On-Farm Nitrogen Management for High Yield Wheat

Manitoba Wheat and Barley Growers Association

Canada

Growing Forward 2
A federal-provincial-territorial initiative

Manitoba

Thank you to the cooperating farmers in this 2-year on-farm-testing project of nitrogen management strategies for high yield and quality of hard red spring wheat.

A special thanks is extended to consulting agronomist Brunel Sabourin of ANTARA Research who aided in record keeping and protocol development, organizing the summer in-field tour and weighing off many of the sites.

On-Farm-Tests for High Yield and High Protein Wheat – 2015-16 Summary (DRAFT 4 March 12)

In 2015-16 some 30 on-farm-tests were conducted to evaluate 3 different nitrogen (N) management strategies for increasing yield and protein of the newer high yield potential spring wheat varieties. These studies were prompted by the struggle to meet protein standards when producers grew high wheat yields in 2013-2014 crop years.

MATERIALS AND METHODS

The 3 N management strategies are simultaneously being evaluated in traditional small plot studies through the University of Manitoba. The strategies selected for on-farm-test evaluation were:

1. Increased N rates. The selected rates were the farmer's base N rate (as determined themselves or with their agronomist), plus an additional 30 and 60 lb N/ac. Usually these rates were applied just before, at or shortly following seeding operations.
2. Use of the controlled release nitrogen fertilizer, ESN. The targeted rate was to be 50% of the farmer's standard fertilizer base rate.
3. Post anthesis nitrogen application. This approach uses a foliar broadcast spray of a UAN solution at 30 lb N/ac diluted 50:50 with water and applied about 7-10 days following anthesis. Most applied in the late evening or morning.

Studies were established using an on-farm-testing procedure with replication and randomization. The rigour of testing was increased in 2016 compared to 2015. The 2015 plots were generally replicated 2-3 times, but replication was increased to 4. In 2015 the yield measurements were done with the farmer's calibrated combine yield monitor and /or grain cart whereas in 2016 we insisted on using standard weigh wagons. The protein samples were taken from the combine hopper or as unloading in 2015 but in 2016 we adapted a sampling tube to the weigh wagon to pull continuous samples during the weigh-off procedure. This design was taken from the Minnesota Wheat On-Farm Research Network.

At most sites measures of N sufficiency were made:

- Flag leaf N: once Flagleaf had fully emerged the leaf was sampled. For example, in Montana 4.2% N is considered sufficient for full yield potential and good protein.
- NDVI as measured with the pocket GreenSeeker.
- UAV flights were intended for all participant fields, but were not all completed.

Data was analysed using ANOVA and differences were considered statistically significant at the 90% confidence interval.

Economics of strategies were calculated on mean values of yield and protein using prices from late February 2017 and spring 2016 fertilizer prices.

Nitrogen Practice 1: Increasing Base N Rates

The farmer used their base N rate and supplemented with an additional 30 and 60 lb N/ac in replicated and randomized strips.

Table 1. Agronomic details for all sites evaluating supplemental N on wheat yield and protein (2015-16).

Farm	A	B	C	D	E	F	G	H	I	J	K	L	Ave CNHR	Ave CWRS
Plant		A 23	M 3	M 2			M 11	M 5			M 3	M 4		
Harvest		A	S 2	S 1				S		A 27	A 19	S 2		
Rain “	14.4	14.9	14.6	13.9	11.2	16.4	15.7	16.6	11.2	9.4	13.3	13.0		
Variety/ Class	Prosper CNHR	Prosper CNHR	Prosper CNHR	Faller CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Brandon CWRS	Brando n CWRS	Cardale CWRS	Pasteur GP		
Prev crop		Dry beans	soys	soys			soys	canola			soys	canola		
Soil type	Sl	Reinland sl	Osborne clay	R River clay	Clay	Clay	Clay	cl	Clay loam	New dale cl	Glen hope sl	Newdale cl		
Soil N	25	86	28	35	-	30	-	na	57	75		25	41	66
OM												4.9%		
Base rate N	140	74	145	160	105	125	120	90	85	70	90	110	120	82
Total N	165	160	173	195	105+	155	120+	90	142	145		135	156	144
N applied	Preplt band urea	Preplt Bcst urea	Topdress UAN	160 MRB NH3,& 60 ESN seedplace			Topdre ss UAN	Fall NH3 & 30 ESN at seeding	Topdress UAN dribbled	Sideba nd urea	Fall NH3 UAN drib	NH3 sideband		
Yield limiting factor*	lodging	lodging* 56 77 86	lodging* 72 71 90	Wetness, lodging		lodging	lodging							

- Rain is the total May-August rainfall from the closest MB Agriculture weather station.
- where lodging differed among treatments it was rated according to a Lodging Index = 1/3 (% area leaning) + 2/3 (% area lodged) + (% area flat)

Table 2. Effect of supplemental N on wheat yield and protein (2015-16).

Farm	A	B	C	D	E	F	G	H	I	J	K	L	*Average CNHR(8)*	*Average CWRS (3)*
Yield bu/ac														
Base N	84	70.4	71.7	78.1	54	62.3	66.1	80.2	81.2	62a	84.5	85.4	70.9	75.9
&30	84	69.8	72.9		54	60.0	65.8	86.5	85.7	65b	83.0	85.2	70.4	77.9
& 60	85	70.0	72.3	75.6	56	62.3	66.0		83.3	65b	80.9	85.3	69.6	76.4
Sign	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	ns	ns	nd	nd
Protein %														
Base N	14.2	14.3	13.2	13.7	14.5	15.2	15.0	13.3	15.0 a	14.9	13.3	11.9	14.2	14.4
&30	14.0	14.2	13.4		14.2	15.6	14.8	13.5	15.1ab	15	13.7	11.9	14.2	14.6
& 60	14.5	14.53	13.5	13.5	14.6	15.3	14.9		15.2 b	15.5	13.2	11.6	14.4	14.6
Sign	ns	ns	ns	ns	ns	ns	ns	ns	*	nd	ns	ns	nd	nd
Test wt lb/bu														
Base N	61.1	60.9	61.7	60.7				59.3	60.4	61.1	59.8	60.8	60.7	60.4
&30	61.1	61.1	61.1	-				59.0	60.2	61.3	59.9	60.6	60.6	60.5
& 60	61.2	60.6	60.6	60.5				-	60.2	60.8	59.6	61.0	60.7	60.2
Sign	ns	ns	ns	ns				ns	ns	ns	ns	ns	nd	nd
Measures of N sufficiency and efficiency														
FLN%	3.9% 4.0% 4.0% ns	4.8% 4.85% 5.13% ns	4.7% 4.75% 4.8% ns	4.42	3.6% 3.8% 3.8% ns	-	-	4.5% 4.7% nd	4.3%	4.2% 4.4% 4.3% ns	4.53%a 4.77%b 4.88%b *	4.46% 4.40% 4.48% ns		
NDVI	0.77 0.77 0.77 ns	0.86 0.86 0.86 ns	0.82 0.83 0.81 ns	0.75	0.53 0.52 0.56 ns				0.51 0.58 0.52 ns	0.85 0.82 0.85 ns	0.77 0.77 0.75 ns	0.71 0.72 0.71 ns		
NUE Lb N/bu	2.0	2.3	2.4	2.5	-	2.5		na	1.8	2.3		1.6	2.3	2.1

- Sign = statistical significance, ns = not significant, nd = not determined, * = significant at 90% probability level and means followed by the same letter are not significantly different.
- FLN = Flagleaf N content at flagleaf emergence
- NDVI = near difference vegetation index as determined by the handheld GreenSeeker sensor at flagleaf emergence.
- NUE = nitrogen use efficiency = the N supply divided by bu produced.

RESULTS AND DISCUSSION

Farmers were generally applying higher N rates to CNHR (120 lb N/ac) than to CWRS (82lb N/ac). Not all growers had soil test information to allow calculation of total N supply, but on average the N supply was 156, 144 and 135 lb N/ac for the CNHR, CWRS and GP wheat classes, respectively (Table 1).

Significant differences for yield and protein were only observed at 1 of 12 sites (Table 2). The yield increase at the site J was slight (only 3 bu/ac) but significant owing to the use of 4 replicates and low field variability. The significant protein increase was only 0.2% at site I. Other sites had greater differences in yield and protein, but they were not significant. Lodging was a yield limiting factor at several sites and was increased by N rate at sires B and C (Table 1).

Test weight was similar across N rates. Similarly the measures of N sufficiency – flag leaf N, SPAD and NDVI showed few differences between N treatments.

Since there was little yield or protein benefit, the added N costs reduced profitability substantially in all but 3 instances (Sites H, I, J in Table 3). At those sites the slight profitability was due to slightly higher yield, not a protein increase with a premium.

In general, for available yield potential in 2015 and 2016, the base N rates used were adequate to meet yield potential and provide high protein levels

Sampling tubes on unloading augers of weigh wagons allowed continuous grain sampling for later protein analysis

Table 3. Economics of supplemental N applications.

Farm	A	B	C	D	E	F	G	H	I	J	K	L	*Average CNHR*	*Average* CWRS
Variety/ Class	Prosper CNHR	Prosper CNHR	Prosper CNHR	Faller CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Brandon CWRS	Brandon CWRS	Cardale CWRS	Pasteur GP		
$/bu														
Base	6.71	6.73	6.46	6.61	6.77	6.84	6.82	6.48	6.82	6.81	6.46	5.09	6.68	6.70
30N	6.39	6.45	6.16		6.45	6.84	6.63	6.19	6.83	6.82	6.58	5.09	6.44	6.74
60N	6.54	6.54	6.19	6.19	6.57	6.84	6.66		6.84	6.87	6.46	5.09	6.50	6.72
GR-N														
Base	563.64	473.79	463.18	516.24	365.58	426.13	450.80	519.70	553.78	422.22	545.87	434.69	472.38	507.29
30N	521.76	435.21	434.06		333.30	395.40	421.25	520.44	570.33	428.30	531.14	418.67	437.35	509.92
60N	525.90	427.80	417.54	437.96	337.92	396.13	409.56		539.77	416.55	492.61	404.18	421.83	482.98
R														
30N	-41.88	-38.58	-29.12		-32.28	-30.73	-29.55	0.74	16.55	6.08	-14.73	-16.02	-28.77	2.63
60N	-37.74	-45.99	-45.65	-78.28	-27.66	-30.00	-41.24		-14.01	-5.67	-53.26	-30.51	-43.79	-24.31

- $/bu = late Feb. 2017 prices with protein
- GR-N = Gross revenue (yield x price/bu) less extra N cost, assumed 30 lb N/ac = $15/ac and 60 lb N/ac = $30/ac
- R = return above base N rate, in $/ac.

Lodging at site B.

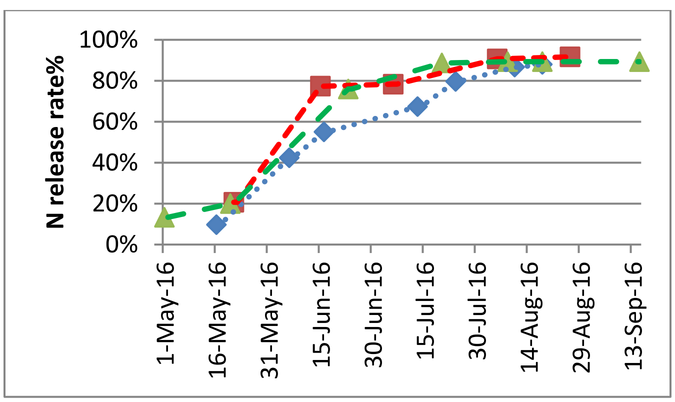
Nitrogen practice 2: Using ESN as a portion of base N rate

In an attempt to better match N supply with grain protein accumulation and to minimize lodging, the controlled release fertilizer, ESN (44-0-0) was applied as a sizable portion of the base N rate.

Table 4. Agronomic details for all sites evaluating ESN on wheat yield and protein (2015-16).

Farm	M	N	O
Pl date	May 1	May 5	May 3
Harv	Aug 27	Sept 15	Sept 1
Rain "	13.9	12.4	13.8
Variety/Class	Penhold/CPS	Prosper CNHR	Faller CNHR
Prev crop	soys	canola	Soys
Soil type	Newdale cl	Sigmund cl	Red River c
Soil N	17	17	45
OM	5.5%	5.1%	
Base rate N	130	98	160
Total N	147	115	205
N:ESN blend	Urea65:ESN65	UAN 49:ESN 49	NH3 100:60 ESN
Placement	Sideband SeedHawk	Sideband Seedmaster	JD 1895 MRB NH3, seedplace ESN
Other placements	80 U sideband& 50 dribble 80 U sideband & 50 coulter		
Yield limiting factors		wetness	Dry early, lodging, wetness

Figure 1. Nitrogen release pattern of field placed ESN (2016)



ESN bags buried for in-season retrieval.

Table 5. Effect of ESN on wheat yield and protein (2016).

Farm	M	N	O
Yield bu/ac			
Base N	78.0	84.6	66.5
ESN blend	79.7	86.9	70.0
UAN drib	78.1		
UAN coulter	78.3		
Sign	ns	ns	ns
Protein %			
Base N	13.7 a	12.4	13.1 a
ESN blend	13.9 ab	12.5	13.5 b
UAN drib	14.0 b		
UAN coulter	13.8 ab		
Sign	*	ns	*
Test wt lb/bu			
Base N	62.1	60.3	60.1
ESN blend	62.1	60.4	60.0
UAN drib	62.1		
UAN coulter	62.2		
Measures of Sufficiency			
FLN%	5.0 5.2 5.0 5.2 ns	4.42 4.53 ns	4.42 4.43 ns
NDVI	0.73 0.74 0.73 0.77 ns	0.77 0.75 ns	0.75 0.75 ns
NUE Lb N/bu	1.9	1.4	3.1

Sign = statistical significance, ns = not significant, * = significant at 90% probability level and means followed by the same letter at not significantly different.

FLN = Flagleaf N content at flagleaf emergence

NDVI = near difference vegetation index as determined by the handheld GreenSeeker sensor at flagleaf emergence.

NUE = nitrogen use efficiency = the N supply divided by bu produced.

Table 6. Economics of ESN applications.

Farm	M	N	O
Variety/Class	Penhold /CPS	Prosper CNHR	Faller CNHR
$/bu			
Base	5.17	5.86	6.07
ESN blend	5.17	5.89	6.19
GR-N ($/ac)			
Base	333.1	440.9	328.5
ESN blend	333.4	451.6	346.1
	0.3	10.7	17.6

$/bu = late Feb. 2017 prices with protein

GR-N = Gross revenue (yield x price/bu) less total N costs, with urea @ $0.54/lb N, NH3 @ $0.47/lb N, UAN @ $0.56/lb N and ESN @ $0.67/lb N (spring 2016 prices)

R = return above base N source in $/ac

RESULTS AND DISCUSSION

Nitrogen release from ESN was determined using the buried bag method through the growing season (Figure 1), with about 10% released at placement (seeding), 30-45% by end of May, 60-80% by end of June and 80-90% by end of July.

Yields with ESN were numerically greater but not significantly higher than the standard practice N (Table 5). Wheat protein was significantly increased at one of the sites. The UAN dribble in-season produced significantly higher protein than the standard urea sideband treatment at farm M.

Test weight was similar between N sources and placement/timings. Similarly other measures of N sufficiency – flag leaf N and NDVI did not differ.

The use of ESN produced positive returns, more due to the effect on yield than protein premium (Table 6).

Nitrogen Practice 3: Post Anthesis Nitrogen

The farmer applied their base N rate and some 7-10 days after anthesis, applied another 30 lb N/ac as UAN (28-0-0), diluted 50:50 with water and applied with spray nozzles. Temperatures in 2015 were generally hot during this period and so leaf burn was greater than observed previously.

able 7. Agronomic details for all sites evaluating past anthesis N (PAN) on wheat yield and protein (2015-16).

Farm	P	Q	R	S	T	U	V	W	X	Y	Z	a	b	c	d
Pl date					M4			M 5	M 5		M3	M7	M2	M6	
Harv					A20	A 13	A 27		A 28	A26	A31	S14	A22	S 14	
Rain	13.9	16.5	15.1	9.7	11.4	15.6	12.9	12.9	16.6	13.8	11.2	9.7	13.9	11.0	15.0
Variety/Class	Prosper CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Faller CNHR	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Penhold CPS	Penhold CPS
Prev crop					beans		soys			peas	canola	soys	soys	canola	millet
Soil type	clay	clay	clay	clay loam	Gnadenthal l	loam	clay loam	clay loam	clay loam	Newdale cl	Newdale cl	Two Creeks l	Neuenberg sl	Sperling loam	clay
Soil N	25	30	-	20	62	-	20	-	19	57	11	22	60	21	52
OM					4.3%					5.1%	4.7%	4.6%	4.3%	6.2%	
Base rate N	143	125	135	116	117	132	146	100	82	89	105	90	95	110	50
Total N	168	155	135+	136	179	132+	166	100+	101	146	116	112	155	131	102
PAN applied	am				JL11		pm	JL 21 midday	JL 14 pm	JL7	JL11	JL6	JL7	late	midday
PAN N rate	30	30	30	30	30	30	30	30	30	35	30	30	30	30	30
Yield limiting factor	Lodging		Lodging			Lodging	lodging	lodging	Excess rain	No lodging	No lodging	No lodging			Leaf burn

Table 8. Effect of post anthesis N (PAN) N on wheat yield and protein (2015-16).

Farm	P	Q	R	S	T	U	V	W	X	Y	Z	a	b	c	d
Yield bu/ac															
Base N	74	62	59	87	66.5	86	74	80.5	51	74.6	59.0	66.3	67.1	71.5	66
&PAN	73	61	57	86	66.2	82	79	79.3	49	77.0	58.6	65.5	67.9	70.5	60
sign	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*
Protein %															
Base N	13.9	15.2	13.7	10.9	14.3	13.7	13.8	15.0	13.9	14.7	13.4	13.9	14.8	13.9	13.7
&PAN	15	15.7	14.6	12.4	14.5	14	14.8	14.8	14.4	15.0	13.4	14.7	15.2	13.7	14.4
sign	*	*	*	*	ns	ns	*	ns	ns	*	ns	*	*	ns	*
Test wt lb/bu															
Base N	59.9		56.2	61.6	59.3		61.0	60.1	59.8	62.1	62.7	59.8	60.8	58.0	
&PAN	59.3		56.0	61.8	59.2		60.7	60.5	59.1	62.0	63.2	59.9	60.9	58.0	
sign	ns		ns	ns			ns	ns	ns						
Measures of N sufficiency and efficiency															
PAN leaf burn	15%	-	-	12%	4.5%	12%	12%	15%	5%	21%	13%	8%	10%		31%
FLN%	3.8%	-	4.1%	4.3%	4.6%	4.1%	4.7%	4.7%	4.5%	4.89%	4.1%	4.2%	4.4%		-
NDVI					0.81					0.83	0.72	0.80	0.77		
NUE Lb N/bu	2.3	2.5	-	1.6	2.7	-	2.2	-	2.0	1.96	1.97	1.7	2.3	1.8	1.5

Sign = statistical significance, ns = not significant, * = significant at 90% probability level. PAN leaf burn = % of flag leaf damaged by UAN.

FLN = Flagleaf N content at flagleaf emergence NDVI = near difference vegetation index by the handheld GreenSeeker sensor at flagleaf emergence.

NUE = nitrogen use efficiency = the N supply divided by bu produced.

Post anthesis N application and leaf burn observations.

Table 9. Effect of post anthesis N (PAN) on wheat class yield and protein (2015-16).

	CNHR (6)	CWRS (7)	CPS (2)
Yield bu/ac			
Base N	80	68	69
Base N & PAN	78	68	65
Protein %			
Base N	13.0	14.2	13.8
Base N & PAN	13.6	14.6	14.1

Table 10. Economics of PAN applications.

Farm	P	Q	R	S	T	U	V	W	X	Y	Z	a	b	c	d
Variety/Class	Prosper CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Prosper CNHR	Faller CNHR	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Brandon CWRS	Penhold CPS	Penhold CPS
$/bu															
Base	6.35	6.75	6.27	5.52	6.48	6.27	6.61	6.82	6.64	6.79	6.50	6.64	6.8	5.17	5.17
PAN	6.69	6.84	6.57	5.86	6.54	6.39	6.8	6.8	6.75	6.82	6.50	6.79	6.84	5.17	5.17
GR-N															
Base	469.90	418.50	369.93	480.24	430.92	539.22	489.14	549.01	338.64	506.53	383.50	440.23	456.28	369.66	341.22
PAN	488.37	417.24	374.49	503.96	432.95	523.98	537.20	539.24	330.75	525.14	380.90	444.75	464.44	364.49	310.20
R-PAN	-1.53	-21.26	-15.44	3.72	-17.97	-35.24	28.06	-29.77	-27.89	-1.39	-22.60	-15.49	-11.84	-25.17	-51.02

- $/bu = late Feb. 2017 prices with protein
- GR-N = Gross revenue (yield x price/bu) less extra PAN cost of $20/ac @ 30 lb N/ac = $15/ac and $5 application.
- R -PAN= return of PAN above base N rate in $/ac

RESULTS AND DISCUSSION

In spite of substantial leaf burn, yields were only significantly reduced in one instance, a location where PAN had been applied in the mid day heat (site d in Table 8). The impact on protein was largely positive and significant at 9 of 15 sites. There was no effect on test weight.

The average protein increase was 0.5%. Based on wheat class, protein generally increased in the order CNHR >CRWS>CPS (Table 9).

Although the protein increase was generally positive and price premiums were obtained, it was largely insufficient to pay for the treatment. Only 2 of the 15 sites would have positive returns– one with a 5 bu yield increase and 1% protein increase (site V) and another with a 1.5% protein increase (site S).

SUMMARY

Also of interest are the general N practices for the different wheat classes. Table 11 summarizes the base treatments of the 30 trials. In this study, farmers fertilized the CNHR greater than the CWRS. The average nitrogen supplied was 2.3 lb N/bu for CNHR, 2.0 for CWRS and 1.7 for CPS.

Yields were often lower than expectations. Rainfall was generally more than adequate and contributed to severe lodging at many sites. Several additional sites did not receive scheduled PAN treatments in 2016 due to excessively wet soil conditions.

Table 11. Overall summary of crop fertility, yield and protein performance.

	CNHR (16 sites)	CWRS (10 sites)	CPS (3 sites)	GP (1)
Soil N lb N/ac	37	40	30	25
Fertilizer N applied lb N/ac	124	95	97	110
Total N supply lb N/ac	158	135	127	135
Yield bu/ac	72	70	72	85
Protein %	13.8	14.3	13.8	11.9
NUE lb N/bu	2.3 (1.4 – 3.1)	2.0 (1.7-2.3)	1.7 (1.5-1.9)	1.6

On Farm Testing Lessons

1. **Suitability of grain carts and yield monitors for on-farm-tests.**

At many sites we tried to collect yield comparisons using a standard weigh wagon (Pioneer Hybrid or ANTARA) versus the farmer's scaled grain cart or calibrated yield monitor (Table 13).

In general weigh wagon and grain cart yield measurements were well related with little difference between measures (Table 13). Yield monitor yield was generally less related to the weigh wagon than the grain cart. The farmer's grain cart and yield monitor yields were generally similar, as they should be since this is the scale commonly used to calibrate the yield monitors.

It is difficult to numerically express the differences observed. Graphs for some of the less accurate measures are shown below (Figure 2). Since yields differed only slightly with the treatments this may not be a appropriate evaluation these systems. Testing over a wider range of yields may be required.

Scaled grain carts should be suitable for on-farm-test plots (providing they are calibrated with a truck scale). Yield monitors may require some additional calibration rigour before being used for on-farm-tests.

Table 13. Relationship of yield measuring techniques – weigh wagon (WW), scaled grain carts (GC) and combine yield monitors (YM).

Farm	GC vs WW			YM vs WW			YM vs GC		
	Difference		Corr.	Difference		Corr	Difference		Corr.
	Bu/ac	%	R2	Bu/ac	%	R2	Bu/ac	%	R2
L	-1.7	-2.0%	0.98	-0.5	-0.6%	0.77	1.2	1.4%	0.71
M	1.8	2.3%	0.98	3.8	4.5%	0.79	2.0	2.4%	0.80
Y	1.0	1.4%	0.89	-0.7	-0.9%	0.91	1.0	1.3%	0.99
N				2.9	3.3%	0.81			
C				-6.7	-9.3%	0.83			
a				-5.4	-8.1%	0.22			
Z				-1.0	-1.7%	0.97			
B	-0.5	-0.7%	0.98						

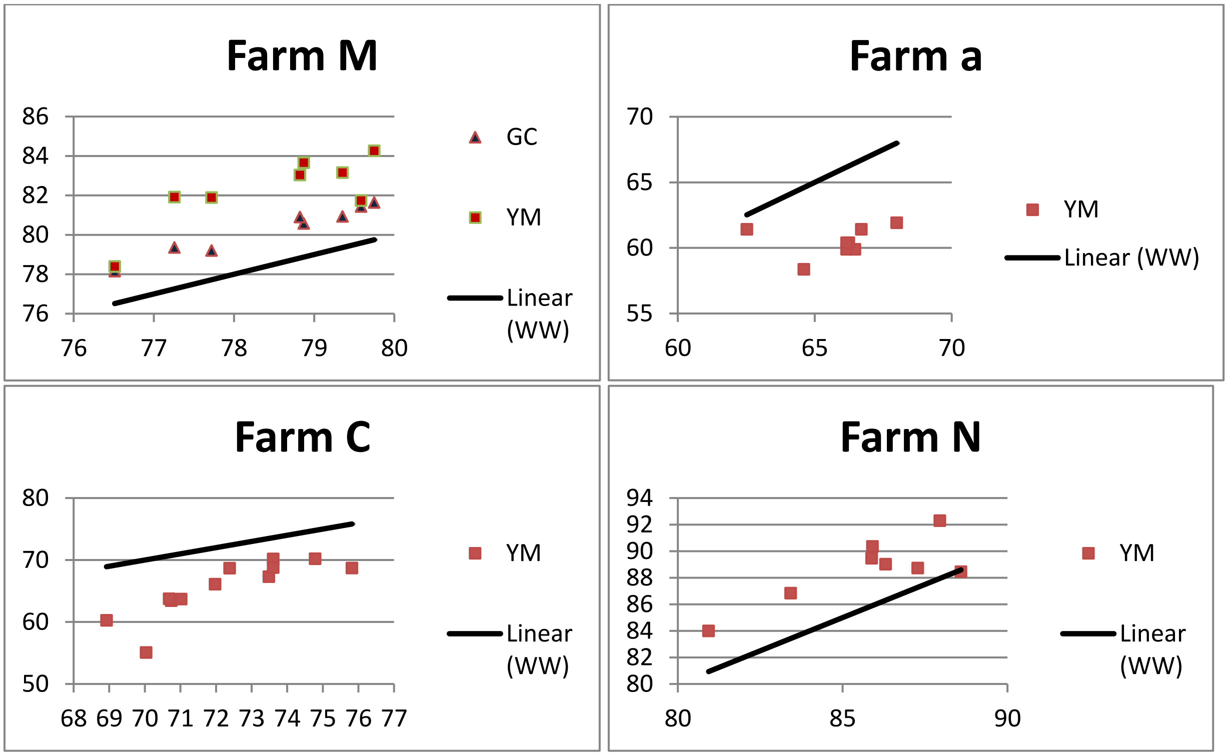


Figure 2. Comparison of yields measured with grain carts and yield monitors

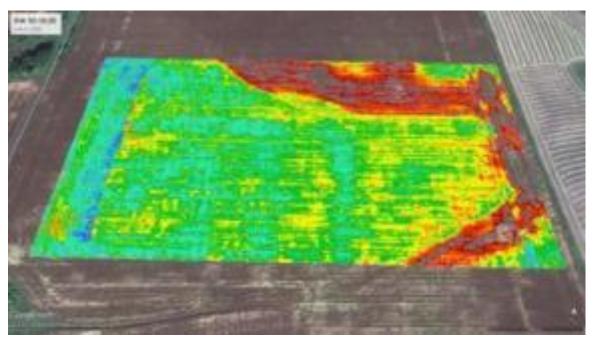
2. **Wheel tracks**

Wheel tracks produced when spraying wheat should either be avoided, or included in all passes. In many instances yield variability was added to the strips by the inclusion of wheel tracks in some passes and not in others. The impact of tracks may have been greater than the treatments we were expecting from nitrogen (Table 12).

Table 12. Impact of wheel tracks on combine yield in bu/ac (% loss)

Farm	No sprayer tracks	1 spray track	2 Spray tracks
Z 36' header	62.7		53.5 (-14.8%)
a 35' header	60.9	57.9 (-4.9%)	55.8 (-8.4%)

3. **UAV or aerial images.**



These images should be taken in season, preferably after the treatments are applied. These should be able to indicate those poor areas of the field that should have replicates trimmed back and not harvested as part of the plot. In many cases plot variability was increased due to wet areas affecting only certain strips. This is a problem with field equipment with such wide strips (100-120') that may contain variability within an individual strip and not consistent across the replicate.

GIS should also be used to place the applied strips over the aerial images.

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