USE OF ACTIVE-OPTICAL SENSORS FOR EARLY SEASON PREDICTION OF SUGARBEET YIELD AND QUALITY

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This project is part of a larger National Science Foundation (NSF) project to use satellite imagery to predict in-season sugarbeet, spring wheat, corn and sunflower nitrogen (N) application, to use satellite imagery to predict in-season N supplemental for these four crops, and to better predict sugarbeet yield and quality early in the season on a wide regional basis. Only first-year research regarding the use of active-optical sensors for early season prediction of sugarbeet yield and quality are presented in this paper.

The first commercial active-optical sensor was developed at Oklahoma State by W.R. Raun and his group of colleagues and students in the 1990's (Raun et al., 2001). The Greenseeker® sensor was acquired by N-Tech Industries, and then most recently acquired by Trimble Navigator Ltd. The concept of the sensor is to shine a directed red and infrared light onto plant leaves in a coded light pulse. Some of the light is reflected by the plant leaves depending on the general plant health and the effective area of the leaves (leaf area index). Some of the light waves are absorbed by the leaves. The ratio of the red to infrared light is effectively a kind of NDVI (normalized difference vegetative index), which when received by a passive light sensor, such as certain earth satellites, as:

(Amount of Near Infrared light – Amount of Red light) / (Amount of Near Infrared light + Amount of Red light)

Raun et al. (2001) constructed the relationship between Greenseeker readings in winter wheat at spring top-dress time with the 'In-season Estimate of Yield' (INSEY). From INSEY determined early in the season, the difference in yield predicted from an N-rich environment within a field within a variety to any other area of the field results in a predicted yield difference. The N required to produce the N-rich yield is determined from the predetermined INSEY relationship. The predicted N deficit divided by an efficiency factor for the N applied resulted in the N prescribed to amend the deficient area.

A more recently developed active-optical sensor is the Holland Scientific Crop Circle Sensor® (Holland Scientific, Lincoln, NE). The algorithms developed for yield and N deficit correction using this sensor is described in Schepers and Holland (2010). The Crop Circle sensor has the option to use near infrared and red light, but also near infrared and red-edge light. The red-edge light explores a similar light as we perceive greenness. Both the Greenseeker and the Holland Crop Circle sensors were used in this study.

METHODS

Two sites were established in fall 2011. The experimental design at both sites was a randomized complete block with 6 treatments (check, 30, 60, 90, 120 and 150 lb N/acre) and 4 replications. Individual plot size was 30 feet long and 30 feet wide. One site was located near Crookston, east of the University of Minnesota, Crookston campus at about 47°47'58.426" N, 96°35'55.461" W. Residual N was 84 lb in the top two feet and the sugarbeets in 2012 following a 2011 spring wheat crop in a conventional tillage system. Fertilizer was applied by hand as ammonium nitrate (34-0-0) April 3, 2012. The field and the plot was planted by the University of Minnesota, Crookston Research Farm staff April 25, using Vanderhavre 36813 RR at a 5-inch seed spacing in 22-inch rows (57,000 seeds per acre). Weed control and bolter control was conducted by the cooperators, except for a hand-weeding at the June 21 sensor reading date. Both Greenseeker and Crop Circle sensor readings (NDVI and Red-Edge NDVI) were obtained from one row of each plot June 4 (918 growing degree days (gdd)), June 21 (1457 gdd) and three harvests were conducted August 15 (3458 gdd), August 31 (3933 gdd) and September 15 (4375 gdd). Harvest consisted of pulling by hand 10 feet of an interior row in each plot. The next harvest was physically separated from the previous harvest by two rows. Tops were removed with a sugarbeet machete tool and placed in a large plastic garbage can. The beets with tops removed were all placed in a tare bag and taken to the East Grand Forks tare laboratory for quality analysis. The tops were weighed fresh from the field, the garbage can weight was recorded as a tare, and a subsample of the tops from each plot were placed in a plastic bag, weighed and stored in a cooler. After harvest was complete, the subsamples were taken to the NDSU campus soil sheds, placed in paper bags and dried at 50° C for two days and reweighed, subtracting tares for both the paper bags and the plastic bag weights.

The second site was located two miles southwest of Amenia at about 46° 58'34.623" N, 97° 15'04.762" W. Plot design was identical to the Crookston site. Beginning soil nitrate to two feet in depth was 136 lb N/acre and the sugarbeets in 2012 followed spring wheat in 2011. Fertilizer N treatments were applied April 4. The field and the experiment were planted by the cooperator using Crystal 095 at 67,500 seeds per acre on April 12. Starter was applied with the seed at 3 gallons per acre 7-17-0 (Riser). Quadris was applied May 17, and 22 ounces per acre Roundup Max was applied May 18, both by the cooperator. The site was weed-free the entire season.

The Greenseeker and Crop Circle (NDVI and Red-Edge NDVI) sensor readings were obtained on May 23 (889 gdd), June 13 (1486 gdd), and at the two harvest dates of August 15 (3832 gdd) and August 30 (4324 gdd). A third harvest date was not taken, as the extreme dry weather was inhibiting additional beet development.

RESULTS

Crookston

There were no significant sugarbeet yield differences with N rate at any of the three harvests (Tables 1, 2 and 3). Per cent sugar decreased with N rate at the first harvest. Per cent sugar loss to molasses and aminio-N increased with N rate at the first harvest, but not at the following harvests. Recoverable sugar per acre was maximized at the 60 lb/acre N rate at the 8/15 and 8/31 harvest dates, and the 30 lb/acre N rate at the 9/15 harvest date. Gross dollar return per acre was maximized at the first harvest date with 30 lb N/acre, and was maximized at the second and third harvest date with the 60 lb N/acre treatment. Sugarbeet top yield increased with N rate at the first harvest date. Top yields increased until the second harvest date, where there was no difference between treatments, and then top yield declined as continued dry conditions affected sugarbeet growth.

Table 1. Sugarbeet yield and quality with N rate, 8/15 harvest date, Crookston, 2012.

Treatment Pounds N Per Acre	Yield Tons Per Acre	Per Cent Net Sugar	SLM%*	Amino-N	Harvest Beets Per Acre	RST†	RSA‡	GRT§	GRA§§	Top Yield Pounds Per Acre
Check	25.9	16.5	1.32	443	48,700	304	7860	$47.47	$1229	2992
30	25.9	17	1.31	435	45,700	314	8140	$50.80	$1316	2962
60	27.2	16.5	1.37	490	48,700	303	8250	$47.3	$1282	3392
90	27.3	16.2	1.42	518	48,700	296	8060	$44.81	$1223	3702
120	27.1	16	1.44	517	46,300	292	7910	$43.52	$1175	4465
150	27.6	15.6	1.57	588	46,300	281	7760	$40.04	$1100	4241
F	0.82	5.52	5.15	6.64	0.20	6.28	0.45	6.28	1.78	24.12
Pr>F	0.56	0.004	0.006	0.002	0.96	0.003	0.81	0.003	0.18	<0.0001
LSD 5%	NS	0.7	0.13	65	NS	14	NS	$4.40	$160	350

*Per cent sugar loss to molasses
†Recoverable sugar per ton ‡Recoverable sugar per acre
§Gross return per ton §§Gross return per acre

Table 2. Sugarbeet yield and quality with N rate, 8/31 harvest date Crookston, 2012.

Treatment Pounds N Per Acre	Yield Tons Per Acre	Per Cent Net Sugar	SLM%*	Amino-N	Harvest Beets Per Acre	RST†	RSA‡	GRT§	GRA§§	Top Yield Pounds Per Acre
Check	28.6	21.1	1.50	520	45,740	355	10640	$64.33	$1930	5602
30	31.2	21.1	1.52	525	48,700	356	11110	$64.77	$2021	5777
60	29.7	21.8	1.38	465	45,100	364	11220	$67.24	$2073	5336
90	30.1	21.4	1.40	485	42,770	365	10450	$67.87	$1938	5785
120	30.6	21.5	1.34	450	51,680	356	10630	$64.82	$1933	5401
150	29.2	20.9	1.37	457	42,174	358	10480	$65.46	$1906	6138
F	0.95	0.77	0.56	0.30	2.22	0.37	0.65	0.37	0.61	0.33
Pr>F	0.48	0.59	0.73	0.90	0.11	0.86	0.67	0.86	0.70	0.89
LSD 5%	NS	NS	NS	NS	8,000	NS	NS	NS	NS	NS

*Per cent sugar loss to molasses
†Recoverable sugar per ton ‡Recoverable sugar per acre
§Gross return per ton §§Gross return per acre

Table 3. Sugarbeet yield and quality with N rate, 9/15 harvest date, Crookston, 2012.

Treatment Pounds N Per Acre	Yield Tons Per Acre	Per Cent Net Sugar	SLM%*	Amino-N	Harvest Beets Per Acre	RST†	RSA‡	GRT§	GRA§§	Top Yield Pounds Per Acre
Check	28.6	19.6	1.50	520	45140	392	11230	$76.70	$2196	2342
30	31.2	19.5	1.52	525	47520	391	12179	$76.28	$2372	2430
60	29.7	20.4	1.38	465	46330	409	12070	$82.15	$2417	2193
90	30.1	20.0	1.40	485	43960	401	12030	$79.46	$2385	2450
120	30.6	20.2	1.34	450	45140	403	12330	$80.40	$2455	2538
150	29.2	19.5	1.37	457	42170	390	11370	$75.87	$2216	2219
F	0.95	0.76	0.56	0.30	0.27	0.76	1.53	0.76	1.48	0.07
Pr>F	0.48	0.59	0.73	0.90	0.92	0.59	0.24	0.59	0.26	0.93
LSD 5%	NS	NS	NS	NS	NS	NS	1100	NS	NS	NS

*Per cent sugar loss to molasses
†Recoverable sugar per ton ‡Recoverable sugar per acre
§Gross return per ton §§Gross return per acre

Amenia

At the first harvest, sugar loss to molasses, amino-N and sugarbeet top yield increased with N rate, but not sugarbeet yield, per cent sugar, beet stand at harvest, recoverable sugar per ton, per acre, or gross return per ton or per acre (Tables 4 and 5). Sugarbeet yield did not increase between the first and second harvest date, although the per cent sugar was greater at the second harvest date. Recoverable sugar per ton increased from the first to the second harvest as did the gross return per ton and per acre.

Table 4. Sugarbeet yield and quality with N rate, 8/15 harvest date, Amenia, 2012.

Treatment Pounds N Per Acre	Yield Tons Per Acre	Per Cent Sugar	SLM%*	Amino-N	Harvest Beets Per Acre	RST†	RSA‡	GRT§	GRA§§	Top Yield Pounds Per Acre
Check	17.7	19.5	1.37	486	51,080	363	6402	67.07	1180	1652
30	18.8	19.3	1.41	516	56,430	358	6669	65.35	1208	1749
60	18.6	19.7	1.49	580	52,270	363	6764	67.15	1250	2310
90	21.0	18.8	1.56	616	52,870	344	7144	60.72	1252	2553
120	21.4	19.0	1.53	620	53,460	348	7419	62.23	1322	2671
150	19.8	19.4	1.79	783	58,210	351	6931	63.19	1245	2926
F	0.96	0.70	6.58	7.93	0.59	0.87	0.99	0.87	0.90	6.56
Pr>F	0.47	0.63	0.002	0.001	0.71	0.52	0.45	0.52	0.51	0.002
LSD 5%	NS	NS	0.18	100	NS	NS	NS	NS	NS	600

*Per cent sugar loss to molasses
†Recoverable sugar per ton ‡Recoverable sugar per acre
§Gross return per ton §§Gross return per acre

Table 5. Sugarbeet yield and quality with N rate, 8/30 harvest date, Amenia, 2012.

Treatment Pounds N Per Acre	Yield Tons Per Acre	Per Cent Net Sugar	SLM%*	Amino-N ppm	Harvest Beets Per Acre	RST†	RSA‡	GRT§	GRA§§	Top Yield Pounds Per Acre
Check	16.2	21.7	1.40	564	51080	405	6566	$81.03	$1311	1892
30	17.7	21.5	1.58	674	56430	399	6997	$78.94	$1377	3112
60	17.9	21.6	1.73	798	52270	397	7105	$78.17	$1400	3527
90	20.5	20.2	1.83	858	52870	367	7426	$68.41	$1367	2881
120	17.9	21.4	.78	827	53460	392	6971	$76.67	$1357	3303
150	17.0	21.6	2.03	998	58210	390	6616	$76.11	$1289	3513
F	1.26	0.74	6.98	6.84	0.59	1.02	0.94	1.02	0.51	2.95
Pr>F	0.33	0.61	0.002	0.002	0.71	0.44	0.48	0.44	0.76	0.05
LSD 5%	NS	NS	0.20	140	NS	NS	NS	NS	NS	1050

*Per cent sugar loss to molasses
†Recoverable sugar per ton ‡Recoverable sugar per acre
§Gross return per ton §§Gross return per acre

Relationship between active optical sensor readings and estimate of yields

The yield results from the two sites were combined with their sensor readings and regression analysis was conducted. Figure 1 illustrates that the Greenseeker INSEY, obtained from the May 23 reading could be used to predict sugarbeet tonnage at the August 15 harvest date. Canopy height obtained the same day improved the relationship. Franzen et al. (2001) previously found that multiplying the Greenseeker reading times canopy height improved the prediction of N content of the sugarbeet tops. Figure 2 shows the relationship between the Greenseeker INSEY, with and without canopy height consideration at the June 13 reading to predict the August 15 harvest tonnage. Figure 3 shows that the May 23 Greenseeker INSEY could also predict the August 30 harvest tonnage.

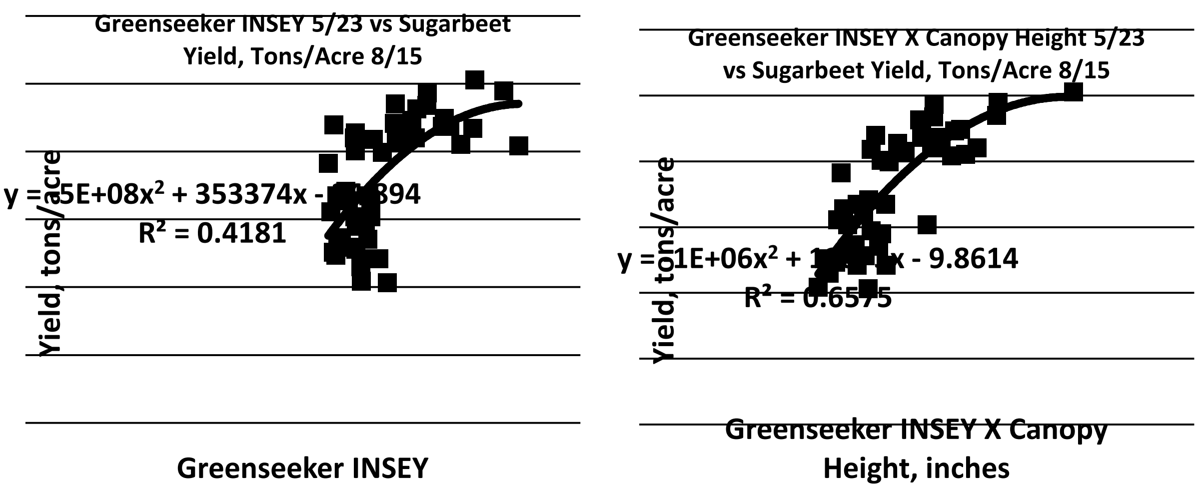

Figure 1. Greenseeker INSEY without (left) and with (right) canopy height consideration, May 23 sensing, 8/15 harvest.

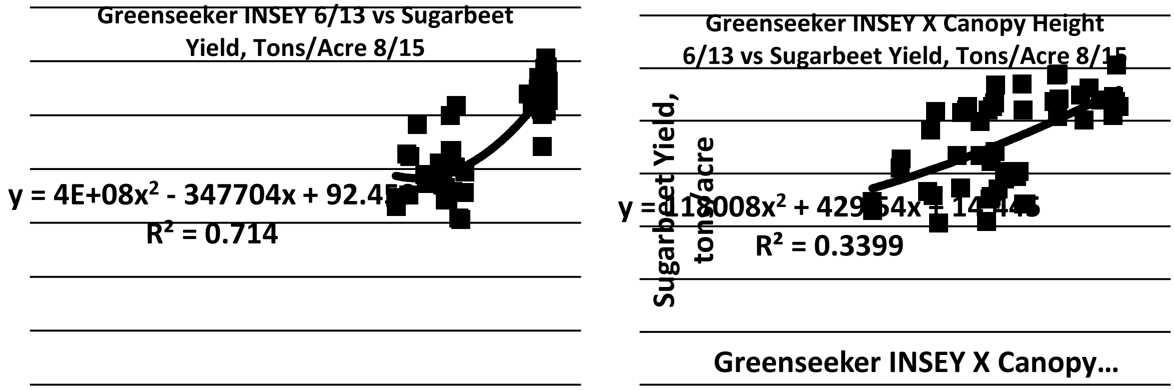

Figure 2. Greenseeker INSEY without (left) and with (right) canopy height consideration, June 13 sensing, 8/15 harvest.

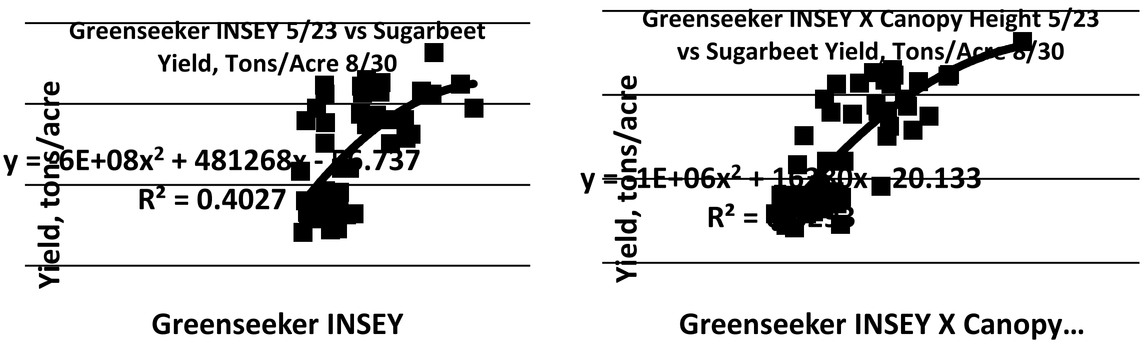

Figure 3. Greenseeker INSEY without (left) and with (right) canopy height considerations, May 23 sensing, 8/30harvest.

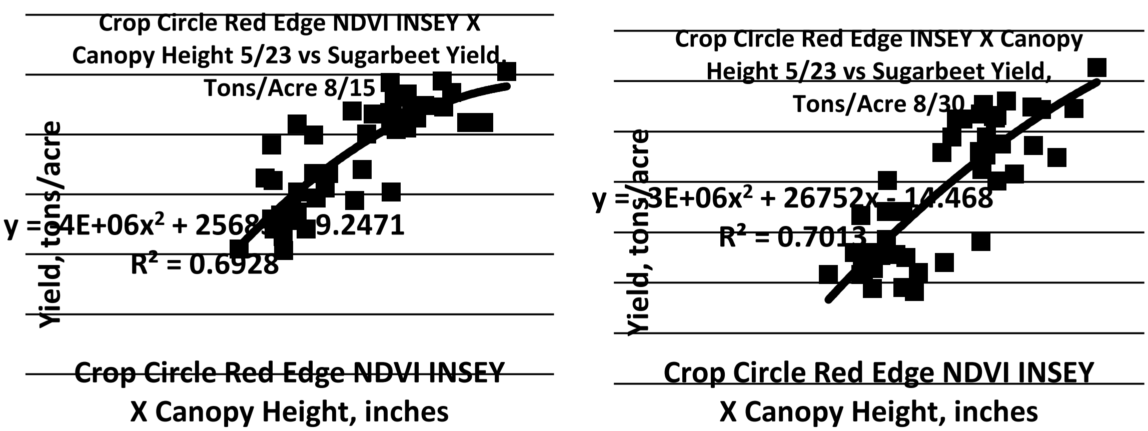

Figure 4. Crop Circle Red Edge INSEY with canopy height considered , May 23 sensing, 8/15 harvest (left), 8/30 harvest (right).

The Crop Circle, using either the NDVI INSEY (not shown) or the red edge INSEY (Figure 4) could similarly predict sugarbeet yield at both the 8/15 and 8/30 harvest dates. All of the sensors could also predict the recoverable sugar per acre from both pre-harvest readings to both harvest dates. Figure 5 illustrates one of the sensor relationships using the Crop Circle Red Edge INSEY X Canopy Height at the May 23 harvest date.

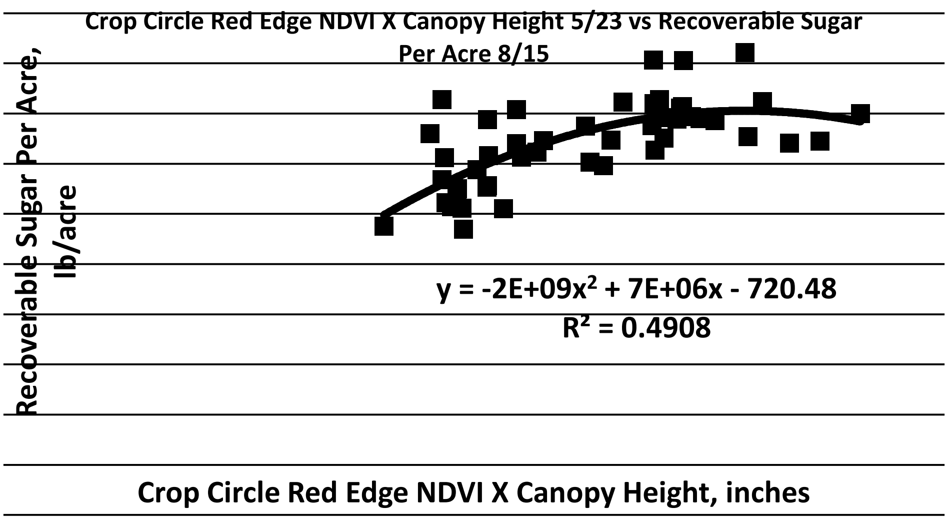

Figure 5. Crop Circle Red Edge INSEY with canopy height considered, May 23 sensing, 8/15 harvest date.

SUMMARY
Both active-optical sensors tested- the Greenseeker and the Holland Crop Circle sensors, were found to predict sugarbeet yield and quality from an early sensing date. Canopy height consideration usually increased the INSEY relationship with yield prediction. The data base will need to be expanded however and tested to improve confidence. An additional aspect of this research will explore using satellite NDVI as a prediction tool to detect both in-season N application needs and rates, as well as better predicting yield and quality through the August-October time period to help logistics of both fertilizer and beet processing logistics.

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