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Determining Nitrogen Nutrition and Yield of Canola Through Existing Remote Sensing Technology

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Abstract: Over the past few decades there has been considerable research evaluating sensor-based technologies for in-season application of Nitrogen (N). The majority of this research has been done on wheat (*Triticum aestivum* L.) and corn (*Zea mays* L.), with little research on other crops. A field study was established in Brookings, SD to evaluate the GreenSeeker Hand Held optical sensor (NTech Industries, Ukiah, CA) for measuring in-season N status on canola (*Brassica napus* L). Sensor readings and plant biomass samples were collected at four different intervals through the rosette to early bud growth stages. The sensor measures reflectance in the red and Near Infrared (NIR) regions of the electromagnetic spectrum and calculates a Normalized Difference Vegetation Index (NDVI). The ability of the sensor readings to measure biomass, plant N uptake and predict seed yield and protein for each sampling date was determined. In general, in-season plant biomass, plant N concentration and seed yield increased with increasing N rate. Sensor readings (NDVI) showed a significant relationship with plant biomass, N uptake and seed yield regardless of sampling dates. Measurements collected in mid May resulted in the highest correlation with plant biomass, while the relationship increase with later sampling dates for yield. Results suggest that existing sensor-based variable nitrogen technology developed has the potential to be utilized for other non-traditional crops such as canola.

Key words: Remote sensing, nitrogen management, NDVI, canola

INTRODUCTION

Precision agriculture might be defined as assessing and understanding the spatial and temporal variability within a field and applying management decisions based on this variability. There is spatial variability in fields because of differences in soil types, landscape positions, past management practices, or many other factors described by Kincheloe (1994). This variability can lead to non-uniform yields and/or uneven yield potential, resulting in areas of the field that should be managed differently for economical or environmental reasons. In the past, management has frequently been based on average conditions for each particular field or the needs of the most limiting area, resulting in some areas receiving more input than needed for optimum yield. These practices could then lead to increased environmental pollution due to over-fertilization and/or increased leaching and runoff of nutrients. Managing according to average field conditions would likely supply less input than needed for optimum yield in portions of the field, thus decreasing yields as a result of nutrient deficiencies.

Over the past 10 to 20 years researchers have been evaluating alternative fertilizer management techniques including on-the-go nitrogen application as a possible method to reduce this field variability. This research has been in response to increase environmental concerns due to over fertilization, causing increased nutrient leaching and runoff and the increased cost associated with fertilizer inputs and has focused on the major cereal crops of North America.

One such technology is currently being marketed for topdress N fertilizer for winter wheat and corn in the southern and central Great Plains. Additional research is needed to advance this technology to other production systems. Early research by Aase and Tanaka (1984) found that reflectance measurements (NIR/red ratios) could be used to estimate leaf dry matter or leaf area in spring and winter wheat. Reflectance in the green region of the visible portion of the electromagnetic spectrum is a good indicator of N concentration in crops including corn (*Zea mays* L.), wheat and bermudagrass (*Cynodon dactylon* (L) *Pers.*) as found by Blackmer *et al.* (1994), Walburg *et al.* (1982), Aase and Tanaka (1984) and Blackmer *et al.* (1994). Stone *et al.* (1996) estimated total winter wheat plant N concentration using spectral radiance measurements in the red (671 nm) and NIR (780 nm) region.

Recent research by Raun *et al.* (2002) founded that plant N use efficiency increased through topdressing winter wheat based on in-season sensor readings (NDVI) collected with a hand held instrument measuring every 1 m^2 area. These measurements could be utilized to estimate grain yield in-season to determine N recommendations; results have found that in-season measurements explain 83% of the variability in measured grain yield (Raun *et al.*, 2001). This technology has the potential of decreasing environmental r isks due to over-fertilization by applying N only where it is needed and/or at the locations most likely to respond to fertilizer N. Raun *et al.* (2005) found that plant N use efficiency was increased by 15% for fertilizer applied based on sensor readings compared to traditional methods. This research was conducted primarily in the southern Great Plains in winter wheat production systems; additional information is needed to expand this technology to other regions and production systems. The objective of our research was to evaluate this technology for predicting in-season N status and seed yield for canola production in the Northern great plains.

MATERIALS AND METHODS

The experiments were located near Brookings, South Dakota on a Lismore silty clay loam (fine-loamy, mixed, pachic Udic Haploboroll) at the USDA, ARS, North Central Agricultural Research Laboratory. Planting occurred on 23 March 2004 with canola variety Aventis 2663 Liberty Link at seeding rates of 277 plants m^{-2}. The experimental design was a randomized complete block design with four replications. The treatments consisted of five by three factorial with five N rates (0, 35, 70, 105 and 140 kg N ha^{-1}) and three S rates (0, 15 and 30 kg S ha^{-1}) applied pre-plant as ammonium nitrate and potassium sulfate, respectively. Plots were 3×3 m with 0.18 m row spacing.

Sensor readings were collected at four different dates (11, 18, 21 and 28 May, 2004) through the rosette to early bud growth stages with a GreenSeeker Model 505 Hand Held optical sensor (NTech Industries, Ukiah, CA). Sensor readings (NDVI) were collected at a height of approximately 1 meter above the canopy. A 0.3 m by 0.6 m area was scanned at each sampling date and samples were collected for biomass production and N concentration analysis. A separate 0.3×0.6 m area was scanned and left for seed yield estimation at maturity.

Biomass samples were dried for 120 h in a forced-air oven at 60°C and weighed to obtain dry matter production. Samples were ground to pass a 2 mm sieve. Total N concentration was determined using dry combustion as described by Schepers *et al.* (1989). Nitrogen uptake was estimated by multiplying total N analysis and dry plant biomass. Seed yield was estimated by hand harvesting the 0.3 m b y 0.6 m area scanned in-season at each samping date. Seed yield was calculated and corrected to 130 g kg^{-1} moisture. Seed N Use Efficiency (NUE) was calculated using the difference method (N uptake in the no N treatment subtracted from N uptake in the fertilized treatment dived by the N rate applied). Statistical analysis was performed on plant biomass, plant N concentration, plant N uptake, seed yield, seed N concentration and seed N uptake using the GLM procedure and correlation coefficients between sensor reading and plant measurements were calculated using the CORR procedure SAS, (1988) utilizing $\alpha = 0.05$.

RESULTS AND DISCUSSION

Plant biomass and seed yield: Application of S did not significantly impact canola biomass, yield or nutrient composition; therefore results will focus on the main effect of N rate on biomass and seed production throughout the results and discussion. Application of N significantly affected biomass production, plant N concentration and plant N uptake regardless of plant sampling date (Table 1). Maximum plant biomass was obtained for the 35 kg N ha^{-1} N rate for the first sampling date (11 May), with an increase 1.9 times that obtained from the no N treatment. Later sampling dates resulted in maximum biomass production at higher N rates (105 kg N ha^{-1} for 18 May; 70 kg N ha^{-1} for 21 May; and 140 kg N ha^{-1} for 28 May with 2.9, 2.1 and 2.4 times greater production than the no N treatment, respectively). A positive response to N application was also found for plant N concentration (Table 1), with maximum plant N concentration and plant N uptake obtained for the 105 kg N ha^{-1} rate for 11 and 15 May and the 140 kg N ha^{-1} rate for the 21 and 28 May sampling dates (Table 1).

Canola seed yield increased with increasing N application, with maximum seed yield obtained for the 105 kg N ha^{-1} N rate, this represents a seed yield increase of 4.4 times above the no N treatment (Table 2). There was positive impact of seed N concentration due to the application of N, but the magnitude of the increase was less than that obtained with seed yield or N uptake. Seed N concentration increased with increasing N applied with the maximum seed N for the 140 kg N ha^{-1} rate with an increase of only 1.08 times that observed for the no N

Table 1: Plant biomass, N concentration and N uptake response to applied N, treatment means and probability of a significant treatment difference to N rate at four sampling dates, Brookings, SD, 2004

N Rate	Biomass, kg ha^{-1}	Plant N, g kg^{-1}	N Uptake, kg ha^{-1}
5/11/04			
0	122	2.93	4.40
35	239	4.01	10.13
70	216	4.57	10.66
105	211	5.50	12.57
140	199	5.40	11.13
Pr > f‡	0.0172	0.0001	0.0056
5/18/04			
0	199	3.38	6.65
35	429	4.32	18.56
70	511	4.70	23.87
105	580	5.28	30.64
140	433	5.29	23.16
Pr > f‡	0.0001	0.0001	0.0001
5/21/04			
0	316	2.53	7.89
35	608	4.13	26.39
70	667	4.66	30.80
105	622	5.02	31.53
140	649	5.44	35.55
Pr > f	0.0001	0.0001	0.0001
5/28/04			
0	647	2.59	18.53
35	1103	3.07	33.18
70	1421	3.76	55.55
105	1452	4.46	64.95
140	1569	5.19	79.96
Pr > f	0.0002	0.0001	0.0001

‡Probability of a significant response to applied N

Table 2: Canola seed yield, N concentration, N uptake and NUE response to applied N, treatment means and probability of a significant treatment difference to N rate, Brookings, SD, 2004

N Rate	Seed Yield, kg ha^{-1}	Seed N, g kg^{-1}	N Uptake, kg ha^{-1}	NUE, %
0	949	3.00	28.58	
35	2083	2.90	59.79	89
70	2972	2.94	87.15	84
105	4193	3.09	131.42	98
140	4072	3.26	134.13	75
Pr > f‡	0.0001	0.0001	0.0001	

‡Probability of a significant response to applied N

treatment (Table 2). Similar to seed yield maximum N uptake was 4.7 times greater for the 140 kg N ha^{-1} rate compared to the no N treatment (134 compared to 29 kg ha^{-1}). Calculated NUE estimates the percent of fertilizer N applied that was removed by the seed. All N rates resulted in NUE greater than 75%. Nitrogen use efficiency commonly reported for cereal crops are around 33% (Mullen *et al*., 2003). Results from this research found NUE of 89, 84, 98 and 75% for the 35, 70, 105 and 140 kg N ha^{-1}, respectively (Table 2).

Table 3: Simple correlation coefficients from linear regression and significance levels for biomass production, plant N concentration, N uptake and seed yield with NDVI spectral readings, Brookings, SD, 2004

Sampling date	In season plant sampling Biomass kg ha^{-1}	Plant N g kg^{-1}	N Uptake kg ha^{-1}
5/11/04	0.84**	0.35*	0.61**
5/18/04	0.89**	0.37**	0.80**
5/21/04	0.87**	0.59**	0.84**
5/28/04	0.81**	0.61**	0.66**
	Seed yield		
Sampling date	Seed yield kg ha^{-1}	Seed N g kg^{-1}	N Uptake kg ha^{-1}
5/11/04	0.33*	0.27*	0.34*
5/18/04	0.42**	0.15	0.41**
5/21/04	0.52**	0.16	0.50**
5/28/04	0.73**	0.19	0.70**

**, * Significant at the 0.01 and 0.05 probability level, respectively

Sensor readings: Simple correlation coefficients for biomass, plant N concentration, N uptake and seed yield with NDVI sensor readings by sampling date are reported in (Table 3). All plant biomass, plant N concentration and N uptake correlations were statistically significant at the 0.01 probability (Table 3). Linear regression results show that the second sampling date (18 May) had the strongest relationship (R^2 = 0.797), while the relationship for the later sampling date (28 May) was no longer linear (Fig. 1). At this sampling date the higher N rate plots had complete ground cover and biomass growth was occurring along the main stem of the plant, while there was not complete ground cover for the lower N treatments. This could have saturated the sensor for the two higher N treatments resulting in a decrease in the linear relationship. In contrast to plant biomass the relationship between the sensor readings and plant N concentration improved for the later sampling dates compared to the earlier sampling dates (Table 3). Results for plant N uptake and NDVI readings were similar to plant biomass, with higher correlation for the 18 and 21 May sampling dates compared to the early and late (11 and 28 May) sampling dates (Table 3).

The ability of the sensor to estimate seed yield was evaluated and results of the simple correlation coefficients are reported in (Table 3). In contrast to plant biomass the correlation coefficients with NDVI improved for the later sampling dates for seed yield and seed N uptake, while coefficients for NDVI and seed N concentration decrease with sampling date. The only significant correlation for seed N and NDVI was obtained at the first sampling date. Results of correlation for seed yield was less than those obtained from biomass samples and corresponding NDVI readings (Table 3).

Due to the reduced simple correlation, we evaluated other non-linear relationships (Fig. 2). A logarithmic equation resulted in the best relationship for sensor readings and seed yield. Similar to simple correlation

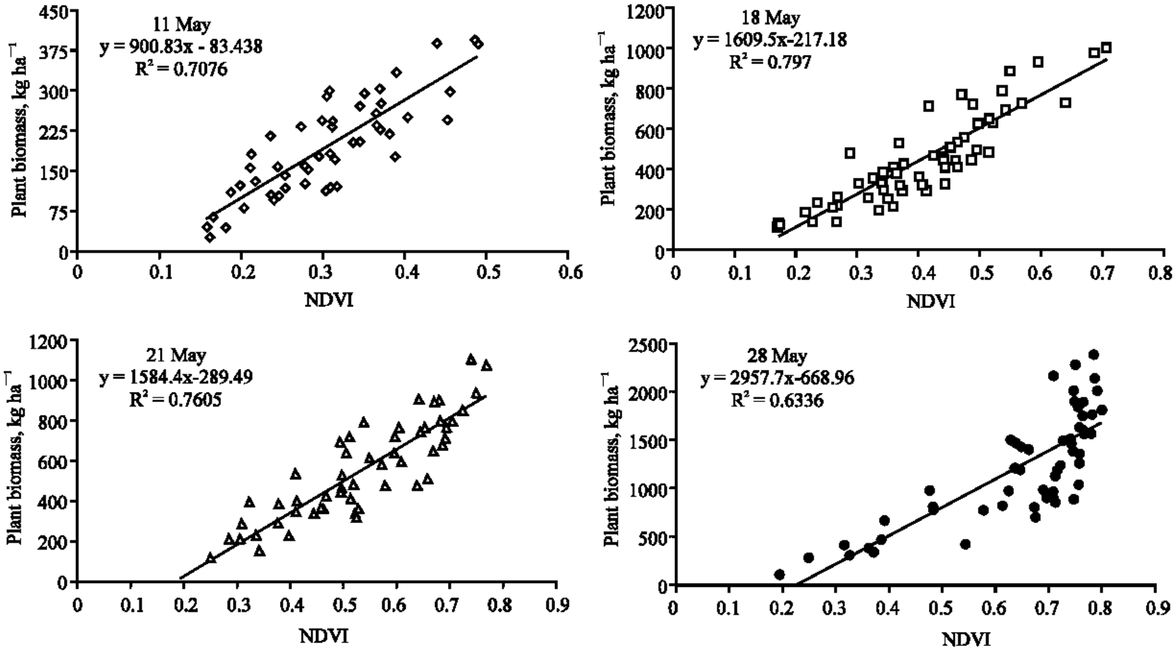

Fig. 1: Relationship between sensor NDVI reading and plant biomass for all N and S rates for all sampling dates, Brookings, SD, 2004

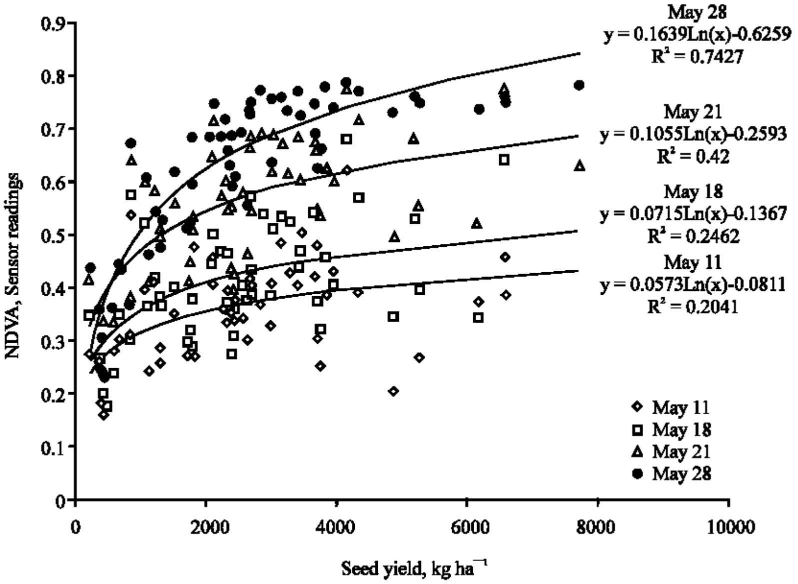

Fig. 2: Relationship between sensor NDVI reading and seed yield for all N and S rates at all sampling dates, Brookings, SD, 2004

results; the highest correlation was obtained for the late sampling date (28 May) resulting in an $R^2 = 0.74$. Overall the magnitude of readings increases with sampling date (Table 3).

CONCLUSION

Plant biomass, seed yield and N nutrient were significantly affected by N application regardless of sampling date, with production increasing with increasing N applied. This positive response to applied N demonstrated that a suitable location was chosen to evaluate the potential of utilizing the GreenSeeker as a possible tool to estimate in-season plant N status and seed yield for canola production in the northern Great Plains. Regardless of sampling date sensor readings showed a significant relationship between sensor readings and plant biomass, but decreased with sampling date. However, the relationship between sensor readings and yield resulted in an increase with later sampling dates. Additional testing is needed to properly evaluate this sensor to determine the impact on N use efficiency and its suitability in our growing conditions, but initial research results are promising. Future research will evaluate the ability of the sensor under extremely different environmental conditions and different agronomic conditions.

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