NORTHEAST AGRICULTURE RESEARCH FOUNDATION

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2009-2010 Detailed Annual Report

Efficacy and Economic Benefits of Variable Rate Fertilizer Project

Summary

Objective: To evaluate effectiveness and economic benefits of variable rate fertilizers in the Melfort-Tisdale area.

Progress: Based on 8 location years of data from 2 wetter than normal growing seasons, similar yield was achieved with 10 lb/ac less fertilizer N using variable compared with fixed rates typical of what farmers would use. The farmer rate had a neutral N balance (removal equalled replacement) while the variable rate had a 10 lb/ac deficit. We estimate that if the variable rate was increased overall by 10 lb/ac yield would have increased by 1.5 bu/ac and N would be nearly balanced (optimum would likely be to increase the variable rate by 15 lb/ac over the rate actually used). Benefits of variable rates tended to increase as field variability increased.

Conclusions; Tentative conclusion is that variable rates have real potential to improve N use efficiency, and reduce environmental risk. However cost of implementing variable rates needs to be moderate or there will be little benefit to producers. This may change as we generate more data over more years with nearer normal climate. Highly uniform, well drained fields respond very little if at all to variable rates, and benefits increase on fields that are more highly variable.

BACKGROUND:

Precision agriculture is based on matching management to varying conditions across fields. The objectives are to achieve an improved combination of reduced costs, higher yields, more efficient use of resources, more uniform crops or reduced risk to the environment.

Nitrogen that crops use comes from a variety of sources. For non N fixing crops, the 2 most important sources are mineralization from soil organic matter and fertilizer. Usually only about 1 to 3% of soil organic matter is mineralized each year, but this small amount can release large amounts of nitrogen. For example, mineralizing 1.5% of the organic matter from a 4% organic matter soil releases 65lb per ac of N. Nitrogen from fertilizer is all available to crops as

soon as it is applied. By contrast, nitrogen from soil organic matter comes available in smaller quantities over the growing season. So even though it is there, nitrogen from soil may not be present in a usable form at the time that the crop needs it. A reasonable estimate of the amount that is available for crops would be about 10 lb/ac for each 1% soil organic matter.
Nitrogen fixing crops like peas fix most of the N that they require from the air, and in some cases they fix more than they need. Typically such crops fix N in the range of 45 to 250 lb/ac/yr.

Non-symbiotic fixation does occur when other crops are grown, but this provides Only about 5-7 lb/ac/yr. another source of N is that contained in rainfall, but this supplies only about 5 lb/ac/yr.

Soil organic matter is a good indicator of the N supplying capacity of soils. Some of the fields in this study were very uniform, while others were very variable. Fields that have organic matter that ranges from 2 to 9% would be expected to respond better to variable rates than ones that vary only from 7.0 to 7.5% as an example.

Phosphorus comes from both the organic and mineral components of soil as well as from fertilizer. P from organic matter is released in much the same way as N, but P from the mineral component is replaced in the soil solution as it is depleted. There is a wealth of research data that suggests that P management should be based on building soil P with fertilizer until it reaches at least 12 ppm in soil, by applying more P than is removed by crops at harvest. At soil P levels between 12 and 24 ppm rates of fertilizer P should match removal, and above 24 ppm, applying less than what is removed is likely appropriate. Since P is highly variable in many of these fields there is considerable potential for variable P rates on these fields. Zones where P is low could have P applied at rates that are 5 -10 lb/ac/yr above rates of removal, while zones where P exceeds 24 ppm could be managed with small deficits of P. One consideration is that P is usually high in zones where crops mature later, so some starter P is needed even where soil P is quite high.
Soil texture reflects the geological history of a field. Typically soils at the upper slope positions are coarser, with finer textures at lower positions and these fields follow that trend. Thousands of years of erosion have moved the smaller particles to the lower slope positions. Most of these fields have medium to fine textures meaning that water holding capacity is moderate to high. His means that capacity to store and supply water for crop production is also moderate to high.
Salinity is reflected in electrical conductivity of the soil. Sensitive crops like corn, bean soybean and flax will incur a yield loss of 10% or more when salinity is about 0.5 Sm^{-1} while more tolerant crops like wheat show similar yield loss at about 0.95 Sm^{-1} and very tolerant crops like barley or hybrid canola are affected similarly at 1.6 Sm^{-1}. Generally a soil is considered saline at 2.0 Sm^{-1}. The fields in this study don’t have serious problems with salinity, but some do have areas where this can be an issue with crops having moderate or low salinity tolerance.
Soil pH affects availability of nutrients, particularly P, which is more available at low pH. At high pH, fertilizer P may be rather quickly converted into forms that are not readily accessed by crops.

METHODS

Ten sites in four rural municipalities in the Melfort / Tisdale area were selected [Table 1] in spring 2009. Each of the co-operating farmers chose one or more fields where past experience suggested that variable rate fertilizer would likely be beneficial. Preference was given to fields where canola was to be grown in 2009, with wheat as a second preference.

Soil mapping and development of prescription fertilizer maps were prepared by CropPro Consulting [Figure 1]. Each prescription map included two check strips; one with no fertilizer N and a second where N was applied at the rate the farmer would normally have used for that field and crop combination. Co-operators had the option to add a third treatment strip. For example at the site in Figure 1, a higher N rate was used to determine if higher rates were needed to optimize yield. This was done at one other site, and a third site varied both N and P in one strip.

Table 1. Location of field sites where variable rate applications were made in 2009.

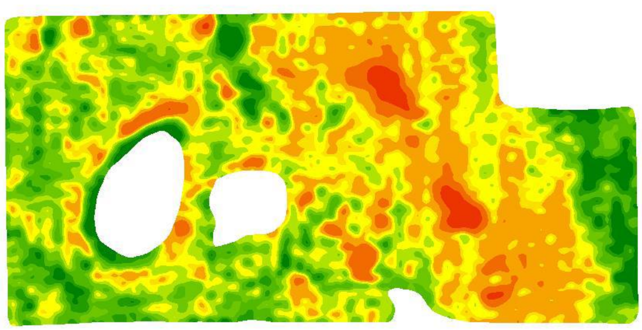
Site	Location	Soil Texture
1.	W ½ 13-43-15-W2 and NE-13-43-15-W2	silty clay-clay loam
2.	E ½ 10-44-15-W2	silt loam
3.	N ½ 23-44-15-W2	clay loam
4.	SW 31-46-13-W2 and all 30-46-13-W2	clay-clay loam
5.	NW 24-46-16-W2	silty clay
6.	E ½ 30-46-15-W2	silty clay-clay
7.	NE 2-47-17-W2	clay loam-clay
8.	W ½ 35-46-17-W2	silt loam
9.	E ½ 6-46-15-W2	silty clay
10.	E ½ 35-45-16-W2	silty clay loam

Figure 1. Typical management zone and prescription fertilizer rate map.

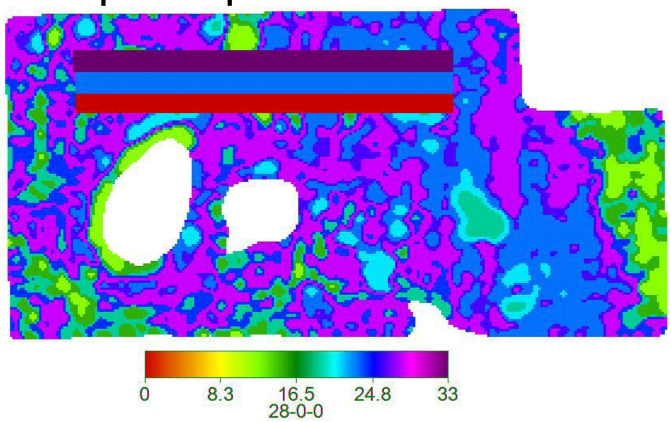
Field 2

N-1/2-23-44-15-W2

Zone Map



Prescription Map



Note: Trial rates are (top to bottom) 33 gal/acre, 23 gal/acre, & 0 gal/acre of 28-0-0

Farmer co-operators used their own equipment to apply fertilizer according to the rates specified by the prescription map. Other agronomic practices [like seeding, and pest management] reflected what that grower would do on other similar fields on his farm.
Measurement of yield response was a critical factor in evaluating the trials. For this reason, it was essential that actual yield not relative yield was measured as accurately as possible. To ensure accuracy, each co-operator was required to calibrate his combine yield monitor against yield determined with a weigh wagon. After this determination, the yield monitor was adjusted to provide the same yield. Thereafter the field was combined in the same direction that the check strips were set down. Where that was not feasible, combining could be done at right angles to the direction of the check strips.
After combining, yield maps were collected by CropPro Consulting and yield maps were overlaid onto the prescription fertilizer maps. After this preliminary step, yield data was extracted from selected areas. This information was analyzed by an independent third party. The analysis involved comparing yield within the zero N strip with yield for the fixed rate and variable rate treatments located nearest each other. Comparisons were to be done for the strips as a whole as well as for similar management zones within each strip. For example, yield comparisons were made across the zero N vs the farmer rate vs the variable rate for a zone requiring a low rate of N; a zone of medium N rate and a high N rate zone at each location. Additional comparisons were made for the entire no N strip vs farmer N vs variable rate N.
We calculated the amount of N removed as grain when the crop has harvested, and subtracted that amount from the fertilizer N added to get an N balance. Negative balanced indicated that amounts removed were not being replaced with fertilizers, while positive balances indicated that soil supplies should be increasing because more was being added as fertilizer that what was removed. Nitrogen use efficiencies were calculated by dividing the yield increase from N over the no N strip by the amount of N added.
Using this same data, both fertilizer used and crop yield were valued in an economic analysis. Thus we generated an economic return on fertilizer use for the farmer rate compared with no fertilizer and economic return for the variable rate compared to the farmer rate. Comparisons were made at the crop management zone level and on a field scale.

RESULTS

Site 1. NE & W13 43 15

This was a highly variable field with class 1, 2, 3 and 4 soils and organic matter ranging from 3.8 to 8.0 % (Table 2). It also included a peat slough which had soil organic matter greater than 24%. Soil P in the original map was uniformly low, but was much higher in the revised map. Class 4 Pathlow soils that have low water holding capacity and are excessively stony appear to be mapped in zones 1 and 2, while class 3 Pathlow soils (structure and stoniness limitations) are mapped in zones 3 and 4. Zones 5 and 6 appear to be mostly class 2 Pathlow soils (soil structural limitations), while zones 7 and 8 appear to be class 2 (limited moisture holding capacity) Blaine Lake soils. The class 1 Melfort soils appear to be mapped in zones 9 and 10. Most of this field is gently sloping (2-5% slopes) but some is very gently sloping (0.5- 2% slopes). Soil survey would suggest that knolls have lost a bit of topsoil but that erosion has not been a major factor affecting productivity.

2009 Results; Canola at site 1 had a plant population that was less than optimal, but was uniformly thin. This may have limited yield, but would not likely invalidate comparisons between treatments.

Yield goal was 40 bu/ac while actual average yield was 41.7 bu/ac for the variable rate, and 43.4 bu/ac for the fixed rate of N , and only 30 bu/ac for zero N (Table 3). Yield data was somewhat spotty because 3 combines were used and yield monitors were not run continuously. Zones 3, 4 and 5 did not respond to fertilizer N while other zones showed good responses. Best N responses were noted in zones 6, 7, 8 and 9, with smaller responses in 1 and 2. Overall the variable rate did an excellent job of matching N removal by the crop, with an N balance of zero, while the fixed rate supplied much more N than was removed by the crop, and the zero N rate resulted in a large deficit. Variable rates worked particularly well here and on this basis it appears that variable rates would be quite beneficial on this field. Zoning the peat slough separately was a big improvement when interpreting data.

We were unable to generate a usable yield map from this field in 2010 due to excess moisture.

Table 2. Selected soil characteristics across zones at Site 1.

ZONE	Acres	% of field	Organic Matter%	N(09) lb/ac	P(09) ppm	Expected N min	K ppm	Cu ppm
1-2	57.8	15	3.8	13	21	38	136	0.6
3-4	97.3	25	3.4	11	17	34	146	0.6
5-6	95.6	24	5.0	15	10	50	199	0.8
7-8	97.4	25	8.0	21	10	80	181	1.1
9-10	48.4	12	24.6	40	22	246	76	1.0

Table 3. Nitrogen rates, yield responses, N balance and N use efficiency in 2009 at site 1.

N Treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0	20	37	17	30	-56	na
Fixed	100	40	44	4	43.4	18	0.134
Variable	72	32	55	33	41.7	0	0.150

Site 2. N23 44 15 W2

This was a highly variable field with soil organic matter ranging from 2.3% on the lighter textured soils to 7.8% in zones 9-10 (Table 4). Levels of P were low in all zones. The field is gently sloping or very gently sloping and salinity is very low. 50% of the area is class 2 soil (Grey Wooded Northern Light), having moderate limitations due to adverse soil structure affecting seedbed conditions, root growth or moisture permeability. Class 1 soil (Dark Grey Tiger Hills) occupies 30% of the field (except the SE corner) and 20% is class 5 soil (gleyed Tiger Hills) with an excessive water limitation (much of the class 5 soil may be uncultivated). Past erosion has been moderate with knolls eroded and soil accumulation in lower slopes. Available Cl is low in zones 1-2 and 7-8 but higher in other zones. Available Cu is low in zones 1-4, and zones 6-10, but quite high in zones 5-6.

Table 4. Selected soil characteristics across zones at Site 2.

ZONE	Acres	% of field	Organic Matter%	N(09)	P(09)	Expected N min	Cl ppm	Cu ppm
1-2	47.9	18	2.3	8	11	23	2	0.6
3-4	67.8	25	3.3	13	12	33	10	0.7
5-6	66.7	24	4.9	11	19	49	12	2.5
7-8	58.7	21	6.6	13	7	66	5	0.7
9-10	32.0	12	7.8	16	15	78	14	0.9

2009 Results: Actual average yield of 51 bu/ac in 2009 was well above target yield of 46 bu/ac (Table 5). Yield data is of limited value because treatments were not applied as planned. Use of 2 combines further complicated any analysis. The zero vs 60 lb/ac fixed rate comparison is valid and showed a good response to N in zones 1&2 as well as 9&10. Yields were good (46 and 47 bu/ac) for zero and 60N in zones 3,4 and 5, but lower (32 and 37 bu/ac respectively) in zones 6,7 and 8. Poor yield in zones 6,7 and 8 may be due to low P in these zones.

Table 5. Nitrogen rates, yield responses, N balance and N use efficiency in 2009 at site 2.

N treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0	32	51	19	41.9	-79	na
Fixed	60	37	60	23	44.5	-24	0.043
Variable	No data	No data	No data	No data	No data		No data

During 2010 we were unable to generate any usable data from this site.

Site 3 E10 44 15 W2

Soil organic matter in this field ranges from 4.0% on knolls to over 7.0% in the depressions (Table 6). Available P is high in zones 7-8 where soil OM is 5.6%, but low in zones 9-10 where soil organic matter is 7%. Low P in zones 9-10 is likely due to higher pH in these zones reducing availability of P. Available K while not particularly high is adequate for most crops in all zones. Available Cl is low in zones 5-6 but high in 7-8. Available Cu is low in zones 1-2, and zones 5-6, but quite high in zones 7-8.

Table 6. Selected soil characteristics over 10 zones in E 10 44 15 W2

ZONE	% of field	O M %	pH	P	K	S	Cl	Texture	Cu ppm
1-2	26	4.1	6.7	16	209	14	10	loam	0.9
3-4	27	4.1	6.6	12	152	16	11	loam	1.9
5-6	24	6.4	7.1	14	245	38	8	clay loam	0.7
7-8	14	6.2	6.6	20	178	58	29	clay loam	4.5
9-10	9	7.3	7.8	13	186	66	19	clay loam	1.3

The field is gently sloping with no salinity. Class 2 (Tiger Hills) soils account for 60% of the area with more than one minor factor affecting yield that combined results in a moderate limitation; 30% is class 3 (Northern Light) soil with a moderately severe limitation to yield caused by inadequate moisture holding capacity and adverse soil structure, while 10% is class 5 because of excess water. The knolls have slightly thinner A horizons, but lower positions do not appear to have gained topsoil.

Table 7. Soil test N (lb/ac) in 2008 and 2009, CWRS wheat yield goals and fertilizer N (as gallons per acre of liquid 28-0-0) prescriptions for 10 management zones on E 10 44 15 W2

Zone	Acres	Soil test N (2008)	Soil test N (2009)	2010 Yield goal (bu/ac)	2010 Liquid N prescription
1	31.9	12	13	45	35
2	24.7	12	13	47	35
3	29.3	12	12	50	34
4	31	12	12	55	33
5	27.9	14	17	60	32
6	26	14	17	60	30
7	18.4	20	17	60	28
8	11.7	20	17	50	25
9	8.5	20	12	45	24
10	11.2	20	12	40	20

2009 results: There was a good response to N across all zones, with the best responses in zones 9-10 (depressions). Actual yield (53 bu/ac) exceeded the yield goal of 44 bu/ac. Both the farmer rate (70 lb/ac) and the variable rate (62 lb/ac)were below optimum, and both ran N deficits when N balance was calculated (Table 8). The high fixed rate (100 lb/ac) came closest to optimizing yield while replacing the N that was removed by the crop. Using 3 combines complicated any yield analysis and reduced reliability of the data, as did cutworm damage.

Table 8. Nitrogen rates, yield responses, N balance and N use efficiency in 2009 at site 3.

N treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0	32	48	16	41	-72	
Fixed 1	70	50	58	8	54	-26	0.186
Fixed 2	100	54	59	5	56	1	0.150
Variable	62	44	58	14	53	-32	0.194

For 2010 a yield goal averaging 52 bu/ac of CWRS wheat was established for the field. The trial area consisted of 2 replicates of the variable rate treatment, a zero N check, a fixed rate of 70 lb/ac (the farmer co-operator rate) of N and a second fixed rate of 120 lb/ac of N (Figure 2).

2010 Results: Wheat yield in 2010 greatly exceeded the yield goal, and increased with increasing N rate across all rates (Table 9). Yield of 48 bu/ac with zero N reflects relatively high productivity this field despite being class 2 and 3 soils. What was surprising was that nitrogen use efficiency was lower for the 70 lb/ac N rate than for the 120 lb/ac N rate. Typically NUE decreases as the N application rate rises. Based on differences in NUE between the 70 and 120 N rates, the predicted NUE for the variable rate should have been about 0.210, but was higher at 0.224. This suggests that the variable rate succeeded in better matching N supply with crop N demand. However, there is no evidence that VRN made yields less variable than what we would predict for a similar fixed rate of N.

Figure 2. Zone map showing trial strips and close-up of trail area yields at Site 3.

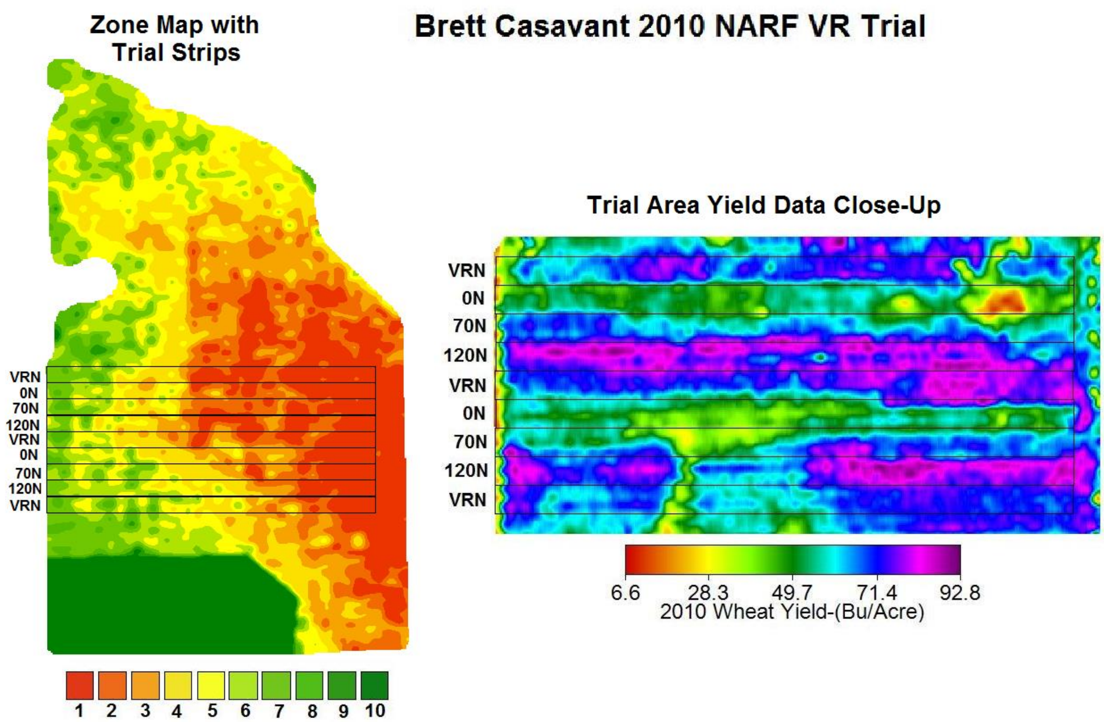


Table 9. Nitrogen rates, wheat yields and fertilizer nitrogen use efficiency (NUE) 2010.

Treatment	Average N rate as lb/ac	Yield (bu/ac)				Fert NUE bu/lb of N
		Low	High	Range	Average	
Zero North	0	30.1	50.4	20.3	50.4	Na
Zero South	0	31.6	62.4	30.8	45.8	Na
Zero Mean	**0**	**30.1**	**62.4**	**32.3**	**48.1**	Na
70 North	70	42.3	79.3	37.0	63.2	0.183
70 South	70	30.4	79.8	49.4	58.2	0.177
70 Mean	**70**	**30.4**	**79.8**	**49.4**	**60.7**	**0.180**
120 North	120	40.5	94.0	53.5	73.2	0.190
120 South	120	38.2	99.8	61.6	78.6	0.273
120 Mean	**120**	**38.2**	**99.8**	**61.6**	**75.9**	**0.231**
VR North	100	48.3	89.8	41.5	69.7	0.193
VR Middle	102	56.9	95.9	39.0	74.5	0.259
VR South	96	33.2	82.4	49.2	66.8	0.219
VR Mean	**99**	**33.2**	**95.9**	**49.2**	**70.3**	**0.224**

At a wheat price of $6.00/bu and a nitrogen cost of $0.50/lb, the marginal return to the farmer rate 70N was $40/ac while that for the variable rate was $84/ac, providing a $44/ac benefit of the variable rate over the farmer rate. However the highest N rate provided the highest net return at $107/ac. Ideally we want to have a variable rate that matches the rate chosen by the farmer. On a field scale, that variable rate was close to the farmer rate, but not on the strips next to the fixed rate strips. In this instance, neither the variable not the farmer rate was the optimum. However there also is evidence that that the variable rate was sufficiently superior to the fixed rate to more than offset costs.

What have we learned from this trial? Despite having a well-planned set of treatments, it is still difficult to structure variable rate trials where we can make simple yet valid comparisons. Even considering these limitations, we can conclude that variable rates worked well on this field in 2010.

Site 4 SW31 & Sec 30 46 13 W2

This is a fairly uniform field with mostly class 1 (Tisdale) soils, with some class 2 (Eldersley) soils on the knolls and upper slopes (Table 10). The class 1 soils appear mostly in zones 3 to 8 while the class 2 soils with limitations due to soil structure appear to be on the knolls and mapped in zones 1 and 2. The small amount of class 3 (Tisdale) soils have an excess water limitation and are mapped in zones 9 and 10. The field is very gently sloping with no evidence of past erosion. Soil organic matter is quite uniform in the 5.4 to 7.3% range and P is much higher in zones 9-10 than any other.

The revised zone map is an improvement, but there really does not appear to be much difference between zones, except that zone 9-10 still has about double the P of other zones. Soils are all clay loams to clays so water holding capacity doesn't differ greatly. No yield data from this field in 2009.

Table 10. Selected soil characteristics across zones at Site 4.

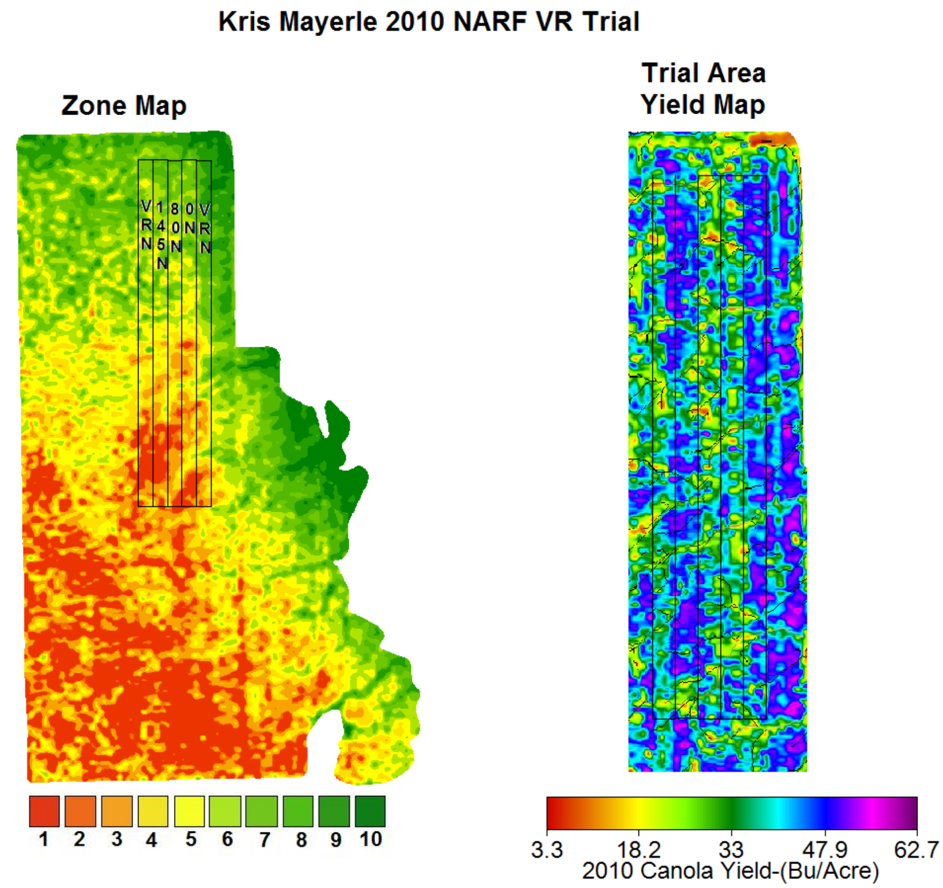
ZONE	Acres	% of field	Organic Matter%	N(09)	P(09)	Expected N min	Cl ppm	Cu ppm
1-2	136.7	21	6.4	14	12	64	14	0.6
3-4	169.8	26	6.3	16	12	63	8	0.7
5-6	171.0	26	4.9	12	10	49	18	0.9
7-8	119.8	18	5.0	10	11	50	11	1.1
9-10	41.7	8	5.6	14	23	56	35	1.0

2010 Results: Throughout the test area, yield was substantially lower than target yield. With zero N, yield was a respectable 33.2 bu per ac suggesting this field has very good nutrient supplying power (Table 11). As N rate increased, yield generally increased, although the east VRN strip with 102.5 lb per ac of N was similar to the 145N fixed rate strip. Four combines were operating in the field, so the yield map may be distorted if they were not all calibrated the same.

Fertilizer NUE was extremely low on this field suggesting that much of it may have been lost. However, NUE did tend to increase with N rate, and was highest for VRN. The only explanation that would fit the data is that most of the N that the crop was able to use came from mineralization from soil organic matter. This likely occurred after the field had dried out. Before that time, most of the fertilizer N had been lost because the field was saturated. The proportion lost must have been lower for the 145N than for the 80N fixed rate, and lower still for the VRN treatment.

Table 11. Nitrogen rates, canola yields and fertilizer nitrogen use efficiency (NUE) 2010.

Treatment	Average N rate as lb/ac	Yield (bu/ac)				Fert NUE bu/lb of N
		Low	High	Range	Average	
Zero	0	10.0	63.0	53.0	33.2	Na
80 N	80	10.3	63.0	52.7	36.4	0.0025
145 N	145	12.5	63.7	51.2	42.2	0.0621
East VRN	102.5	19.3	63.3	44.0	42.9	0.0946



If we assign a value of $11.00 per bu for canola and $0.50 per lb for N, then the 80N rate resulted in a $5 per ac loss, the 145N rate showed a $27 per ac profit while the VRN showed a $55 profit. Both the NUE and economic analysis suggests that there was a benefit to VRN.

What have we learned from this trial. Again despite having a well-planned set of treatments, it is still difficult to structure variable rate trials where we can make simple yet valid comparisons. An added complicating factor is how to accommodate multiple combines while ensuring integrity of the data. These lessons need to be incorporated into future trials. Even considering these limitations, the data we have suggests that variable rates worked well on this field in 2010.

Site 5; NW 24 46 16 W2

This field is a mixture of Black/Thick Black (Melfort) and Dark Gray (Tisdale) soils with good water holding capacity (Table 12). It is very gently sloping with slight erosion on knolls. Depressions may be slightly saline, with limited drainage. Class 1 soil occupies 80% of the area, and class 3 at 20%, with a limitation due to excessive water. This site has very uniform organic matter in the 7.1 – 7.5% range. Phosphate was lowest on knolls, and elevated on lower slopes and depressions. Varying P across zones may have some benefit. Knolls would likely benefit from P rates that exceed P removal (P building), while other areas likely only need P rates that match removal.

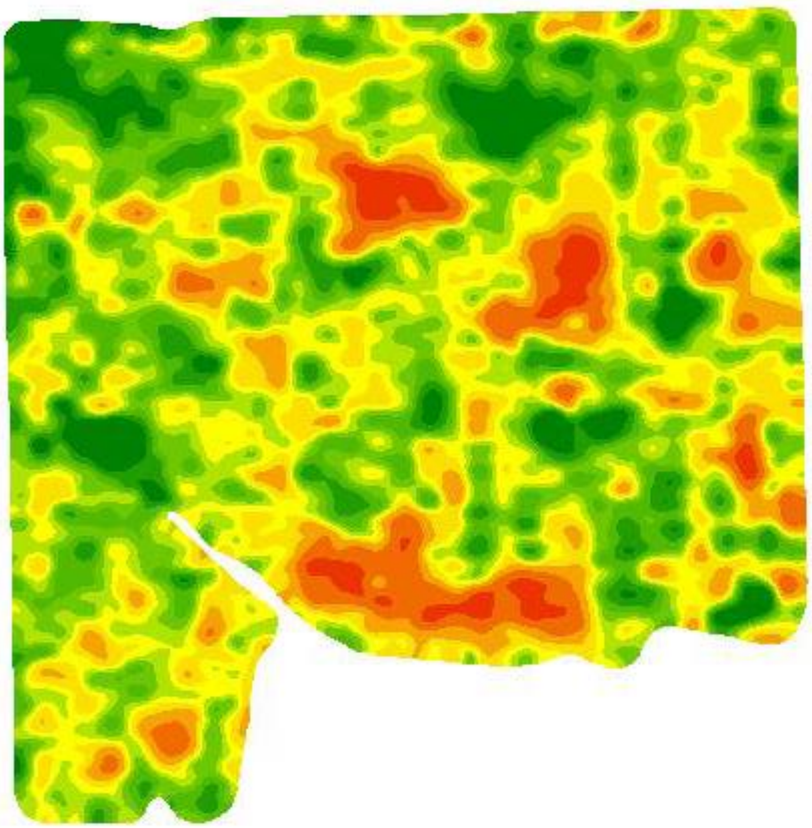


Table 12. Selected soil characteristics at Site 5.

ZONE	Acres	% of field	Organic Matter%	N(08)	P(08)	Expected N min
1-2	9.7	7	7.3	30	10	73
3-4	27.8	21	7.2	32	12	72
5-6	44.5	34	7.4	18	15	73
7-8	34.9	26	7.5	23	22	75
9-10	15.9	12	7.1	30	31	71

2009 Response; This field responded well to N, but yield differed very little (+/- 5%) across zones, except in zones 7-8 where the north VR yielded 43 and the south VR 34 bu/ac. The variable rate treatment did result in a significant savings on fertilizer N, but this may be related to overall yields that were 10 bu / ac below target yield (Table 13). Soil uniformity and yield uniformity suggests this field isn't a great candidate for variable rates to pay dividends.

Table 13. Nitrogen rates, yield response, N balance and N use efficiency in 2009 at site 5.

N Treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0	30	36	6	31.8	-60	na
Fixed	90	36	38	2	37.2	20	0.060
Variable	57	36	43	7	37.7	-14	0.104

Site 6: E30 46 15 W2

This field is a level to gently sloping Dark Gray Tisdale with good water holding capacity, and no salinity (Table 14). It is 80% class1 and 20% class 3 with an excess water limitation. These soils typically show no evidence of having incurred erosion in the past.

This field had lower and more variable organic matter (5.8-7.8%) than the previous field, and soil P tends to be high in zones 7 to 10 [particularly 9-10]. Low soil organic matter in zones 7-8 may be related to the manure history of this field, or it may be that these were treed areas where tree removal also resulted in some soil removal. Applying manure at high rates on knolls and upper slopes and at very low or zero rates on lower slopes and depressions would explain the organic matter distribution across this field. Soil pH was below 6 in zones 1-6.

Table 14. Selected soil characteristics at Site 6.

ZONE	Acres	% of field	Organic Matter%	N(08)	P(08)	Expected N min
1-2	22.6	7	7.8	42	16	78
3-4	70.5	23	6.8	51	18	68
5-6	106.5	35	6.8	39	14	68
7-8	73.9	22	5.8	32	29	58
9-10	31.7	10	7.3	35	45	73

2009 Results: Yield was quite uniform across this field, and responses to N were small. The variable rate did save 19 lb/ac of N with little impact on yield. Considering the manure history this is not surprising. Overall the variable rate did a better job of optimizing yield and of matching crop removal of N than did the fixed rate of N (Table 15). Varying P across zones similar to what is discussed for the preceding field, either alone or in combination with N may improve performance of variable rates.

Table 15. Nitrogen rates, yield response, N balance and N use efficiency in 2009 at site 6.

N Treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0				36.2	-64	
Fixed	90				41.8	15	0.062
Variable	71				40.9	1	0.066

Site 7: W35 46 17 W2

Most of this field is gently sloping while about 20% is very gently sloping, with little evidence of past erosion. Weak salinity in low lying areas is unlikely to affect canola, but could affect more susceptible crops like flax. About half the field is class 1 (mostly Tiger Hills), while one third is class 2(Northern Light), most with an adverse structure limitation. The remaining area is class 5 with an excess water limitation and a small amount of class 4 (water limitation) along the west side. Class 5 soil may be mostly uncultivated. Organic matter is high and fairly uniform across the field at 7.1 to 9.6%. Soil P is generally low but is higher in zones 9 and 10.

Target yield of 45 bu / ac was close to actual yield of 40-45 bu/ac. Treatments were laid down as planned, but the field did require reseeding. A good yield map was generated. In general yield was lowest in zones 1 and 2, intermediate in zones 3 to 6, high in 7 to 9 and very high in zone 10. It appears that zones 1 and 2 are class 2 soils while class 1 soils occupy zones 3 to 9. Ditching to improve drainage may have improved productivity of the soils in zone 10, which appears to have been class 5 soil.

Table 16. Selected soil characteristics at Site 7.

ZONE	Acres	% of field	Organic Matter%	N(09)	P(09)	Expected N min
1-2	28.0	9	7.1	18	7	71
3-4	89.7	29	8.4	16	7	84
5-6	101.3	33	7.8	14	6	78
7-8	57.2	19	8.6	26	15	86
9-10	30.4	10	9.6	78	10	96

Yield for the fixed rate was similar to that for the variable rate, while the variable rate had a slightly higher N deficit that the fixed rate (Table 17). However, the range in yield was considerably less for the variable rate than for the fixed rate.

Table 17. Nitrogen rates, yield response, N balance and N use efficiency in 2009 at site 7.

N Treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0	31	59	28	43.6	-77	na
Fixed	90	45	65	20	51.3	-1	0.086
Variable	80	48	55	7	50.0	-9	0.080

Site 8: NE2 47 17 W2

This field is very gently sloping with no salinity or erosion problems, but the topsoil on knolls is slightly thinner. Soil organic matter is quite variable ranging from 3.6 to 9.2%. Soil P is quite variable ranging from 9 to 44 ppm. Approximately 40% is class 1 (Kamsack) soils, 40% class 2 (Blaine Lake) soils with a water holding capacity limitation and 20% class 5 (Kamsack) soils with an excess water limitation. Ditching appears to have at least partially addressed to excess water limitation on the class 5 soils.

There were excellent responses to N across all zones. Yield was relatively uniform across zones 1 to 8 and higher in zones 9 and 10, at least with 90N. The variable rate strategy to reduce N in zones 9 and 10 did not appear to work very well, as yield was reduced. Zones 3 and 4 could be the most N responsive due to their low organic matter, but with limited data points it is difficult to address this adequately.

Table 18. Selected soil characteristics at Site 8.

ZONE	Acres	% of field	Organic Matter%	N(09)	P(09) ppm	Expected N min	Cl ppm	Cu ppm
1-2	21.9	14	5.6	16	11	56	9	0.7
3-4	40.2	26	3.6	12	9	36	4	0.7
5-6	48.6	31	5.5	22	10	55	5	0.7
7-8	30.3	20	9.2	22	43	92	5	0.9
9-10	13.5	9	7.5	22	44	75	7	1.3

Overall, the fixed rate of N provided substantially higher and more stable yield and better matched crop removal of N compared with the variable rate. Varying P along with N might improve performance of variable rates on this field.

Table 19. Nitrogen rates, yield response, N balance and N use efficiency in 2009 at site 8

N Treatment	N Rate (lb/ac)	Yield (bu/ac)				N Bal lb/ac	NUE Bu/lb
		Min	Max	Range	Mean		
Check	0	24	35	11	31.2	-49	na
Fixed	90	50	61	11	57.3	4	0.290
Variable	61	43	59	16	48.3	-11	0.280

Site 9: E6 46 15 W2

The field is gently sloping with no salinity problems. It has experienced some water erosion but this is minor. Soil organic matter ranges from 3.9 to 8.2%, and P varies from 8 to 31. Most of this field is class 1 (Tisdale) soils with about 10% class 4 (Eldersley) soils with an excess water limitation. Ditching may have addressed some of the excess water limitations. It appears that the class 1 soils are mapped in zones 1-8, while the class 4 soils are in zones 9 and 10.

There is no yield data on the field. N management on class 4 soils with excess water can be complicated because N is lost due to denitrification when they become waterlogged, while water-logging reduces yield potential. By contrast, during dry years they have very high yield potential. Management of P is less complicated because these areas usually are high in P so low rates that ensure a productive crop, but that don’t further elevate soil P are most appropriate.

Table 19. Selected soil characteristics at Site 9.

ZONE	Acres	% of field	Organic Matter%	N(09)	P(09)	Expected N min
1-2	21.6	9	3.5	12	6	35
3-4	42.0	18	4.1	12	6	41
5-6	74.1	35	5.5	18	6	55
7-8	65.4	26	5.9	28	9	59
9-10	28.0	12	6.1	22	23	61

Site 10: E35 45 16 W2

This field is all Arborfield soils with weakly solonetzic class 3 soils on mid and upper slopes and strongly solonetzic soils on lower slopes and poorly drained class 4 soils in depressions. The class 3 soils have a soil structure limitation related to their weakly solonetzic properties while the class 4 soils have an excess water limitation, related to their being solonetzic. The field is gently sloping to level with little past erosion. Soil organic matter is quite uniform between 5.5 and 6.7%, but is unusual because it is lowest in the depressions. This likely reflects the more strongly solonetzic character of soils in depressions.

There is no yield map for this field.

Table 20. Selected soil characteristics at Site 10.

ZONE	Acres	% of field	Organic Matter%	N(09)	P(09)	Expected N min
1-2	53.7	17	6.7	8	33	67
3-4	73.2	23	6.7	14	13	67
5-6	85.8	27	6.2	8	14	62
7-8	62.4	20	6.1	10	18	61
9-10	44.1	14	5.5	10	30	55