Introducing Precision Ag Tools to over-100 year old Historical Experiment

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Abstract. The historic Knorr-Holden experimental site near Scottsbluff, Nebraska, US, established in 1912 is the oldest irrigated maize plot in North America. Over years, the treatment has been revised a few times to reflect and address contemporary practices. The N fertilization is found to be capable of restoring most of production capacity of the soil. After a full century of the experiment, in 2014, N treatments were revised again. Now, the experiment is a split-plot randomized complete block design with four replications. The main factor is manure treatment (0 and 67 Mg ha^{-1}) and the sub-plot is N treatment, which includes 0, 56, 112, and 168 kg urea-N ha^{-1}. There are additional N treatments of 224 and 280 kg urea-N ha^{-1} in non-manured plots and urea-N treatments based on spring soil test (SST) and crop sensing at V6 (CS) in manured plots. Manured plots received 67 Mg ha^{-1} of cattle manure in 2014 and will continue at same rate every four year. Collection of crop vegetative indices for all N treatment plots at several growth stages was initiated using a passive sensor, Crop Circle® in 2017. The normalized difference red edge index (NDRE) at different maize growth stages (V6, V8, V10, and R1) were correlated with urea-N rates and maize grain yield. Grain yield in manured plots were greater than in non-manured plots. Grain yield in the control treatment was the lowest of all in 2017. When N treatments in manured and non-manured plots were analyzed separately, no significant effect of N treatment was observed in manured plots. Among N treatments in non-manured plots, the control treatment had the lowest grain yield among all. The 56 kg N ha^{-1} treatment had significantly lower grain yield compared to the 280 kg N ha^{-1}. The NDRE at all growth stages were significantly correlated to urea-N treatments in non-manured plots only. The regression relationship between NDRE and corresponding grain yields was the best at growth stage V10. The NDRE had poor correlation with urea-N treatments in manured plots, highlighting the importance of accounting for N supply from other N input such as manure while using crop sensor data and need for calibration of sensor for manured fields.

Keywords. *Continuous maize, active crop sensor, manure, urea, NDRE*

Introduction

Optimization of nitrogen (N) management in agriculture is a key to addressing economic and environmental issues associated with N fertilization. Presence of in-field spatial variability makes the task more challenging. Therefore, it is important to determine variability in crop N status within a field and that has been studied in depth (Kitchen et al., 2010; Roberts et al., 2010). A strong relationship between total chlorophyll content in a maize canopy and the crop N status has been well established (Dellinger et al., 2008; Barker and Sawyer, 2010; Schmidt et al., 2011). Recent research into detecting crop N status has focused on non-destructive sampling techniques. Non-destructive techniques focus on remote sensing to correlate with and quantify canopy chlorophyll content. Studies have suggested different strategies for in-season N management using remote sensing that monitor differences in crop N status by evaluating relative crop response to applied N (Scharf et al., 2011, Zillmann et al., 2006; Dellinger et al., 2008; Raun et al., 2008; Holland and Schepers, 2010; Kitchen et al., 2010; Thompson et al., 2015). In-season N application practices guided by canopy sensor have been validated for maize produced on non-manured fields and may also be a way to manage manure in maize field.

Long-term field experiments have a unique advantage as they yield valuable information about the production principles. As new and advanced agricultural technologies are introduced, it will only benefit if we can determine ways to integrate them to historic experiment sites. The goal of this study was to introduce crop sensors to irrigated continuous maize in over-100 year old experimental plot. The objectives are to determine canopy reflectance in different urea-N treatments in manured and non-manured plots in this historic plot and correlate it to N rates and maize grain yield.

Materials and Methods

This study was conducted on the historical Knorr-Holden plots at the University of Nebraska's Panhandle Research and Extension Center, Scottsbluff, NE. The Knorr-Holden plots are the oldest irrigated maize plots and the third-oldest maize research plots in North America after the Morrow Plots at the University of Illinois and Sanborn Field at the University of Missouri (Blanco-Canqui et al. 2015). The Knorr-Holden plots are located in a semiarid region with a mean annual precipitation of 396 mm. The soil is a Tripp very fine sandy loam soil (coarse-silty, mixed, superactive, mesic Aridic Haplustolls).

In 1910, native short grass prairie was broken out and land was seeded to oats in spring 1911. Then, in 1912, several non-replicated rotation study including continuous maize under conventional till was initiated at the site. The Knorr-Holden was unfertilized continuous maize plots since its establishment in 1912 until 1941. In 1942, the Knorr-Holden plot was split into two beef cattle manure treatment levels (0 and 27 Mg ha^{-1} yr^{-1}). In 1953, a second replication was added and the manure treatments were split into subplots to include six inorganic fertilizer treatments; 0, 45, 90, 135, 135 (+ 56 kg P ha^{-1}) and 180 kg urea-N ha^{-1}. That effectively made the experiment a split-plot design with manure treatments as main factor and N fertilizer treatments as subplots and with two replications. The main plots were 33 m wide and 12.5 m long, while the subplots were 5.5 m wide by 12.5 m long.

In 2013, at the turn of the century for the experiment, detailed soil samples (0-150cm) were collected from all plots and no N was added that year in preparation for revising N treatments. In 2014, area adjacent to the experiment was added to increase treatment replication from two to four. Baseline soil samples were collected from all plots. The main plot is now composted manure at 0 and 67 Mg ha^{-1} (applied every four year). The sub-plot is N treatment that includes 0, 56, 112, 168, 224 and 280 kg urea-N ha^{-1} in non-manured plots and 0, 56, 112, 168 kg urea-N ha^{-1} and urea-N treatments based on spring soil test (SST) and crop sensing at V6 (CS) in manured plots. The urea-N applied in SST and CS plots in 2017 were 190 and 95 kg N ha^{-1}.

The plots were plowed to about a 25-cm depth each spring and were furrow irrigated. The furrows were formed in late June each year. Broadcast beef feedlot manure accumulated during the previous year in nearby cattle feedlot was spread in the spring 2014. Manure was incorporated into the soil to about a 25-cm depth. Maize grain yields were measured annually from each plot.

Collection of crop vegetative indices for all N treatment plots at several growth stages using a crop sensor was initiated in 2017. A Crop Circle RapidScan® CS-45 active sensor (Holland Scientific, Lincoln, NE, USA) was used for collecting crop canopy reflectance. Same sensor was used in determining N rate for the CS treatment. The sensor measured reflectance at 670, 730, and 780 nm from a modulated, polychromatic LED light source in the unit. The sensor output averaged data collected between a manually triggered start and stop and logged reflectance in individual waveband as well as calculated normalized difference red edge (NDRE) index. For each plot, reflectance data was collected from two rows separately and mean value was used for analysis. The NDRE were collected at different maize growth stages (V6, V8, V10, and R1). The NDRE were regressed against applied urea-N rate and grain yield by growth stages using PROC REG (SAS Institute Inc., Cary, NC, USA).

Effect of manure and urea-N treatments on maize grain yield was determined using Proc Mixed in SAS where manure and urea-N treatment were fixed factors and rep was a random factor. Since there were two different additional N treatments in manured and non-manured plots, ANOVA was used to evaluate effects of N treatments in manured and non-manured plots separately as well.

Results and Discussion

There were significant main effects of manure and N treatment on maize grain yield (Figure 1). Grain yield in the manured plot was significantly greater than in the non-manured plot. Grain yield in the control treatment (0N) was the lowest among N treatments.

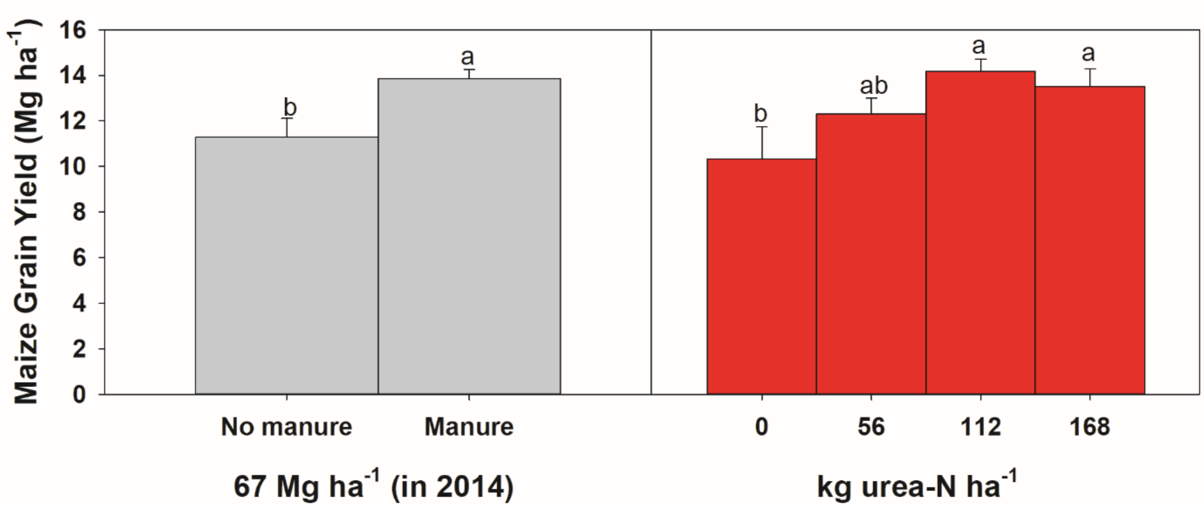

Figure 1. Maize grain yield in 2017 averaged by manure and N treatment. Manure treatment included no manure and manure at 67 Mg ha^{-1} applied in 2014. N treatment included urea at 0, 56, 112, and 168 kg N ha^{-1} in both manured and non-manured plots. Different mean separation letters refer to significantly different mean values.

There were additional N treatments in both manured and non-manured plots two in each. When N treatments in manured and non-manured plots were analyzed separately, no significant effect of N treatment was observed in manured plots (Figure 2). Among N treatments in non-manured plots, the control treatment had the lowest grain yield among all. The 56 kg N ha^{-1} treatment had significantly lower grain yield compared to the 280 kg N ha^{-1}.

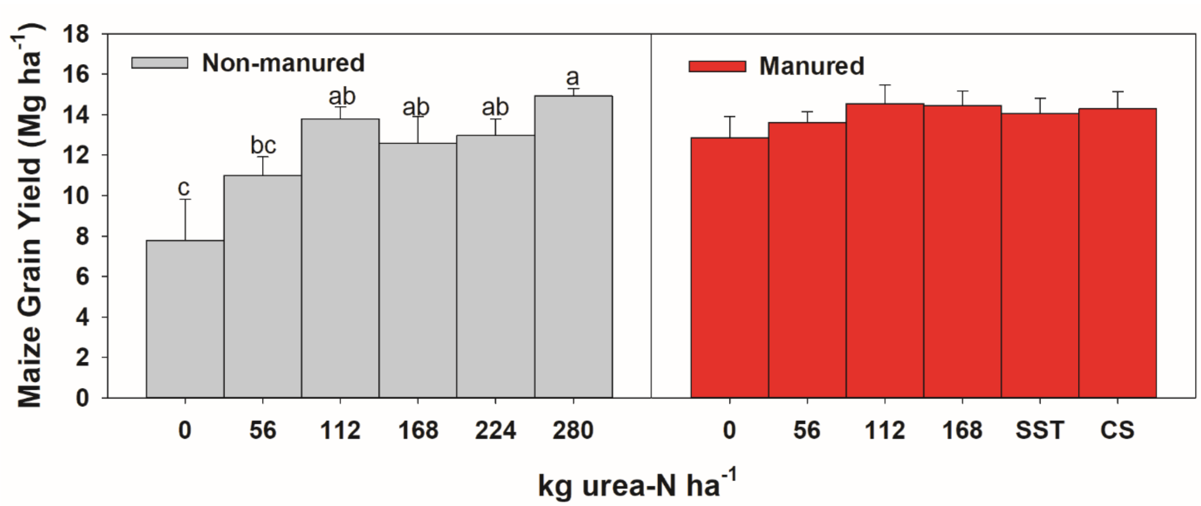

Figure 2. Mean maize grain yield N treatments in non-manured and manured plots separately. Nitrogen treatments in both non-manured and manured plots included urea at 0, 56, 112, and 168 kg N ha^{-1}. Additional N treatments were 224 and 268 kg urea-N ha^{-1} in non-manured and N rates based on spring soil test (SST) and crop circle at V6 (CS) in manured plots. Different mean separation letters refer to significantly different mean values.

The 2017 was the third year following manure application in manured plot in 2014. Considering for low N availability from manure in the third year after its application, grain yield in the control plot in manured plot was very high. It is important to note that this average yield values constitute of two reps from legacy plots where manure has been applied for over 100 years. Therefore, it would require segregating this dataset by old and new reps to determine N treatment effect on grain yield based on long- and short-term manure application.

Grain yield in the CS treatment in manured plot was as good as in all N treatments including the 224 and 280 kg N ha-1 treatments in non-manured plots and SST treatment in manured plot. The N rate (95 kg N ha^{-1}) applied in CS treatment was much lower compared to those other high N input treatment. This suggests that crop canopy reflectance can potentially be used in manured systems as well. Canopy sensor guided in-season N application practices have been validated for maize produced on non-manured fields. The canopy sensor practices may need calibration for manured fields, possibly with variations due to manure type and years since manure was applied.

Linear or quadratic yield response to applied N rate is a well-known fact (Maharjan et al., 2016) and in this study, grain yield was significantly correlated to applied N rate in non-manured plots (Figure 3). Regression coefficient will get much higher if mean yield values are used for regression. In the case of manured plots, the regression relationship between yield and applied N rate was very low and insignificant at $P < 0.05$. Nitrogen availability from the manure is not well quantified and may occur too late in the season to improve yield and quality (Lentz and Lehrsch, 2012). In the case of this study, manure-N availability after three years of its application becomes harder to determine and it could vary spatially as well. The observation that yield in the control (0N) treatment in manured plot was significantly greater than its counterpart in the non-manured plot underscores the fact that manure, even following three years since its application was supplying N. Manure is also known to improve soil physical properties that can affect yield (Blanco-Canqui et al., 2015).

Cost of fertilizers typically represents 24 – 30 % (or more) of the total variable costs of production (Lu et al., 2000). During times of economic uncertainty and decline, all costs of agricultural production including fertilizers become important and require re-evaluation. As Gareau (2004) suggested in their meta-analysis study, manured-based systems that incur no or minimal cost on purchase and transport can be considerably more profitable than conventional systems. However, uncertainty of N availability from applied manure complicates attempt to supplement N using inorganic N fertilizer as evidenced by low and insignificant correlation between yield and N rate in this study.

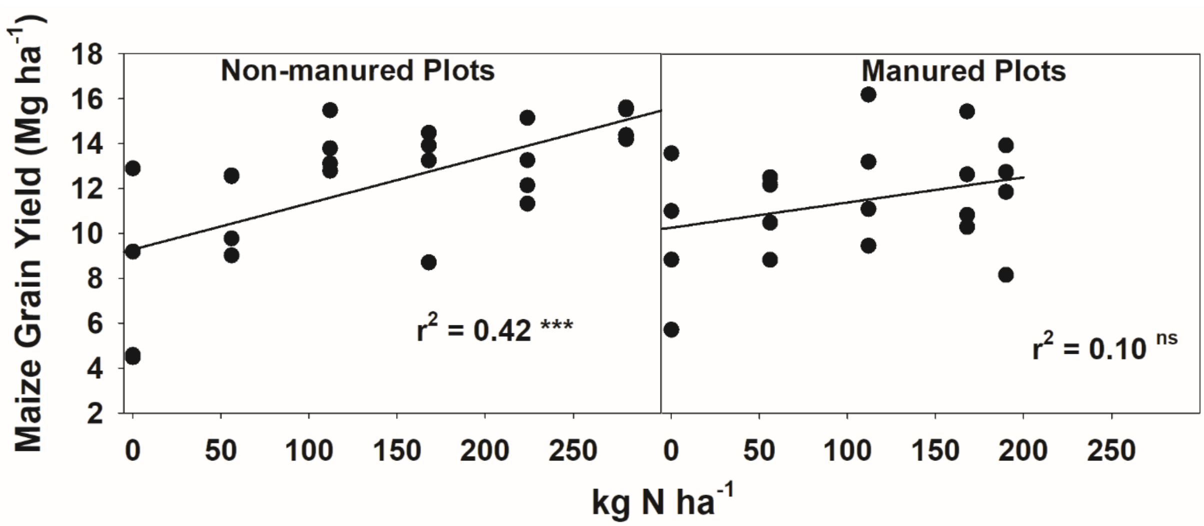

*Figure 3. Single factor linear regression results for maize grain yield versus applied urea-N rates in non-manured and manured plots. *** Significant at $P < 0.001$; ns- not significant at $P < 0.05$*

Linear regression relationship between grain yield and NDRE was significant at all growth stages in both non-manured and manured plots (Table 1). Regression coefficient suggested that the best time for canopy reflectance sensing was between growth stages V8 - V10 in non-manured plots. The corresponding growth stages were V6 - V8 in manured plots. Regression coefficient was considerably lower in manured plots compared to non-manured at all growth stages.

Table 1. Single factor linear regression results for maize grain yield versus NDRE at growth stages V6, V8, V10, and R1 in non-manured and manured plots.

Non-manured Plots		**Manured Plots**	
Growth Stage	r^2	Growth Stage	r^2
V6	0.68***	V6	0.40**
V8	0.72***	V8	0.44**
V10	0.75***	V10	0.25*
R1	0.47***	R1	0.28*

** Significant at $P < 0.05$; ** significant at $P < 0.01$; *** significant at $P < 0.001$*

Linear regression relationship between applied N rate and NDRE was consistently insignificant at all growth stages in manured plots. This signifies canopy sensor technology would require calibration for manured fields for its effective use. Applied N rate was significantly correlated to NDRE at all growth stages in non-manured plots. The growth stage V8 – V10 had the greatest correlation suggesting that growth stage range is the best time to determine crop N status.

Table 2. Single factor linear regression results for applied N rate versus NDRE at growth stages V6, V8, V10, and R1 in non-manured and manured plots.

Non-manured Plots		**Manured Plots**	
Growth Stage	r^2	Growth Stage	r^2
V6	0.36**	V6	0.47^{ns}
V8	0.41***	V8	0.62^{ns}
V10	0.46***	V10	0.66^{ns}
R1	0.32**	R1	0.42^{ns}

** Significant at P < 0.05; ** significant at P < 0.01; *** significant at P < 0.001; ns- not significant at P < 0.05*

Conclusion

Evaluation of crop N status using crop sensor was more effective in non-manured than in manured plots. However, the finding of this study suggests that there is a potential for using crop sensor in in-season N management in manured fields as evidenced by considerably high grain yield achieved by sensor based urea-N treatment. Further research is warranted to adapt crop sensor to N management in manured fields**.**

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