NITROGEN FERTILIZER MANAGEMENT AND TILE DRAINAGE EFFECTS ON SUGARBEET YIELD, SOIL NITROGEN AVAILABILITY, AND NITROUS OXIDE EMISSIONS IN HIGH CLAY SOIL

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INTRODUCTION

Drainage and flooding are critical problems in the Red River Valley of North Dakota and Minnesota due to the flat topography and dominant poorly drained clay soils (Jin et al. 2008). Since 1993 excess water has significantly affected crop production in the Northern Great Plains. The precipitation received at critical growth stages has a greater impact than total annual rainfall. In June 2011, the North Dakota state average precipitation was 4.51 inches, which is above the 1971-2000 normal of 3.19 inches according to the North Dakota Agricultural Weather Network (NDAWN). The Prosper NDAWN observation site recorded 3.14, 5.17, and 5.91 inches rainfall in May, June, and July respectively in 2011. Water-logging has been shown to quickly decrease root-zone oxygen through displacement of the soil air by water. One option to manage water-logging is through subsurface tile drainage. Although subsurface drainage is common in the Corn Belt, the adoption of tile drainage in the Red River Valley is relatively new. Installing subsurface drainage can reduce the chance of water logging and prevent saturation by lowering the water table.

Shifting water and temperature regimes influence the below ground nitrogen (N) dynamics (Bouwman et al. 2010). Saturated conditions (undrained) increase the potential of available N loss in the form of nitrous oxide (N_2O), known as denitrification. Denitrification is an anaerobic process and saturated field conditions accelerate the denitrification process. Hence, subsurface drainage has the potential to reduce denitrification N losses through the reduction of saturation. Nitrogen (N) fertilization is essential for optimizing crop yields and economic returns. Nitrogen is the most limiting nutrient in row crop production systems and N fertilizer is extensively applied to corn, wheat, and other non-leguminous crops. Common N-fertilizer management strategies include split applications of the total recommended rate and application of nitrification or urease inhibitors. Poorly-drained soils in the Red River Valley that warrant targeted N management include soils with high clay content. Knowledge of the trade-offs between N_2O emissions from N fertilizer management practices and crop yield under subsurface drainage is therefore an essential requirement (Millar et al. 2010).

Objectives: This research experiment will determine how nitrogen (N) fertilizer management practices influence (1) sugarbeet yield and quality, (2) inorganic soil nitrogen availability, and (3) denitrification loss of nitrogen in the form of nitrous oxide (N_2O) from soils under sugarbeet production.

MATERIALS AND METHODS

A field experiment will be conducted on the NDSU agricultural plot near Fargo, ND on a Fargo-Ryan silty clay soil complex. The soil is classified as fine, smectitic, superactive, frigid, Typic Epiaquerts. A Randomized Complete Block Design will be laid out with four replicates in split-plot arrangement with (1) subsurface drainage and (2) undrained conditions as the main plot factors and nitrogen management practices: 1) control (0 N), (2) 130 lb N ac^{-1} (146 kg N ha^{-1}) in the form of urea, (3) 160 lb N ac^{-1} (180 kg N ha^{-1}) in the form of urea , (4) 130 lb N ac^{-1} in the form of urea with instinct, (5) 100 lb N ac^{-1} (112 kg N ha^{-1}) as urea, plus 30 lb N ac^{-1} (34 kg N ha^{-1}) as urea at 3/4 leaf stage.as the sub plot factors.

Each individual plot measured 20 feet long by 11 feet wide. On May 10th, the required rates of urea fertilizers were uniformly broadcasted with hand and were incorporated using Triple K field cultivator with rolling basket. On the same day, sugarbeet variety Crystal 985 Roundup Ready was planted with a John Deere Max Emerge II planter. The seeds were placed 1.25 inches deep with 22 inch row spacing and 3 inch in-row spacing. On 26th June, the plots were thinned manually to maintain a plant population of 63,360 plants per acre. Roundup herbicide (48 fl oz acre^{-1}) was applied for weed control on 22nd June The remaining split N treatment (30 lb N acre^{-1}) was applied on 25th June. On September 17th, two middle rows from each plot were machine harvested and weighed instantly. Subsamples of the sugarbeet roots were sent to American Crystal Sugar Quality Tare Lab, East Grand Forks, MN for yield determinations and quality analysis. The daily precipitation events throughout the sugarbeet growing season (2012) recorded at the research site by North Dakota Agricultural Weather Network (NDAWN) is shown in figure 1.

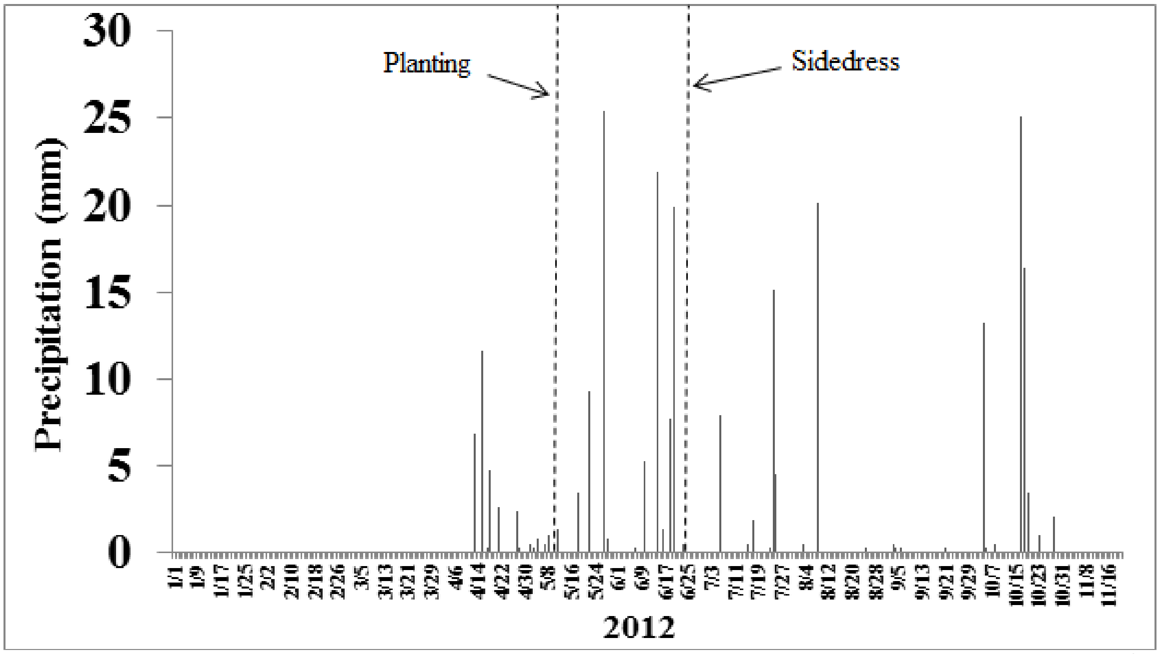

Figure 1. Daily precipitation events in sugarbeet growing season at NW22, near Fargo, ND. The dash lines correspond to the dates for the N fertilizer applications (planting and sidedress).

Soil Sampling and analyses: On 30th April, three soil cores of 3.6 cm diameter up to a depth of 4 feet with depth intervals of 0-12 inch, 12-24 inch, and 24-48 inch were collected and composited per block in order to determine initial soil inorganic N levels. Also, separate soil cores were taken from the upper 6 inch soil surface to determine bulk density. After planting, soil samples were collected from the upper 12 inch soil profile-with 6 inch increments on 11th May, 26th June, 27th July, 23rd August and 22nd September. Two soil cores (2 cm diam.) were collected and composited for each plot. Soil samples were transferred to the laboratory in a cooler and stored at -4°C until analyzed. In the laboratory, approximately 6.5 grams of field moist soil was extracted with 25 ml of 2M KCl after shaking the mixture for 30 mins in a reciprocal shaker. The soil suspension was then centrifuged for 5 mins and filtered through a Whatman no. 2 filter paper. The extracts were then analyzed for inorganic N (NH_4^+-N and NO_3^--N) contents using Automated Timberline TL2800 Ammonia Analyzer. Soil moisture content was also determined by gravimetric weight loss on heating a separate soil sample at 105°C for 24 hours and used to calculate the bulk density of the soil cores and to convert the inorganic N concentrations on dry weight basis.

N_2O emission measurement: Nitrous oxide emission rate from surface soil was measured using semi-permanent vented static PVC chamber (25.4 cm internal diameter and 10 cm height) following the GRACEnet project protocol outlined by Parkin and Venterea, 2010. A PVC anchor ring with beveled edge was inserted into the soil between sugarbeet rows in each plot on 11th May. Gas samples were collected on 17th May, 4th June, 8th June, 15th June, 22nd June, 6th July, and 25th July in between 8 am and noon of the day assuming to represent the average flux of the day. On the observation day, the height of the anchor ring above the soil surface was recorded, in order to calculate the headspace volume after chamber enclosure. A chamber was placed on the anchor and gas samples (30 mL) were collected from the chamber headspace at 0, 15, and 30 mins with a graduated polypropylene syringe. The samples were then transferred to 12 mL pre-evacuated glass serum vials and transported to the laboratory for analysis. All the gas samples were analyzed within a day of their samplings, using a Dani Master gas chromatograph (Dani Instruments, Milan, Italy) - equipped with an electron capture detector. The rate of change in N_2O concentration in the chamber over time was calculated using linear regression. In addition, soil temperature and moisture content at each chamber were also measured by using GS3 soil moisture-temperature sensor (Decagon Devices, Inc., Pullman, WA 99163).

Gas samples were analyzed using a Dani Master gas chromatograph (Dani Instruments, Milan, Italy), which is equipped with an electron capture detector (N_2O). Assuming a linear increase in gas concentration, flux of individual gases will be calculated using the following equation:

$$F = k\, d \left(\frac{273}{T}\right)\left(\frac{V}{A}\right)\left(\frac{\Delta C}{\Delta t}\right)$$

Where F is the rate of gas emission (mass $ha^{-1}d^{-1}$), k is unit conversion (N_2O:144), d is gas density (g cm^{-3}) at 273K, T is the air temperature (K), V is the chamber volume (cm^3), A is soil area covered by chamber (cm^2) and $\Delta C/\Delta t$ is the rate of change of concentration over 15 and 30 min intervals (Ginting et al. 2003). The estimations of daily average gas flux was calculated by (Parkin and Kasper 2003, 2006):

$$\text{Daily average gas flux} = FQ^{(DAT-T)/10}$$

Where DAT is the daily average temperature, Q is the Q_{10} factor for N_2O (3.72).

Statistical Analyses- Data will be analyzed using an RCBD with a split plot arrangement with drainage and nitrogen fertilizer management as main factors for the analysis of variance as calculated by SAS PROC MIXED process. Mean separation will be tested using Fisher's least significant difference at alpha level=0.05.

RESULTS

During 2012 growing season, rainfall was comparatively lower than usual and water table depth did not reach the level to turn on the tile line. For this reason, tile effect was not considered and only fertilizer-N management effect on crop and soil parameters were compared. Management of N application had no effect on beet yield (Table 1). Previous year (2011), these plots were under corn and no significant yield differences in between with and without nitrogen application indicate significant residual soil nitrogen concentration and/or low response to fertilizer-N under dry condition. Percentage of sugar loss to molasses (SLM%) significantly increased with high N application rate of 160 lb/ac than recommended rate of 130 lb/ac or control.

Table 1. Nitrogen fertilizer management effect on sugarbeet yields during 2012 growing season. Least significant difference (LSD) values provided for P<0.05; 'n.s.' indicates no significant differences. Different lower case letters within the same column indicate significant difference at 95% significance level.

Treatments	Root Yield (Tons/acre)	Gross Sucrose (%)	[†]SLM (%)	Net Sucrose (%)	[‡]RSA (lb/acre)	[*]RST (lb/ton)	Tare (%)	[§]Gross Ton ($/ton)	[¶]Gross Acre ($/acre)
Control	21.23	18.42	1.65^{c}	16.76	6053	335	0.25	64.17	1157
130 lb/a N	21.36	18.57	1.80^{bc}	16.78	7376	335	0.49	64.18	1407
160 lb/a	21.09	17.80	1.95^{a}	15.85	7057	317	0.46	58.65	1304
130 lb/a + Instinct	20.16	18.66	1.85^{ab}	16.79	6839	336	0.40	64.42	1311
Split (100+30) lb/a	21.16	18.39	1.88^{ab}	16.51	7284	330	0.25	62.62	1382
LSD (P<0.05)	n.s.	n.s.	0.15	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

[†] SLM = Sucrose Loss to Molasses, a measure of impurity content

[‡] RSA = Recoverable Sucrose per Acre

[*] RST = Recoverable Sucrose per Ton

[§] Gross Ton = Gross Revenue per Ton

[¶] Gross Acre = Gross Revenue per Acre

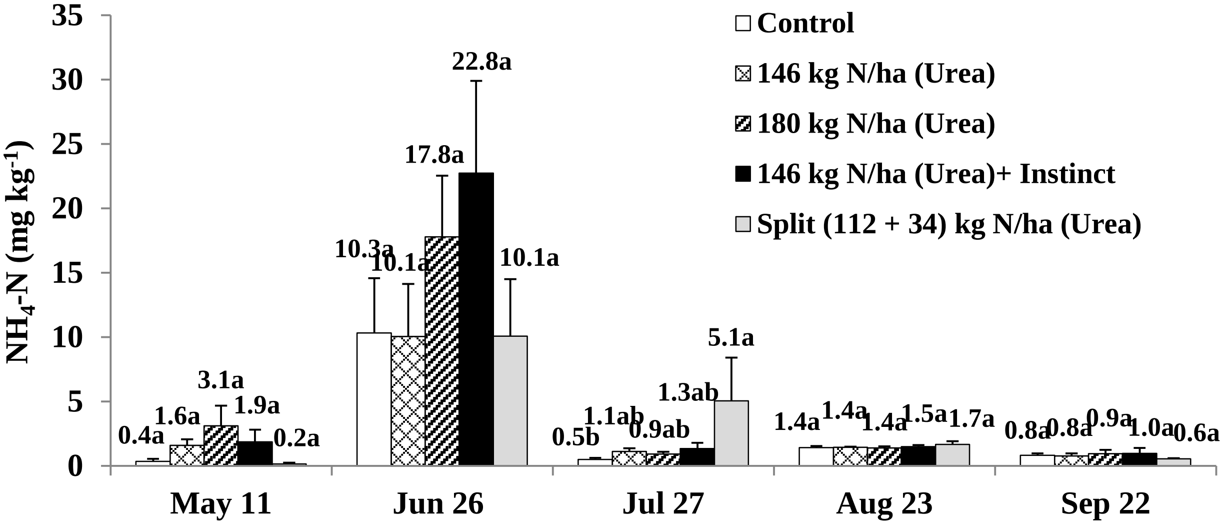

Figure 2: Effect of fertilizer N management on soil ammonium N (mg kg^{-1}) within 0-30 cm depth under sugarbeet. Bars represent standard errors (n=8). Different lowercase letters within a sampling date are different at 0.05 significance level.

Soil inorganic N availability was significantly influenced by fertilizer N management practices within 30 cm soil depth (Figure 2 and 3). Maximum soil ammonium-N (NH_4-N) concentration was observed for soils sampled on 26th June. Soil NH_4-N varied widely among replications as evident from standard error values and probably mask treatment differences. For soils sampled on 27th July, soil NH_4-N availability was significantly higher in soils receiving split N application than control soil due to late application of 34 kg N ha^{-1} on 25th June.

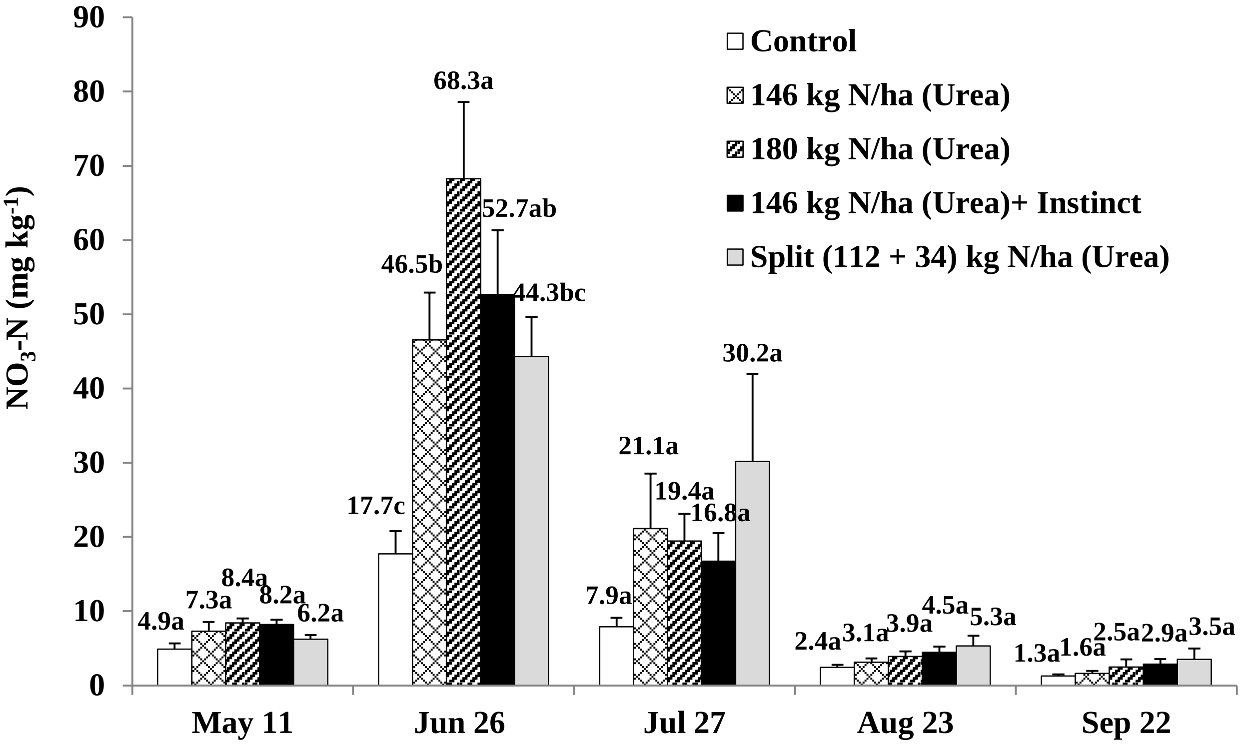

Figure 3. Effect of fertilizer N management on soil nitrate N (mg kg^{-1}) within 0-30 cm depth under sugarbeet. Bars represent standard errors (n=8). Different lowercase letters within a sampling date are different at 0.05 significance level.

Fertilizer N management effect on soil nitrate-N (NO_3-N) concentration was significant for soils sampled only on 26th June (Figure 3). On 26th June, application of N at the rate of 180 kg N ha^{-1} had significantly higher soil NO_3-N concentration than other N treatments except recommend N rate of 146 kg N ha^{-1} with instinct application.

Fertilizer-N management effect on soil N_2O-N loss was not significant throughout the growing season (Figure 4) mainly because of high variations among replications. Control plot had always the lowest N_2O-N loss than soils with fertilizer-N application. Among different fertilizer-N application treatments, soils with higher fertilizer N application rate (180 kg N ha^{-1}) released more N_2O-N loss than recommended dose (146 kg N ha^{-1}) and with instinct application.

CONCLUSION

During 2012 growing season, nitrogen fertilizer management practices did not show any significant effect on beet yield and quality. Significant differences in soil N availability were limited within early to mid growing season. Soil N_2O-N loss rate did not show any statistical difference among N treatments but higher N_2O-N flux rates were associated with higher fertilizer-N application rate than recommended rate. However, intensive soil-N and N_2O-N flux sampling for next two growing season will be critical to determine the fertilizer-N management practices on sugarbeet production under tile condition.

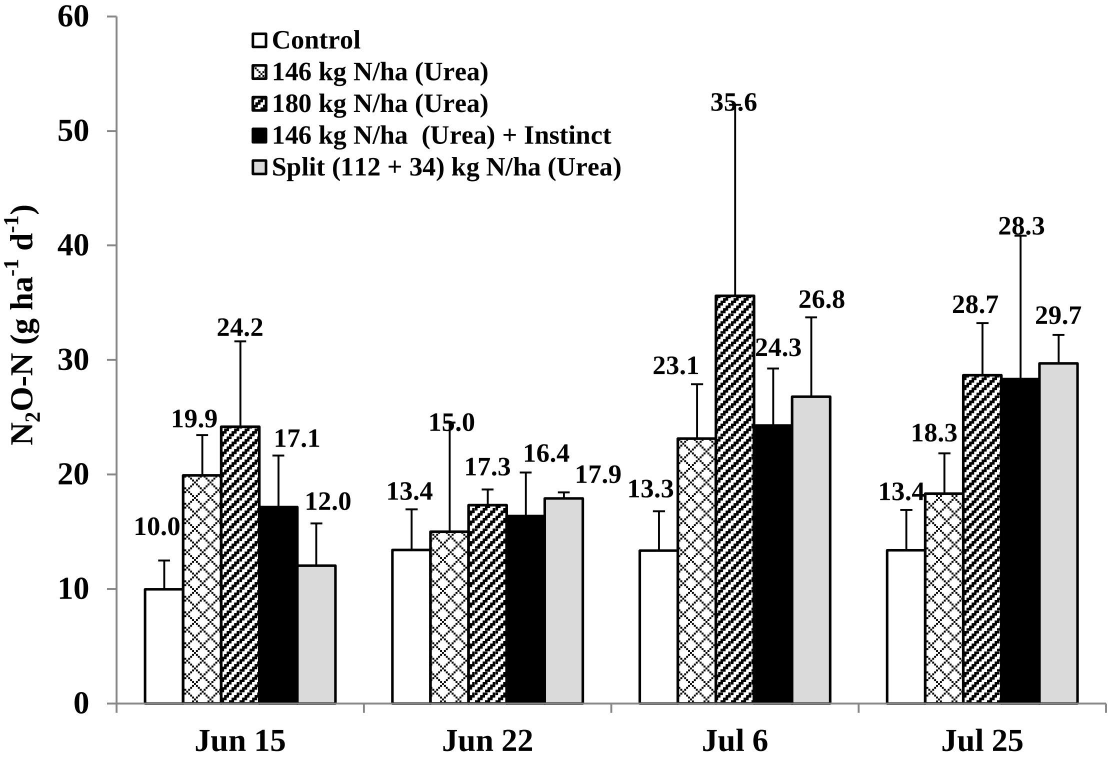

Fig.4. Soil N_2O fluxes after the application of different nitrogenous fertilizer treatments under sugarbeet. Bars indicate standard errors (n = 4).

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