SITE SPECIFIC EVALUATION OF ENHANCED EFFICIENCY NITROGEN FERTILIZERS: LEAF NITROGEN, SENSORS AND REFLECTANCE METERS SOIL PROPERTIES, 2007 AND 2008

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Jan 6, 2010

ABSTRACT

This report summarizes data collected in 2007 and 2008 as part of a three year study of leaf nitrogen, crop sensors and reflectance meters and soil properties on site specific evaluation of enhanced efficiency fertilizers. Analysis of residual soil N, leaf N, Greenseeker, Dualex and SPAD data collected in 2007 and 2008, showed significant variability between upper and lower landforms for silty clay and clay loam soils. This was attributed to differences in soils and landforms which represented considerable variability in soil properties for fields in cereal production. Landform elements interacted with fertilizer treatments with respect to leaf N.

In 2007 and 2008 Greenseeker and SPAD readings were significantly related to leaf N. Reflectance for Greenseeker and SPAD meters was significantly different in an interaction between sites and landforms during June and July. SPAD measurements were not significantly (P=0.05) related to leaf nitrogen on June 27, but treatment differences were observed July 19, with the lowest values for the controls. Leaf nitrogen response to fertilizer treatments was manifested in July or later dates during the growing season. However the correlation between leaf N and crop yield was low. The correlation between Greenseeker and SPAD data for mid July and the significant differences in reflectance between sites and landforms, indicates that these sensors can be used as a predictive variable for field scale variability. Greenseeker readings were more highly correlated with plant cover compared to leaf nitrogen, and detected areas in the field with high plant populations. Further analysis of soil, leaf N and sensor data collected in 2009 is required to confirm these observations.

The complexity and variability of leaf N response to interactions of landform, seeding date and fertilizer inputs provide a challenge for variable management. Leaf N sensors have the potential to quantify spatial and temporal variability in producers' fields, without intense soil sampling or yield monitoring. However, the short growing season in Western Canada and the delay in development of leaf N deficiencies till mid-July reduce the period for detection and variable application of N fertilizer. The Greenseeker, which

detects plant cover early in the growing season, may be effective provided variability in landform, seeding date, rate, form and timing of nitrogen fertilizer are included in the variable rate prescription.

INTRODUCTION

Spatially variable application of inputs to field crops requires sub-division of a field into 'management zones' – areas that show relatively little variation and may be treated uniformly. Delineation of management zones (MZ) requires geo-referenced yield and soil data. Currently, four types of data are available: remotely-sensed images, yield maps, elevation maps, and bulk soil electrical conductivity (EC) maps (e.g. Stafford and Lark, 1997; Fraisse et al., 2001; Boydell and McBratney, 2002; Fridgen et al., 2004; Kitchen et al., 2005).

Delineation of management zones, based on yield and environmental factors is a function of the dynamic relationships between crop and soil properties, which change spatially, between and within seasons (Van-Alphen and Stoorvogel, 2000). Previous research in Western Canada reported considerable variability in crop yield in space and time with the availability of soil moisture governing response to applied nitrogen fertilizer (Walley et al 2001). Analysis of cropping parameters with high temporal dependence, such as soil N supply and crop N demand may be ineffective for precision N management based on general management zones (Pierce and Nowak, 1999; Fergusson et al., 2002). Because of temporal variability in soil N supply, strategies based on detecting crop N status at early, critical crop growth stages, and meeting crop N requirements with carefully timed fertilization may ultimately be more successful in improving N-use efficiency than strategies which attempt to estimate soil N supply ahead of time (Van-Alphen and Stoorvogel, 2000; Fergusson et al., 2002).

This study will assess the potential to detect crop N status with leaf N analysis and reflectance sensors during the growing season to refine or re-define variable management of N fertilizer, and to quantify spatial variability of soil fertility. The results of the study will provide information to producers regarding the most effective methods to manage N fertilizers on a temporal and spatial basis.

OBJECTIVES

1. Determine spatial and temporal variability of leaf N.

2. Correlate spatial and temporal variability of the nitrogen status of the crop with reflectance measured by ground based sensors.

3. Determine the potential of these technologies to identify leaf N deficiency for variable application of nitrogen.

This report is a preliminary analysis of data collected in 2007 and 2008 growing seasons for leaf nitrogen, Dualex, SPAD, Greenseeker and soil test N, P, K and S. Laboratory analyses for soil and plant samples collected in 2009 is not complete.

MATERIALS AND METHODS

Site selection

In 2006, study sites on a silty clay soil (Brandon) and a clay loam soil (Phillips) near Brandon, Manitoba were selected for field work from 2007 to 2009. The criteria for selection of the study sites were:

1. Spatial variability of crop yield and elevation in two soil associations with upper and lower landforms.

2. Proximity to the Brandon Research Centre.

Soils at the sites were sampled in 2006 to characterize the study sites prior to the imposition of fertilizer treatments in 2007 and 2008. Soil samples were air-dried, ground to pass a 2 mm sieve prior to analysis. Soil test nitrate nitrogen, phosphorus and potassium were measured in the 0-15 cm increment. Total organic carbon, total soil nitrogen, soil texture and hot KCL extracted N were determined for the control plots at each location for the 2007 sites. Nitrate nitrogen and sulfate sulfur were measured in the 15- 30 and 30-60 cm depth increments. Elevation at the sites was determined with survey grade (0.5 m accuracy) global positioning systems (survey grade GPS accuracy 1.0 to 2.0 m). Data for 2006, 2007 and 2008 were reported as laboratory analyses for leaf and soil samples collected 2009 were not available.

Experimental protocol

Seven treatments (Table 1) were selected for determination of leaf N and reflectance measurements and soil analysis. This subset of treatments was selected to assess a range of nitrogen rates and comparison with control release urea (CRU). Agronomic management and analyses are described in the report by Grant et al (2010).

Table 1. Treatments sampled in 2007, 2008 and 2009.

Fertilizer Treatment
Control no nitrogen
Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (Feekes stage 5-6) 2" off seed row
Spring side-banded CRU at 0.5 x recommended rate
Spring side-banded CRU at 1.0 x recommended rate
Spring side-banded urea N at 0.5 x recommended rate
Spring side-banded urea N at 1.0 x recommended rate
Spring side-banded urea N at 1.5 x recommended rate

GreenSeeker, (Ntech Industries, Inc., Ukiah, CA now owned by Trimble Navigation Limited, Sunnyvale, California) Dualex (FORCE A Orsay France) and SPAD(Konica Minolta, Tokyo, Japan) sensor data were collected for three dates in 2007, 2008 and six in 2009; at the Brandon and Phillips site in two locations per plot during the growing season. Leaf nitrogen was determined by combustion for samples collected in 2007, 2008 and 2009. Analyses of soil samples, sensor data and leaf N for 2009 is not complete.

In fall 2007, 2008 and 2009 after harvest, soil was sampled in 0-15 cm, 15-30 cm, and 30 -60 cm depth increments within the upper and lower landforms. Soil nitrate nitrogen, Olsen-P, potassium and sulfate sulfur were determined for 0-15 cm, 15-30 cm, and 30 -60 cm depth increments after harvest.

Data were analyzed separately by sample date and site for reflectance and leaf N data. Landform, seeding date and fertilizer treatments were analyzed as fixed effects using residual maximum likelihood. Fertilizer treatment, date of seeding treatments and the interaction were nested within landform, considered as random and means compared if the percentage of variance exceeded 10% of total variance. Significant treatments were compared with Tukey's HSD-test or Fisher's protected LSD and were considered significant at $P<0.05$. Data combined for all factors combined were also analyzed with date as an independent variable in regression analysis. Partial least squares were used to assess the relationship between spectral data and leaf N. All statistical analyses were conducted with JMP v 8.0.2 (SAS Institute 2009).

2007 AND 2008 RESULTS

Meteorological data

Mean daily temperatures in 2007 was warmer than 2008 and the climate normals, Total growing season precipitation was low in 2007 and high in 2008 relative to climate normals.

Leaf Nitrogen

Leaf N, sites and dates, 2007 and 2008

In general leaf N varied significantly between dates within and between sites for 2007 and 2008 (Table 2) though there were several significant interactions between combinations of site, landform and treatment effects at various dates. Leaf N decreased to less than 42 mg g^{-1} for the last sampling dates in 2007 and 2008. This is the critical value cited by Tindall et at (1995) for flag leaves at heading, and may affect yield. Crop heading occurred in mid to late July in this study (Table 4). Although the relationships in 2007 and 2008 between leaf N near heading and grain yield in this study were significant, the correlations were low.

Table 2. Leaf nitrogen by site and seeding date, 2007 and 2008

Site across Dates					
2007			2008		
Brandon	Phillips		Brandon	Phillips	
Leaf N (mg g^{-1})					
50.1A[z]	50.1A		41.0A	38.6A	
Date across Sites					
2007 (SE 0.03)			2008 (SE 0.04)		
June-14	June-27	July-17	June 24	July21	August 5
Leaf N (mg g^{-1})					
58.8A[y]	50.6B	40.9C	47.1A	43.0B	29.4C
Leaf N Std Dev					
4.5	6.1	5.1	5.7	5.6	7.8

[z] Letters indicate significant differences P < 0.05 within years, Fisher Protected t-test
[y] Letters indicate significant differences P < 0.05 within years, Tukey HSD

2007

Leaf N concentrations were above 42.0 mg g^{-1} in 2007 with the exception of July 17, 2007 at the Phillips site with a significant interaction between seeding date and treatment for some dates (Table 5). Fertilizer treatments significantly affected leaf N for all sample dates. Grain yield was significantly related to leaf N ($p<0.0315$) near heading on July 17 but the correlation was low ($R^2 = 0.02$).

2008

Leaf N was significantly lower than 42 mg g^{-1} for samples collected on August 5, 2008. The difference between years was attributed to N movement from leaf to grain in August of 2008. In 2008 leaf N was significantly affected by seeding date and by an interaction between seeding date and fertilizer treatment within land for June 24 but the interaction was not present for later dates. (Table 3, Table 4). Treatment effects varied significantly by date through the growing season, with lower leaf N for the control relative to fertilized treatments, and for late compared to early seeding dates. Landform significantly affected fertilizer response on June 24 (Table 3). Leaf N in treatments without fertilizer were consistently low on June 24, but interacted with seeding date on July 21 (Table 3). Crop yield was related to leaf N measured on July 21, 2008 ($P<0.0561$), though the R^2 for the correlation was very low ($R^2=0.016$).

Table 3. Leaf N seeding by fertilizer interaction nested within landform across sites, June 24, 2008

Level		Leaf N (mg g^{-1})
[Upper]Late Seeded, Spring side-banded urea N at 1.5 x rec rate	A [z]	55.4
[Lower] Late Seeded, Spring side-banded urea N at 1.5 x rec rate	A	54.3
[Lower] Late Seeded, Spring side-banded urea N at 1.0 x rec rate	A	54.2
[Upper] Late Seeded, Spring side-banded urea N at 1.0 x rec rate	AB	52.0
[Upper] Late Seeded, Spring side-banded CRU at 1.0 x rec rate	ABC	50.6
[Lower] Late Seeded, Spring side-banded CRU at 1.0 x rec rate	ABCD	50.4
[Lower] Late Seeded, Spring side-banded urea N at 0.5 x rec rate	BCD	47.9
[Lower]Early Seeded, Spring side-banded urea N at 1.5 x rec rate	BCDE	47.6
[Lower] Late Seeded, Spring side-banded CRU at 0.5 x rec rate	BCDEF	46.7
[Lower] Late Seeded, Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (feekes stage 5-6) 2" off seed row	CDEF	45.9
[Upper] Late Seeded, Spring side-banded urea N at 0.5 x rec rate	CDEFG	45.7
[Upper] Late Seeded, Spring side-banded CRU at 0.5 x rec rate	CDEFG	45.4
[Lower] Early Seeded, Spring side-banded CRU at 1.0 x rec rate	CDEFG	45.4
[Lower] Early Seeded, Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (feekes stage 5-6) 2" off seed row	CDEFG	45.2
[Lower] Early Seeded, Spring side-banded urea N at 1.0 x rec rate	DEFG	45.0
[Upper]Late, Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (feekes stage 5-6) 2" off seed row	DEFG	45.0
[Upper] Early Seeded, Spring side-banded urea N at 1.0 x rec rate	EFG	44.6
[Lower] Early Seeded, Spring side-banded urea N at 0.5 x rec rate	EFG	44.5
[Upper] Early Seeded, Spring side-banded urea N at 1.5 x rec rate	EFG	44.1
[Upper] Early Seeded, Spring side-banded urea N at 0.5 x rec rate	EFG	44.1
[Upper] Early Seeded, Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (feekes stage 5-6) 2" off seed row	EFG	43.9
[Lower] Early Seeded, Spring side-banded CRU at 0.5 x rec rate	EFG	43.7
[Upper] Early Seeded, Spring side-banded CRU at 1.0 x rec rate	EFG	43.2
[Upper] Early Seeded, Spring side-banded CRU at 0.5 x rec rate	EFG	43.0
[Lower] Late Seeded, Control - no N	EFG	42.9
[Upper] Late Seeded, Control - no N	EFG	42.8
[Lower] Early Seeded, Control - no N	FG	41.7
[Upper] Early Seeded, Control - no N	G	40.3

[z] Letters indicate significant differences $P < 0.05$ within years, Tukey HSD

Table 4. Leaf nitrogen seeding by treatment interaction July 21, 2008, Brandon site by sample date

Level		Leaf N (mg g^{-1})
Late Seeded, Spring side-banded urea N at 1.5 x rec rate	A [z]	50.3
Late Seeded, Spring,Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (feekes stage 5-6) 2" off seed row	A	50.2
Late Seeded, Spring side-banded urea N at 0.5 x rec rate	A	50.1
Late Seeded, Spring side-banded CRU at 1.0 x rec rate	A	50.1
Late Seeded, Spring side-banded urea N at 1.0 x rec rate	A	49.7
Late Seeded, Spring side-banded CRU at 0.5 x rec rate	A	49.2
Late Seeded, Seeded, Control - no N	A	49.1
Early Seeded, Spring side-banded urea N at 1.0 x rec rate	B	41.4
Early Seeded, Spring side-banded urea N at 1.5 x rec rate	B	41.1
Early Seeded, Split N application 2- 0.5 side-banded at seeding and 0.5 dribble-banded as UAN at late tillering to early stem extension (feekes stage 5-6) 2" off seed row	B	40.6
Early Seeded, Spring side-banded CRU at 1.0 x rec rate	BC	40.3
Early Seeded, Spring side-banded urea N at 0.5 x rec rate	BC	39.9
Early Seeded, Spring side-banded CRU at 0.5 x rec rate	BC	39.2
Early Seeded, Control - no N	C	37.8

[z] Letters indicate significant differences $P < 0.05$ within years, Tukey HSD

Sensors

Greenseeker and SPAD measurements varied during the growing season, with site and landform effects occurring in June 2007, followed by N fertilizer in July 2007. Correlations between SPAD measurements and leaf N increased during the growing season. This was attributed to high values of leaf N early in the growing season, increasing variability with time, and delayed plant response to soil N deficiencies and fertilizer N treatments. Although SPAD measurements were not significantly (P=0.05) related to leaf nitrogen on June 27, N treatment differences were observed July 19, with the lowest values for the controls. Leaf nitrogen response to fertilizer N treats was observed at later dates in the growing season. Significant differences in leaf nitrogen may not be detectible in the Black Soil Zone of Western Canada until later in the growing season during early to mid July.

Greenseeker, Dualex and SPAD readings were affected by fertilizer N treatments though not consistently for data collected in June of 2007 and 2008. Greenseeker readings were more highly correlated with plant cover relative to leaf N in 2008, Holzapfel et al. (2009) reported that the Greenseeker effectively applies nitrogen fertilizer at variable rates in late June or early July, which may be due to the correlation with plant cover. Dualex readings were also significantly related to leaf N.

Although there was significant variability in soil NO_3-N between landforms and sites in fall 2006 prior to the study, residual soil NO_3-N did not show significant differences. In contrast to 2007, significant differences in residual soil NO_3-N were observed due to an interaction between seeding date, landform and fertilizer treatments following harvest in fall 2008.

This study identified several logistical and agronomic challenges to variable management of N fertilizer during the growing season based on sensor readings. First, leaf N response in 2007 and 2008 was complex due to interactions between landform, seeding date, type of fertilizer, rate and timing of application. Second the correlation between leaf N near heading and crop yield was low. Third, the short growing season in Western Canada, combined with the delay in development of leaf N deficiencies till mid-July, reduce the period during which nitrogen fertilizer can be applied based on in-crop sensor readings. Greenseeker readings, which were highly correlated with plant cover, may be used early in the growing season for variable rate management if variability in landform, seeding date, type and application timing of nitrogen fertilizer are considered.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Dr. Yafit Cohen and Dr. Victor Alchanatis, Agricultural Research Organization, Israel who contributed to the literature review and research methodology for a similar study on potatoes. Mike Svistovski, Brian Hadley, Grant Gillis and Matt O’Hara, provided technical assistance.

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