Validating Post-Emergent N Application Algorithms for the GreenSeeker[tm] Optical Sensor in Cereals and Canola using Small Plot Studies and UAN Solution (Final Report)

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1.0 INTRODUCTION

Nitrogen (N) fertility management encompasses four major components, source, placement, timing and rate (Malhi et al. 2001). Research has demonstrated that there is very little difference between fertilizer forms, providing they are managed appropriately (Johnston et al. 1997; Grant et al. 2002). Placing the fertilizer in the soil, as opposed to on the surface, greatly minimizes losses from volatilization and immobilization and enhances overall N fertilizer recovery (Malhi and Nyborg 1991; Malhi et al. 2001; Grant et al. 2002). The timing of N application should be such that it is available close to the time of maximum crop uptake which in cereal grains extends from the start of elongation until heading with peak uptake during flag leaf extension (Bauer et al. 1987) and in canola from the start of flowering to the end of pod formation (Malhi et al. 2007).

The current N fertilizer rate recommendations on the Canadian prairies generally consider factors such as soil texture, residual soil nitrate levels, soil moisture at seeding, average growing season precipitation, previous crop grown, crop to be grown, target grain yield, expected commodity prices and N fertilizer prices (McKenzie 1998; Anonymous 2007). However there is much uncertainty with all of these factors due to year to year variations in climatic conditions and to spatial and temporal variability in soil nutrient levels and the inherent fertility of the soil. Nitrogen release during the growing season and the major pathways of N losses (immobilization, volatilization, denitrification and leaching) are also greatly influenced by climatic conditions, making their amounts very difficult to estimate. Consequently, much uncertainty exists in determining crop N requirements and the rate of application can easily be under or overestimated with important economic and/or environmental consequences in either case.

There is interest in exploring post-emergent N applications in annual crops to refine our ability to arrive at more optimal rates of N fertilizer. Delaying some or all of the N fertilizer until after crop emergence may allow for a better sense of temporal changes in yield potential and growing conditions. Recent research with spring wheat and canola using post-emergent N applications as an N management tool compared applying all fertilizer at time of seeding in the soil with in-crop surface banded applications of liquid urea-ammonium nitrate at different times after seeding. Holzapfel et al. (2007) showed no adverse effects in canola but some yield depression was observed in spring wheat, especially in those years where little precipitation was received after N application. In order to reduce the risks associated with post-emergent N applications, recent research showed that applying 50% or more of the recommended N at seeding enhances the opportunity for in-crop applications of nitrogen in spring wheat and canola to better match the soil and climatic conditions while reducing the risks associated with these practices (Lafond et al. 2008)

With the recent introduction of commercial optical sensors as a nitrogen management tool, it is now possible to estimate crop yield potential early in the growing season in cereals (5-6 leaf stage) and canola (mid-bolting stage) allowing enough time to adjust the rates of N to realize that potential (Raun et al. 2002).

The main objective of this study was to test application algorithms developed to date for the GreenSeeker optical sensor in spring and winter wheat, durum, oat, malting barley and canola using small plots in order to assess the algorithms developed to date. The validation consisted of applying specific amounts of UAN at the 6-7 leaf stage in cereals and the mid-bolting stage of canola using rates determined by the algorithms and comparing this to the standard practice of putting all the fertilizer down in the spring at seeding.

2.0 MATERIALS AND METHODS

2.1: Test of the application algorithms for the GreenSeeker optical sensor.

2.2.1 Crops: Spring wheat, Durum, Oat, Malting Barley and Canola.

Treatments:

1. Check plot - no nitrogen added

2. N Rich strip: Rate of N 1.5-2.0x the average rate for the area and adjusted for residual Nitrate N.

3. Farmer Practice: Based on residual N level and adjusted for soil moisture conditions at time of seeding, area, soil type and crop using the recommendations from the FARM PHASE II program in use by Enviro-Test Labs.

4. Reduced N rate: 66% of rate used in Farmer Practise treatment and no further N applied.

5. 50% of Farmer Practice Rate at seeding and the balance 50% of N applied at the 6-7 leaf stage in cereals and mid-bolting stage in canola using UAN as a surface dribble.

6. 66% of Farmer Practice Rate at seeding and the balance 34% of N applied at the 6-7 leaf stage in cereals and mid-bolting stage in canola using UAN as a surface dribble.

7 50% of Farmer Practice Rate at seeding and the balance of the N applied using the application algorithm developed for the GreenSeeker optical sensor.

8. 66% of Farmer Practice Rate at seeding and the balance of the N applied using the application algorithm developed for the GreenSeeker optical sensor.

2.2.2 Crops: Winter wheat

Treatments:

1. Check No N

Field Code Changed

2. N-Rich 175% of recommended applied as UAN in early spring

3. 100% of recommended in early spring using a surface band of UAN

4. 66% of recommended in early spring using a surface band of UAN

5. 66% of Fertilizer recommended using liquid UAN surface banded early in the spring and brought to 100% at between crop growth stage Feekes 4 and 5 using UAN.

6. 66% of Fertilizer recommended using liquid UAN surface banded early in the spring and topped up using the algorithm and the GreenSeeker sensor between crop growth stage Feekes 4 and 5.

7. 34% of Fertilizer recommended using liquid UAN surface banded early in the spring and brought to 100% at between crop growth stage Feekes 4 and 5 using UAN.

8. 34% of Fertilizer recommended using liquid UAN surface banded early in the spring and topped up using the algorithm and the GreenSeeker sensor between crop growth stage Feekes 4 and 5.

2.2 Application algorithms developed for the GreenSeeker Sensor

Table 1 provides a description of the yield potential equations used for each crop and year. The equations were derived from small plot trials for each crop where different yield potentials were generated with different rates of N and sensor readings taken at times deemed appropriate for use with the GreenSeeker sensor. Grain yields were collected from each plot and equations developed to relate the sensor readings to final grain yields.

2.3 Other Agronomic details:

These studies were carried out at the Indian Head Research Farm in Indian Head, SK. The soil type is a Rego Black Chernozem (Udic Haploboroll

All plots were seeded with an Edwards High Clearance Hoe press drill with a row spacing of 8" for the years 2006-2008. Each plot was 8' x 35'. All nitrogen fertilizer was mid-row banded between every second opener. The phosphorus fertilizer was placed with the seed for all cereals and canola. Mono-ammonium phosphate (11-52-00) was applied at a rate of 50 kg/ha for spring wheat, durum, oat and barley and winter wheat and 58 kg/ha for canola. The nitrogen source used in both experiments was urea (46-00-00). In 2009, a different plot seeder was used which consisted of 8 SeedMaster openers on 12" spacing (www.seedmaster.ca) which sidebands the fertilizer about 2.5 cm to the side and 2.5 cm below the seed. All nitrogen and phosphorus fertilizers were applied together in the side-band with this opener.

All pest management was done as required using recommended products and rates appropriate for the area and conditions.

3.0 RESULTS AND DISCUSSION

In order to provide a focused discussion, a series of three relevant agronomic questions in the context of this study are asked and answered using the results obtained during the course of this study with all crops. It should be noted that a response to nitrogen was observed for all crops and in all years of the investigation. The N rate of the Nitrogen Rich strip (NR) was established at about 1.5-2.0x the rate used in the Farmer Practice (FP). FP was based on soil test nitrate results for the 0-60 soil layer, taken the previous fall and the rate of N determined using FARMPHASE II. This approach was used for all crops and in all years to determine the FP rate. When the recommended N rate was low, a 2.0xFP rate was used for NR and a 1.5xFP rate was used when the recommended N rates were high. No data for grain protein is provided for any of crops for 2009 because the results had not yet been obtained from the analytical laboratory for this final report.

Question #1: Were the grain yields and grain protein different between NR and FP?

Question #2: Were the yields and grain protein for FP the same as the applications of nitrogen using the same rates but split using a 50/50 or 66/34 proportion, the first number being the applied at seeding?

Questions #3: Were the grain yields and grain protein of FP the same as when using the GreenSeeker with different levels of starter N (50% or 66% of FP)?

The actual data summaries for each crop and year are given at the end of the paper. The variables of interest were grain yield, nitrogen fertilizer used, NDVI (Normalized Difference Vegetation Index – values provided by the GreenSeeker which is an indirect estimate of biomass production) and grain

protein. For barley, refer to Tables 2 & 3, for durum Tables 4 & 5, for spring wheat Tables 6 & 7, for oat Tables 8 & 9, for winter wheat Tables 10, 11 & 12 and for canola Tables 13 & 14.

3.1 Nitrogen Rates for N Rich Strip (NR) vs Farmer Practise (FP) N rates on Grain Yield and Grain Protein:

With barley, the grain yield for NR was the same as FP in 2 of 3 years but in one year (2009), the yield was greater with NR suggesting that more N could have been used to maximize grain yields. With grain protein in 2007 and 2009, NR was greater than FP and the opposite in 2008. Grain protein is an important quality characteristic in malting barley and should not exceed 13.0%.

With durum, grain yields of NR and FP were the same in 2007 and 2008 but NR > FP in 2009. With grain protein, NR was greater than FP in 2007 and the same in 2008. For grain protein, NR was greater than FP in 2007 and 2009 and the same in 2008.

With spring wheat, grain yields for NR were the same as FP in all three years and as well as for grain protein except for 2009 where grain protein levels were greater in NR than FP.

With oat, grain yields of NR were the same as FP in 2007 and 2008 but NR was greater than FP in 2009. Grain protein concentrations were the same in 2007 and 2008 but higher for NR in 2009.

With winter wheat, NR was the same as FP in all years for grain yields but grain protein was greater for NR than FP in 2006 and 2007 and no difference in 2008.

With canola, grain yield for NR was greater than FP in 2007 but the same in the other two years.

SUMMARY: Out of 19 possible trials, 26% of trials showed higher grain yields for NR than FP signifying that a higher N rate could have been used for the FP treatment. On the other hand, in 74% of the cases, the rate of nitrogen used for FP was able to maximize grain yield. The study also incorporated a reduced rate of N at seeding (RR) which was 66% of the N rate used for the FP treatment with no additional N added. In 18 trials incorporating this treatment, FP was greater than RR in 33% of the trials with no differences in the other 67% of the trials. This is an indication that the N rate used in the FP treatment was higher than required in 67% of the trials and of the difficulties in arriving at the optimum N rate.

3.2. Split Applications of N versus Applying all the N at Time of Seeding on Grain Yield and Grain Protein.

We are interested in answering the question of the merits of using split applications of post-emergent nitrogen applications when compared to applying it all at time of seeding. In this case, the split applications consisted of either 50 of 66% of the FP rate at time of seeding and the balance to 100% at the 5-6 leaf stage in cereal and mid-bolting stage in canola. The use of the GreenSeeker sensor hinges on the concept of post-emergent N applications.

In barley, a reduction in yield with split applications relative to the FP treatment was observed in one year but only when 50% of the target N rate was applied at seeding. When 66% of the target N rate was applied at seeding, a difference in yield was not observed. Grain protein was lower with the Split N treatments than the FP treatments in 2009 but no difference in 2007 and 2009.

In durum, only in one year did we observe a higher grain yield with FP over the split applications and this occurred only when 50% of the target N rate was used at time of seeding. A similar observation was noted for grain protein as well. Providing that 66% of the target N rate was applied at seeding and the balance to 100% at the 5-6 leaf stage, there was no difference for grain yield and grain protein when compared to the FP treatment where all N was applied at time of seeding. In 2009, where 50% of the N was applied at the 5-6 leaf stage, higher grain protein was observed.

In spring wheat, the FP and Split-N treatments gave equivalent grain yields and grain protein concentration.

In oat, the FP and Split-N treatments gave equivalent grain yields and grain protein concentration.

In winter wheat, providing that 66% of the target N rate was applied early in the spring (end of April) and the remainder at start of elongation, the split applications of N gave similar grain yields and grain protein to when all nitrogen was applied early in the spring.

In canola, there was no difference between the FP treatment and the Split N applications. Similar grain yields were obtained.

SUMMARY: The results clearly showed that split-applications of nitrogen are feasible in the five crops examined in this study with no differences in grain yield when compared to the FP treatment. Providing that 66% of the target N rate is applied at seeding, the risks associated with post-emergent N applications on grain yield and grain protein can be greatly minimized opening the door to the use of optical sensors.

3.3. How Did the Grain Yields and the Grain Protein Levels Compare between the FP Treatments and the Treatments where the GreenSeeker was used?

At the 5-6 leaf stage of cereals and mid-bolting stage of canola, readings with the GreenSeeker (GS) optical sensor were done on the N-Rich strip separately for each replicate of the study and the two GreenSeeker treatments. One of the GS treatment consisted of applying 50% of the target N rate at seeding and the balance based on the GS using the algorithms presented in Table 1. The other GS treatment consisted of applying 66% of the target N rate at seeding and the balance applied based on the readings from the GS. Depending on the difference in NDVI reading between the GS and the NR treatments in a given replicate, nitrogen was applied accordingly using a nitrogen use efficiency of 50% and a pre-established N content in the grain. This approach also allows for a detailed evaluation of spatial and temporal variability.

In barley, FP grain yields were greater that the GS grain yields in 2 of 3 years. However, when 66% of the target N rate was used, a lower yield was only experienced in one of those years. Grain protein was either lower when an effect was observed or the same as FP. Lower nitrogen rates were used when the final rate was arrived at with the GreenSeeker sensor.

In durum, FP grain yields were greater than GS grain yields in 2 of 3 years. However, like barley, when 66% of the target N rate was applied at seeding, only one year was observed where FP was greater than GS. With grain protein, FP was greater than GS, regardless of the amount of starter N used in 2007 and 2009 but no difference in 2008.

In spring wheat, FP grain yields were the same as GS grain yields in all years. With grain protein, providing that 66% of the target N rate was applied at seeding, no effects were detected on grain protein level.

In oat, only one year was observed where FP had higher grain yields than the GS treatments with no effects observed in any years on grain protein between FP and GS.

In winter wheat, FP was greater than GS in 2 of 4 years but when 66% of the target N rate was applied early in the spring, by the end of April, a difference was only observed in one year. FP had higher grain protein than GS in one year.

In canola, FP grain yields were greater than GS in 2 of 3 years but only in one year when 66% of the target N rate was used at time of seeding.

SUMMARY: When considering the situation where 66% of the N was applied at seeding and the balance with the GS, FP grain yields were the same as GS grain yields in 14 of 19 trials or 74% of the time and in 26% of the time, FP grain yields were higher than GS. In all cases, less N was used with GS than in FP which implies higher nitrogen use efficiencies in 74% of the trials. What do we do about the other 26% of the time where a decrease in grain yield was observed? Is this acceptable or can we improve on it.

4.0 CONCLUSIONS

The study has established that arriving at the correct rate of N, which accounts for both spatial and temporal variability, is very difficult. When comparing the FP grain yields to the NR grain yields and the RR grain yields, the correct N rate for FP was only obtained 24% of the time. In 26% of the trials, the N rate used for FP did not maximize grain yield while in 66% of the time, the N rate used was too high based on the yield comparison between FP and RR.

The study also established that post-emergent split N applications are feasible for all crops tested providing that 66% of the target N rate is used at time of seeding. This makes the use of the GreenSeeker for fine-tuning N applications feasible given that it relies on the concept of post-emergent N applications. This supports previous reported results (Lafond et al. 2008).

When the GS was used, it was successful in arriving at a more optimum rate given the year and field history in 74% of the trials. However, in 26% of the trials, the grain yields with GS were lower than FP. The question of interest is how do we improve the performance of the GreenSeeker such that its success is greater than 74% of the time? It should be noted that in spring wheat, equivalent grain yields between FP and GS were observed in all years. The spring wheat algorithm is complete while the ones for barley, durum and winter wheat are still under development. However the canola algorithm is also complete and yet grain yields between FP and GS were only equivalent in 2 of 3 years, providing that 66% of the target N rate was used.

5.0 REFERENCES

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Table 1. List of yield potential equations for each crop used in the study from 2006 - 2008. Each equation presented for any given year and crop represents the sum total of all data collected to date to generate the yield potential equations. The equations presented for 2009 would represent all the data collected up to 2008 from various plot studies.

Crop	Year	Yield Potential Equation[1]
Canola	2006	$Y = 595.61\ e^{1210.8*insey}$
	2007	$Y = 595.6\ e^{1186.5*insey}$
	2008	$Y = 739.25\ e^{877.85*insey}$
	2009	$Y = 701.9\ e^{632.9*insey}$
Spring wheat	2007	$Y = 993.3\ e^{853.59*insey}$
	2008	$Y = 855.04\ e^{913.90*insey}$
	2009	$Y = 853.2\ e^{902.9*insey}$
Barley	2007	$Y = 1655.8\ e^{704.22*insey}$
	2008	$Y = 1211.7\ e^{925.79*insey}$
	2009	$Y = 1957.3\ e^{628.5*insey}$
Oat	2007	$Y = 1592.1\ e^{790.05*insey}$
	2008	$Y = 1567.5\ e^{764.08*insey}$
	2009	$Y = 1675.6\ e^{726.7*insey}$
Durum	2007	$Y = 993.3\ e^{853.59*insey}$
	2008	$Y = 565.31\ e^{1390.5*insey}$
	2009	$Y = 688.8\ e^{1271.5*insey}$
Winter wheat	2006	$Y = 1692.6\ e^{710.81*insey}$
	2007	$Y = 1813.3\ e^{703.2*insey}$
	2008	$Y = 2082.2\ e^{475.6*insey}$
	2009	$Y = 2007.1\ e^{478.3*insey}$

[1] insey=NDVI/GDD where NDVI is the reading from GreenSeeker sensor and GDD is the number of growing degree days using a base temperature of 0^{o}C from seeding to day of sensing.

Table 2. The response of barley to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	2007			2008			2009		
	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate kg/ha	Grain Yield kg/ha	Grain Protein %
1. Check	0	2034	12.6	0	2538	11.0	0	2694	8.4
2. N Rich	160	4049	14.4	160	3921	10.9	120	4873	9.5
3. Farmer Practice (FP)	105	4005	13.5	105	3699	11.3	59	4223	8.8
4. 66% of FP (RR)	69	3337	13.2	69	3619	11.1	39	3671	8.4
5. 50% N at Seeding + 50% at 6 leaf stage	105	3841	13.6	105	3981	10.7	59	3841	8.9
6. 66% N at Seeding + 34% at 6 leaf stage	105	3776	13.7	105	3882	11.0	59	4023	8.7
7. 50% N at Seeding + GreenSeeker	64	3497	12.8	52	3263	11.1	33	3531	8.6
8. 66% N at Seeding + GreenSeeker	95	3681	13.5	73	3688	11.1	45	3698	8.8
LSD(05)	-	426	0.5	-	493	0.6	-	309	0.6
cv(%)	-	8.2	2.3	-	9.4	3.4	-	5.5	7.8
Contrasts	***p*-values**								
Check vs Rest (1 vs 2-8)	-	0.0001	0.0001	-	0.001	ns	-	0.0001	0.039
N Rich vs Remaining N treatments (2 vs 3-8)	-	0.03	0.0001	-	ns	ns	-	0.0001	0.008
N Rich vs FP (2 vs 3)	-	ns	0.0008	-	ns	ns	-	0.0003	0.023
FP vs RR (3 vs 4)	-	0.004	ns	-	ns	ns	-	0.0013	ns
FP vs Split (3 vs 5+6)	-	ns	ns	-	ns	0.04	-	0.035	ns
FP vs GS (3 vs 7+8)	-	0.029	ns	-	ns	ns	-	0.001	ns
FP vs Split 50% (3 vs 5)	-	ns	ns	-	ns	0.019	-	0.018	ns
FP vs Split 66% (3 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs GS 50% (3 vs 7)	-	0.022	0.005	-	ns	ns	-	0.0001	ns
FP vs GS 66% (3 vs 8)	-	ns	ns	-	ns	ns	-	0.002	ns
Split vs GS (5+6 vs 7+8)	-	ns	0.008	-	0.013	ns	-	0.007	ns
Split 50% vs GS 50% (5 vs 7)	-	ns	0.002	-	0.006	ns	-	0.049	ns
Split 66% vs GS 66% (6 vs 8)	-	ns	ns	-	ns	ns	-	0.041	ns
Split 50% vs Split 66% (5 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
GS 50% vs GS 66% (7 vs 8)	-	ns	0.005	-	ns	ns	-	ns	ns
RR vs Split (4 vs 5+6)	-	0.015	0.023	-	ns	ns	-	0.06	ns
RR vs GS (4 vs 7+8)	-	ns	ns	-	ns	ns	-	ns	ns

Table 3.The response of barley to different post-emergent nitrogen management strategies including post –emergent N applications on with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	**NDVI**		
	2007	**2008**	**2009**
1. Check	0.39	0.53	0.56
2. N Rich	0.64	0.65	0.66
3. Farmer Practice (FP)	0.58	0.65	0.68
4. 66% of FP (RR)	0.57	0.67	0.66
5. 50% N at Seeding + 50% at 6 leaf stage	0.58	0.65	0.63
6. 66% N at Seeding + 34% at 6 leaf stage	0.55	0.68	0.67
7. 50% N at Seeding + GreenSeeker	0.60	0.69	0.64
8. 66% N at Seeding + GreenSeeker	0.53	0.67	0.64
LSD(05)	0.06	0.05	0.05
cv(%)	7.5	5.5	4.8
Contrasts	***p*-values**		
Check vs Rest (1 vs 2-8)	0.0001	0.0001	0.0001
N Rich vs Remaining N treatments (2 vs 3-8)	0.006	ns	ns
N Rich vs FP (2 vs 3)	0.016	ns	ns
FP vs RR (3 vs 4)	ns	ns	ns
FP vs Split (3 vs 5+6)	ns	ns	ns
FP vs GS (3 vs 7+8)	ns	ns	0.039
FP vs Split 50% (3 vs 5)	ns	ns	0.023
FP vs Split 66% (3 vs 6)	ns	ns	ns
FP vs GS 50% (3 vs 7)	ns	ns	ns
FP vs GS 66% (3 vs 8)	ns	ns	0.053
Split vs GS (5+6 vs 7+8)	ns	ns	ns
Split 50% vs GS 50% (5 vs 7)	ns	ns	ns
Split 66% vs GS 66% (6 vs 8)	ns	ns	ns
Split 50% vs Split 66% (5 vs 6)	ns	ns	0.042
GS 50% vs GS 66% (7 vs 8)	0.031	ns	ns
RR vs Split (4 vs 5+6)	ns	ns	ns
RR vs GS (4 vs 7+8)	ns	ns	ns

Table 4.The response of durum wheat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	2007			2008			2009		
	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate kg/ha	Grain Yield kg/ha	Grain Protein %
1. Check	0	1389	12.8	0	2077	17.1	0	2684	12.9
2. N Rich	130	3351	14.9	130	3098	16.9	130	4701	14.5
3. Farmer Practice (FP)	90	3123	14.2	90	2672	17.3	67	4100	12.6
4. 66% of FP (RR)	59	2846	12.8	59	2961	17.0	44	3681	12.9
5. 50% N at Seeding + 50% at 6 leaf stage	90	2568	13.3	90	2794	17.6	67	3861	13.7
6. 66% N at Seeding + 34% at 6 leaf stage	90	2926	13.9	90	3034	17.4	67	3975	12.8
7. 50% N at Seeding + GreenSeeker	52	2459	12.6	46	2618	17.1	40	3548	12.3
8. 66% N at Seeding + GreenSeeker	82	2853	12.8	64	2624	16.1	46	3592	12.2
LSD(05)	-	357	0.7	-	668	1.6	-	363	1.0
cv(%)	-	9.0	3.3	-	16.6	6.3	-	6.6	5.3
Contrasts	***p*-values**								
Check vs Rest (1 vs 2-8)	-	0.0001	0.011	-	0.006	ns	-	0.0001	ns
N Rich vs Remaining N treatments (2 vs 3-8)	-	0.0004	0.0001	-	ns	ns	-	0.0001	0.0002
N Rich vs FP (2 vs 3)	-	ns	0.037	-	ns	ns	-	0.0024	0.001
FP vs RR (3 vs 4)	-	ns	0.0001	-	ns	ns	-	0.026	ns
FP vs Split (3 vs 5+6)	-	0.020	0.043	-	ns	ns	-	ns	ns
FP vs GS (3 vs 7+8)	-	0.005	0.0001	-	ns	ns	-	0.002	ns
FP vs Split 50% (3 vs 5)	-	0.004	0.009	-	ns	ns	-	ns	0.044
FP vs Split 66% (3 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs GS 50% (3 vs 7)	-	0.0009	0.0001	-	ns	ns	-	0.005	ns
FP vs GS 66% (3 vs 8)	-	ns	0.0003	-	ns	ns	-	0.009	ns
Split vs GS (5+6 vs 7+8)	-	ns	0.0008	-	ns	ns	-	0.01	0.023
Split 50% vs GS 50% (5 vs 7)	-	ns	0.044	-	ns	ns	-	ns	0.031
Split 66% vs GS 66% (6 vs 8)	-	ns	0.0032	-	ns	ns	-	0.039	ns
Split 50% vs Split 66% (5 vs 6)	-	0.049	ns	-	ns	ns	-	ns	ns
GS 50% vs GS 66% (7 vs 8)	-	0.032	ns	-	ns	ns	-	ns	ns
RR vs Split (4 vs 5+6)	-	ns	0.002	-	ns	ns	-	ns	ns
RR vs GS (4 vs 7+8)	-	ns	ns	-	ns	ns	-	ns	ns

Table 5. The response of durum wheat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	**NDVI**		
	2007	**2008**	**2009**
1. Check	0.52	0.53	0.56
2. N Rich	0.73	0.61	0.69
3. Farmer Practice (FP)	0.79	0.64	0.72
4. 66% of FP (RR)	0.73	0.60	0.69
5. 50% N at Seeding + 50% at 6 leaf stage	0.72	0.65	0.69
6. 66% N at Seeding + 34% at 6 leaf stage	0.77	0.67	0.70
7. 50% N at Seeding + GreenSeeker	0.69	0.64	0.69
8. 66% N at Seeding + GreenSeeker	0.73	0.64	0.71
LSD(05)	0.05	0.05	0.05
cv(%)	5.0	5.8	4.6
Contrasts			
Check vs Rest (1 vs 2-8)	0.0001	0.0001	0.0001
N Rich vs Remaining N treatments (2 vs 3-8)	ns	ns	ns
N Rich vs FP (2 vs 3)	ns	ns	ns
FP vs RR (3 vs 4)	ns	ns	ns
FP vs Split (3 vs 5+6)	ns	ns	ns
FP vs GS (3 vs 7+8)	0.024	ns	ns
FP vs Split 50% (3 vs 5)	ns	ns	ns
FP vs Split 66% (3 vs 6)	ns	ns	ns
FP vs GS 50% (3 vs 7)	0.007	ns	ns
FP vs GS 66% (3 vs 8)	ns	ns	ns
Split vs GS (5+6 vs 7+8)	ns	ns	ns
Split 50% vs GS 50% (5 vs 7)	ns	ns	ns
Split 66% vs GS 66% (6 vs 8)	ns	ns	ns
Split 50% vs Split 66% (5 vs 6)	0.036	ns	ns
GS 50% vs GS 66% (7 vs 8)	ns	ns	ns
RR vs Split (4 vs 5+6)	ns	0.018	ns
RR vs GS (4 vs 7+8)	ns	ns	ns

Table 6. The response of spring wheat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	2007			2008			2009		
	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate (kg/ha)	Grain Yield (kg/ha)[1]	Grain Protein (%)	N Rate kg/ha	Grain Yield kg/ha	Grain Protein %
1. Check	0	1488	14.7	0	2068	16.7	0	3439	14.2
2. N Rich	130	2606	16.2	130	2736	16.1	130	4472	15.3
3. Farmer Practice (FP)	90	2425	15.8	90	2687	17.4	62	4063	14.0
4. 66% of FP (RR)	59	2118	14.8	59	2615	16.5	42	3771	13.9
5. 50% N at Seeding + 50% at 6 leaf stage	90	2407	15.7	90	2552	15.7	62	4310	14.4
6. 66% N at Seeding + 34% at 6 leaf stage	90	2357	15.5	90	2552	16.8	62	4189	14.6
7. 50% N at Seeding + GreenSeeker	52	2523	15.5	53	2533	14.7	36	3768	13.8
8. 66% N at Seeding + GreenSeeker	68	2586	15.4	68	2642	16.7	48	3913	14.4
LSD(05)	-	496	0.9	-	262	2.0	-	567	1.3
cv(%)	-	14.6	4.2	-	6.9	8.3	-	9.7	6.4
Contrasts	***p*-values**								
Check vs Rest (1 vs 2-8)	-	0.0001	0.02	-	0.0001	ns	-	0.0059	ns
N Rich vs Remaining N treatments (2 vs 3-8)	-	ns	0.04	-	ns	ns	-	0.035	0.028
N Rich vs FP (2 vs 3)	-	ns	ns	-	ns	ns	-	ns	0.048
FP vs RR (3 vs 4)	-	ns	0.036	-	ns	ns	-	ns	ns
FP vs Split (3 vs 5+6)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs GS (3 vs 7+8)	-	ns	ns	-	ns	0.054	-	ns	ns
FP vs Split 50% (3 vs 5)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs Split 66% (3 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs GS 50% (3 vs 7)		ns	ns		ns	0.011		ns	ns
FP vs GS 66% (3 vs 8)	-	ns	ns	-	ns	ns	-	ns	ns
Split vs GS (5+6 vs 7+8)	-	ns	ns	-	ns	ns	-	0.046	ns
Split 50% vs GS 50% (5 vs 7)	-	ns	ns	-	ns	ns	-	0.059	ns
Split 66% vs GS 66% (6 vs 8)	-	ns	ns	-	ns	ns	-	ns	ns
Split 50% vs Split 66% (5 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
GS 50% vs GS 66% (7 vs 8)	-	ns	ns	-	ns	0.050	-	ns	ns
RR vs Split (4 vs 5+6)	-	ns	0.053	-	ns	ns	-	0.035	ns
RR vs GS (4 vs 7+8)	-	0.047	ns	-	ns	ns	-	ns	ns

[2] Plant populations in 2008 were only 115 plants per meter square versus 266 in 2007 and 331 in 2010. A seeding error occurred in 2008.

Table 7. The response of spring wheat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	**NDVI**		
	2007	**2008**	**2009**
1. Check	0.61	0.38	0.69
2. N Rich	0.79	0.41	0.79
3. Farmer Practice (FP)	0.79	0.57	0.78
4. 66% of FP (RR)	0.74	0.39	0.73
5. 50% N at Seeding + 50% at 6 leaf stage	0.76	0.39	0.75
6. 66% N at Seeding + 34% at 6 leaf stage	0.76	0.41	0.73
7. 50% N at Seeding + GreenSeeker	0.77	0.41	0.77
8. 66% N at Seeding + GreenSeeker	0.75	0.37	0.77
LSD(05)	0.06	0.05	0.05
cv(%)	5.0	9.4	4.9
Contrasts	***p*-values**		
Check vs Rest (1 vs 2-8)	0.0001	ns	0.0018
N Rich vs Remaining N treatments (2 vs 3-8)	ns	ns	ns
N Rich vs FP (2 vs 3)	ns	ns	ns
FP vs RR (3 vs 4)	0.05	ns	ns
FP vs Split (3 vs 5+6)	ns	ns	ns
FP vs GS (3 vs 7+8)	ns	ns	ns
FP vs Split 50% (3 vs 5)	ns	ns	ns
FP vs Split 66% (3 vs 6)	ns	ns	ns
FP vs GS 50% (3 vs 7)	ns	ns	ns
FP vs GS 66% (3 vs 8)	ns	ns	ns
Split vs GS (5+6 vs 7+8)	ns	ns	ns
Split 50% vs GS 50% (5 vs 7)	ns	ns	ns
Split 66% vs GS 66% (6 vs 8)	ns	ns	ns
Split 50% vs Split 66% (5 vs 6)	ns	ns	ns
GS 50% vs GS 66% (7 vs 8)	ns	ns	ns
RR vs Split (4 vs 5+6)	ns	ns	ns
RR vs GS (4 vs 7+8)	ns	ns	ns

Table 8. The response of oat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	2007			2008			2009		
	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate kg/ha	Grain Yield kg/ha	Grain Protein %
1. Check	0	3581	11.3	0	3733	7.9	0	3764	8.1
2. N Rich	120	4022	11.5	112	4574	9.9	120	5435	9.6
3. Farmer Practice (FP)	60	3975	11.7	56	4206	9.3	59	5051	8.8
4. 66% of FP (RR)	40	3982	10.8	37	4256	9.0	39	4268	8.1
5. 50% N at Seeding + 50% at 6 leaf stage	60	4018	11.9	56	4306	9.5	59	4988	8.8
6. 66% N at Seeding + 34% at 6 leaf stage	60	4065	11.4	56	4461	9.5	59	4976	8.4
7. 50% N at Seeding + GreenSeeker	38	3908	11.7	30	4046	8.6	35	4582	8.2
8. 66% N at Seeding + GreenSeeker	49	4080	11.4	37	4406	9.3	48	4741	8.1
LSD(05)	-	285	1.1	-	335	0.8	-	324	0.8
cv(%)	-	4.9	6.5	-	5.4	5.7	-	4.6	6.5
Contrasts									
Check vs Rest (1 vs 2-8)	-	0.0005	ns	-	0.001	0.0001	-	0.0001	ns
N Rich vs Remaining N treatments (2 vs 3-8)	-	ns	ns	-	0.026	0.019	-	0.0001	0.006
N Rich vs FP (2 vs 3)	-	ns	ns	-	0.033	ns	-	0.023	0.047
FP vs RR (3 vs 4)	-	ns	ns	-	ns	ns	-	0.013	ns
FP vs Split (3 vs 5+6)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs GS (3 vs 7+8)	-	ns	ns	-	ns	ns	-	0.008	ns
FP vs Split 50% (3 vs 5)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs Split 66% (3 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
FP vs GS 50% (3 vs 7)	-	ns	ns	-	ns	0.077	-	0.007	ns
FP vs GS 66% (3 vs 8)	-	ns	ns	-	ns	ns	-	0.06	ns
Split vs GS (5+6 vs 7+8)	-	ns	ns	-	ns	0.036	-	0.009	ns
Split 50% vs GS 50% (5 vs 7)	-	ns	ns	-	ns	0.018	-	0.017	ns
Split 66% vs GS 66% (6 vs 8)	-	ns	ns	-	ns	ns	-	ns	ns
Split 50% vs Split 66% (5 vs 6)	-	ns	ns	-	ns	ns	-	ns	ns
GS 50% vs GS 66% (7 vs 8)	-	ns	ns	-	ns	0.077	-	ns	ns
RR vs Split (4 vs 5+6)	-	ns	0.07	-	ns	ns	-	0.016	ns
RR vs GS (4 vs 7+8)	-	ns	ns	-	ns	ns	-	ns	ns

Table 9. The response of oat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	2007			2008			2009		
	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate (kg/ha)	Grain Yield (kg/ha)	Grain Protein (%)	N Rate kg/ha	Grain Yield kg/ha	Grain Protein %[1]
1. Check	0	3581	11.3	0	3733	7.9	0	3764	-
2. N Rich	120	4022	11.5	112	4574	9.9	120	5435	-
3. Farmer Practice (FP)	60	3975	11.7	56	4206	9.3	59	5051	-
4. 66% of FP (RR)	40	3982	10.8	37	4256	9.0	39	4268	-
5. 50% N at Seeding + 50% at 6 leaf stage	60	4018	11.9	56	4306	9.5	59	4988	-
6. 66% N at Seeding + 34% at 6 leaf stage	60	4065	11.4	56	4461	9.5	59	4976	-
7. 50% N at Seeding + GreenSeeker	38	3908	11.7	30	4046	8.6	35	4582	-
8. 66% N at Seeding + GreenSeeker	49	4080	11.4	37	4406	9.3	48	4741	-
LSD(05)	-	285	1.1	-	335	0.8	-	324	-
cv(%)	-	4.9	6.5	-	5.4	5.7	-	4.6	-
Contrasts									
Check vs Rest (1 vs 2-8)	-	0.0005	ns	-	0.001	0.0001	-	0.0001	-
N Rich vs Remaining N treatments (2 vs 3-8)	-	ns	ns	-	0.026	0.019	-	0.0001	-
N Rich vs FP (2 vs 3)	-	ns	ns	-	0.033	ns	-	0.023	-
FP vs RR (3 vs 4)	-	ns	ns	-	ns	ns	-	0.013	-
FP vs Split (3 vs 5+6)	-	ns	ns	-	ns	ns	-	ns	-
FP vs GS (3 vs 7+8)	-	ns	ns	-	ns	ns	-	0.008	-
FP vs Split 50% (3 vs 5)	-	ns	ns	-	ns	ns	-	ns	-
FP vs Split 66% (3 vs 6)	-	ns	ns	-	ns	ns	-	ns	-
FP vs GS 50% (3 vs 7)	-	ns	ns	-	ns	0.077	-	0.007	-
FP vs GS 66% (3 vs 8)	-	ns	ns	-	ns	ns	-	0.06	-
Split vs GS (5+6 vs 7+8)	-	ns	ns	-	ns	0.036	-	0.009	-
Split 50% vs GS 50% (5 vs 7)	-	ns	ns	-	ns	0.018	-	0.017	-
Split 66% vs GS 66% (6 vs 8)	-	ns	ns	-	ns	ns	-	ns	-
Split 50% vs Split 66% (5 vs 6)	-	ns	ns	-	ns	ns	-	ns	-
GS 50% vs GS 66% (7 vs 8)	-	ns	ns	-	ns	0.077	-	ns	-
RR vs Split (4 vs 5+6)	-	ns	0.07	-	ns	ns	-	0.016	-
RR vs GS (4 vs 7+8)	-	ns	ns	-	ns	ns	-	ns	-

[1] Data not received from the laboratory.

Table 10. The response of oat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2007-2009.

Treatments	**NDVI**		
	2007	**2008**	**2009**
1. Check	0.65	0.55	0.56
2. N Rich	0.77	0.63	0.62
3. Farmer Practice (FP)	0.77	0.66	0.65
4. 66% of FP (RR)	0.74	0.67	0.61
5. 50% N at Seeding + 50% at 6 leaf stage	0.75	0.63	0.60
6. 66% N at Seeding + 34% at 6 leaf stage	0.75	0.65	0.61
7. 50% N at Seeding + GreenSeeker	0.75	0.65	0.60
8. 66% N at Seeding + GreenSeeker	0.75	0.66	0.62
LSD(05)	0.03	0.04	0.06
cv(%)	2.8	4.6	6.3
Contrasts	***p*-value**		
Check vs Rest (1 vs 2-8)	0.0001	0.0001	0.019
N Rich vs Remaining N treatments (2 vs 3-8)	ns	ns	ns
N Rich vs FP (2 vs 3)	ns	ns	ns
FP vs RR (3 vs 4)	ns	ns	ns
FP vs Split (3 vs 5+6)	ns	ns	ns
FP vs GS (3 vs 7+8)	ns	ns	ns
FP vs Split 50% (3 vs 5)	ns	ns	ns
FP vs Split 66% (3 vs 6)	ns	ns	ns
FP vs GS 50% (3 vs 7)	ns	ns	ns
FP vs GS 66% (3 vs 8)	ns	ns	ns
Split vs GS (5+6 vs 7+8)	ns	ns	ns
Split 50% vs GS 50% (5 vs 7)	ns	ns	ns
Split 66% vs GS 66% (6 vs 8)	ns	ns	ns
Split 50% vs Split 66% (5 vs 6)	ns	ns	ns
GS 50% vs GS 66% (7 vs 8)	ns	ns	ns
RR vs Split (4 vs 5+6)	ns	ns	ns
RR vs GS (4 vs 7+8)	ns	ns	ns

Table 11. The response of winter wheat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker in 2006.

Treatments	**2006**			
	N Rate (kg/ha)	**NDVI**	**Grain Yield (kg/ha)**	**Grain Protein (%)**
1. Check	0	0.53	2754	11.4
2. N Rich (NR)	207	0.49	3753	13.6
3. Farmer Practice (FP)	118	0.45	3588	12.4
5. 66% N at Seeding + 34% at Feekes 4-5 (Split)	118	0.45	3411	12.5
6. 66% N at Seeding + GreenSeeker at Feekes 4-5 (GS)	103	0.45	3630	11.7
LSD(05)	-	0.05	464	0.7
cv(%)	-	8.7	11.2	4.7
Contrasts	***p*-value**			
Check vs Rest (1 vs 2,3,5,6)	-	0.0011	0.0001	0.0003
Check vs Rest without the N Rich Treatment 1 vs 3,5,6	-	0.0005	0.0001	0.0095
N Rich vs FP (2 vs 3)	-	ns	ns	0.0015
FP vs Split (3 vs 5)	-	ns	ns	ns
FP vs GS (3 vs 6)	-	ns	ns	0.039
Split vs GS (5 vs 6)	-	ns	ns	0.019

Table 12. The response of winter wheat to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker in 2007.

Treatments	**2007**			
	N Rate (kg/ha)	**NDVI**	**Grain Yield (kg/ha)**	**Grain Protein (%)**
1. Check	0	0.52	1424	11.7
2. N Rich	206	0.78	4000	13.4
3. Farmer Practice (FP)	118	0.76	4038	12.0
4. 66% of FP (RR)	78	0.74	3057	10.9
5. 66% N at Seeding + 50% at Feekes 4-5	-[1]	-	-	-
6. 66% N at Seeding + GreenSeeker at Feekes 4-5	92	0.73	3174	11.5
7. 34% N at Seeding + 66% at Feekes 4-5	118	0.75	4181	12.2
8. 34% N at Seeding + GreenSeeker at Feekes 4-5	62	0.68	3113	11.6
LSD(05)	-	0.07	524	1.1
cv(%)	-	6.7	10.7	6.2
Contrasts	*p*-values			
Check vs Rest (1 vs 2-8)	-	0.0001	0.0001	ns
N Rich vs Remaining N treatments (2 vs 3-8)	-	ns	0.02	0.0003
N Rich vs FP (2 vs 3)	-	ns	ns	0.015
FP vs RR (3 vs 4)	-	ns	0.001	0.050
FP vs Split (3 vs 7)	-	ns	ns	ns
FP vs GS (3 vs 6+8)	-	ns	0.0006	ns
FP vs Split34% (3 vs 7)	-	ns	ns	ns
FP vs GS 66% (3 vs 6)	-	ns	0.003	ns
FP vs GS34% (3 vs 8)	-	0.027	0.002	ns
Split 34% vs GS34% (7 vs 8)	-	ns	0.0005	ns
GS66% vs GS 34% (6 vs 8)	-	ns	ns	ns
RR vs Split (4 vs 7)	-	ns	0.0003	0.033
RR vs GS (4 vs 6 + 8)	-	ns	ns	ns

[1] Incorrect application of nitrogen fertilizer in the spring resulting in the treatment having to be discarded.

Table 13. The response of winter wheat to different post-emergent nitogen management strategies including post –emergent N pplications with the optical sensor GreenSeeker for the years 2008-2009.

Treatments	2008				2009		
	N Rate (kg/ha)	**NDVI**	**Grain Yield (kg/ha)**	**Grain Protein %**[1]	**N Rate kg/ha**	**NDVI**	**Grain Yield kg/ha**
1. Check	0	0.37	1913	15.5	0	0.56	3818
2. N Rich	207	0.45	2825	14.7	142	0.63	4460
3. Farmer Practice (FP)	118	0.46	2725	15.5	80	0.64	4596
4. 66% of FP (RR)	78	0.42	2546	15.1	53	0.66	4324
5. 66% N at Seeding + 50% at Feekes 4-5	118	0.44	2901	16.9	80	0.64	4455
6. 66% N at Seeding + GreenSeeker at Feekes 4-5	80	0.44	2754	16.3	54	0.65	4506
7. 34% N at Seeding + 66% at Feekes 4-5	118	0.42	2739	15.6	80	0.62	4130
8. 34% N at Seeding + GreenSeeker at Feekes 4-5	44	0.43	2624	16.2	30	0.61	3995
LSD(05)	-	0.04	237	1.7	-	0.07	342
cv(%)	-	6.0	6.0	7.2	-	5.4	5.4
Contrasts	*p*-values						
Check vs Rest (1 vs 2-8)	-	0.0001	0.0001	ns	-	0.005	0.0003
N Rich vs Remaining N treatments (2 vs 3-8)	-	ns	ns	0.062	-	ns	ns
N Rich vs FP (2 vs 3)	-	ns	ns	ns	-	ns	ns
FP vs RR (3 vs 4)	-	ns	ns	ns	-	ns	ns
FP vs Split (3 vs 5+7)	-	ns	ns	ns	-	ns	0.045
FP vs GS (3 vs 6+8)	-	ns	ns	ns	-	ns	0.024
FP vs Split 66% (3 vs 5)	-	ns	ns	ns	-	ns	ns
FP vs Split 34% (3 vs 7)	-	ns	ns	ns	-	ns	0.01
FP vs GS 66% (3 vs 6)	-	ns	ns	ns	-	ns	ns
FP vs GS 34% (3 vs 8)	-	ns	ns	ns	-	ns	0.002
Split vs GS (5+7 vs 6+8)	-	ns	ns	ns	-	ns	ns
Split 66% vs GS 66% (5 vs 6)	-	ns	ns	ns	-	ns	ns
Split 34% vs GS 34% (7 vs 8)	-	ns	ns	ns	-	ns	ns
Split 34% vs Split 66% (5 vs 7)	-	ns	ns	ns	-	ns	0.062
GS 50% vs GS 66% (6 vs 8)	-	ns	ns	ns	-	ns	0.005
RR vs Split (4 vs 5+7)	-	ns	0.011	ns	-	ns	ns
RR vs GS (4 vs 6+8)	-	ns	ns	ns	-	ns	ns

[1] Data not received from the laboratory for 2009.

Table 14. The response of canola to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker in 2007.

Treatments	N Rate (kg/ha)	NDVI	Grain Yield (kg/ha)
1. Check	0	0.44	1480
2. N Rich	150	0.73	2517
3. Farmer Practice (FP)	100	0.74	2051
4. 66% of FP (RR)	66	0.70	1711
5. 66% N at Seeding + 34% at 6 leaf stage	100	0.71	2399
6. 66% N at Seeding + GreenSeeker – Algorithm #1	68	0.74	2197
7. 66% N at Seeding + Algorithm #2	67	0.73	2160
LSD(05)	-	-	-
cv(%)	-	5.0	14.2
Contrasts			
Check vs Rest (1 vs 2-7)	-	0.0001	0.0004
Check vs Rest less NR (1 vs 3-7)		0.0001	0.0011
N Rich vs Remaining N treatments Less Check (2 vs 3-8)	-	ns	0.023
FP vs RR (3 vs 4)		ns	ns
N Rich vs FP (2 vs 3)	-	ns	0.038
NR vs Split (2 vs 5)	-	ns	ns
NR vs GS (2 vs 6+7		ns	ns
FP vs Split (3 vs 5)	-	ns	ns
FP vs GS1 (3 vs 6)	-	ns	ns
FP vs GS2 (3 vs 7)	-	ns	ns
RR vs Split (4 vs 5)	-	ns	0.004
Split vs GS (5 vs 7+8)	-	ns	ns
GS#1 vs GS #2 (7 vs 8)	-	ns	ns

Table 15. The response of canola to different post-emergent nitrogen management strategies including post –emergent N applications with the optical sensor GreenSeeker for the years 2008 and 2009.

Treatments	2008			2009		
	N Rate (kg/ha)	NDVI	Grain Yield (kg/ha)	N Rate (kg/ha)	NDVI	Grain Yield (kg/ha)
1. Check	0	0.64	1359	0	0.70	1361
2. N Rich	148	0.76	2481	150	0.75	2758
3. Farmer Practice (FP)	114	0.77	2463	103	0.73	2433
4. 66% of FP (RR)	75	0.78	2209	68	0.79	2307
5. 50% N at Seeding + 50% at 6 leaf stage	114	0.75	2267	103	0.77	2420
6. 66% N at Seeding + 34% at 6 leaf stage	114	0.77	2386	103	0.73	2296
7. 50% N at Seeding + GreenSeeker	59	0.78	2158	60	0.78	1839
8. 66% N at Seeding + GreenSeeker	75	0.80	2096	68	0.77	2030
LSD(05)	-	0.06	-	-	0.06	444
cv(%)	-	4.9	5.0	-	5.5	13.9
Contrasts						
Check vs Rest (1 vs 2-8)	-	0.0001	0.0001	-	0.016	0.0001
N Rich vs Remaining N treatments (2 vs 3-8)	-	ns	0.0019	-	ns	0.0035
N Rich vs FP (2 vs 3)	-	ns	ns	-	ns	ns
FP vs RR (3 vs 4)	-	ns	0.0038	-	ns	ns
FP vs Split (3 vs 5+6)	-	ns	ns	-	ns	ns
FP vs GS (3 vs 7+8)	-	ns	0.0001	-	ns	0.014
FP vs Split 50% (3 vs 5)	-	ns	ns	-	ns	ns
FP vs Split 66% (3 vs 6)	-	ns	ns	-	ns	ns
FP vs GS 50% (3 vs 7)	-	ns	0.0008	-	ns	0.011
FP vs GS 66% (3 vs 8)	-	ns	0.0001	-	ns	ns
Split vs GS (5+6 vs 7+8)	-	ns	0.001	-	ns	0.0108
Split 50% vs GS 50% (5 vs 7)	-	ns	ns	-	ns	0.0130
Split 66% vs GS 66% (6 vs 8)	-	ns	0.0013	-	ns	ns
Split 50% vs Split 66% (5 vs 6)	-	ns	ns	-	ns	ns
GS 50% vs GS 66% (7 vs 8)	-	ns	ns	-	ns	ns
RR vs Split (4 vs 5+6)	-	ns	ns	-	ns	ns
RR vs GS (4 vs 7+8)	-	ns	ns	-	ns	0.058