.0	7684	192	0.59
UntiledxT2xM2xR3	16.9	84289	23.2	8714	190	0.61
UntiledxT2xM3xR1	17.8	87068	22.9	7186	179	0.63
UntiledxT2xM3xR2	17.3	86141	23.2	8035	187	0.63
UntiledxT2xM3xR3	16.8	84906	23.0	7449	182	0.67
UntiledxT2xM4xR1	18.2	83980	23.0	5899	175	0.51
UntiledxT2xM4xR2	16.4	89538	22.9	6820	183	0.49
UntiledxT2xM4xR3	16.3	88303	23.1	7466	187	0.58
UntiledxT2xM5xR1	19.4	80275	23.0	6931	185	0.59
UntiledxT2xM5xR2	17.7	86141	23.2	7073	183	0.58
UntiledxT2xM5xR3	17.5	88303	22.9	6876	182	0.62
Probability	0.06	0.92	0.68	0.44	0.57	0.67

Table A 18. Effect of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	16.2	70873	24.5	8657	185	0.70
Conventional	16.4	75265	24.5	9015	186	0.73
Probability	0.13	0.05	0.51	0.07	0.97	0.09
LSD ($P \leq 0.1$)		3474		300		0.03

Table A19. Effect of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	13.0	60194	25.6	8494	187	0.71
Conventional	12.8	66363	25.6	8920	184	0.79
Probability	0.12	0.20	0.18	0.25	0.55	0.09
LSD (P≤0.1)						0.07

Table A20. Effect of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	18.7	79291	23.6	8772	184	0.69
Conventional	19.2	82407	23.5	9091	187	0.69
Probability	0.09	0.22	0.36	0.23	0.05	0.80
LSD (P≤0.1)	0.45				2.04	

Table A21. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled 2012.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	13.9	58086	25.1	6742	171	0.62
Conventional	13.6	65743	25.7	6442	154	0.74
Probability	0.33	0.25	0.12	0.02	0.08	0.35
LSD (P≤0.1)				67	14	

Table A22. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled 2012.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	13.5	58127	25.0	6295	167	0.59
Conventional	13.4	66731	25.6	6719	158	0.75
Probability	0.36	0.02	0.22	0.21	0.39	0.29
LSD (P≤0.1)		1819				

Table A23. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal 2012.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	11.8	72453	26.2	10182	192	0.79
Conventional	11.8	69469	26.1	10521	197	0.80
Probability	0.96	0.02	0.24	0.39	0.05	0.27
LSD (P≤0.1)		1635			3.6	

Table A24. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper 2012.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	13.0	51973	26.0	10785	220	0.82
Conventional	12.6	63603	26.1	11788	225	0.86
Probability	0.01	0.02	0.29	0.22	0.04	0.00
LSD (P≤0.1)	0.15	6043			3.34	0.01

Table A25. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled 2013.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	16.9	86862	23.3	7474	182	0.75
Conventional	17.4	85709	23.1	7396	184	0.73
Probability	0.40	0.70	0.34	0.90	0.61	0.02
LSD (P≤0.1)						0.01

Table A26. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled 2013.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	17.6	83342	23.4	7363	179	0.73
Conventional	17.9	86059	23.2	7970	185	0.72
Probability	0.41	0.13	0.39	0.19	0.01	0.64
LSD (P≤0.1)					2.4	

Table A27. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal 2013.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	21.0	72536	24.1	11855	199	0.76
Conventional	22.1	76158	23.7	11666	199	0.70
Probability	0.15	0.13	0.08	0.56	0.99	0.07
LSD (P≤0.1)			0.3			0.05

Table A28. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville 2013.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	17.9	81881	24.0	9181	190	0.69
Conventional	18.4	81407	24.0	9363	194	0.68
Probability	0.55	0.68	0.90	0.11	0.03	0.56
LSD (P≤0.1)					1.9	

Table A29. Effects of tillage systems on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton 2013.

Tillage	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	--kg ha^{-1}--	--cm--	--NDVI--
Raised Beds	20.3	71836	23.4	8023	170	0.45
Conventional	20.2	82704	23.4	9087	173	0.45
Probability	0.76	0.05	0.82	0.09	0.27	0.31
LSD (P≤0.1)		8291		1001		

Table A30. Effect N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	16.0	72312	24.4	8834	187	0.72
MP 2¶	16.1	71489	24.6	8942	187	0.73
MP 3††	16.3	73221	24.5	8820	185	0.72
MP 4‡‡	16.6	74233	24.5	8705	184	0.70
MP 5¶¶	16.3	74090	24.5	8877	185	0.72
Probability	0.26	0.03	0.74	0.78	0.02	0.08
LSD (P≤0.1)		1817			1.84	0.01

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A31. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	13.0	61016	25.8	8325	186	0.74
MP 2¶	13.0	60392	25.7	8708	188	0.75
MP 3††	12.9	63126	25.7	8688	183	0.74
MP 4‡‡	12.9	65625	25.7	8887	186	0.75
MP 5¶¶	12.9	66231	25.7	8927	185	0.77
Probability	0.13	0.02	0.74	0.46	0.23	0.10
LSD (P≤0.1)		3412				0.02

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A32. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	18.5	81140	23.4	9182	187	0.69
MP 2¶	18.6	80161	23.6	9107	187	0.70
MP 3††	19.0	81211	23.5	8932	186	0.70
MP 4‡‡	19.6	81191	23.4	8591	183	0.67
MP 5¶¶	19.1	80542	23.6	8842	184	0.69
Probability	0.13	0.76	0.60	0.03	0.00	0.01
LSD (P≤0.1)				299	1.71	0.01

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A33. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2012.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	13.8	60206	25.3	6482	164	0.67
MP 2¶	13.8	59898	25.5	6637	163	0.70
MP 3††	13.8	59176	25.4	6541	164	0.66
MP 4‡‡	13.7	62676	25.4	6175	158	0.68
MP 5¶¶	13.6	67616	25.4	7125	163	0.70
Probability	0.62	0.27	0.79	0.16	0.42	0.88

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A34. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2012.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	13.5	61133	25.3	6559	163	0.64
MP 2¶	13.6	53310	25.3	6102	165	0.69
MP 3††	13.5	64941	25.2	6274	157	0.63
MP 4‡‡	13.4	66176	25.4	6539	161	0.69
MP 5¶¶	13.4	66586	25.3	7062	167	0.68
Probability	0.25	0.01	0.73	0.15	0.17	0.29
LSD (P≤0.1)		6251				

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A35. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2012.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	11.8	68388	26.3	9599	195	0.80
MP 2¶	11.7	71681	26.2	11046	198	0.79
MP 3††	11.7	71836	26.1	10339	191	0.80
MP 4‡‡	11.8	72299	26.2	10681	198	0.80
MP 5¶¶	11.8	70601	26.1	10092	191	0.79
Probability	0.86	0.03	0.72	0.11	0.05	0.94
LSD (P≤0.1)		2154			5	

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A36. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper in 2012.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	12.8	54700	26.0	10840	223	0.84
MP 2¶	12.8	55318	25.9	10871	224	0.84
MP 3††	12.8	56553	26.1	11289	219	0.84
MP 4‡‡	12.8	61287	26.0	11854	224	0.85
MP 5¶¶	12.7	61081	26.1	11578	223	0.85
Probability	0.24	0.00	0.58	0.04	0.53	0.49
LSD (P≤0.1)		3534		649		

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A37. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Langdon in 2012.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	18.4	78217	22.7	8575	221	0.88
MP 2¶	18.6	78628	22.6	8759	222	0.89
MP 3††	19.0	79040	22.2	8975	222	0.89
MP 4‡‡	19.0	79658	22.3	9101	217	0.88
MP 5¶¶	18.9	78731	22.4	9106	219	0.89
Probability	0.19	0.90	0.08	0.18	0.86	0.82
LSD (P≤0.1)			0.4			

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A38. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2013.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	17.2	85729	23.3	7916	186	0.75
MP 2¶	16.9	86450	23.2	7646	185	0.74
MP 3††	17.2	87171	23.2	7411	183	0.73
MP 4‡‡	17.0	86554	23.2	7073	181	0.71
MP 5¶¶	17.5	85524	23.2	7129	181	0.74
Probability	0.43	0.86	0.69	0.02	0.18	0.15
LSD (P≤0.1)				477		

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A39. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2013.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	17.5	86346	23.4	7930	184	0.73
MP 2¶	17.2	82950	23.2	7469	181	0.72
MP 3††	17.4	85215	23.2	7609	183	0.74
MP 4‡‡	18.5	87532	23.2	7592	180	0.69
MP 5¶¶	18.1	81458	23.4	7732	181	0.74
Probability	0.00	0.02	0.37	0.60	0.24	0.12
LSD (P≤0.1)	0.5	3232				

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A40. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2013.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	21.5	74564	23.9	11692	199	0.70
MP 2¶	21.2	72712	24.1	11963	200	0.76
MP 3††	21.6	74718	23.8	11704	200	0.73
MP 4‡‡	21.9	74204	23.8	11572	196	0.74
MP 5¶¶	21.6	75540	23.9	11872	199	0.73
Probability	0.22	0.62	0.16	0.83	0.70	0.16
LSD (P≤0.1)						

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A41. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville in 2013.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	18.0	83568	24.1	9616	191	0.67
MP 2¶	18.2	80739	24.0	9404	194	0.70
MP 3††	18.4	81562	24.0	9697	193	0.69
MP 4‡‡	18.0	81098	24.0	8822	191	0.68
MP 5¶¶	18.1	81253	24.0	8819	190	0.67
Probability	0.55	0.12	0.86	0.00	0.25	0.67
LSD (P≤0.1)				474		

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A42. Effect of N fertilizer management practices on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton in 2013.

MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP 1‡	18.4	75488	23.6	8798	174	0.49
MP 2¶	19.7	77958	23.6	9205	174	0.50
MP 3††	20.4	77393	23.4	8267	172	0.49
MP 4‡‡	22.4	76570	23.0	7880	165	0.40
MP 5¶¶	20.3	78936	23.4	8626	172	0.47
Probability	0.00	0.54	0.00	0.01	0.00	0.01
LSD (P≤0.1)	1.6		0.2	568	4	0.05

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.

Table A43. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low	16.6	73389	118	8508	183	0.71
Medium	16.2	72986	119	8908	186	0.72
High	16.1	72830	119	9091	187	0.73
Probability	0.02	0.58	0.12	0.01	0.02	0.16
LSD (P≤0.1)	0.24			279	2.01	

Table A44. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (135)	12.9	64341	25.8	8678	186	0.76
Medium (180)	12.9	63397	25.7	8714	186	0.75
High (225)	13.0	62096	25.7	8729	185	0.74
Probability	0.38	0.18	0.71	0.98	0.82	0.04
LSD (P≤0.1)						0.01

Table A45. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (45)	19.4	80707	23.3	8386	181	0.67
Medium (90)	18.8	80621	23.6	9060	187	0.69
High (135)	18.6	81221	23.6	9346	188	0.70
Probability	0.00	0.59	0.12	0.00	0.00	0.03
LSD (P≤0.1)	0.28			228	1.47	0.02

Table A46. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2012.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (135)	13.6	63294	25.3	6711	163	0.69
Medium (180)	13.7	61750	25.4	6553	161	0.68
High (225)	13.8	60700	25.4	6511	163	0.68
Probability	0.41	0.73	0.09	0.76	0.63	0.93
LSD (P≤0.1)			0.13			

Table A47. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2012.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (135)	13.5	61627	25.3	6447	164	0.67
Medium (180)	13.4	65023	25.2	6508	162	0.67
High (225)	13.5	60639	25.4	6567	162	0.66
Probability	0.45	0.29	0.01	0.92	0.64	0.92
LSD (P≤0.1)			0.1			

Table A48. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2012.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (135)	11.8	71477	26.2	9916	193	0.80
Medium (180)	11.8	70983	26.2	10543	196	0.80
High (225)	11.8	70427	26.1	10595	195	0.79
Probability	0.95	0.58	0.60	0.21	0.43	0.96

Table A49. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper 2012.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (135)	12.7	60268	26.0	11620	223	0.85
Medium (180)	12.8	56779	26.1	11051	224	0.84
High (225)	12.8	56316	26.0	11189	221	0.84
Probability	0.15	0.04	0.64	0.15	0.35	0.26
LSD (P≤0.1)		2737				

Table A50. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Langdon in 2012.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (67)	18.7	79164	22.5	8585	218	0.89
Medium (112)	19.2	77249	22.1	9120	220	0.88
High (157)	18.5	80152	22.7	9005	222	0.89
Probability	0.01	0.05	0.01	0.02	0.55	0.47
LSD (P≤0.1)	0.4	1934	0.3	332		

Table A51. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2013.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (45)	17.7	85306	23.1	6916	179	0.71
Medium (90)	17.0	86912	23.3	7490	185	0.74
High (135)	16.7	86635	23.2	7898	187	0.76
Probability	0.00	0.40	0.03	0.00	0.00	0.00
LSD (P≤0.1)	0.4		0.1	369	3	0.02

Table A52. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2013.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (45)	18.1	85124	23.3	7103	177	0.71
Medium (90)	17.4	82992	23.4	7945	184	0.73
High (135)	17.7	85986	23.2	7952	184	0.73
Probability	0.02	0.13	0.15	0.00	0.00	0.46
LSD (P≤0.1)	0.41			383	3	

Table A53. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2013.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (45)	22.1	73297	23.7	11239	195	0.71
Medium (90)	21.3	74997	24.0	12004	200	0.75
High (135)	21.2	74750	24.0	12039	202	0.73
Probability	0.00	0.43	0.00	0.01	0.01	0.17
LSD (P≤0.1)	0.4		0.1	470	4	

Table A54. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville in 2013.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (45)	18.4	82157	23.9	8537	188	0.66
Medium (90)	18.1	81293	24.1	9541	195	0.69
High (135)	18.0	81480	24.0	9737	193	0.69
Probability	0.10	0.59	0.04	0.00	0.00	0.11
LSD (P≤0.1)	0.3		0.2	367	3	

Table A55. Effect of N fertilizer rates on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton in 2013.

Nitrogen rate	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
--kg ha^{-1}--	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
Low (45)	20.7	77649	23.1	8133	167	0.42
Medium (90)	20.4	76911	23.4	8349	171	0.48
High (135)	19.5	77249	23.6	9183	176	0.51
Probability	0.26	0.90	0.00	0.00	0.00	0.00
LSD (P≤0.1)			0.85	439	3	0.04

Table A56. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	16.0	70259	118	8604	186	0.69
T2 x MP2¶	16.1	68513	118	8670	186	0.71
T2 x MP3††	16.2	70595	118	8741	186	0.71
T2 x MP4‡‡	16.5	72628	118	8566	185	0.69
T2 x MP5¶¶	16.2	72369	119	8711	184	0.72
T1¶¶¶ x MP1	16.1	74362	119	9064	187	0.74
T1 x MP2	16.1	74466	119	9213	188	0.75
T1 x MP3	16.5	75846	119	8901	184	0.73
T1 x MP4	16.8	75836	118	8844	182	0.72
T1 x MP5	16.5	75812	118	9044	186	0.73
Probability	0.68	0.27	0.08	0.64	0.01	0.14

†MP=management practices.
‡MP 1=urea alone.
¶MP 2=urea plus nitrapyrin.
††MP 3=urea plus PCU.
‡‡MP 4=urea plus UAN.
¶¶MP 5=urea plus UAN with DCD plus NBPT.
†††T=tillage system.
‡‡‡T2=raised beds tillage.
¶¶¶T1=conventional tillage.

Table A57. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations 2012.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	13.1	57766	25.6	7992	187	0.70
T2 x MP2¶	13.1	55854	25.5	8501	189	0.70
T2 x MP3††	13.0	59189	25.5	8651	185	0.70
T2 x MP4‡‡	13.0	63370	25.5	8750	190	0.73
T2 x MP5¶¶	13.0	64791	25.6	8575	186	0.73
T1¶¶¶ x MP1	12.9	64269	25.9	8658	185	0.78
T1 x MP2	12.9	64926	25.9	8915	186	0.80
T1 x MP3	12.9	67065	25.9	8724	180	0.78
T1 x MP4	12.8	67881	25.9	9023	181	0.78
T1 x MP5	12.8	67671	25.9	9279	185	0.80
Probability	0.95	0.21	0.08	0.69	0.09	0.28

Table A58. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations 2013.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	18.3	79924	23.3	9007	185	0.68
T2 x MP2¶	18.5	78257	23.6	8793	184	0.70
T2 x MP3††	18.7	79492	23.6	8839	186	0.70
T2 x MP4‡‡	19.3	80070	23.5	8441	182	0.66
T2 x MP5¶¶	18.7	78711	23.7	8782	183	0.71
T1¶¶¶ x MP1	18.7	82355	23.5	9358	188	0.70
T1 x MP2	18.7	82066	23.6	9421	189	0.71
T1 x MP3	19.3	82930	23.4	9026	187	0.70
T1 x MP4	19.8	82313	23.3	8741	183	0.68
T1 x MP5	19.4	82375	23.4	8902	186	0.68
Probability	0.68	0.88	0.13	0.47	0.16	0.04

Table A59. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2012.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	13.9	57633	25.1	6681	175	0.63
T2 x MP2¶	14.1	55370	25.2	6848	171	0.60
T2 x MP3††	14.1	51253	25.0	6574	174	0.58
T2 x MP4‡‡	13.8	60310	25.2	6369	169	0.64
T2 x MP5¶¶	13.6	65867	25.1	7237	167	0.67
T1¶¶¶ x MP1	13.7	62780	25.6	6282	154	0.71
T1 x MP2	13.5	64425	25.7	6426	155	0.79
T1 x MP3	13.6	67102	25.8	6509	153	0.74
T1 x MP4	13.5	65043	25.6	5981	147	0.71
T1 x MP5	13.5	69365	25.6	7012	159	0.74
Probability	0.66	0.58	0.33	0.99	0.29	0.63

Table A60. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2012.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	13.6	55370	25.2	5946	166	0.54
T2 x MP2¶	13.8	45695	25.0	5927	169	0.62
T2 x MP3††	13.5	63190	24.9	6530	165	0.57
T2 x MP4‡‡	13.5	62985	25.0	6617	169	0.61
T2 x MP5¶¶	13.4	63397	25.1	6455	167	0.60
T1¶¶¶ x MP1	13.4	66895	25.5	7172	161	0.74
T1 x MP2	13.5	60927	25.6	6277	161	0.76
T1 x MP3	13.5	66690	25.6	6019	150	0.69
T1 x MP4	13.3	69365	25.7	6461	152	0.76
T1 x MP5	13.3	69778	25.6	7669	167	0.76
Probability	0.86	0.52	0.14	0.10	0.18	0.82

Table A61. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2012.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	11.8	72042	26.3	9752	191	0.79
T2 x MP2¶	11.7	71835	26.2	10996	196	0.77
T2 x MP3††	11.7	71939	26.1	10302	191	0.79
T2 x MP4‡‡	11.7	74204	26.2	10458	197	0.80
T2 x MP5¶¶	12.0	72248	26.3	9400	186	0.78
T1¶¶¶ x MP1	11.8	64734	26.3	9447	199	0.81
T1 x MP2	11.8	71526	26.2	11096	201	0.81
T1 x MP3	11.8	71734	26.1	10375	191	0.80
T1 x MP4	11.8	70395	26.1	10905	199	0.80
T1 x MP5	11.7	68955	26.0	10783	195	0.80
Probability	0.2	0.04	0.68	0.59	0.64	0.81

Table A62. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper in 2012.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	13.0	46313	25.9	9894	220	0.81
T2 x MP2¶	13.0	48577	25.7	10244	221	0.82
T2 x MP3††	13.0	50326	26.0	10880	214	0.82
T2 x MP4‡‡	13.0	56193	26.0	11459	224	0.84
T2 x MP5¶¶	12.9	58457	26.2	11447	222	0.83
T1¶¶¶ x MP1	12.6	63089	26.1	11787	226	0.87
T1 x MP2	12.6	62059	26.1	11498	227	0.86
T1 x MP3	12.6	62780	26.1	11699	225	0.86
T1 x MP4	12.6	66381	26.1	12249	223	0.86
T1 x MP5	12.5	63706	26.0	11709	225	0.87
Probability	0.99	0.10	0.03	0.29	0.34	0.38

Table A63. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2013.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	17.0	86038	23.4	7910	187	0.77
T2 x MP2¶	16.7	87994	23.2	7481	183	0.75
T2 x MP3††	17.1	88303	23.3	7264	183	0.74
T2 x MP4‡‡	17.1	85833	23.3	7417	180	0.73
T2 x MP5¶¶	16.7	86141	23.3	7298	179	0.74
T1¶¶¶ x MP1	17.3	85420	23.1	7921	185	0.74
T1 x MP2	17.2	84906	23.2	7811	187	0.74
T1 x MP3	17.3	86038	23.1	7557	183	0.72
T1 x MP4	17.0	87273	23.0	6729	182	0.70
T1 x MP5	18.2	84906	23.0	6960	183	0.73
Probability	0.06	0.69	0.26	0.34	0.71	0.97

Table A64. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2013.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	17.5	87685	23.4	7935	182	0.73
T2 x MP2¶	17.0	80171	23.2	6903	179	0.73
T2 x MP3††	17.1	83363	23.3	7393	182	0.73
T2 x MP4‡‡	18.3	87480	23.4	7284	176	0.69
T2 x MP5¶¶	18.1	78010	23.5	7298	176	0.77
T1¶¶¶ x MP1	17.6	85010	23.4	7926	185	0.73
T1 x MP2	17.3	85729	23.2	8034	184	0.72
T1 x MP3	17.7	87068	23.2	7825	185	0.75
T1 x MP4	18.7	87581	23.1	7899	184	0.69
T1 x MP5	18.1	84906	23.2	8166	185	0.71
Probability	0.88	0.09	0.46	0.38	0.54	0.36

Table A65. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2013.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	20.6	74512	24.1	11664	197	0.71
T2 x MP2¶	21.1	69572	24.1	11919	198	0.77
T2 x MP3††	20.8	74100	24.0	11936	201	0.77
T2 x MP4‡‡	21.2	71835	24.0	11733	199	0.78
T2 x MP5¶¶	21.0	72660	24.2	12025	199	0.77
T1¶¶¶ x MP1	22.4	74614	23.7	11720	201	0.68
T1 x MP2	21.2	75849	24.0	12007	201	0.76
T1 x MP3	22.4	75335	23.7	11471	199	0.68
T1 x MP4	22.6	76570	23.7	11410	194	0.69
T1 x MP5	22.2	78423	23.6	11720	199	0.70
Probability	0.07	0.33	0.19	0.92	0.47	0.53

Table A66. Effect of the T xM interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville in 2013.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	17.9	83259	24.0	9443	190	0.67
T2 x MP2¶	17.7	81406	23.9	9064	190	0.71
T2 x MP3††	17.9	80789	24.1	9934	193	0.69
T2 x MP4‡‡	17.7	82436	23.9	8543	191	0.69
T2 x MP5¶¶	18.1	81510	24.1	8920	187	0.69
T1¶¶¶ x MP1	18.2	83876	24.2	9789	193	0.68
T1 x MP2	18.6	80070	24.1	9744	199	0.69
T1 x MP3	18.9	82333	23.9	9460	193	0.69
T1 x MP4	18.4	79761	24.1	9102	190	0.68
T1 x MP5	18.1	80996	23.9	8718	193	0.65
Probability	0.19	0.39	0.21	0.20	0.12	0.89

Table A67. Effect of the T x M interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton in 2013.

T††† x MP†	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2‡‡‡ x MP1‡	18.6	68130	23.4	8107	171	0.45
T2 x MP2¶	20.2	72144	23.5	8905	172	0.46
T2 x MP3††	20.8	70909	23.4	7688	169	0.43
T2 x MP4‡‡	22.1	72761	23.0	7086	166	0.41
T2 x MP5¶¶	19.8	75231	23.5	8329	171	0.48
T1¶¶¶ x MP1	18.2	82849	23.7	9487	178	0.53
T1 x MP2	19.3	83775	23.6	9504	176	0.54
T1 x MP3	20.0	83876	23.4	8846	174	0.55
T1 x MP4	22.6	80379	22.9	8675	165	0.38
T1 x MP5	20.7	82641	23.2	8922	172	0.45
Probability	0.86	0.32	0.40	0.46	0.52	0.04

Table A68. Effect of the T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	16.3	71716	118	8395	183	0.69
T2 x R2††	16.2	70916	119	8755	187	0.71
T2 x R3‡‡	16.1	69985	119	8824	186	0.71
T1††† x R1	16.8	75063	118	8621	183	0.72
T1 x R2	16.2	75056	119	9061	186	0.73
T1 x R3	16.1	75673	119	9357	188	0.75
Probability	0.14	0.13	0.90	0.20	0.11	0.52

†T=tillage.
‡R=rate.
¶R1=low N rate.
††R2=medium N rate.
‡‡R3=high N rate.
¶¶T2=raised bed tillage.
†††T1=conventional tillage.

Table A69. Effect of the T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	13.0	61985	25.6	8497	187	0.73
T2 x R2††	13.0	60858	25.5	8619	189	0.71
T2 x R3‡‡	13.1	57739	25.5	8365	187	0.70
T1††† x R1	12.8	66697	25.9	8858	185	0.80
T1 x R2	12.8	65937	25.9	8808	183	0.79
T1 x R3	12.8	66453	25.9	9094	183	0.78
Probability	0.55	0.20	0.39	0.55	0.25	0.92

†T=tillage.
‡R=rate.
¶R1=low N rate (135 kg ha^{-1}).
††R2=medium N rate (180 kg ha^{-1}).
‡‡R3=high N rate (225 kg ha^{-1}).
¶¶T2=raised bed tillage.
†††T1=conventional tillage.

Table A70. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	18.9	79546	23.3	8305	180	0.68
T2 x R2††	18.8	78929	23.7	8875	186	0.70
T2 x R3‡‡	18.5	79398	23.7	9136	186	0.69
T1††† x R1	19.9	81868	23.2	8466	182	0.67
T1 x R2	18.9	82313	23.6	9245	188	0.69
T1 x R3	18.8	83041	23.6	9557	190	0.72
Probability	0.14	0.58	0.93	0.20	0.33	0.01

†T=tillage.
‡R=rate.
¶R1=low N rate (45 kg ha^{-1}).
††R2=medium N rate (90 kg ha^{-1}).
‡‡R3=high N rate (135 kg ha^{-1}).
¶¶T2=raised bed tillage.
†††T1=conventional tillage.

Table A71. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2012.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	13.7	60762	25.0	6917	172	0.65
T2 x R2††	14.0	56563	25.1	6544	169	0.60
T2 x R3‡‡	14.0	56934	25.2	6764	172	0.62
T1††† x R1	13.5	65826	25.6	6505	155	0.73
T1 x R2	13.5	66937	25.7	6563	153	0.76
T1 x R3	13.7	64467	25.7	6258	154	0.73
Probability	0.51	0.72	0.86	0.62	0.93	0.53

Table A72. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2012.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	13.6	56563	25.0	6161	169	0.58
T2 x R2††	13.4	63479	24.9	6526	169	0.60
T2 x R3‡‡	13.6	54340	25.1	6199	163	0.59
T1††† x R1	13.4	66690	25.6	6733	160	0.77
T1 x R2	13.4	66567	25.5	6490	154	0.73
T1 x R3	13.4	66937	25.7	6935	161	0.74
Probability	0.49	0.24	1.00	0.39	0.14	0.45

Table A73. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2012.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	11.8	73236	26.3	9640	189	0.78
T2 x R2††	11.7	73421	26.2	10710	195	0.79
T2 x R3‡‡	11.8	70704	26.2	10195	192	0.79
T1††† x R1	11.8	69716	26.2	10192	197	0.81
T1 x R2	11.8	68543	26.1	10376	196	0.80
T1 x R3	11.7	70148	26.0	10996	197	0.79
Probability	0.21	0.09	0.94	0.41	0.42	0.41

Table A74. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper in 2012.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	12.9	56131	25.9	11370	220	0.83
T2 x R2††	13.0	50944	26.0	10470	222	0.82
T2 x R3‡‡	13.1	48844	26.0	10514	219	0.81
T1††† x R1	12.6	64405	26.1	11870	227	0.86
T1 x R2	12.6	62615	26.1	11630	226	0.86
T1 x R3	12.6	63788	26.1	11865	223	0.86
Probability	0.02	0.13	0.60	0.34	0.64	0.32

Table A75. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2013.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	17.2	87129	23.2	7030	178	0.72
T2 x R2††	17.0	87068	23.5	7468	183	0.77
T2 x R3‡‡	16.6	86388	23.3	7924	186	0.76
T1††† x R1	18.3	83486	23.1	6802	179	0.70
T1 x R2	17.0	86759	23.1	7513	186	0.72
T1 x R3	16.9	86882	23.1	7872	187	0.76
Probability	0.07	0.23	0.04	0.82	0.90	0.20

Table A76. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2013.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	18.2	83795	23.3	6802	172	0.72
T2 x R2††	17.1	80522	23.4	7645	183	0.74
T2 x R3‡‡	17.4	85709	23.3	7642	181	0.73
T1††† x R1	18.0	86450	23.2	7404	182	0.70
T1 x R2	17.7	85462	23.3	8243	185	0.73
T1 x R3	18.0	86265	23.2	8263	186	0.73
Probability	0.18	0.35	0.81	1.00	0.11	0.85

Table A77. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2013.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	21.0	70642	24.1	11572	197	0.76
T2 x R2††	21.0	73668	24.1	11938	200	0.77
T2 x R3‡‡	20.9	73297	24.1	12056	199	0.75
T1††† x R1	23.2	75953	23.3	10906	193	0.66
T1 x R2	21.7	76323	23.9	12070	199	0.73
T1 x R3	21.6	76200	23.9	12021	204	0.71
Probability	0.00	0.58	0.00	0.33	0.10	0.28

Table A78. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville in 2013.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	18.0	82807	23.9	8414	186	0.67
T2 x R2††	17.9	81757	24.1	9560	194	0.71
T2 x R3‡‡	17.8	81078	24.0	9568	191	0.68
T1††† x R1	18.7	81510	23.9	8660	190	0.65
T1 x R2	18.3	80831	24.2	9521	195	0.68
T1 x R3	18.3	81881	24.1	9906	196	0.70
Probability	0.66	0.45	0.07	0.67	0.43	0.33

Table A79. Effect of T x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton in 2013.

†T x ‡R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2¶¶ x R1¶	20.1	73359	23.1	7709	167	0.41
T2 x R2††	21.0	71630	23.4	7877	170	0.45
T2 x R3‡‡	19.8	70519	23.6	8483	174	0.49
T1††† x R1	21.4	81942	23.1	8557	168	0.43
T1 x R2	19.8	82189	23.3	8821	172	0.51
T1 x R3	19.3	83980	23.7	9882	178	0.53
Probability	0.26	0.32	0.84	0.59	0.78	0.69

Table A80. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	16.1	72586	116	8432	183	0.71
MP1 x R2	16.0	71477	119	8819	188	0.72
MP1 x R3	16.1	72872	119	9252	190	0.73
MP2 x R1	16.4	71176	118	8510	185	0.71
MP2 x R2	16.0	72309	119	9028	187	0.74
MP2 x R3	16.0	70985	119	9287	189	0.73
MP3 x R1	16.8	74179	118	8538	182	0.70
MP3 x R2	16.3	73129	119	9031	187	0.73
MP3 x R3	15.9	72354	119	8893	186	0.73
MP4 x R1	17.0	74130	118	8301	181	0.68
MP4 x R2	16.5	74290	119	8743	185	0.71
MP4 x R3	16.3	74280	119	9071	186	0.72
MP5 x R1	16.5	74878	118	8760	185	0.73
MP5 x R2	16.3	73730	119	8920	185	0.72
MP5 x R3	16.2	73663	119	8951	185	0.72
Probability	0.72	0.31	0.82	0.48	0.08	0.46

Table A81. Effect of the M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	13.0	62471	25.8	8158	187	0.74
MP1 x R2	12.9	59292	25.7	8260	185	0.73
MP1 x R3	13.0	61288	25.8	8558	187	0.75
MP2 x R1	12.9	59379	25.8	8522	190	0.76
MP2 x R2	13.0	62358	25.7	8806	186	0.74
MP2 x R3	13.0	59438	25.6	8797	188	0.74
MP3 x R1	12.9	65376	25.8	8399	180	0.75
MP3 x R2	12.9	64138	25.7	9012	187	0.74
MP3 x R3	13.0	59868	25.7	8652	181	0.72
MP4 x R1	12.9	66263	25.7	8943	184	0.75
MP4 x R2	12.9	65709	25.7	8802	187	0.75
MP4 x R3	12.9	64907	25.7	8915	185	0.75
MP5 x R1	12.8	68221	25.7	9366	187	0.80
MP5 x R2	12.9	65490	25.7	8688	185	0.77
MP5 x R3	13.0	64981	25.7	8725	184	0.73
Probability	0.33	0.02	0.55	0.85	0.42	0.54

Table A82. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	18.5	80646	22.7	8595	180	0.67
MP1 x R2	18.4	80801	23.7	9209	189	0.70
MP1 x R3	18.6	81974	23.7	9743	191	0.70
MP2 x R1	19.1	80213	23.5	8488	182	0.67
MP2 x R2	18.4	80431	23.7	9202	188	0.71
MP2 x R3	18.3	79843	23.7	9630	190	0.72
MP3 x R1	19.8	81172	23.4	8615	182	0.67
MP3 x R2	18.9	80431	23.7	9099	188	0.70
MP3 x R3	18.3	82036	23.5	9084	189	0.72
MP4 x R1	20.2	80831	23.3	7872	178	0.65
MP4 x R2	19.4	81110	23.5	8728	184	0.67
MP4 x R3	19.1	81634	23.5	9173	186	0.68
MP5 x R1	19.4	80678	23.5	8359	184	0.69
MP5 x R2	19.0	80337	23.6	9064	185	0.68
MP5 x R3	18.8	80616	23.6	9103	185	0.70
Probability	0.45	0.98	0.67	0.40	0.01	0.87

Table A83. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2012.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	13.9	62676	25.3	6372	169	0.64
MP1 x R2	13.9	57428	25.3	6609	163	0.66
MP1 x R3	13.7	60515	25.4	6463	161	0.72
MP2 x R1	13.6	61441	25.4	7284	167	0.72
MP2 x R2	13.9	59589	25.6	6450	159	0.70
MP2 x R3	13.8	58663	25.4	6176	164	0.67
MP3 x R1	13.6	64838	25.2	6497	163	0.70
MP3 x R2	13.8	58971	25.4	6838	165	0.67
MP3 x R3	14.1	53723	25.5	6288	163	0.61
MP4 x R1	13.5	60206	25.3	6014	156	0.67
MP4 x R2	13.7	64220	25.4	6088	154	0.65
MP4 x R3	13.8	63603	25.5	6423	163	0.71
MP5 x R1	13.5	67308	25.2	7388	161	0.73
MP5 x R2	13.6	68543	25.4	6781	163	0.70
MP5 x R3	13.6	66999	25.5	7205	164	0.68
Probability	0.97	0.94	0.71	0.73	0.78	0.90

Table A84. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2012.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	13.6	61441	25.4	6502	162	0.59
MP1 x R2	13.4	62676	25.2	6665	161	0.66
MP1 x R3	13.4	59280	25.4	6510	167	0.68
MP2 x R1	13.6	48783	25.2	5937	167	0.68
MP2 x R2	13.5	55266	25.2	6313	168	0.67
MP2 x R3	13.7	55884	25.5	6056	160	0.71
MP3 x R1	13.5	68543	25.4	6210	157	0.64
MP3 x R2	13.4	69778	25.0	6331	159	0.63
MP3 x R3	13.5	56501	25.3	6283	157	0.64
MP4 x R1	13.5	62368	25.2	6346	164	0.70
MP4 x R2	13.4	69778	25.2	6036	156	0.69
MP4 x R3	13.3	66381	25.6	7236	162	0.67
MP5 x R1	13.3	66999	25.4	7242	172	0.75
MP5 x R2	13.3	67616	25.3	7195	165	0.69
MP5 x R3	13.4	65146	25.4	6749	163	0.61
Probability	0.91	0.64	0.55	0.79	0.75	0.35

Table A85. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2012.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	11.9	69007	26.5	8539	194	0.82
MP1 x R2	11.7	67463	26.1	10206	193	0.79
MP1 x R3	11.8	68698	26.2	10053	197	0.77
MP2 x R1	11.8	70242	26.3	10464	201	0.80
MP2 x R2	11.8	72865	26.2	10986	194	0.77
MP2 x R3	11.6	71939	26.1	11689	199	0.80
MP3 x R1	11.8	71786	26.2	8925	182	0.79
MP3 x R2	11.7	73947	26.0	11396	198	0.81
MP3 x R3	11.7	69778	26.0	10696	193	0.79
MP4 x R1	11.7	73483	26.1	10842	194	0.79
MP4 x R2	11.9	70704	26.2	10385	203	0.81
MP4 x R3	11.7	72712	26.1	10818	195	0.80
MP5 x R1	11.7	72865	26.0	10809	192	0.78
MP5 x R2	11.8	69931	26.3	9743	190	0.79
MP5 x R3	12.0	69007	26.2	9723	190	0.80
Probability	0.51	0.34	0.72	0.19	0.12	0.59

Table A86. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper in 2012.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	12.8	57428	25.8	11487	224	0.85
MP1 x R2	12.8	50944	26.1	9917	222	0.81
MP1 x R3	12.8	55728	26.1	11117	223	0.84
MP2 x R1	12.7	55422	26.1	10603	224	0.84
MP2 x R2	12.8	58201	25.8	11181	223	0.84
MP2 x R3	13.0	52334	25.8	10829	225	0.83
MP3 x R1	12.8	60053	26.0	12090	221	0.84
MP3 x R2	12.8	55113	26.1	10687	225	0.84
MP3 x R3	12.8	54493	26.0	11091	212	0.83
MP4 x R1	12.7	64067	26.0	11973	223	0.85
MP4 x R2	12.8	60979	26.2	12145	225	0.85
MP4 x R3	12.9	58818	26.0	11443	223	0.85
MP5 x R1	12.7	64373	26.0	11946	224	0.86
MP5 x R2	12.8	58663	26.1	11323	224	0.84
MP5 x R3	12.7	60206	26.2	11467	222	0.84
Probability	0.39	0.61	0.36	0.31	0.69	0.68

Table A87. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2013.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	17.9	84442	23.2	7094	175	0.70
MP1 x R2	16.8	85215	23.3	7843	189	0.75
MP1 x R3	16.9	87529	23.3	8811	195	0.81
MP2 x R1	17.7	85524	23.2	7078	179	0.71
MP2 x R2	16.6	88456	23.2	7610	188	0.78
MP2 x R3	16.6	85368	23.3	8251	187	0.74
MP3 x R1	17.5	86450	23.0	6888	179	0.70
MP3 x R2	17.5	88456	23.4	7806	184	0.75
MP3 x R3	16.7	86603	23.1	7538	185	0.76
MP4 x R1	17.7	85833	23.1	6585	179	0.69
MP4 x R2	16.9	86450	23.3	7000	179	0.73
MP4 x R3	16.5	87376	23.2	7635	185	0.72
MP5 x R1	18.1	84289	23.1	6939	181	0.74
MP5 x R2	17.2	85986	23.3	7193	182	0.71
MP5 x R3	17.1	86294	23.2	7255	181	0.76
Probability	0.85	0.96	0.63	0.59	0.06	0.09

Table A88. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2013.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	17.6	87068	23.4	7075	177	0.71
MP1 x R2	17.2	85679	23.5	8482	188	0.74
MP1 x R3	17.8	86294	23.3	8234	185	0.74
MP2 x R1	17.2	82745	23.2	6973	176	0.73
MP2 x R2	17.1	79966	23.3	7337	183	0.72
MP2 x R3	17.2	86141	23.2	8097	186	0.72
MP3 x R1	18.2	86914	23.2	7146	177	0.72
MP3 x R2	16.8	81357	23.4	8092	187	0.73
MP3 x R3	17.2	87376	23.1	7589	186	0.78
MP4 x R1	18.6	89229	23.2	6998	176	0.67
MP4 x R2	18.1	87376	23.3	7764	181	0.73
MP4 x R3	18.6	85986	23.2	8015	182	0.68
MP5 x R1	18.9	79658	23.3	7322	180	0.75
MP5 x R2	17.8	80584	23.3	8048	182	0.75
MP5 x R3	17.6	84133	23.4	7826	180	0.72
Probability	0.48	0.62	0.93	0.73	0.57	0.48

Table A89. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2013.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	21.4	76417	23.8	11281	194	0.71
MP1 x R2	21.3	75026	23.9	11567	199	0.69
MP1 x R3	21.8	72248	24.0	12227	203	0.68
MP2 x R1	21.7	71630	23.9	11537	194	0.74
MP2 x R2	21.0	74409	24.2	12600	202	0.80
MP2 x R3	20.8	72094	24.1	11754	203	0.75
MP3 x R1	21.8	73021	23.8	11679	197	0.71
MP3 x R2	22.2	75335	23.7	11394	198	0.72
MP3 x R3	20.9	75799	24.0	12037	205	0.75
MP4 x R1	23.3	72556	23.4	10621	189	0.70
MP4 x R2	21.1	73174	24.2	12409	200	0.78
MP4 x R3	21.3	76879	23.9	11684	199	0.74
MP5 x R1	22.2	72865	23.7	11076	199	0.70
MP5 x R2	21.2	77034	24.0	12050	199	0.78
MP5 x R3	21.4	76726	24.0	12491	198	0.72
Probability	0.01	0.61	0.08	0.30	0.69	0.77

Table A90. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville in 2013.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	18.4	81972	24.1	9142	186	0.63
MP1 x R2	17.6	83516	24.1	9489	193	0.71
MP1 x R3	18.2	85215	24.1	10217	195	0.67
MP2 x R1	18.3	83671	23.7	8768	191	0.66
MP2 x R2	18.1	79349	24.4	9285	193	0.71
MP2 x R3	18.2	79196	24.0	10160	198	0.72
MP3 x R1	18.7	80584	23.9	8869	189	0.68
MP3 x R2	18.6	80893	24.2	10314	199	0.71
MP3 x R3	17.9	83209	23.9	9907	192	0.68
MP4 x R1	18.0	81201	23.9	7929	185	0.69
MP4 x R2	18.0	82901	23.9	9154	196	0.67
MP4 x R3	18.1	79193	24.2	9385	191	0.69
MP5 x R1	18.6	83363	23.9	7979	188	0.66
MP5 x R2	18.0	79813	24.1	9460	192	0.67
MP5 x R3	17.7	80584	24.0	9017	190	0.69
Probability	0.38	0.04	0.26	0.47	0.44	0.61

Table A91. Effect of M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton in 2013.

M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
MP1 x R1	17.6	73327	23.2	8381	166	0.43
MP1 x R2	19.1	74562	23.6	8746	178	0.54
MP1 x R3	18.5	78576	23.9	9266	179	0.51
MP2 x R1	20.7	77496	23.2	8133	171	0.45
MP2 x R2	19.4	79966	23.5	9591	175	0.52
MP2 x R3	19.1	76414	23.9	9890	177	0.53
MP3 x R1	22.7	78884	22.9	8564	168	0.44
MP3 x R2	19.5	76106	23.6	7888	170	0.51
MP3 x R3	19.1	77188	23.7	8349	176	0.52
MP4 x R1	23.2	75335	22.8	7108	161	0.34
MP4 x R2	22.9	75644	22.8	6987	162	0.38
MP4 x R3	20.9	78731	23.2	9545	172	0.47
MP5 x R1	19.6	83209	23.4	8480	171	0.44
MP5 x R2	21.0	78269	23.2	8532	169	0.46
MP5 x R3	20.2	75335	23.5	8864	175	0.50
Probability	0.44	0.31	0.38	0.04	0.45	0.85

Table A92. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	15.8	70731	115	8319	181	0.69
T2 x M1 x R2	16.1	69279	119	8509	189	0.70
T2 x M1 x R3	16.1	70770	119	8983	189	0.69
T2 x M2 x R1	16.3	68350	118	8310	184	0.69
T2 x M2 x R2	16.1	70155	119	8859	187	0.72
T2 x M2 x R3	15.9	67036	118	8841	189	0.71
T2 x M3 x R1	16.4	71991	118	8416	182	0.68
T2 x M3 x R2	16.4	70783	119	8918	189	0.71
T2 x M3 x R3	15.8	69009	118	8888	186	0.73
T2 x M4 x R1	16.6	74117	118	8334	184	0.68
T2 x M4 x R2	16.6	71971	118	8656	186	0.69
T2 x M4 x R3	16.3	71798	119	8708	186	0.69
T2 x M5 x R1	16.3	73391	119	8597	183	0.73
T2 x M5 x R2	16.0	72396	119	8832	186	0.72
T2 x M5 x R3	16.2	71316	120	8703	183	0.71
T1 x M1 x R1	16.4	74441	118	8544	184	0.73
T1 x M1 x R2	15.8	73673	119	9127	186	0.74
T1 x M1 x R3	16.2	74974	119	9523	191	0.76
T1 x M2 x R1	16.5	74001	119	8711	187	0.74
T1 x M2 x R2	15.9	74463	119	9196	188	0.75
T1 x M2 x R3	16.0	74932	120	9733	190	0.75
T1 x M3 x R1	17.2	76367	118	8660	181	0.72
T1 x M3 x R2	16.1	75476	119	9144	186	0.74
T1 x M3 x R3	16.1	75696	119	8898	186	0.74
T1 x M4 x R1	17.4	74144	118	8267	177	0.69
T1 x M4 x R2	16.5	76607	119	8830	184	0.72
T1 x M4 x R3	16.4	76760	119	9434	186	0.75
T1 x M5 x R1	16.8	76365	118	8924	187	0.73
T1 x M5 x R2	16.6	75063	118	9007	184	0.71
T1 x M5 x R3	16.2	76007	118	9199	187	0.74
Probability	0.58	0.48	0.84	0.83	0.61	0.23

Table A93. Effect of the T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	13.1	59082	25.7	8029	187	0.69
T2 x M1 x R2	13.1	55652	25.6	7909	187	0.68
T2 x M1 x R3	13.1	58559	25.6	8037	189	0.72
T2 x M2 x R1	13.0	56331	25.6	8297	189	0.70
T2 x M2 x R2	13.1	58537	25.5	8733	187	0.71
T2 x M2 x R3	13.2	52700	25.5	8473	192	0.70
T2 x M3 x R1	13.0	61345	25.6	8133	182	0.70
T2 x M3 x R2	13.0	60826	25.5	9076	191	0.69
T2 x M3 x R3	13.1	55397	25.5	8743	181	0.71
T2 x M4 x R1	13.0	65922	25.6	8925	189	0.74
T2 x M4 x R2	13.0	64237	25.4	8990	193	0.72
T2 x M4 x R3	13.0	59957	25.6	8335	188	0.72
T2 x M5 x R1	12.8	67248	25.6	9103	185	0.80
T2 x M5 x R2	13.0	65040	25.7	8384	188	0.75
T2 x M5 x R3	13.2	62081	25.5	8236	184	0.65
T1 x M1 x R1	12.9	65860	25.9	8287	187	0.79
T1 x M1 x R2	12.8	62933	25.8	8610	183	0.78
T1 x M1 x R3	12.8	64017	26.0	9079	186	0.78
T1 x M2 x R1	12.8	62427	26.0	8746	190	0.82
T1 x M2 x R2	12.9	66179	25.9	8878	185	0.78
T1 x M2 x R3	12.9	66179	25.8	9120	184	0.79
T1 x M3 x R1	12.9	69407	25.9	8664	178	0.79
T1 x M3 x R2	12.8	67448	25.9	8947	183	0.80
T1 x M3 x R3	12.9	64336	25.9	8561	180	0.74
T1 x M4 x R1	12.7	66604	25.9	8961	180	0.77
T1 x M4 x R2	12.9	67184	26.0	8615	181	0.79
T1 x M4 x R3	12.8	69857	25.9	9496	183	0.79
T1 x M5 x R1	12.8	69195	25.8	9630	188	0.81
T1 x M5 x R2	12.8	65937	25.8	8992	183	0.78
T1 x M5 x R3	12.7	67878	26.0	9215	185	0.81
Probability	0.79	0.27	0.54	0.86	0.82	0.20

Table A94. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	18.0	79966	22.4	8482	177	0.68
T2 x M1 x R2	18.5	79534	23.8	8915	190	0.69
T2 x M1 x R3	18.5	80275	23.7	9622	189	0.68
T2 x M2 x R1	18.9	77682	23.5	8287	180	0.67
T2 x M2 x R2	18.5	79411	23.7	8986	186	0.71
T2 x M2 x R3	18.2	77682	23.6	9106	187	0.71
T2 x M3 x R1	19.1	80090	23.5	8563	181	0.67
T2 x M3 x R2	19.0	78731	23.7	8925	187	0.72
T2 x M3 x R3	18.1	79658	23.6	9029	189	0.71
T2 x M4 x R1	19.5	81078	23.5	7951	181	0.66
T2 x M4 x R2	19.4	78423	23.6	8458	182	0.66
T2 x M4 x R3	19.0	80707	23.6	8917	184	0.66
T2 x M5 x R1	19.0	78917	23.6	8246	181	0.70
T2 x M5 x R2	18.5	78546	23.7	9093	185	0.71
T2 x M5 x R3	18.7	78670	23.8	9008	182	0.71
T1 x M1 x R1	19.1	81325	23.1	8707	182	0.67
T1 x M1 x R2	18.3	82066	23.6	9503	189	0.72
T1 x M1 x R3	18.8	83671	23.7	9863	194	0.72
T1 x M2 x R1	19.3	82745	23.5	8690	184	0.67
T1 x M2 x R2	18.3	81448	23.7	9418	190	0.72
T1 x M2 x R3	18.5	82004	23.8	10155	193	0.72
T1 x M3 x R1	20.4	82251	23.2	8667	183	0.68
T1 x M3 x R2	18.8	82128	23.6	9273	188	0.69
T1 x M3 x R3	18.6	84412	23.5	9139	189	0.73
T1 x M4 x R1	20.9	80584	23.1	7794	175	0.64
T1 x M4 x R2	19.4	83795	23.4	8998	185	0.67
T1 x M4 x R3	19.2	82560	23.5	9429	187	0.71
T1 x M5 x R1	19.9	82436	23.3	8472	186	0.68
T1 x M5 x R2	19.6	82128	23.4	9035	185	0.65
T1 x M5 x R3	18.9	82560	23.4	9198	188	0.69
Probability	0.52	0.62	0.64	0.83	0.38	0.58

Table A95. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2012.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	13.9	58663	25.1	6642	181	0.58
T2 x M1 x R2	14.3	50018	24.9	6151	175	0.58
T2 x M1 x R3	13.5	64220	25.2	7250	168	0.73
T2 x M2 x R1	13.8	60515	25.0	7803	178	0.63
T2 x M2 x R2	14.1	52488	25.4	6527	162	0.62
T2 x M2 x R3	14.3	53105	25.1	6214	173	0.54
T2 x M3 x R1	13.6	58663	24.8	6553	171	0.64
T2 x M3 x R2	14.2	51870	24.9	6684	175	0.51
T2 x M3 x R3	14.4	43225	25.2	6485	177	0.60
T2 x M4 x R1	13.7	58663	25.1	6103	169	0.71
T2 x M4 x R2	14.0	61133	25.1	6514	164	0.56
T2 x M4 x R3	13.9	61133	25.3	6491	174	0.66
T2 x M5 x R1	13.6	67308	25.1	7482	162	0.69
T2 x M5 x R2	13.6	67308	25.3	6847	168	0.71
T2 x M5 x R3	13.6	62985	25.1	7383	169	0.60
T1 x M1 x R1	13.8	66690	25.5	6103	158	0.70
T1 x M1 x R2	13.5	64838	25.6	7068	151	0.74
T1 x M1 x R3	13.9	56810	25.7	5676	154	0.71
T1 x M2 x R1	13.3	62368	25.7	6766	155	0.81
T1 x M2 x R2	13.7	66690	25.8	6373	155	0.79
T1 x M2 x R3	13.4	64220	25.6	6139	155	0.79
T1 x M3 x R1	13.6	71013	25.7	6441	156	0.75
T1 x M3 x R2	13.3	66073	26.0	6993	155	0.83
T1 x M3 x R3	13.8	64220	25.7	6091	149	0.62
T1 x M4 x R1	13.4	61750	25.5	5924	144	0.63
T1 x M4 x R2	13.4	67308	25.7	5662	145	0.74
T1 x M4 x R3	13.6	66073	25.6	6356	152	0.76
T1 x M5 x R1	13.4	67308	25.4	7293	160	0.76
T1 x M5 x R2	13.6	69778	25.6	6716	158	0.69
T1 x M5 x R3	13.6	71013	25.9	7027	159	0.77
Probability	0.81	0.90	0.55	0.80	0.87	0.54

Table A96. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2012.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	13.7	50018	25.3	5958	166	0.47
T2 x M1 x R2	13.3	62368	24.9	6500	161	0.59
T2 x M1 x R3	13.7	53723	25.3	5380	169	0.57
T2 x M2 x R1	14.1	39520	24.7	5425	173	0.55
T2 x M2 x R2	13.6	51253	24.9	5860	174	0.60
T2 x M2 x R3	13.6	46313	25.2	6495	160	0.70
T2 x M3 x R1	13.4	67925	25.0	7072	164	0.55
T2 x M3 x R2	13.5	70395	24.7	6148	168	0.57
T2 x M3 x R3	13.5	51253	24.8	6370	162	0.60
T2 x M4 x R1	13.9	62368	24.9	5386	167	0.59
T2 x M4 x R2	13.3	67925	24.7	6911	173	0.65
T2 x M4 x R3	13.3	58663	25.4	7555	168	0.59
T2 x M5 x R1	13.2	62985	25.1	6964	176	0.71
T2 x M5 x R2	13.3	65455	25.2	7207	170	0.60
T2 x M5 x R3	13.6	61750	25.0	5193	154	0.48
T1 x M1 x R1	13.5	72865	25.4	7046	159	0.72
T1 x M1 x R2	13.5	62985	25.5	6830	161	0.72
T1 x M1 x R3	13.1	64838	25.6	7640	165	0.79
T1 x M2 x R1	13.2	58045	25.6	6448	162	0.81
T1 x M2 x R2	13.5	59280	25.5	6766	163	0.74
T1 x M2 x R3	13.9	65455	25.7	5617	159	0.73
T1 x M3 x R1	13.7	69160	25.7	5348	149	0.72
T1 x M3 x R2	13.2	69160	25.3	6512	149	0.69
T1 x M3 x R3	13.5	61750	25.8	6196	152	0.67
T1 x M4 x R1	13.2	62368	25.6	7305	162	0.80
T1 x M4 x R2	13.5	71630	25.8	5160	139	0.74
T1 x M4 x R3	13.3	74100	25.9	6916	155	0.75
T1 x M5 x R1	13.4	71013	25.7	7520	168	0.78
T1 x M5 x R2	13.4	69778	25.4	7183	160	0.78
T1 x M5 x R3	13.3	68543	25.7	8305	172	0.73
Probability	0.06	0.88	0.24	0.03	0.56	0.46

Table A97. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2012.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	11.9	72248	26.5	8852	187	0.81
T2 x M1 x R2	11.7	71013	26.1	10614	189	0.77
T2 x M1 x R3	11.9	72865	26.2	9789	196	0.79
T2 x M2 x R1	11.7	73174	26.3	10337	195	0.77
T2 x M2 x R2	11.7	72248	26.4	11050	193	0.79
T2 x M2 x R3	11.6	70086	26.0	11601	198	0.76
T2 x M3 x R1	11.9	69778	26.3	7811	182	0.78
T2 x M3 x R2	11.5	75953	26.0	11948	200	0.79
T2 x M3 x R3	11.6	70086	25.9	11148	190	0.81
T2 x M4 x R1	11.6	75953	26.1	11179	193	0.79
T2 x M4 x R2	11.9	75026	26.2	10731	204	0.81
T2 x M4 x R3	11.7	71630	26.4	9464	193	0.81
T2 x M5 x R1	11.7	75026	26.0	10020	186	0.76
T2 x M5 x R2	11.9	72865	26.5	9205	189	0.80
T2 x M5 x R3	12.3	68851	26.4	8976	184	0.79
T1 x M1 x R1	11.8	65764	26.4	8227	201	0.84
T1 x M1 x R2	11.8	63911	26.2	9797	197	0.82
T1 x M1 x R3	11.7	64529	26.2	10317	198	0.76
T1 x M2 x R1	11.9	67308	26.3	10591	207	0.83
T1 x M2 x R2	11.8	73483	26.1	10922	195	0.75
T1 x M2 x R3	11.7	73791	26.2	11776	200	0.83
T1 x M3 x R1	11.8	73791	26.2	10039	182	0.81
T1 x M3 x R2	11.9	71939	26.1	10844	196	0.82
T1 x M3 x R3	11.8	69469	26.0	10244	196	0.78
T1 x M4 x R1	11.7	71013	26.2	10506	195	0.79
T1 x M4 x R2	11.9	66381	26.3	10038	202	0.82
T1 x M4 x R3	11.7	73791	25.9	12171	198	0.79
T1 x M5 x R1	11.7	70704	25.9	11598	198	0.79
T1 x M5 x R2	11.7	66999	26.2	10280	192	0.79
T1 x M5 x R3	11.6	69160	25.9	10470	195	0.81
Probability	0.66	0.19	0.87	0.65	0.96	0.34

Table A98. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Prosper in 2012.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	13.0	51561	25.6	10914	219	0.84
T2 x M1 x R2	13.2	41373	26.2	8736	223	0.77
T2 x M1 x R3	12.9	46004	25.9	10032	219	0.81
T2 x M2 x R1	12.7	49400	26.0	10049	217	0.82
T2 x M2 x R2	13.0	53723	25.5	11015	218	0.82
T2 x M2 x R3	13.4	42608	25.8	9669	228	0.81
T2 x M3 x R1	13.0	54958	26.1	11965	217	0.82
T2 x M3 x R2	13.0	47548	26.0	9924	221	0.82
T2 x M3 x R3	13.1	48474	25.9	10750	203	0.81
T2 x M4 x R1	12.9	62368	25.8	11889	225	0.85
T2 x M4 x R2	12.9	55266	26.1	11741	225	0.84
T2 x M4 x R3	13.1	50944	26.0	10746	221	0.83
T2 x M5 x R1	12.8	62368	26.0	12032	220	0.85
T2 x M5 x R2	12.9	56810	26.3	10935	225	0.82
T2 x M5 x R3	13.0	56193	26.3	11376	222	0.81
T1 x M1 x R1	12.7	63294	26.1	12060	229	0.87
T1 x M1 x R2	12.5	60515	26.0	11098	222	0.86
T1 x M1 x R3	12.6	65455	26.3	12203	227	0.87
T1 x M2 x R1	12.6	61441	26.2	11157	231	0.86
T1 x M2 x R2	12.6	62676	26.2	11347	228	0.86
T1 x M2 x R3	12.6	62059	25.9	11989	221	0.86
T1 x M3 x R1	12.6	65146	26.0	12214	226	0.86
T1 x M3 x R2	12.6	62676	26.2	11450	229	0.86
T1 x M3 x R3	12.6	60515	26.1	11433	220	0.86
T1 x M4 x R1	12.6	65764	26.2	12058	220	0.85
T1 x M4 x R2	12.6	66690	26.3	12548	226	0.86
T1 x M4 x R3	12.6	66690	25.9	12141	224	0.87
T1 x M5 x R1	12.6	66381	25.9	11860	229	0.87
T1 x M5 x R2	12.6	60515	25.9	11711	223	0.86
T1 x M5 x R3	12.4	64220	26.1	11557	221	0.87
Probability	0.11	0.91	0.37	0.92	0.48	0.96

Table A99. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-untiled in 2013.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	18.0	86141	23.3	7227	172	0.72
T2 x M1 x R2	16.3	85524	23.4	7736	192	0.77
T2 x M1 x R3	16.8	86450	23.5	8766	195	0.81
T2 x M2 x R1	17.2	87685	23.1	7122	179	0.72
T2 x M2 x R2	16.8	89846	23.3	7534	185	0.79
T2 x M2 x R3	16.2	86450	23.3	7789	184	0.74
T2 x M3 x R1	17.1	85833	23.1	6589	179	0.68
T2 x M3 x R2	17.6	90773	23.5	7578	182	0.77
T2 x M3 x R3	16.6	88303	23.1	7625	188	0.79
T2 x M4 x R1	17.2	87685	23.1	7268	183	0.72
T2 x M4 x R2	17.5	83363	23.6	7178	175	0.77
T2 x M4 x R3	16.7	86450	23.3	7804	183	0.70
T2 x M5 x R1	16.7	88303	23.1	6946	177	0.75
T2 x M5 x R2	16.7	85833	23.4	7312	182	0.73
T2 x M5 x R3	16.8	84289	23.4	7634	179	0.75
T1 x M1 x R1	17.8	82745	23.1	6960	177	0.68
T1 x M1 x R2	17.2	84906	23.1	7949	185	0.74
T1 x M1 x R3	17.0	88611	23.1	8856	194	0.81
T1 x M2 x R1	18.2	83363	23.4	7033	179	0.70
T1 x M2 x R2	16.4	87068	23.0	7686	191	0.77
T1 x M2 x R3	16.9	84289	23.3	8714	190	0.74
T1 x M3 x R1	17.9	87068	22.9	7186	180	0.71
T1 x M3 x R2	17.4	86141	23.2	8035	187	0.73
T1 x M3 x R3	16.8	84906	23.0	7450	182	0.73
T1 x M4 x R1	18.2	83980	23.0	5901	174	0.66
T1 x M4 x R2	16.4	89538	22.9	6822	183	0.68
T1 x M4 x R3	16.3	88303	23.1	7466	187	0.75
T1 x M5 x R1	19.4	80275	23.0	6932	185	0.72
T1 x M5 x R2	17.7	86141	23.2	7073	183	0.69
T1 x M5 x R3	17.5	88303	22.9	6875	182	0.76
Probability	0.43	0.53	0.60	0.88	0.33	0.41

Table A100. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Fargo-tiled in 2013.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	17.6	88920	23.5	7246	175	0.73
T2 x M1 x R2	17.3	85215	23.5	8480	187	0.73
T2 x M1 x R3	17.7	88920	23.2	8078	184	0.72
T2 x M2 x R1	16.9	78423	23.2	6243	172	0.74
T2 x M2 x R2	17.0	77496	23.2	6925	182	0.73
T2 x M2 x R3	17.1	84598	23.3	7542	184	0.72
T2 x M3 x R1	18.5	84906	23.3	7320	175	0.69
T2 x M3 x R2	16.5	77805	23.4	7572	185	0.73
T2 x M3 x R3	16.4	87376	23.2	7287	185	0.78
T2 x M4 x R1	18.2	91081	23.1	6209	170	0.70
T2 x M4 x R2	17.8	84906	23.6	7509	181	0.72
T2 x M4 x R3	18.8	86450	23.4	8136	176	0.65
T2 x M5 x R1	20.0	75644	23.5	6988	171	0.76
T2 x M5 x R2	17.2	77188	23.4	7742	180	0.78
T2 x M5 x R3	17.1	81201	23.6	7164	178	0.76
T1 x M1 x R1	17.7	85215	23.2	6903	180	0.68
T1 x M1 x R2	17.1	86141	23.5	8483	189	0.75
T1 x M1 x R3	18.0	83671	23.3	8390	187	0.76
T1 x M2 x R1	17.5	87068	23.1	7702	180	0.72
T1 x M2 x R2	17.2	82436	23.4	7748	184	0.71
T1 x M2 x R3	17.3	87685	23.2	8651	188	0.72
T1 x M3 x R1	18.0	88920	23.1	6973	180	0.75
T1 x M3 x R2	17.2	84906	23.4	8612	190	0.73
T1 x M3 x R3	18.0	87376	23.1	7891	187	0.77
T1 x M4 x R1	19.1	87376	23.3	7787	182	0.64
T1 x M4 x R2	18.5	89846	23.1	8018	181	0.74
T1 x M4 x R3	18.5	85524	23.0	7894	188	0.70
T1 x M5 x R1	17.7	83671	23.1	7655	189	0.74
T1 x M5 x R2	18.5	83980	23.3	8356	184	0.71
T1 x M5 x R3	18.1	87068	23.2	8488	183	0.67
Probability	0.08	0.96	0.52	0.60	0.79	0.62

Table A101. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Hitterdal in 2013.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	19.8	76570	24.2	11552	192	0.76
T2 x M1 x R2	20.8	77496	24.2	11557	202	0.75
T2 x M1 x R3	21.3	69469	24.0	11882	195	0.62
T2 x M2 x R1	21.5	66381	24.0	11574	191	0.74
T2 x M2 x R2	21.2	71630	24.2	12648	203	0.80
T2 x M2 x R3	20.7	70704	24.1	11537	200	0.76
T2 x M3 x R1	20.7	73174	24.1	11818	201	0.79
T2 x M3 x R2	21.4	76261	23.9	11830	201	0.76
T2 x M3 x R3	20.4	72865	24.0	12161	201	0.76
T2 x M4 x R1	21.7	71013	24.0	11924	200	0.78
T2 x M4 x R2	20.9	68543	24.1	11891	198	0.77
T2 x M4 x R3	21.1	75953	24.0	11383	198	0.80
T2 x M5 x R1	21.3	66073	24.0	10991	200	0.73
T2 x M5 x R2	20.7	74409	24.2	11763	197	0.77
T2 x M5 x R3	21.0	77496	24.3	13321	199	0.80
T1 x M1 x R1	23.0	76261	23.4	11010	196	0.66
T1 x M1 x R2	21.8	72556	23.7	11578	196	0.63
T1 x M1 x R3	22.3	75026	24.0	12573	210	0.74
T1 x M2 x R1	22.0	76879	23.8	11498	197	0.74
T1 x M2 x R2	20.8	77188	24.2	12552	201	0.79
T1 x M2 x R3	20.8	73483	24.1	11970	206	0.75
T1 x M3 x R1	22.8	72865	23.5	11541	194	0.63
T1 x M3 x R2	23.0	74409	23.5	10959	195	0.68
T1 x M3 x R3	21.5	78731	24.0	11913	208	0.75
T1 x M4 x R1	25.0	74100	22.8	9318	178	0.62
T1 x M4 x R2	21.2	77805	24.4	12927	203	0.78
T1 x M4 x R3	21.5	77805	23.8	11985	200	0.68
T1 x M5 x R1	23.1	79658	23.3	11161	198	0.67
T1 x M5 x R2	21.6	79658	23.8	12338	202	0.78
T1 x M5 x R3	21.9	75953	23.7	11662	197.08	0.64
Probability	0.71	0.15	0.14	0.14	0.15	0.08

Table A102. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Barnesville in 2013.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	18.2	83054	24.0	8708	185	0.65
T2 x M1 x R2	17.6	82436	24.0	9352	193	0.70
T2 x M1 x R3	18.0	84289	24.1	10270	192	0.67
T2 x M2 x R1	17.7	85833	23.7	8964	191	0.70
T2 x M2 x R2	17.7	81510	24.3	8749	188	0.70
T2 x M2 x R3	17.8	76879	23.8	9479	190	0.71
T2 x M3 x R1	17.9	79349	23.9	8613	183	0.66
T2 x M3 x R2	18.3	80584	24.3	10615	200	0.74
T2 x M3 x R3	17.6	82436	23.9	10573	197	0.67
T2 x M4 x R1	17.7	83671	24.1	7773	186	0.69
T2 x M4 x R2	17.8	83980	23.8	8967	196	0.68
T2 x M4 x R3	17.5	79658	23.9	8890	192	0.70
T2 x M5 x R1	18.5	82128	23.8	8014	187	0.67
T2 x M5 x R2	17.9	80275	24.1	10117	194	0.73
T2 x M5 x R3	17.9	82128	24.4	8629	182	0.67
T1 x M1 x R1	18.5	80893	24.2	9575	188	0.61
T1 x M1 x R2	17.6	84598	24.3	9627	193	0.73
T1 x M1 x R3	18.4	86141	24.1	10164	198	0.68
T1 x M2 x R1	18.9	81510	23.7	8571	192	0.63
T1 x M2 x R2	18.5	77188	24.4	9820	199	0.71
T1 x M2 x R3	18.5	81510	24.2	10841	205	0.73
T1 x M3 x R1	19.5	81819	23.9	9126	195	0.70
T1 x M3 x R2	19.0	81201	24.1	10014	198	0.67
T1 x M3 x R3	18.1	83980	23.8	9242	187	0.69
T1 x M4 x R1	18.3	78731	23.6	8085	185	0.69
T1 x M4 x R2	18.1	81819	24.0	9340	195	0.66
T1 x M4 x R3	18.7	78731	24.6	9880	190	0.67
T1 x M5 x R1	18.6	84598	23.9	7944	188	0.65
T1 x M5 x R2	18.1	79349	24.1	8804	190	0.62
T1 x M5 x R3	17.5	79040	23.6	9405	199	0.70
Probability	0.93	0.28	0.07	0.15	0.02	0.37

Table A103. Effect of T x M x R interaction on moisture, corn stand, test weight, yield, plant height, and NDVI at Casselton in 2013.

T x M x R	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
	--%--	-plants ha^{-1}-	-- kg bu^{-1}--	-kg ha^{-1}-	--cm--	--NDVI--
T2 x M1 x R1	16.6	65146	22.7	7676	161	0.34
T2 x M1 x R2	20.4	66999	23.7	7450	175	0.50
T2 x M1 x R3	18.8	72248	23.9	9197	177	0.52
T2 x M2 x R1	21.5	70086	23.2	7623	167	0.39
T2 x M2 x R2	19.9	76570	23.4	9909	175	0.50
T2 x M2 x R3	19.2	69778	23.8	9184	175	0.49
T2 x M3 x R1	21.5	77188	23.3	8537	169	0.46
T2 x M3 x R2	21.4	68234	23.4	7031	167	0.37
T2 x M3 x R3	19.4	67308	23.6	7497	172	0.47
T2 x M4 x R1	22.5	71939	22.9	6421	164	0.40
T2 x M4 x R2	23.2	71321	22.9	6466	160	0.36
T2 x M4 x R3	20.7	75026	23.3	8370	172	0.48
T2 x M5 x R1	18.6	82436	23.5	8290	172	0.46
T2 x M5 x R2	20.1	75026	23.6	8529	170	0.51
T2 x M5 x R3	20.7	68234	23.5	8167	172	0.48
T1 x M1 x R1	18.5	81510	23.7	9086	172	0.52
T1 x M1 x R2	17.8	82128	23.5	10043	181	0.57
T1 x M1 x R3	18.2	84906	23.9	9334	181	0.51
T1 x M2 x R1	19.9	84906	23.2	8644	175	0.51
T1 x M2 x R2	18.9	83363	23.6	9274	175	0.53
T1 x M2 x R3	19.0	83054	24.0	10596	179	0.56
T1 x M3 x R1	23.8	80584	22.5	8591	168	0.42
T1 x M3 x R2	17.6	83980	23.9	8745	173	0.66
T1 x M3 x R3	18.7	87068	23.7	9201	181	0.57
T1 x M4 x R1	24.0	78731	22.7	7795	158	0.28
T1 x M4 x R2	22.7	79966	22.8	7508	164	0.39
T1 x M4 x R3	21.1	82436	23.2	10720	172	0.47
T1 x M5 x R1	20.5	83980	23.3	8670	170	0.42
T1 x M5 x R2	21.9	81510	22.8	8536	168	0.40
T1 x M5 x R3	19.7	82436	23.6	9560	178	0.53
Probability	0.86	0.44	0.09	0.22	0.74	0.03

Table A104. Environment and interactions with environment probabilities for moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all nine environments (years and locations).

SOV	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
Environment (E)	0.00	0.00	0.00	0.00	0.00	0.00
E x T	0.27	0.00	0.11	0.24	0.00	0.02
E x M	0.00	0.08	0.74	0.05	0.15	0.75
E x R	0.61	0.40	0.05	0.03	0.05	0.15
E x M x R	0.03	0.37	0.00	0.34	0.56	0.08
E x T x M	0.42	0.03	0.84	0.61	0.62	0.70
E x T x R	0.01	0.17	0.75	0.86	0.47	0.60
E x T x M x R	1.00	0.82	0.99	0.50	0.63	0.74

Table A105. Environment and interactions with environment probabilities for moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2012.

SOV	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
Environment (E)	0.00	0.19	0.06	0.00	0.00	0.08
E x T	0.09	0.01	0.09	0.41	0.01	0.06
E x M	0.55	0.15	0.63	0.31	0.42	0.53
E x R	0.55	0.46	0.80	0.32	0.49	1.00
E x M x R	0.98	0.54	0.56	0.27	0.30	0.62
E x T x M	0.62	0.07	0.48	0.38	0.23	0.82
E x T x R	0.46	0.15	0.99	0.51	0.41	0.39
E x T x M x R	0.11	0.92	0.92	0.76	0.91	0.13

Table A106. Probabilities for environment and interactions with environment for moisture, corn stand, test weight, yield, plant height, and NDVI averaged over all locations in 2013.

SOV	Moisture	Corn stand	Test weight	Yield	Plant height	Greenness
Environment (E)	0.00	0.09	0.03	0.00	0.00	0.03
E x T	0.53	0.02	0.47	0.15	0.40	0.20
E x M	0.02	0.54	0.67	0.28	0.47	0.90
E x R	0.89	0.61	0.19	0.44	0.51	0.25
E x M x R	0.08	0.38	0.00	0.62	0.91	0.04
E x T x M	0.40	0.16	0.79	0.81	0.83	0.72
E x T x R	0.06	0.37	0.57	0.95	0.50	0.95
E x T x M x R	0.92	0.48	0.86	0.11	0.16	0.66

Soil nitrogen test results

Table A107. ANOVA for NH_4^+, and total N (NO_3 + NH_4^+) soil test results 0-31 cm deep at the six collar leaf and milk growth stage in corn averaged over all nine environments (years and locations).

SOV		Six collar leaf stage		Milk stage	
	df	NH_4	Total N	NH_4	Total N
Tillage (T)	1	0.78	0.12	0.77	0.51
Management Practices (M)	4	0.24	0.00	0.45	0.98
T x M	4	0.14	0.08	0.06	0.28
Environment (E)	8	0.03	0.00	0.00	0.00
E x T	8	0.40	0.31	0.85	0.23
E x M	32	0.99	0.84	0.55	0.26
E x T x M	32	0.01	0.02	0.16	0.35

Table A108. ANOVA for NH_4^+ , and total N (NO_3 + NH_4^+) soil test results 0-31 cm deep at the six collar leaf and milk growth stage in corn averaged over all four environments in 2012 (Langdon not included).

SOV		Six collar leaf stage		Milk stage	
	df	NH_4	Total N	NH_4	Total N
Tillage (T)	1	0.81	0.12	0.58	0.55
Management Practices (M)	4	0.27	0.18	0.45	0.98
T x M	4	0.13	0.19	0.04	0.46
Environment (E)	3	0.29	0.26	0.00	0.04
E x T	3	0.28	0.51	0.59	0.25
E x M	12	0.90	0.66	0.31	0.27
E x T x M	12	0.11	0.11	0.52	0.36

Table A109. ANOVA for NH_4^+, and total N (NO_3 + NH_4) soil test results 0-31 cm deep at the six collar leaf and milk growth stage in corn averaged over all five environments in 2013.

SOV		Six collar leaf stage		Milk stage	
	df	NH_4	Total N	NH_4	Total N
Tillage (T)	1	0.87	0.87	0.13	0.94
Management Practices (M)	4	0.09	0.00	0.82	0.89
T x M	4	0.83	0.11	0.45	0.74
Environment (E)	4	0.00	0.09		
E x T	4	0.51	0.13	0.96	0.86
E x M	16	0.61	0.56	0.85	0.89
E x T x M	16	0.27	0.42	0.16	0.03

Table A110. Tillage system probability for NH_4^+, and total N ($NO_3 + NH_4^+$) soil test results 0-31 cm deep at the six collar leaf and milk growth stage in corn at all nine individual locations, all locations in 2012 combined not including Langdon 2012, all locations in 2013 combined, and all locations in 2012 and 2013 combined, excluding Langdon 2012.

	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
Fargo-untiled 12	0.37	0.54	0.36	0.36
Fargo-tiled 2012	0.30	0.78	0.64	0.22
Hitterdal 2012	0.89	0.15	0.82	0.88
Prosper 2012	0.08	0.04	0.56	0.30
Fargo-untiled 13	0.42	0.47	0.73	0.76
Fargo-tiled 2013	0.43	0.17	0.49	0.60
Hitterdal 2013	0.98	0.10	0.48	0.19
Barnesville 2013	0.51	0.31	0.83	0.57
Casselton 2013	0.25	0.61	0.22	0.77
2012	0.81	0.12	0.58	0.55
2013	0.87	0.87	0.13	0.94
2012 & 2013	0.78	0.12	0.77	0.51

Table A111. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the 2012 & 2013 combined analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	17.9	95.2	15.8	53.1
Beds x urea plus nitrapyrin	28.6	122.3	16.9	54.3
Beds x urea plus PCU	17.2	95.2	16.1	53.8
Beds x urea plus UAN	25.4	95.7	16.9	57.7
Beds x urea plus UAN with DCD plus NBPT	20.9	91.1	21.2	65.5
Conv x urea alone	30.7	133.5	16.3	61.7
Conv x urea plus nitrapyrin	22.1	117.3	20.3	61.9
Conv x urea plus PCU	25.8	124.1	21.2	62.5
Conv x urea plus UAN	19.7	93.8	15.5	58.5
Conv x urea plus UAN with DCD plus NBPT	16.7	93.2	15.2	55.8
Probability	0.14	0.08	0.06	0.28

Table A112. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the 2012 combined analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	26.8	158.2	23.8	96.9
Beds x urea plus nitrapyrin	49.3	206.6	25.7	97.7
Beds x urea plus PCU	23.8	162.6	23.3	96.7
Beds x urea plus UAN	43.8	176.6	23.8	105.8
Beds x urea plus UAN with DCD plus NBPT	33.9	164.6	35.0	121.0
Conv x urea alone	55.6	240.0	24.3	114.1
Conv x urea plus nitrapyrin	35.6	209.8	33.5	115.0
Conv x urea plus PCU	42.9	212.9	35.5	113.6
Conv x urea plus UAN	30.5	171.4	23.5	107.8
Conv x urea plus UAN with DCD plus NBPT	24.0	171.4	22.2	104.2
Probability	0.13	0.19	0.04	0.46

Table A113. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the 2013 combined analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	10.9	44.9	9.4	18.0
Beds x urea plus nitrapyrin	11.9	54.9	9.9	19.6
Beds x urea plus PCU	11.9	41.5	10.4	19.4
Beds x urea plus UAN	10.6	30.9	11.4	19.3
Beds x urea plus UAN with DCD plus NBPT	10.5	32.3	10.1	21.2
Conv x urea alone	10.8	48.4	9.9	19.7
Conv x urea plus nitrapyrin	11.2	43.4	9.8	19.5
Conv x urea plus PCU	12.1	53.0	9.8	21.6
Conv x urea plus UAN	11.0	31.7	9.2	19.0
Conv x urea plus UAN with DCD plus NBPT	10.9	30.5	9.6	17.2
Probability	0.83	0.11	0.45	0.74

Table A114. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Fargo-untiled 2012 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	29.9	102.1	5.8	69.3
Beds x urea plus nitrapyrin	56.5	142.6	2.0	59.6
Beds x urea plus PCU	34.3	97.1	2.8	66.5
Beds x urea plus UAN	29.4	93.5	1.5	32.9
Beds x urea plus UAN with DCD plus NBPT	51.4	140.5	23.5	103.4
Conv x urea alone	105.7	194.5	2.6	59.8
Conv x urea plus nitrapyrin	47.0	120.9	4.8	48.3
Conv x urea plus PCU	58.9	154.8	1.1	44.3
Conv x urea plus UAN	50.3	149.6	0.7	31.4
Conv x urea plus UAN with DCD plus NBPT	23.7	71.7	2.0	48.6
Probability	0.15	0.16	0.48	0.70

Table A115. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Fargo-tiled 2012 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	27.8	78.6	1.7	63.3
Beds x urea plus nitrapyrin	86.8	155.5	1.5	26.9
Beds x urea plus PCU	20.8	61.5	0.6	33.3
Beds x urea plus UAN	101.8	210.5	7.6	68.5
Beds x urea plus UAN with DCD plus NBPT	41.5	101.4	16.4	49.6
Conv x urea alone	47.9	157.8	2.3	58.5
Conv x urea plus nitrapyrin	27.3	96.4	2.4	55.5
Conv x urea plus PCU	46.2	127.0	33.8	89.9
Conv x urea plus UAN	24.1	99.1	6.8	119.0
Conv x urea plus UAN with DCD plus NBPT	28.6	96.5	2.2	70.3
Probability	0.08	0.02	0.34	0.66

Table A116. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Hitterdal 2012 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	18.4	223.9	34.9	140.9
Beds x urea plus nitrapyrin	20.3	290.9	34.5	157.4
Beds x urea plus PCU	22.3	310.2	35.3	181.5
Beds x urea plus UAN	18.4	223.9	29.5	167.9
Beds x urea plus UAN with DCD plus NBPT	18.8	251.2	37.6	181.3
Beds x no N applied	27.6	172.5	38.8	67.6
Conv x urea alone	26.1	347.2	32.4	174.3
Conv x urea plus nitrapyrin	20.0	363.5	42.6	179.0
Conv x urea plus PCU	21.9	300.3	29.9	154.5
Conv x urea plus UAN	19.6	230.1	36.4	130.5
Conv x urea plus UAN with DCD plus NBPT	16.1	282.2	34.1	193.1
Beds x no N applied	19.9	144.6	30.3	51.9
Probability	0.64	0.20	0.24	0.36

Table A117. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Prosper 2012 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	31.1	228.1	52.9	114.1
Beds x urea plus nitrapyrin	33.8	237.5	64.8	146.8
Beds x urea plus PCU	18.0	181.4	54.5	105.6
Beds x urea plus UAN	25.7	178.4	56.8	153.9
Beds x urea plus UAN with DCD plus NBPT	23.8	165.2	65.6	142.5
Beds x no N applied	36.9	141.8	52.9	77.6
Conv x urea alone	42.6	260.4	59.9	163.7
Conv x urea plus nitrapyrin	48.3	258.3	84.4	177.0
Conv x urea plus PCU	44.5	269.6	77.1	165.8
Conv x urea plus UAN	28.0	206.5	49.9	150.4
Conv x urea plus UAN with DCD plus NBPT	27.6	235.3	50.3	104.7
Beds x no N applied	28.4	112.6	48.0	62.0
Probability	0.18	0.09	0.01	0.05

Table A118. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Fargo-untiled 2013 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	13.5	47.8	10.6	17.9
Beds x urea plus nitrapyrin	14.0	51.9	12.0	18.4
Beds x urea plus PCU	13.6	41.0	12.8	22.9
Beds x urea plus UAN	15.2	32.6	18.9	31.8
Beds x urea plus UAN with DCD plus NBPT	13.5	32.1	12.2	20.7
Conv x urea alone	15.4	44.9	12.7	20.5
Conv x urea plus nitrapyrin	15.3	38.8	11.6	21.2
Conv x urea plus PCU	14.8	47.4	11.2	19.4
Conv x urea plus UAN	14.0	24.4	10.2	18.3
Conv x urea plus UAN with DCD plus NBPT	14.3	23.0	14.5	22.3
Probability	0.54	0.81	0.20	0.57

Table A119. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Fargo-tiled 2013 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	13.2	20.5	10.6	14.5
Beds x urea plus nitrapyrin	16.6	45.8	12.5	17.6
Beds x urea plus PCU	14.6	42.8	12.9	19.6
Beds x urea plus UAN	11.8	18.5	14.6	21.9
Beds x urea plus UAN with DCD plus NBPT	14.2	18.1	13.9	20.6
Conv x urea alone	14.9	36.0	11.3	16.3
Conv x urea plus nitrapyrin	14.7	44.2	11.4	19.3
Conv x urea plus PCU	15.8	47.5	12.6	21.9
Conv x urea plus UAN	14.9	21.9	12.0	17.0
Conv x urea plus UAN with DCD plus NBPT	16.1	25.7	10.3	15.6
Probability	0.45	0.80	0.38	0.06

Table A120. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Hitterdal 2013 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	4.7	24.1	7.5	13.1
Beds x urea plus nitrapyrin	4.6	27.9	7.7	11.9
Beds x urea plus PCU	6.0	32.6	7.5	14.5
Beds x urea plus UAN	4.2	21.8	6.2	11.3
Beds x urea plus UAN with DCD plus NBPT	6.3	23.1	7.7	15.8
Beds x no N applied	4.0	17.5	7.2	10.8
Conv x urea alone	3.4	59.5	6.9	21.8
Conv x urea plus nitrapyrin	5.3	30.0	7.2	13.1
Conv x urea plus PCU	6.3	49.6	7.1	17.7
Conv x urea plus UAN	5.1	26.2	7.0	12.9
Conv x urea plus UAN with DCD plus NBPT	4.4	18.5	7.2	19.3
Beds x no N applied	5.1	15.2	6.3	9.1
Probability	0.12	0.02	0.88	0.51

Table A121. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Barnesville 2013 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	7.7	57.1	7.4	21.7
Beds x urea plus nitrapyrin	10.4	87.6	7.2	30.8
Beds x urea plus PCU	9.9	41.7	7.1	17.5
Beds x urea plus UAN	9.6	49.2	6.1	12.3
Beds x urea plus UAN with DCD plus NBPT	7.1	56.5	6.5	30.1
Beds x no N applied	8.6	18.5	7.5	11.5
Conv x urea alone	8.5	45.6	6.8	17.7
Conv x urea plus nitrapyrin	9.9	41.9	8.6	21.8
Conv x urea plus PCU	9.4	57.1	6.7	22.5
Conv x urea plus UAN	7.0	42.4	7.3	31.2
Conv x urea plus UAN with DCD plus NBPT	8.1	40.6	6.3	13.3
Beds x no N applied	8.0	30.1	6.8	10.2
Probability	0.51	0.11	0.42	0.03

Table A122. Effect of the Tillage (T) x N fertilizer management practices (M) interaction on NH_4^+ and total N in the 0-31 cm soil depth at the six collar leaf stage and milk stage in corn for the Casselton 2013 analysis.

T x M	Six collar leaf stage		Milk stage	
	NH_4	Total N	NH_4	Total N
	--------------kg ha^{-1} of N---------------			
Beds x urea alone	15.1	74.9	11.2	22.7
Beds x urea plus nitrapyrin	14.0	61.2	10.3	19.6
Beds x urea plus PCU	14.9	47.2	11.5	22.4
Beds x urea plus UAN	12.4	32.6	11.2	19.0
Beds x urea plus UAN with DCD plus NBPT	11.4	31.6	10.4	18.6
Beds x no N applied	14.1	33.5	11.6	17.7
Conv x urea alone	11.8	55.9	11.8	22.2
Conv x urea plus nitrapyrin	11.1	61.9	9.9	22.3
Conv x urea plus PCU	14.0	63.2	11.3	26.7
Conv x urea plus UAN	14.0	43.7	9.4	15.6
Conv x urea plus UAN with DCD plus NBPT	11.5	44.9	10.0	15.3
Beds x no N applied	10.9	27.8	9.5	14.5
Probability	0.28	0.30	0.64	0.36