Estimating the Nitrogen Supplying Power of Manitoba Soils

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AGVISE Seminar – March 14, 2018

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Recommended Rate of Nutrient to Apply = Crop Nutrient Requirement - Soil Nutrient Supply

But how is the soil's supply of N affected by:

- residual plant available N in soil
- N mineralization, immobilization, and losses
  - site and year
  - historical nutrient & crop mgmt. practices
  - current nutrient & crop mgmt. practices

And how do we predict those effects?

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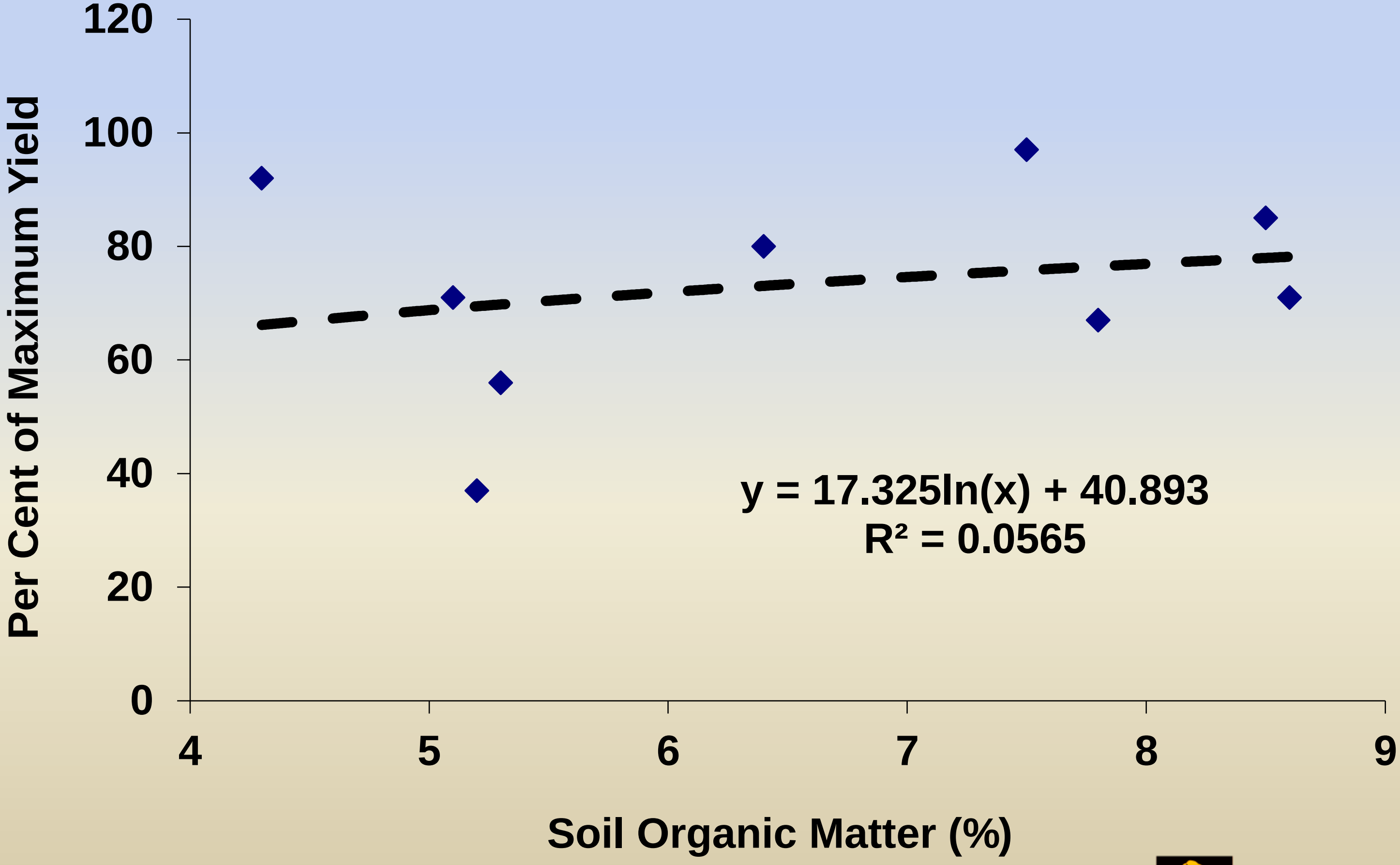
1. Accounting for the effect of residual plant available N in soil

Effect of Soil Test N on Yield Response of Barley to Fertilizer N (Soper & Huang 1963)

Soil Test Method	R^2 *
Soil organic matter (0-6”)	0.06
Easily hydrolyzed organic N (0-6”)	0.70
N release during incubation (0-6”)	0.69
Water soluble nitrate-N (0-48”)	0.90

* Correlation between % of max. yield and log of soil test N for 9 experiments in 1960. Nitrate-N and incubation N were also significantly correlated with each other (R^2 = 0.38)

Effect of Soil Organic Matter on Relative Yield of Barley in Unfertilized vs. Fertilized Treatments (Soper & Huang 1963)



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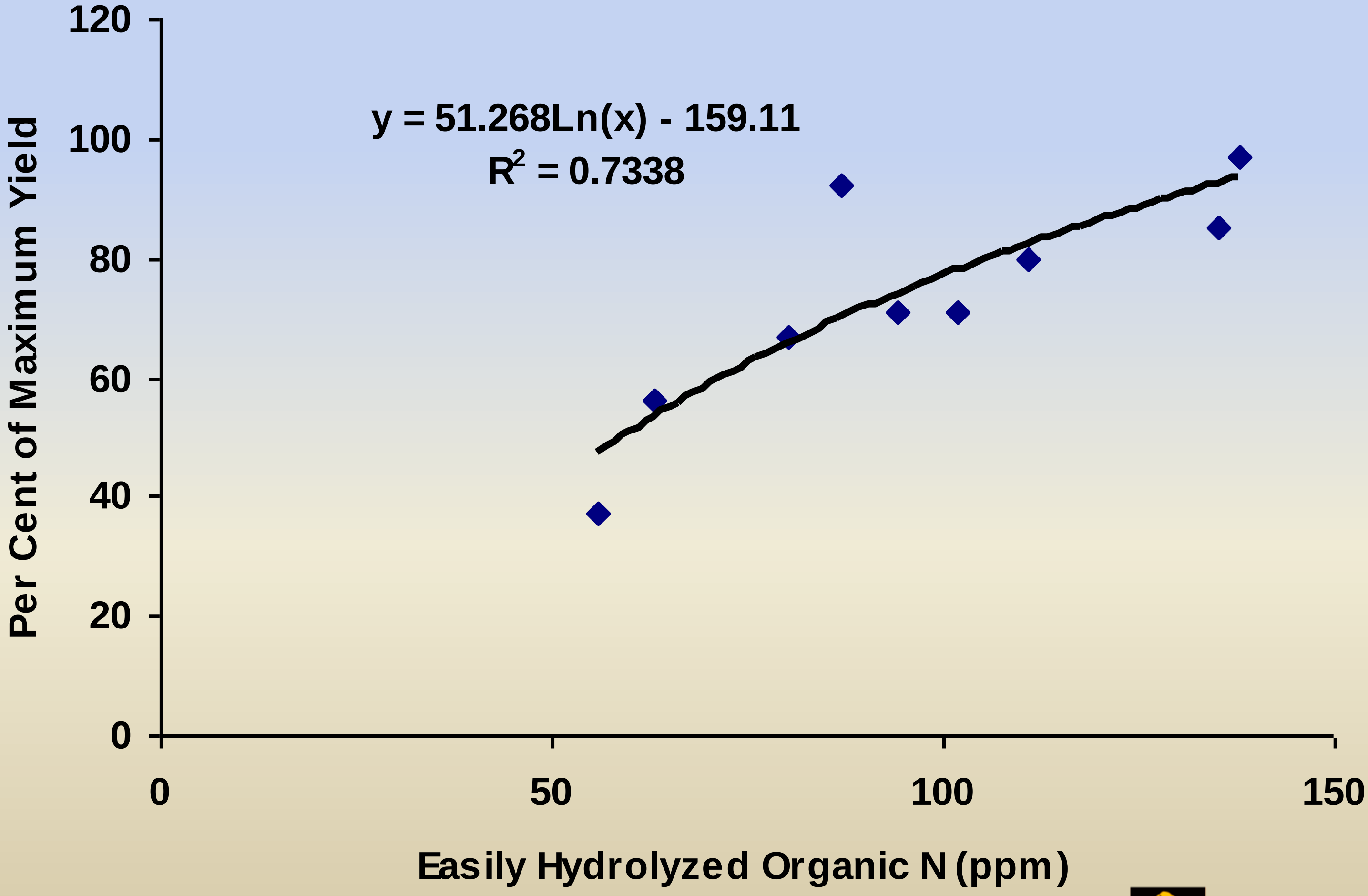
Effect of Easily Hydrolyzed Organic N on Relative Yield of Barley in Unfertilized vs. Fertilized Treatments (Soper & Huang 1963)



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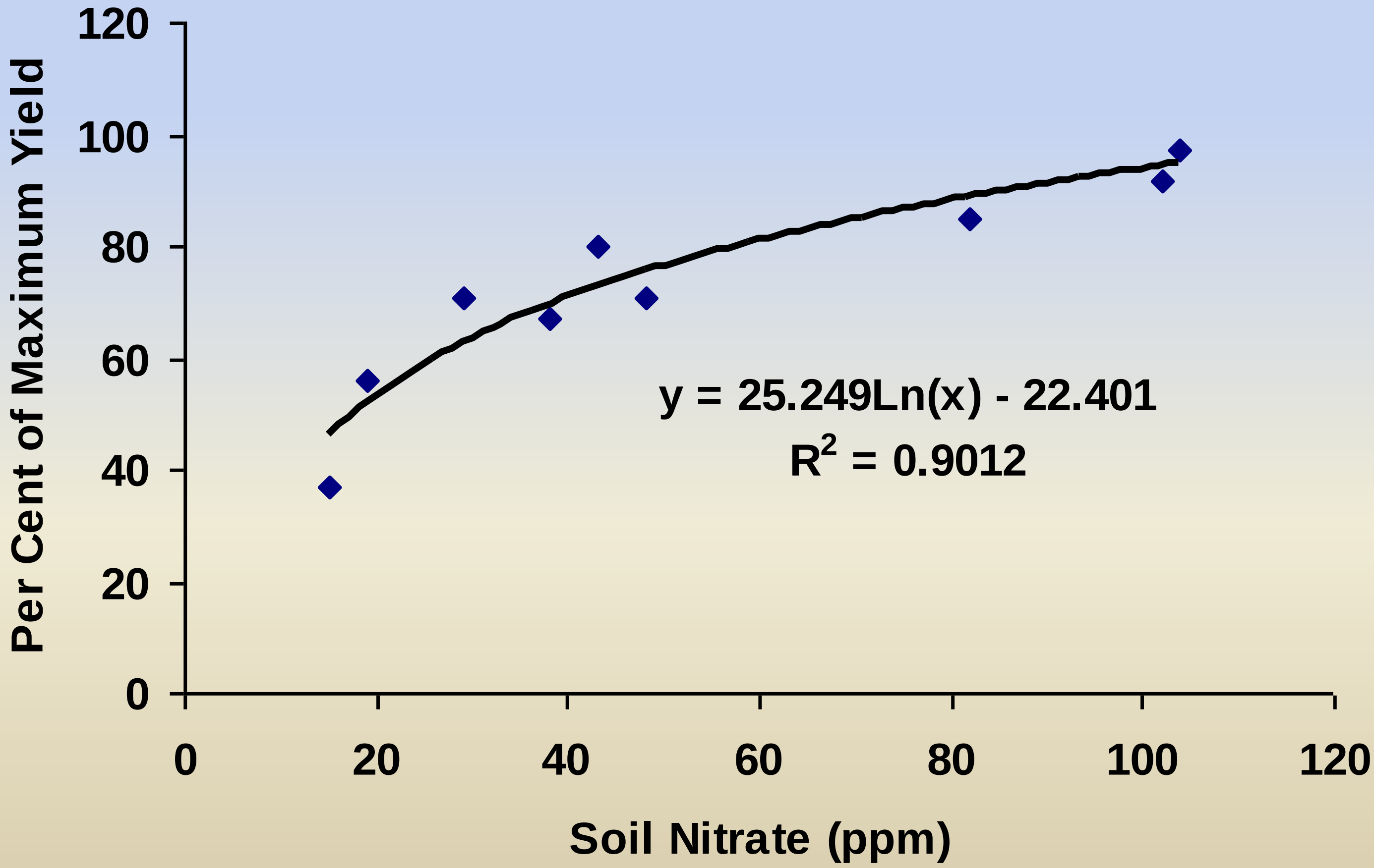
Effect of Soil Nitrate-N on Relative Yield of Barley in Unfertilized vs. Fertilized Treatments (Soper & Huang 1963)



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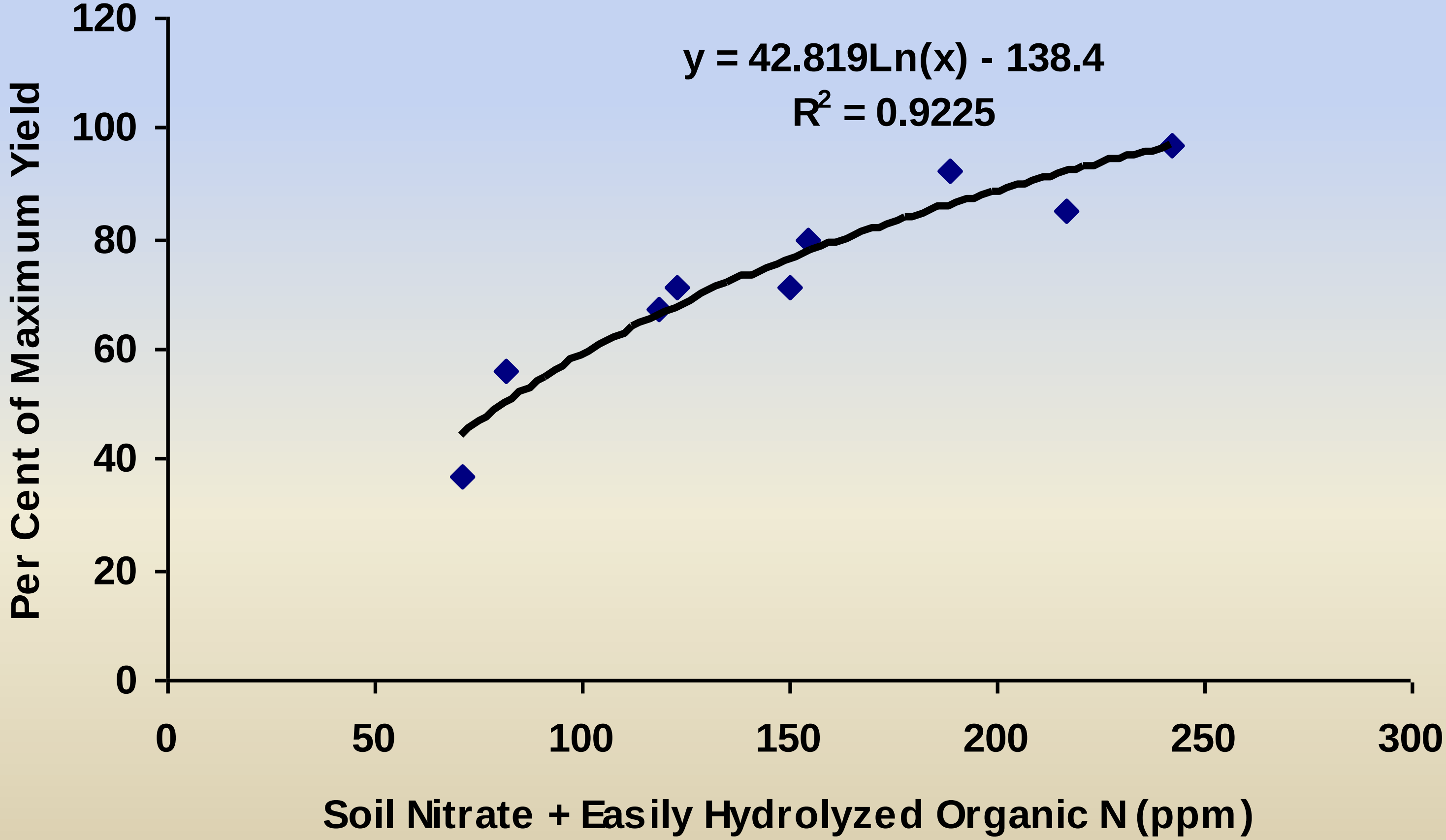
Effect of Soil Nitrate-N + Easily Hydrolyzed N on Relative Yield of Barley in Unfertilized vs. Fertilized Treatments (adapted from Soper & Huang 1963)



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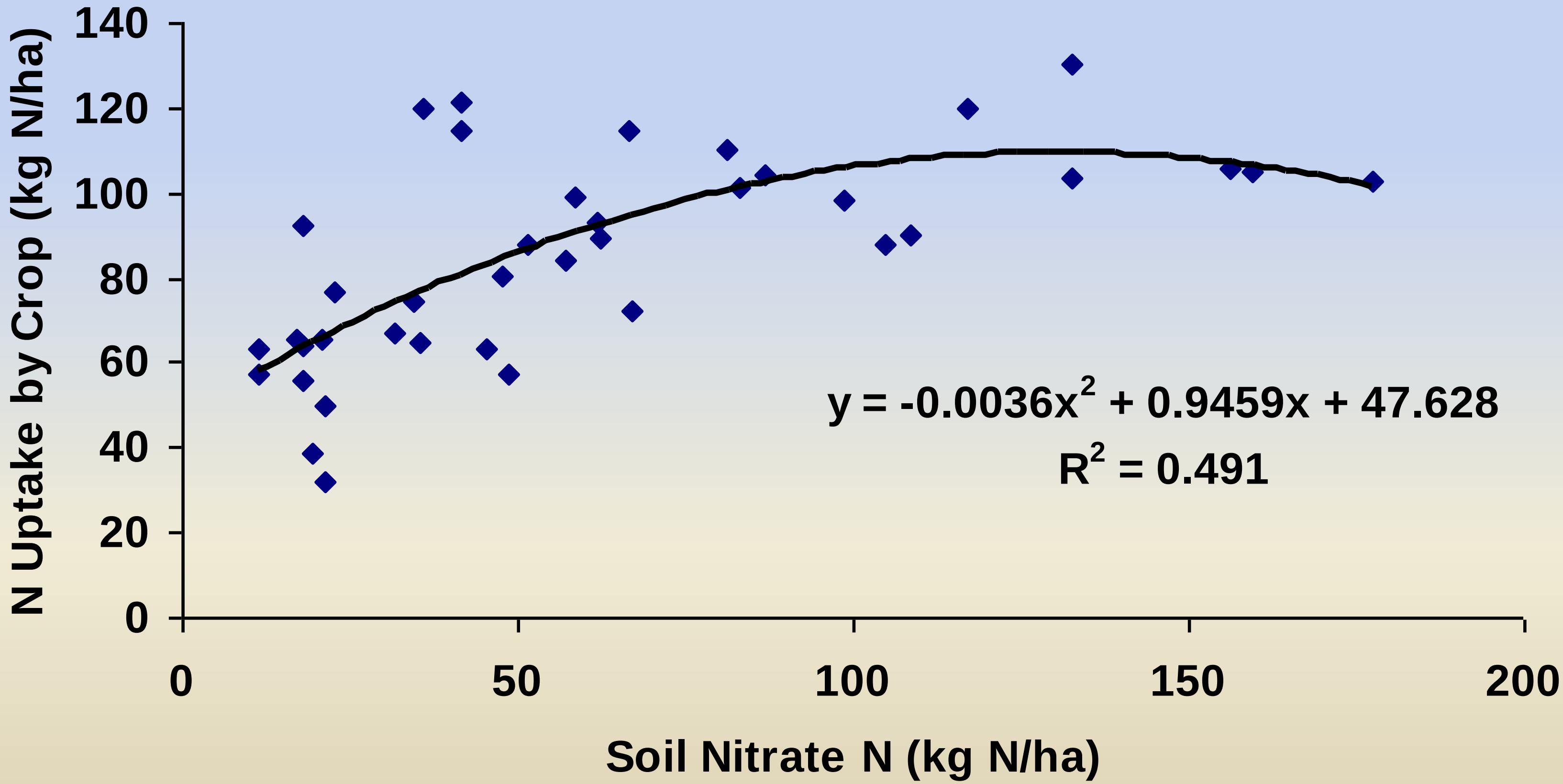
Effect of Soil Nitrate-N on Uptake of N by Spring Wheat in Unfertilized Treatments (Unger and Flaten 1999-2000)*



* 10 site years in AB, SK, MB in 1999, 2000 (Unger and Flaten)

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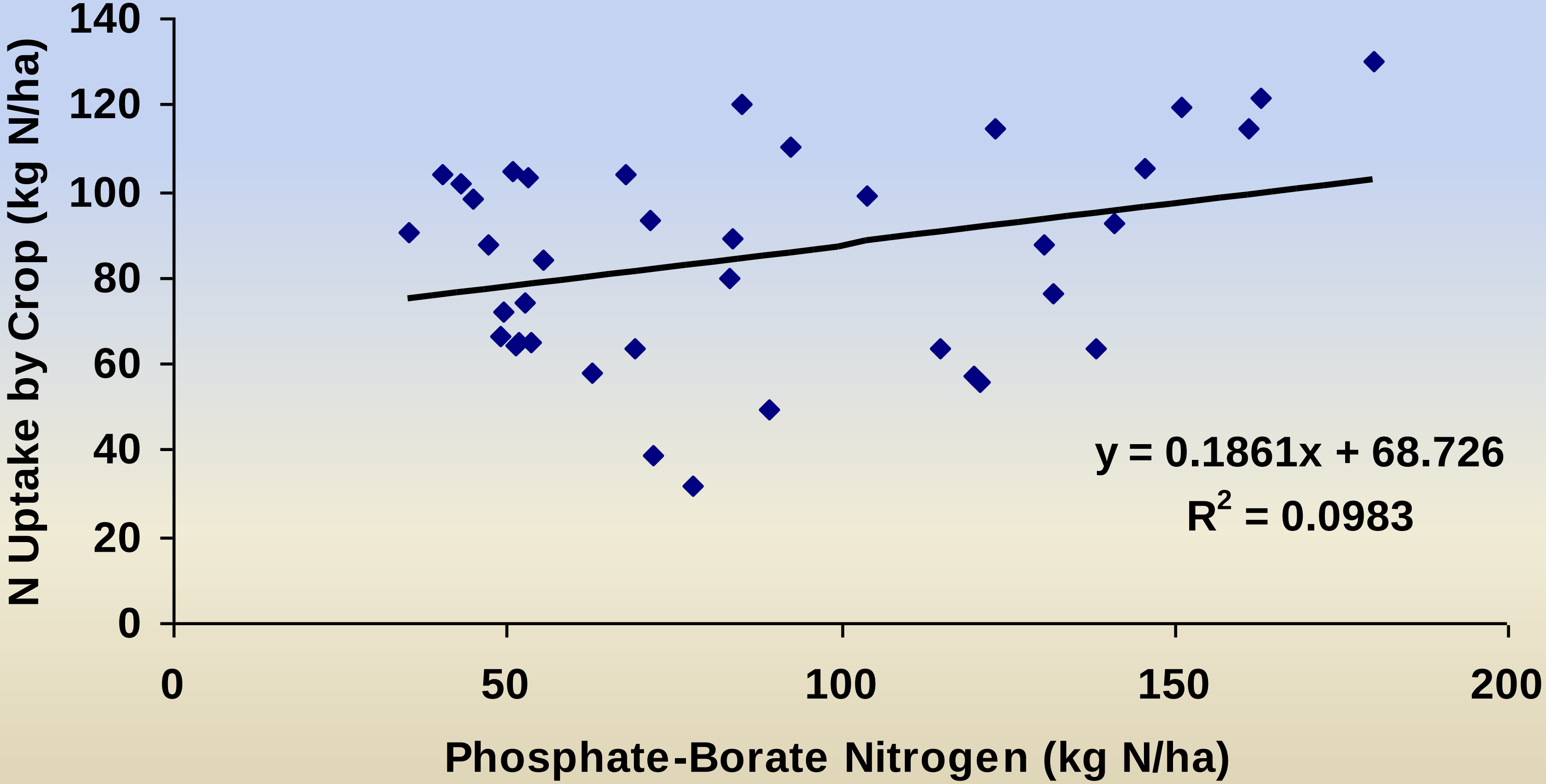
Effect of Phosphate-Borate Extractable N on Uptake of N by Spring Wheat in Unfertilized Treatments*



* 10 site years in AB, SK, MB in 1999, 2000 (Unger and Flaten)

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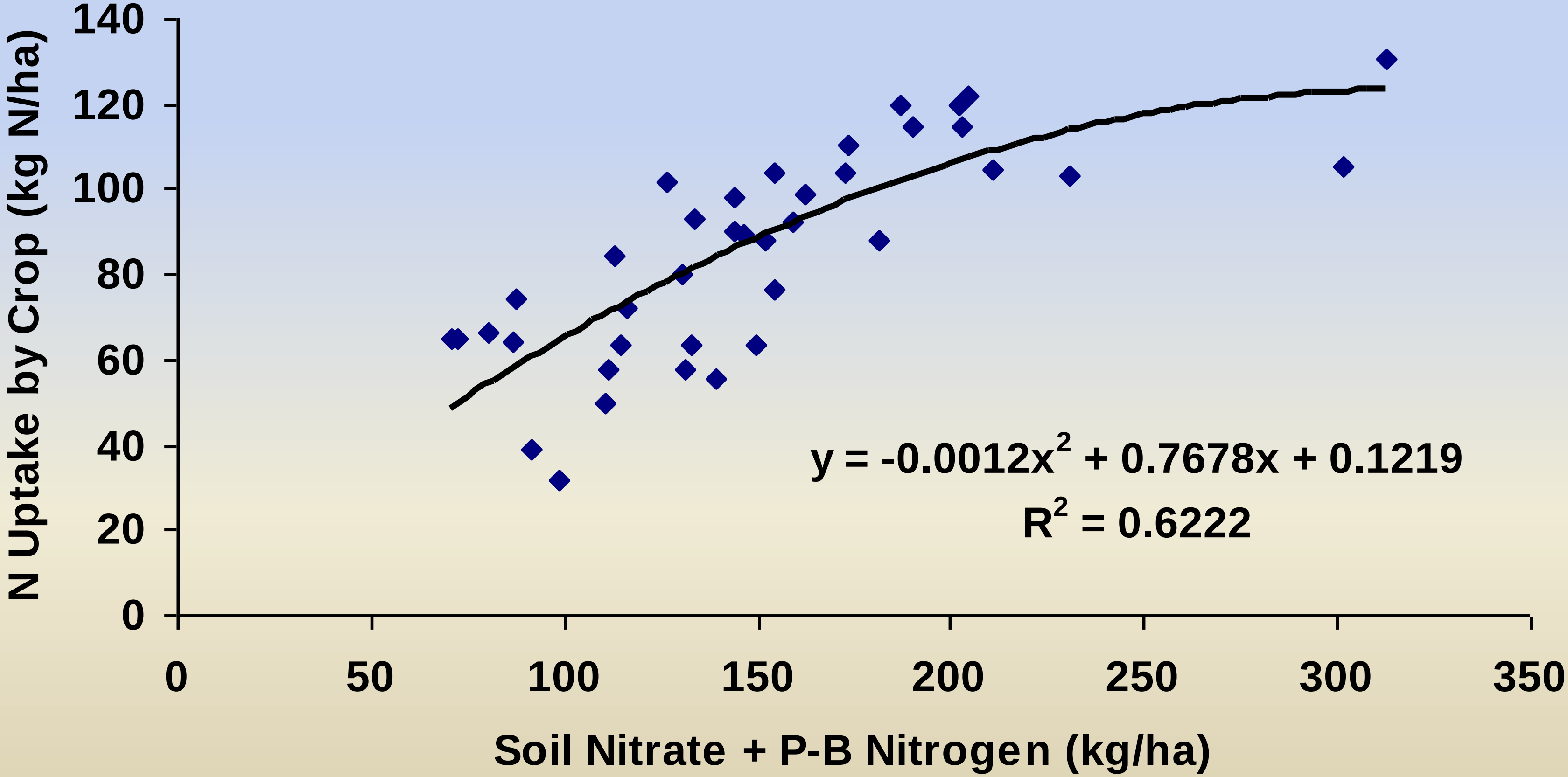
Effect of Nitrate plus Phosphate-Borate N on Uptake of N by Spring Wheat in Unfertilized Treatments*



* 10 site years in AB, SK, MB in 1999, 2000 (Unger and Flaten)

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2. **Accounting for the effect of historic and current nutrient and crop management on N mineralization from soil organic matter.**

   eg. land fertilized with manure vs. synthetic fertilizer; perennial vs. annual cropping systems

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NCLE Long Term Field Laboratory for Manure and Crop Management (U of MB Glenlea Research Station)

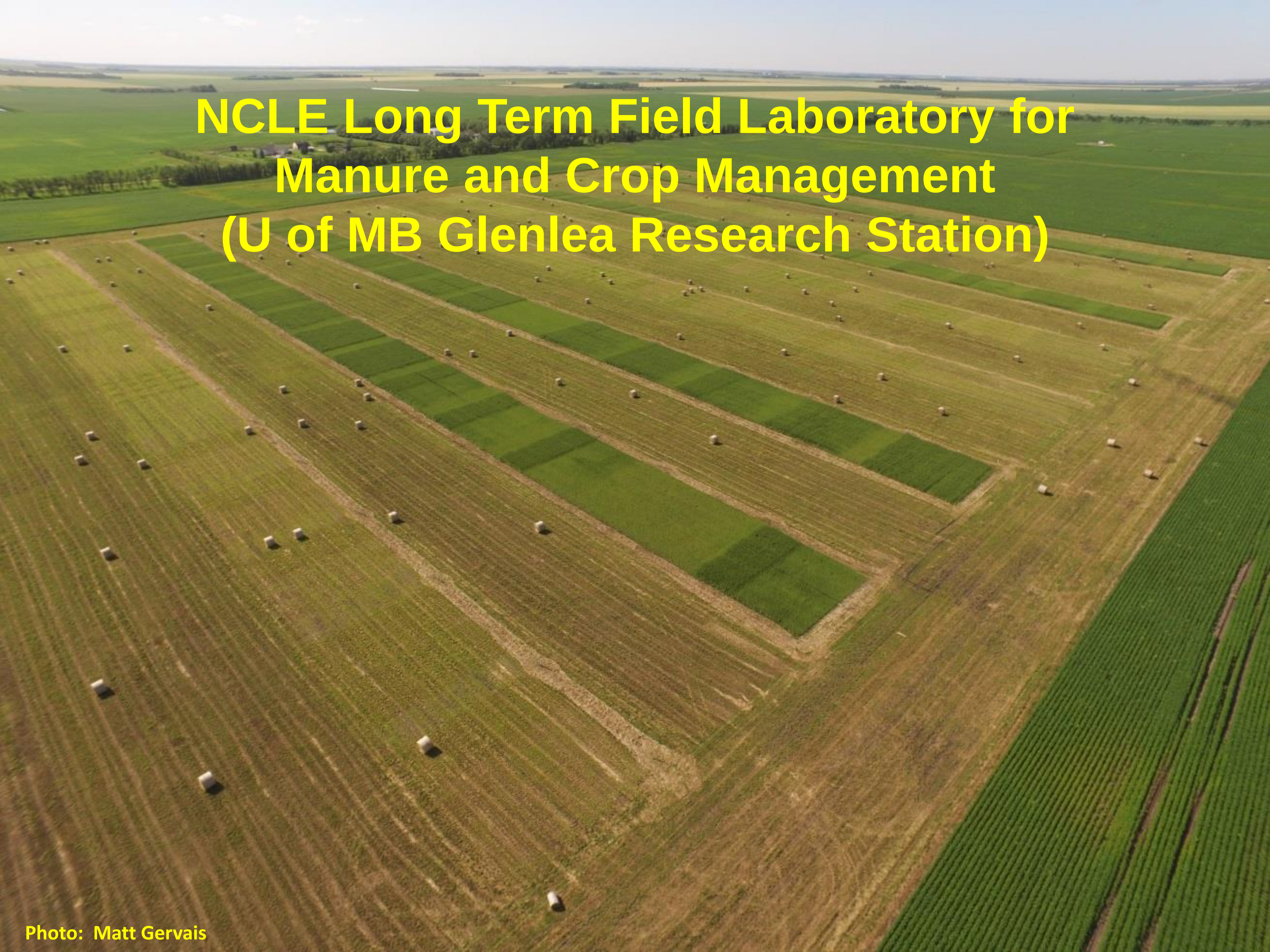

Photo: Matt Gervais

Phase 1 (2007-2015)

Four Types of Nutrients

- Liquid pig manure
- Solid pig manure
- Solid dairy manure
- Synthetic fertilizer

Two Manure Application Rates

- Yearly applications to meet crop N requirements
- Intermittent app’ns to meet crop N requirements

Two cropping systems

- Annual crops only
- Perennial
  - Grass forage (Fall 2008-2011, Fall 2014-present)
  - Annual crop (2008, 2012-2014)

Measurements:

- Soil nutrients, pH & salinity
- Crop nutrient uptake & yield

Phase 2 (2015-2017)

- **Intermittent Manure Applications**
- **P Drawdown**
- **N Mineralization**
  - **measured as crop yield, N uptake, and changes in residual NO_3-N in plots where manure and/or synthetic fertilizer applications have been discontinued, as of fall 2015**
- **Project Sponsors:**
  - **University of Manitoba**
  - **Manitoba Pork Council**
  - **Dairy Farmers of Manitoba**
  - **Manitoba Livestock Manure Mgmt. Initiative**
  - **Canada/Manitoba Growing Forward 2 Program**

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Effect of discontinued yearly synthetic fertilizer nitrogen and discontinued yearly N-based applications of manure on seed yield for the annual cropping system

Treatment	Harvested Seed Yield kg ha^{-1} HRS Wheat 2016	Harvested Seed Yield kg ha^{-1} Canola 2017	Cumulative Mean Yield %CONT[a]	Cumulative Mean Yield Increase %FERT[b]
Control	1010 C	770 C	100 C	0 C
Continuous Synthetic Fertilizer	3810 AB	3360 A	408 A	100 A
Discontinued Synthetic Fertilizer	2960 AB	2000 B	277 B	59 B
Discontinued Liquid Pig Manure	4090 A	2650 AB	375 AB	91 AB
Discontinued Solid Pig Manure	3090 B	2810 AB	336 AB	77 AB
Discontinued Solid Dairy Manure	4080 AB	3280 A	415 A	103 A
S.D.	1230	1190	129	41.9
C.V. (%)	37.4	47	39.4	56.1
ANOVA (p-value)	<.0001 *	<.0001 *	<.0001 *	<.0001 *

* Indicates significance at $p<0.05$. Within each column means followed by the same letter are not significantly different.

[a] Mean yield index value across all crop years and crop types. Yield index was calculated separately for each replicate and expressed as a percentage of the mean from the control treatment.

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Effect of discontinued yearly synthetic fertilizer nitrogen and discontinued yearly N-based applications of manure on estimated N mineralization for the annual cropping system

Treatment	N Mineralization kg ha^{-1} HRS Wheat 2016		N Mineralization kg ha^{-1} Canola 2017		Cumulative Mineralized N[a]		Cumulative Increase in Mineralized N[b]	
Control	25	D	36	B	60	D	0	D
Continuous Synthetic Fertilizer	-		-		-		-	
Discontinued Synthetic Fertilizer	76	C	73	AB	149	C	89	C
Discontinued Liquid Pig Manure	115	B	74	A	189	BC	128	BC
Discontinued Solid Pig Manure	111	BC	95	A	207	AB	146	AB
Discontinued Solid Dairy Manure	158	A	104	A	262	A	201	A
S.D.	51.8		32.6		79		79	
C.V. (%)	51		41.4		43.8		65.8	
ANOVA (p-value)	<.0001	*	0.0004	*	<.0001	*	<.0001	*

* Indicates significance at $p<0.05$. Within each column means followed by the same letter are not signif. different.

[a] The cumulative sum of mineralized nitrogen in 2016 and 2017.

[b] The cumulative sum of mineralized nitrogen in 2016 and 2017 expressed as an increase from the site mean mineralized nitrogen from the control.

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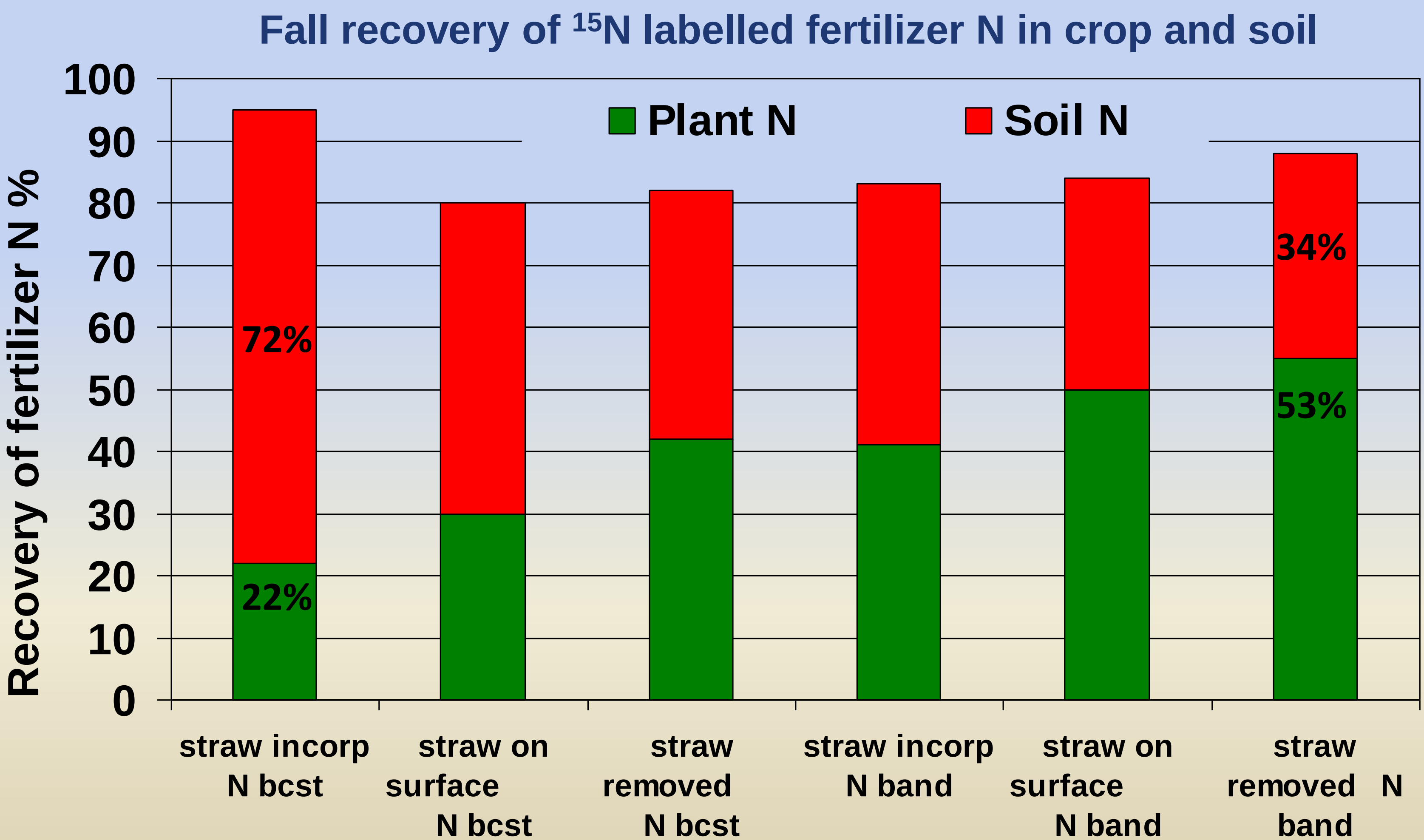
Immobilization ties up a large portion of fertilizer N and is reduced by in-soil banding



(Tomar and Soper, AJ 1981)

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Effect of discontinued yearly synthetic fertilizer nitrogen and discontinued yearly N-based applications of manure on dry matter yield for the perennial cropping system

Treatment	Total Dry Matter Yield kg ha^{-1} – Forage Grasses 2016[a]		Total Dry Matter Yield kg ha^{-1} – Forage Grasses 2017[a]		Cumulative Mean Yield %CONT[b]		Cumulative Mean Yield Increase %FERT[c]	
Control	3380	C	1050	D	100	C	0	C
Continuous Synthetic Fertilizer	8510	A	3710	A	302	A	100	A
Discontinued Synthetic Fertilizer	4610	C	1240	D	127	C	16	C
Discontinued Liquid Pig Manure	6540	B	1800	CD	182	B	45	B
Discontinued Solid Pig Manure	6370	B	2530	B	214	B	57	B
Discontinued Solid Dairy Manure	6720	AB	2460	BC	216	B	59	B
S.D.	2430		910		72.5		37.4	
C.V. (%)	39.7		42.6		37.7		79.2	
ANOVA (p-value)	<.0001	*	<.0001	*	<.0001	*	<.0001	*

* Indicates significance at p<0.05. Within each column means followed by the same letter are not significantly different.

[a] No second cut.

[b] Mean yield index value across all crop years and crop types. Yield index was calculated separately for each replicate and expressed as a percentage of the mean from the control treatment.

[c] Mean yield index value across all crop years and crop types. Yield index was calculated separately for each replicate and expressed as a percentage of the mean from the synthetic fertilizer treatment.

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Effect of discontinued yearly synthetic fertilizer nitrogen and discontinued yearly N-based applications of manure on estimated N mineralization for the perennial cropping system

Treatment	N Mineralization kg ha^{-1} Forage Grasses 2016[a]		2017[ab]		Cumulative Mineralized N[c]		Cumulative Increase in Mineralized N[d]	
Control	24	D	13	B	37	D	0	D
Continuous Synthetic Fertilizer	-		-		-		-	
Discontinued Synthetic Fertilizer	32	CD	13	B	47	CD	10	CD
Discontinued Liquid Pig Manure	39	BC	25	A	64	BC	27	BC
Discontinued Solid Pig Manure	49	A	32	A	83	A	46	A
Discontinued Solid Dairy Manure	51	AB	29	A	82	AB	45	AB
S.D.	18.5		12		25		25	
C.V. (%)	46		47.4		38		87.5	
ANOVA (p-value)	<.0001	*	0.0002	*	<.0001	*	<.0001	*

* Indicates significance at $p<0.05$. Within each column means followed by the same letter are not signific. different.
[a] No second cut.
[b] Data were log-normally distributed. Statistical analysis was performed on natural log transformed data. Back-transformed geometric means are reported.
[c] The cumulative sum of mineralized nitrogen in 2016 and 2017.
[d] The cumulative sum of mineralized nitrogen in 2016 and 2017 expressed as an increase from the site mean mineralized nitrogen from the control.

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Predicting N Mineralization from Manured Soils in a Growth Room Environment

Jeff Seward,
B.Sc.Agroecology Project

April 2016

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Treatments Selected from the Long Term Manure Mgmt. Trial for Growth Room Experiment

Soil was collected from 8 nutrient treatments:

- Solid Dairy N-Based Annual Applications
- Solid Pig N-Based Annual Applications
- Liquid Pig N-Based Annual Applications

- Solid Dairy Intermittent (1x in fall 2007)
- Solid Pig Intermittent (1x in fall 2007)
- Liquid Pig Intermittent (1x in fall 2007)

- Synthetic Fertilizer annual to match MSFG rec.
- Control - without any nutrient app'n since spring 2007

for 2 cropping systems (annual and perennial) ... which totals up to 16 treatments

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Methods for Growth Room Experiment

- Grew wheat in growth room in pots for 7 weeks.
  - 8 nutrient treatments x 2 cropping systems x 2 duplicates = 32 pots in total
  - No additional N added as manure or fertilizer
- Measured above ground plant biomass and determined plant nitrogen uptake
- Evaluated the Les Henry Soil N Test, among others
  - Zip-lock bags filled with field moist soil and stored 4 weeks at room temperature
  - Measured soil test nitrate-N before (pre-plant NO_3-N) and after incubation (gross incubated N); N mineralization estimated by difference between these two (net mineralized N)

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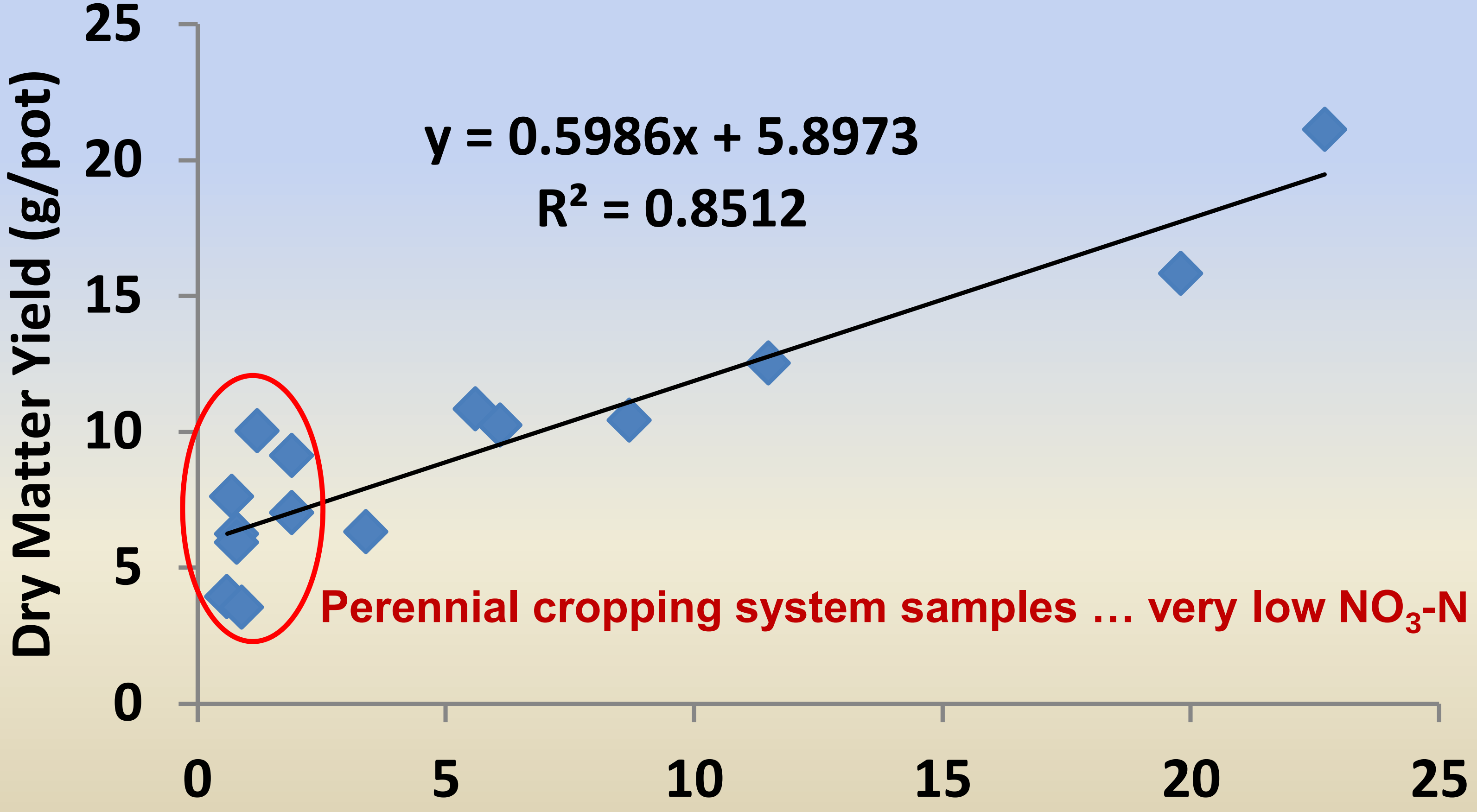
Preplant Soil Nitrate vs Wheat Dry Matter Yield



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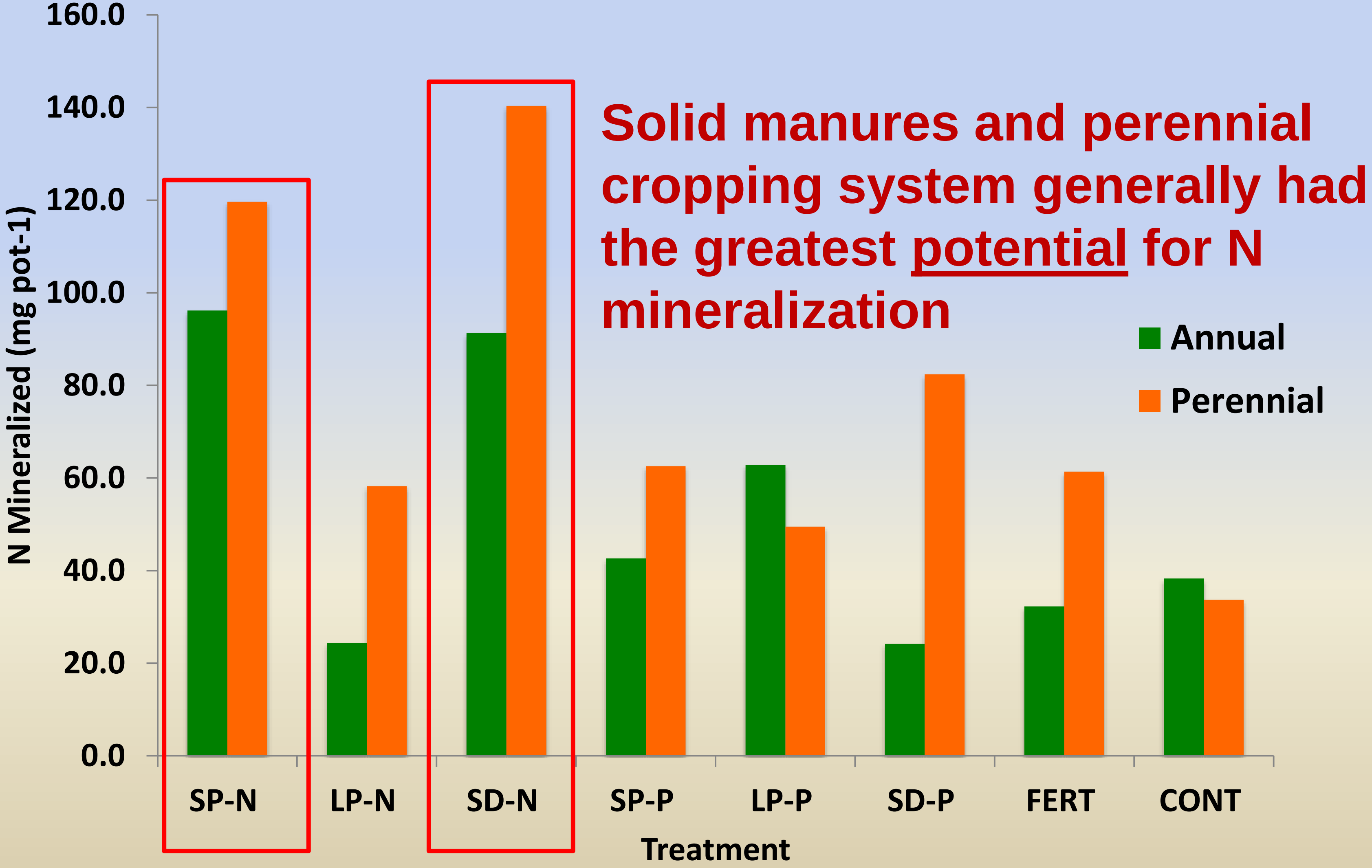
Nitrogen mineralized during wheat growth in growth room experiment



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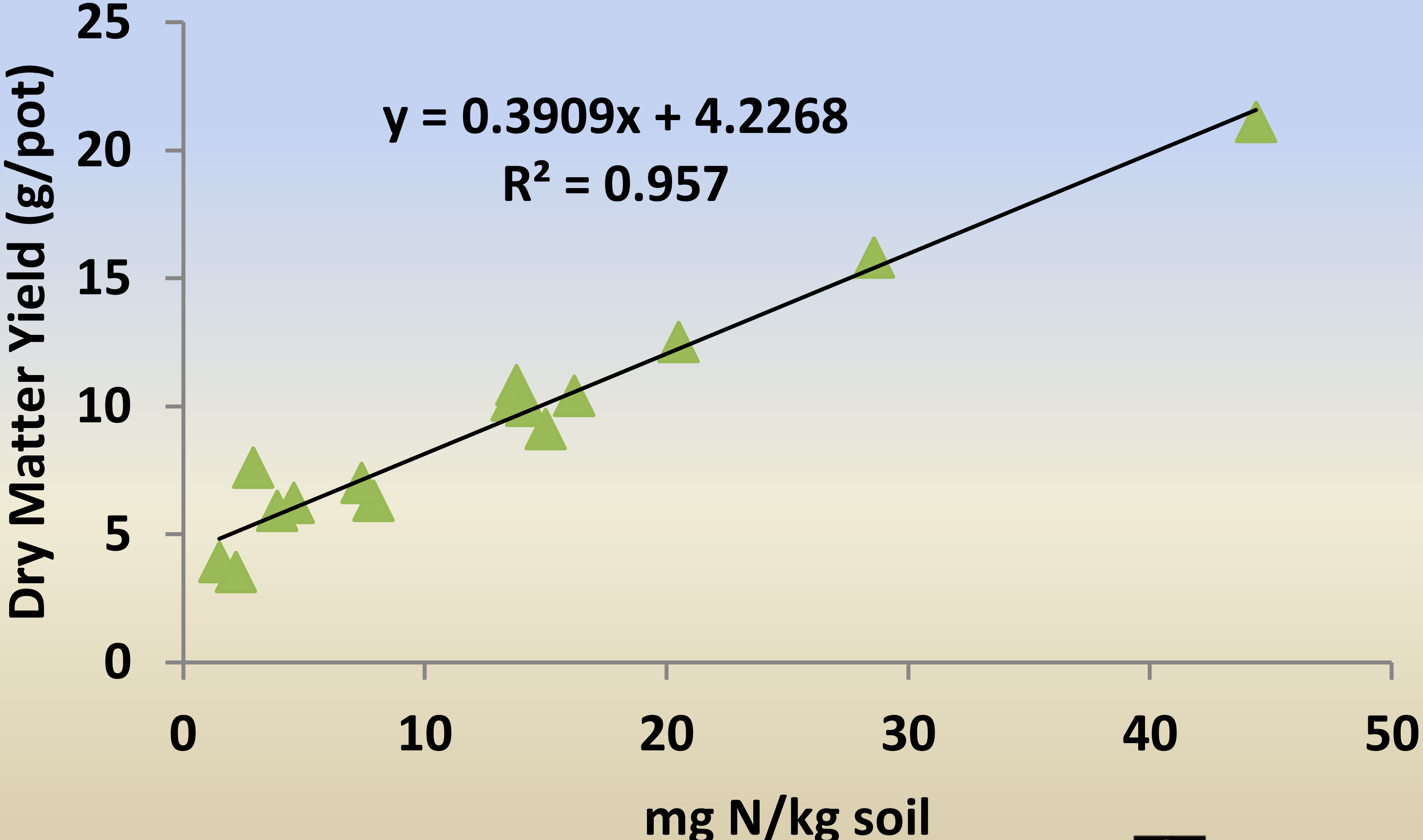
Les Henry's Gross Incubated N vs Wheat Dry Matter Yield



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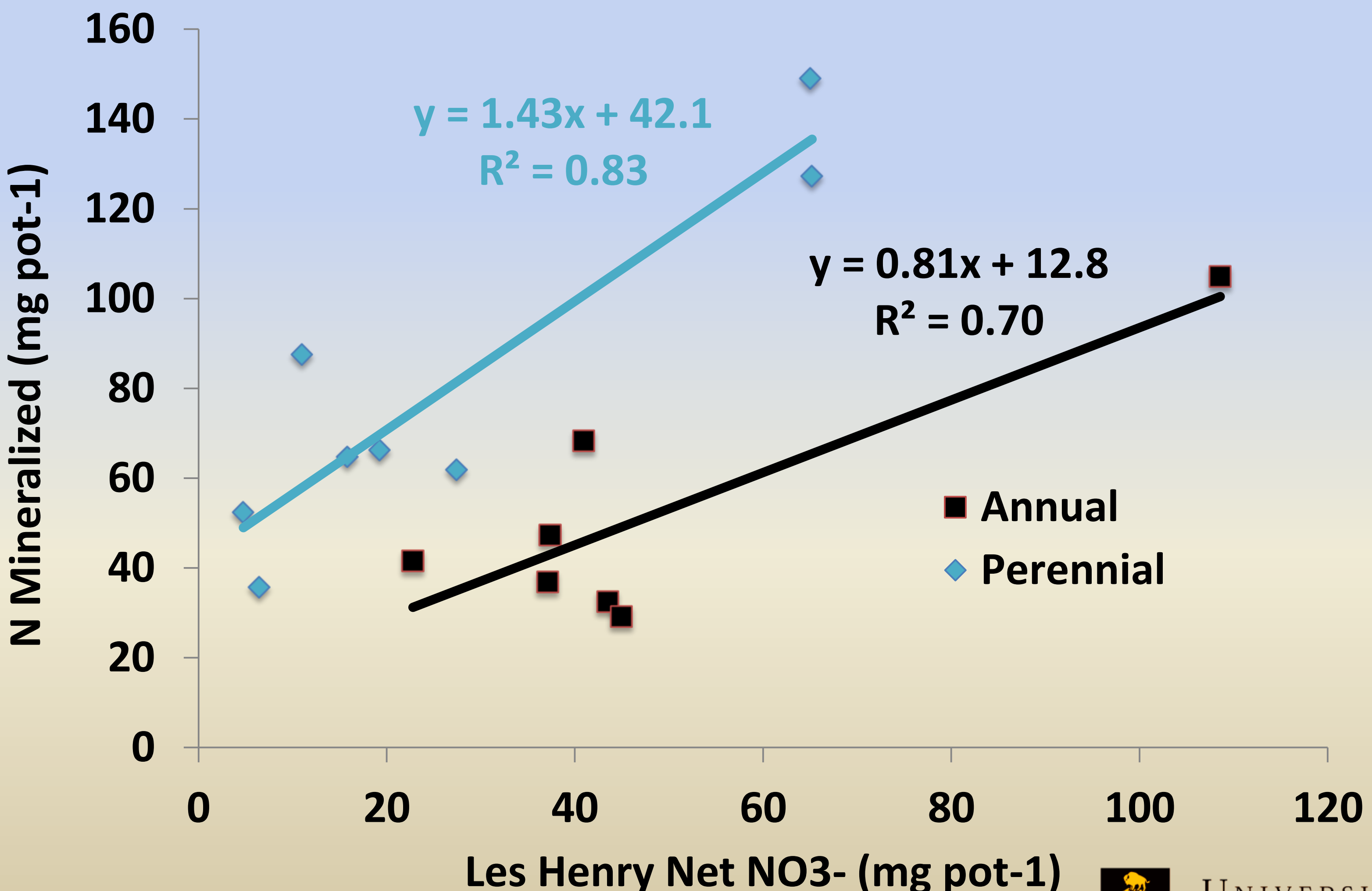
Les Henry's Incubation Test for N Mineralization vs. N Mineralization for Wheat Grown in Growth Chamber



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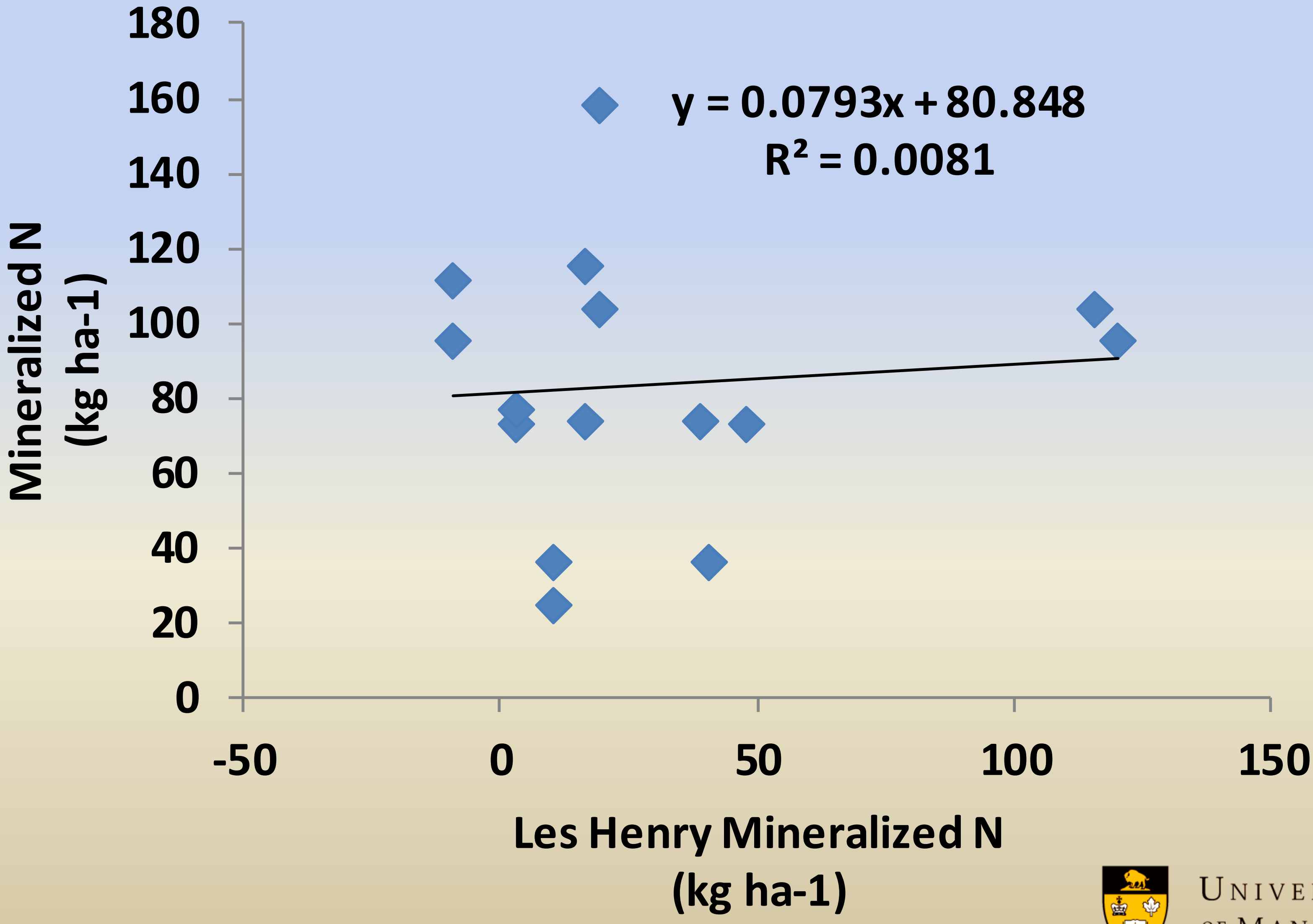
Les Henry's N Mineralization Test vs. N Mineralization in NCLE Long Term Annual Crop Field Plots



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2. Accounting for the effect of historic and current nutrient and crop management on N mineralization from soil organic matter. eg. row crops

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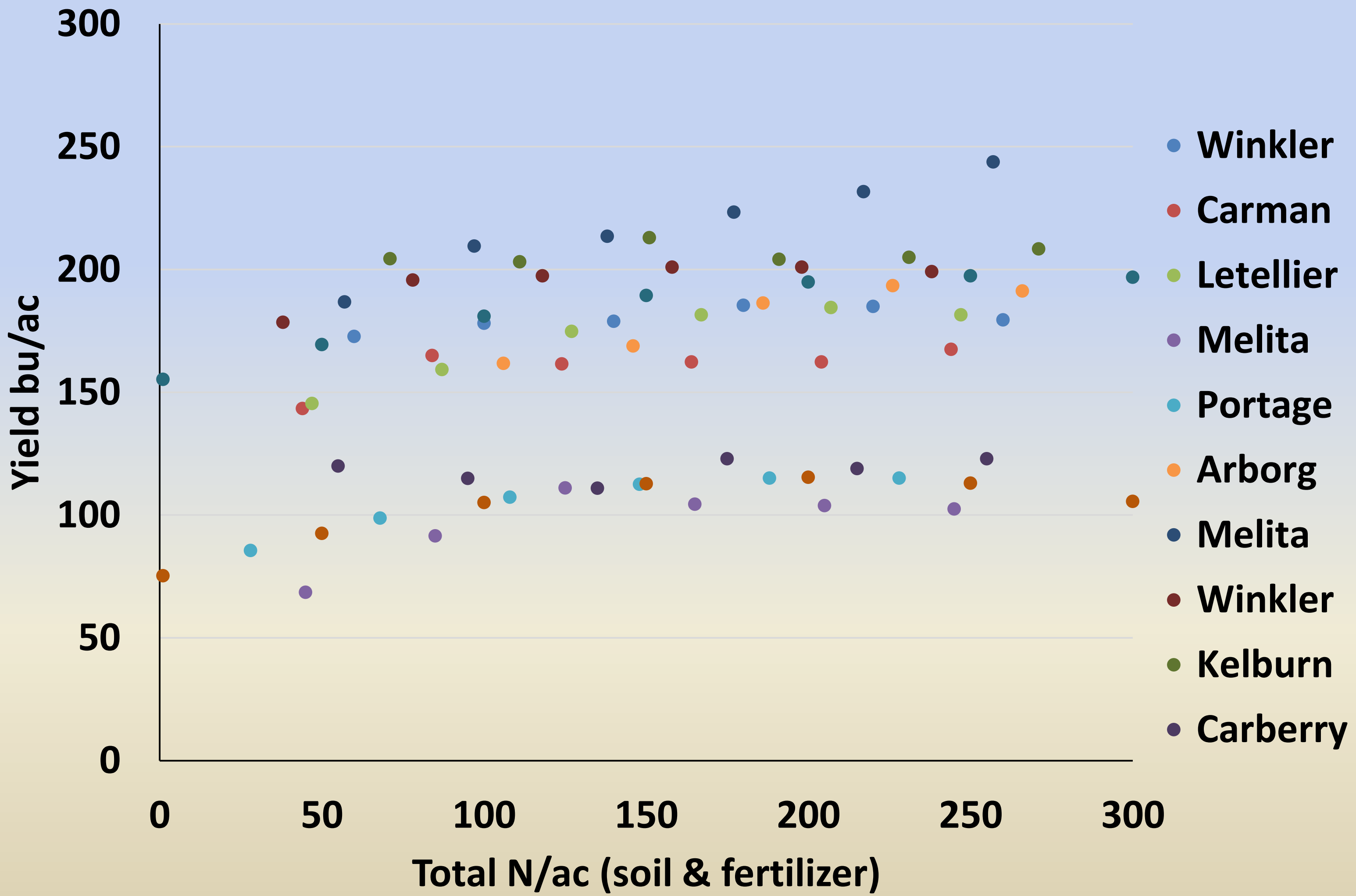
Nitrogen Fertilization for Corn

John Heard, Manitoba Agriculture

MERN@ $4/bu corn and $0.40/lb N



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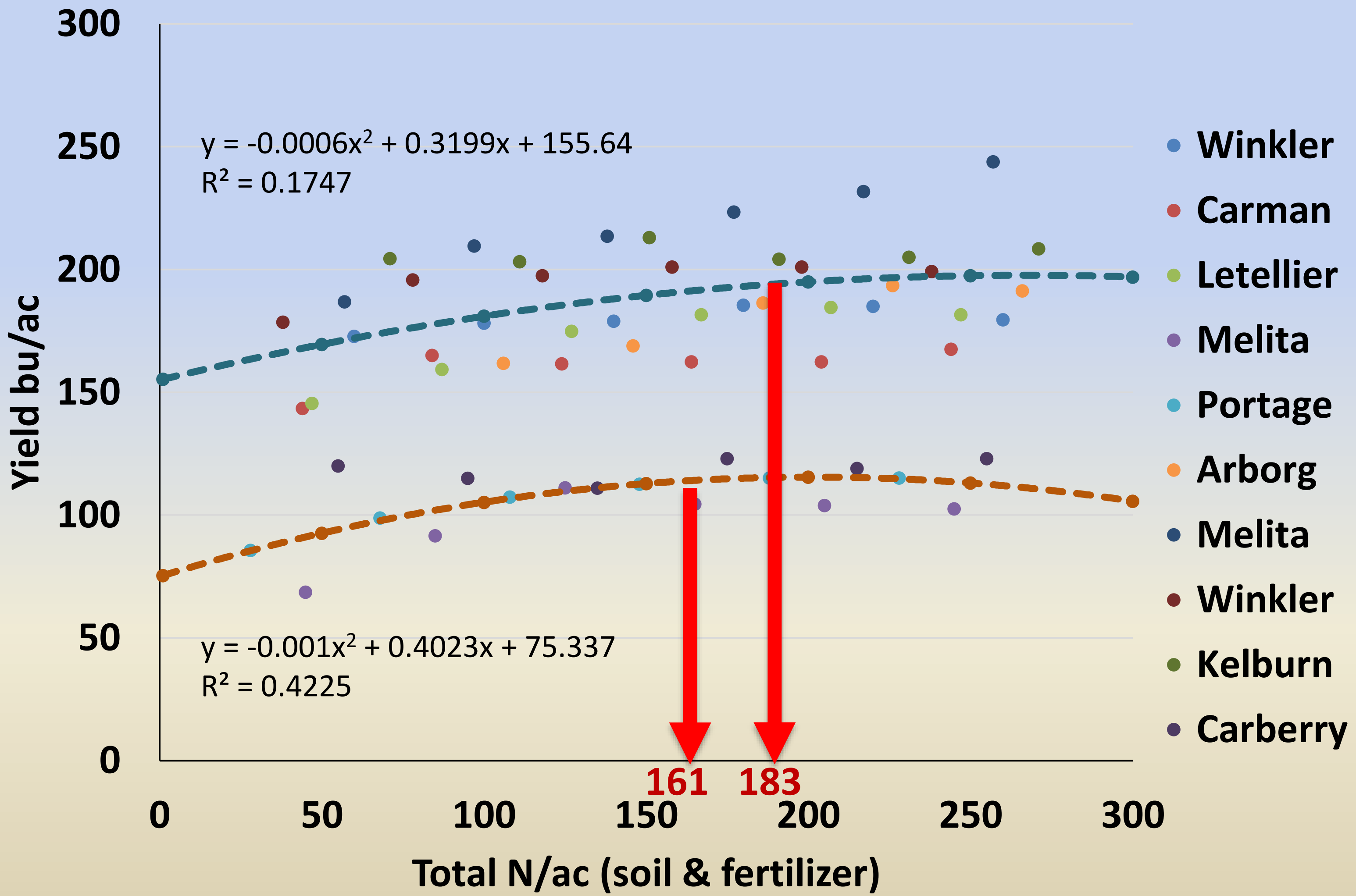
MERN@ $4/bu corn and $0.40/lb N



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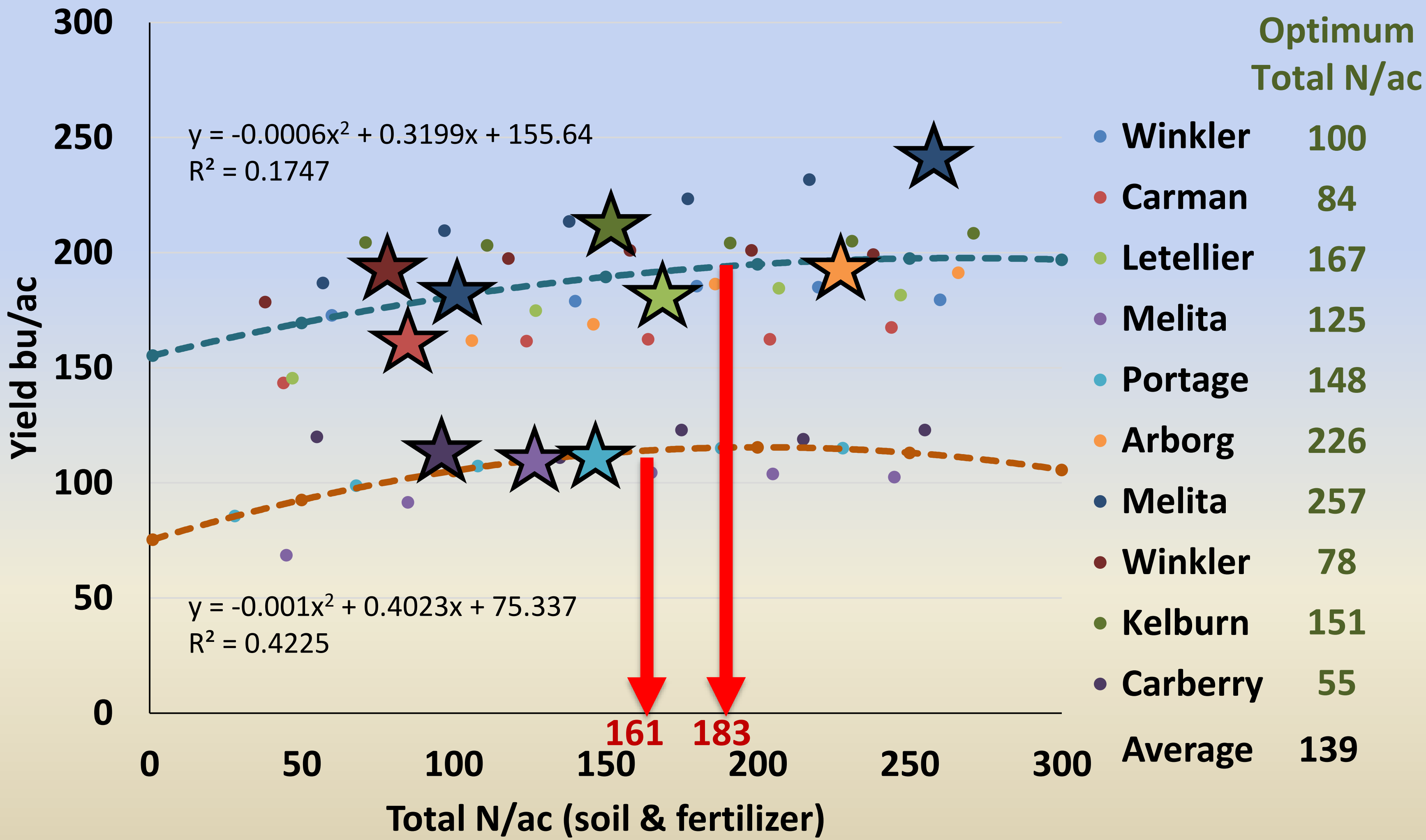
MERN@ $4/bu corn and $0.40/lb N



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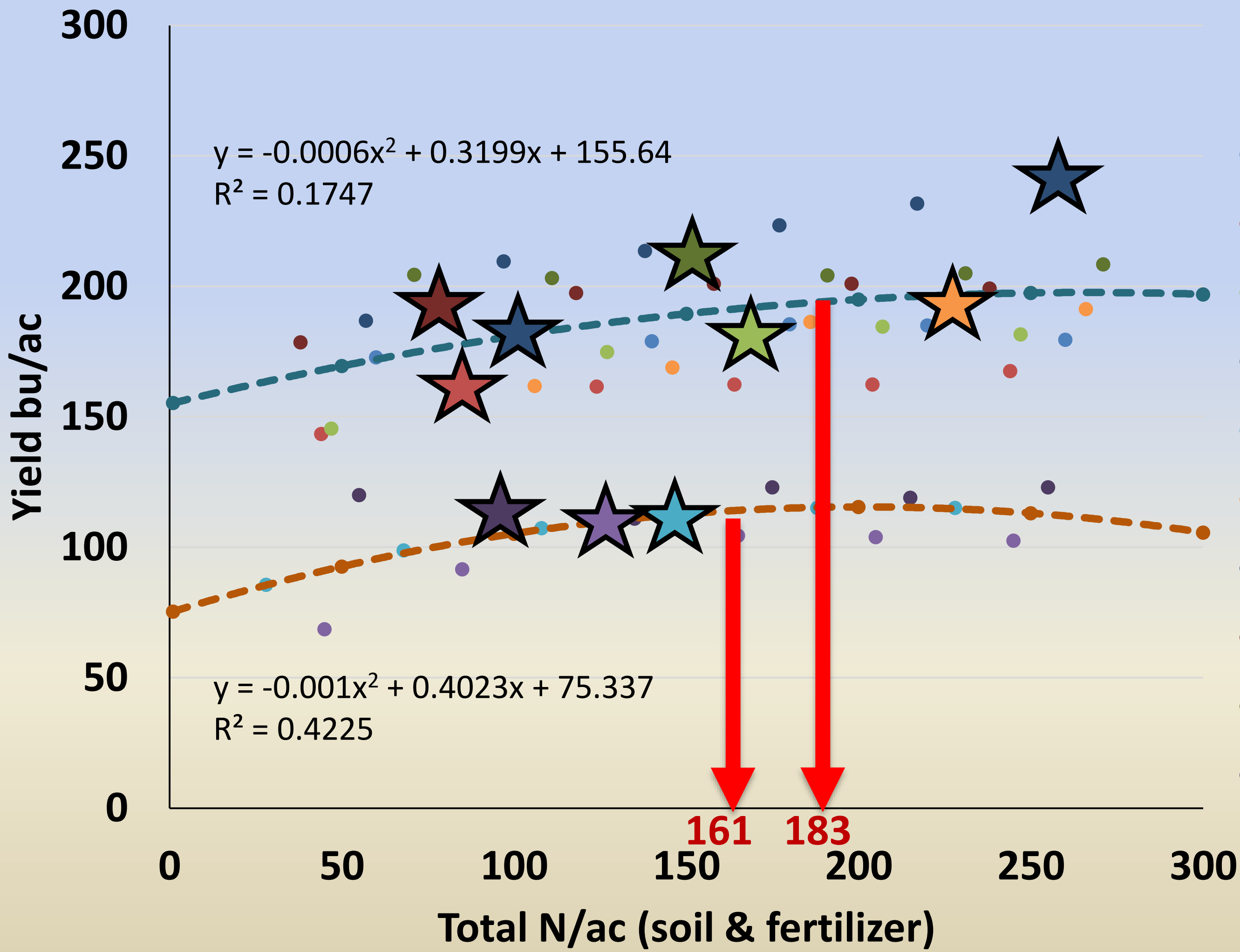
MERN@ $4/bu corn and $0.40/lb N



	Optimum Total N/bu
Winkler	0.56
Carman	0.51
Letellier	0.92
Melita	1.13
Portage	1.31
Arborg	1.17
Melita	1.05
Winkler	0.40
Kelburn	0.71
Carberry	0.46
Average	0.82

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Preliminary Estimates of N Mineralization

Site	Check Yield	Est .N uptake	ΔSoil nitrate	Starter fertilizer N	Mineralized N est.*
	Bu/ac	lb N/ac			
St Adolphe	202	226	-71**	4	151+
Carberry	120	134	-55**	6	73+
Arborg	154	172	-106**	10	56+
Morden	178	199	-38**	4	157+
Melita	187	209	-57**	4	148+
Winkler	173	194	-47	-	147
Carman	143	160	-12	-	148
Letellier	146	164	-15	-	139
Melita	69	77	-74**	-	3+
Portage	86	96	-61**	-	35+

*Estimate is based on using a 1.12 lb whole plant N uptake/bu less soil nitrate depletion, less starter fertilizer N. **No fall NO_3 samples, so spring NO_3 was assumed to be fully depleted.

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What happens to organic matter in row cropped soils?

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Historical & Current Nutrient & Crop Management Practices

- **Regular applications of synthetic fertilizer and livestock manure build substantial reserves of soil organic N that can mineralize in later years**
- **N mineralization rates vary greatly with:**
  - **nutrient management history (eg. rate & frequency of manure and fertilizer application)**
  - **current and historical cropping management practices (eg. land <u>historically</u> in perennial forage may have more potentially mineralizable N than annual crop land, but land <u>currently</u> in perennial forage mineralizes N more slowly than annual crop land)**
- **N mineralization rates are probably greater for row crops than solid seeded crops**

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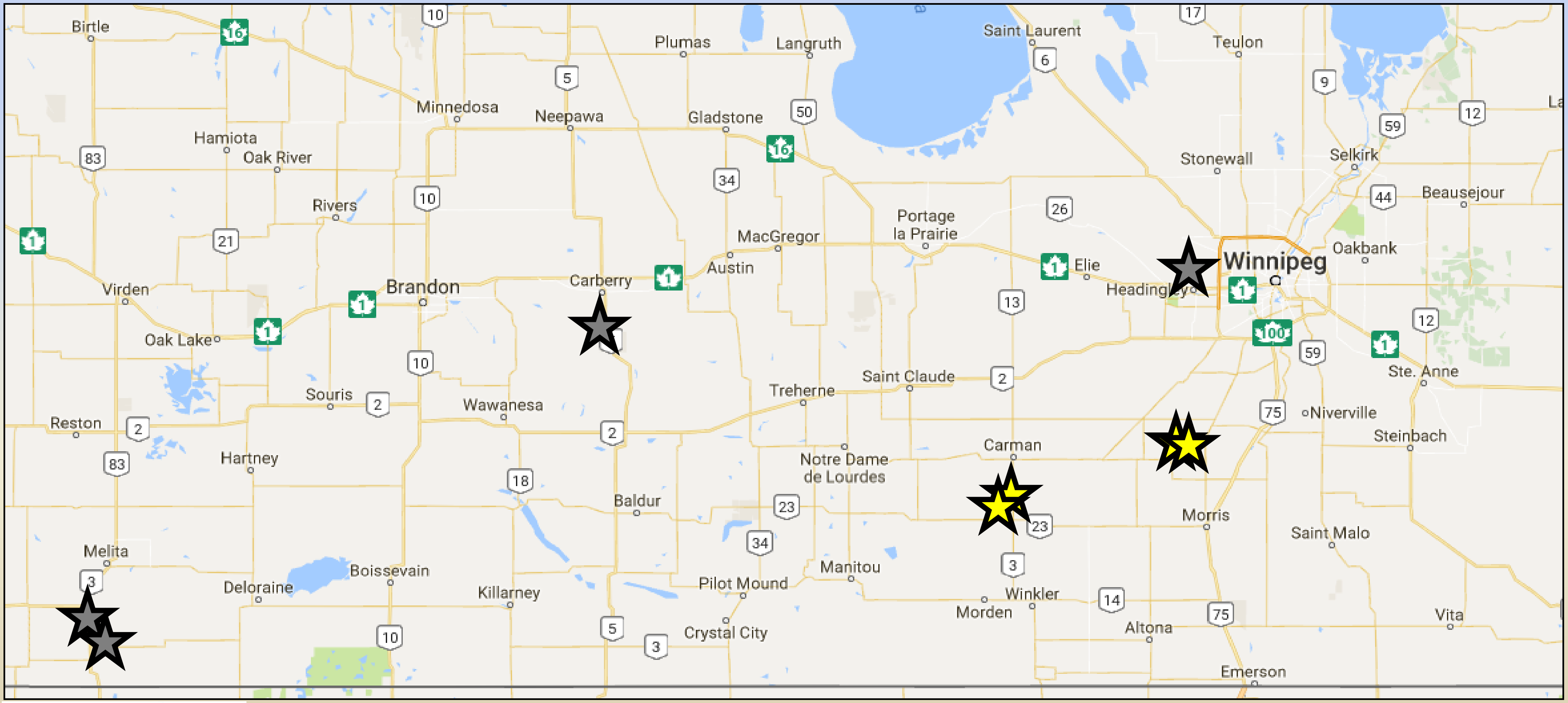
3. Accounting for the effect of site and year on N mineralization from soil organic matter

eg. Amy Mangin's studies on optimizing nitrogen fertilizer management strategies for high-yielding spring wheat



Optimum N Rate for Spring Wheat: Gold Level Sites (Mangin et al. 2018)

Site-year	Spring NO_3-N (0-60cm)	Economic Optimum N Rate*	Yield at Economic Optimum N Rate	N Supply per Bushel (Spring NO_3-N + Fert N)	Estimated N Min'n During Growing Season
	lbs. N/ac	lbs. N/ac	bu/ac	lbs. N/bu	lbs. N/ac
Carman 2016	47	140	62	3.0	67
Brunkild 2016	40	140	75	2.4	35
Carman 2017	43	140	96	1.9	73
Brunkild 2017	43	140	110	1.7	45

Average soil test N + Fertilizer N per bushel:
1.7 – 3.0 lbs N/bu

*Wheat prices from Jan 5, 2018, Nitrogen prices based off 5-years AVG urea price ($0.43/lbs N)

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Optimum N Rate for Spring Wheat: Silver Level Sites (Mangin et al. 2018)

Site-year	Spring NO_3-N (0-60cm)	Economic Optimum N Rate*	Yield at Economic Optimum N Rate	N Supply per Bushel (Spring NO_3-N + Fert N)	Estimated N Min'n During Growing Season
	lbs. N/ac	lbs. N/ac	bu/ac	lbs. N/bu	lbs. N/ac
Melita 2016	43	80	60	2.1	47
Carberry 2016	89	50	95	1.5	130
Melita 2017	11	140	74	2.0	85
Grosse Isle 2017	65	110	75	2.3	46

Range of soil test N + Fertilizer N per bushel:
1.5 – 2.3 lbs N/bu

*Wheat prices from Jan 5, 2018, Nitrogen prices based off 5-years AVG urea price ($0.43/lbs N)

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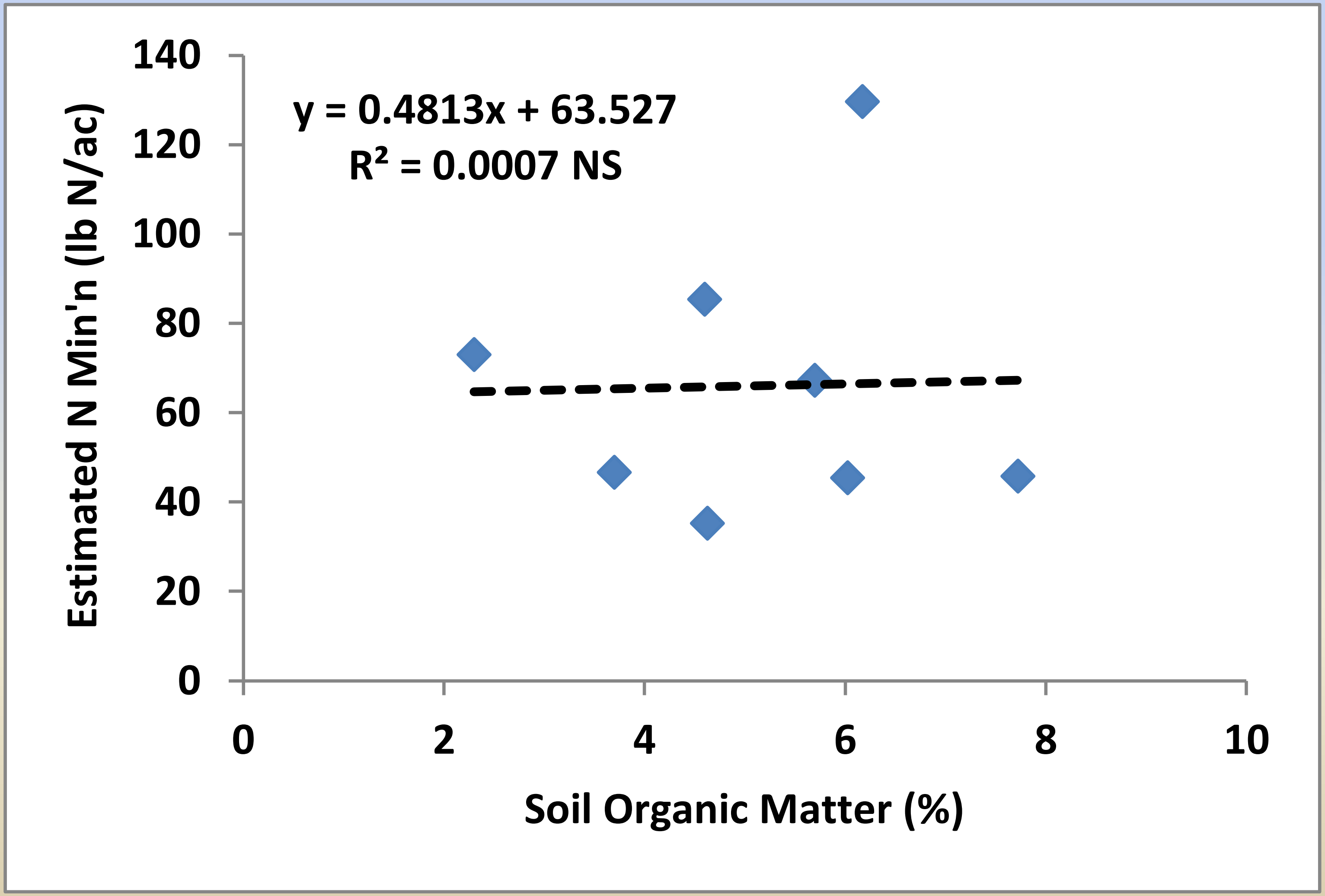
Predicting N Mineralization in Wheat N Study Using % Soil Organic Matter



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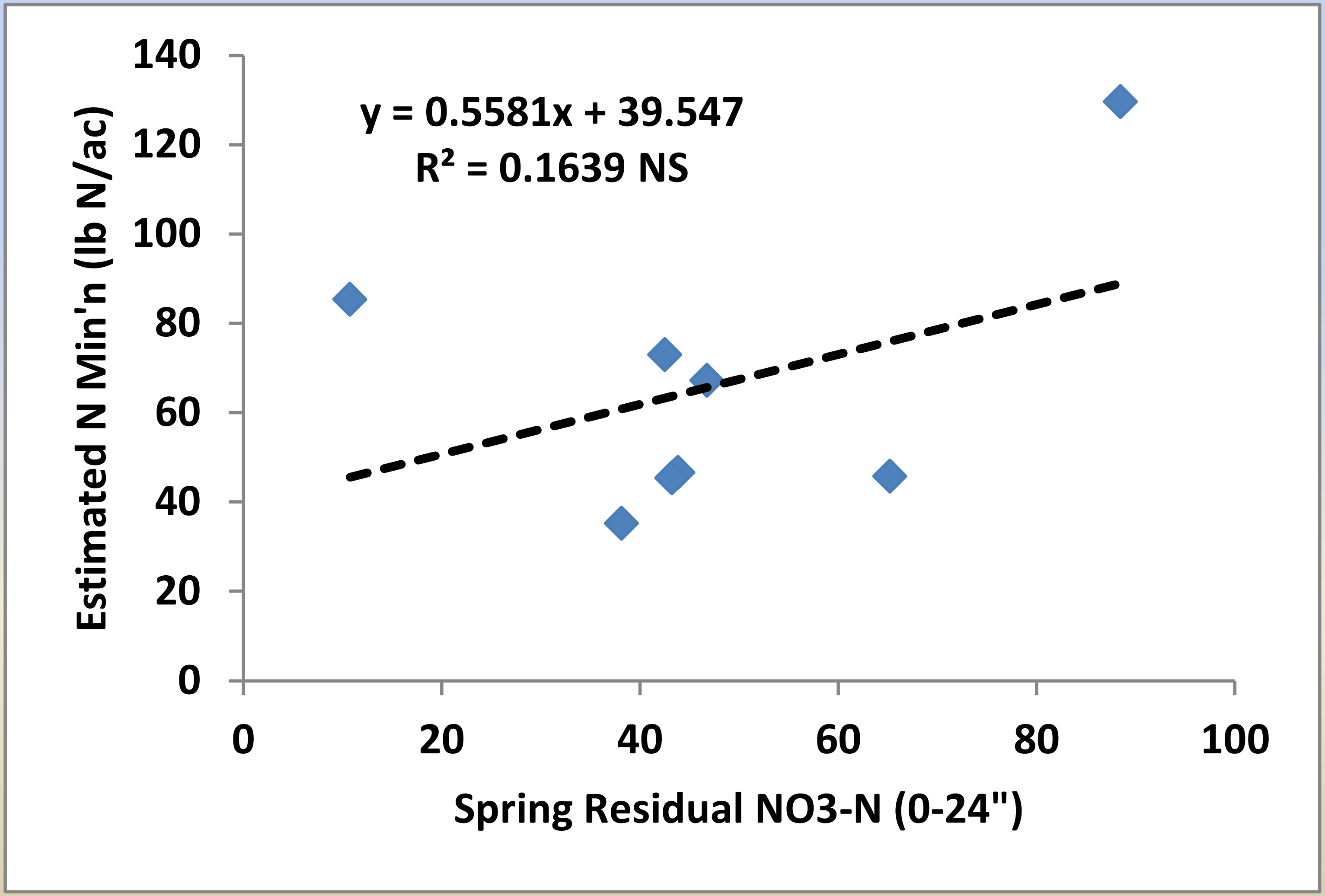
Predicting N Mineralization in Wheat N Study Using Spring Residual N (0-24")



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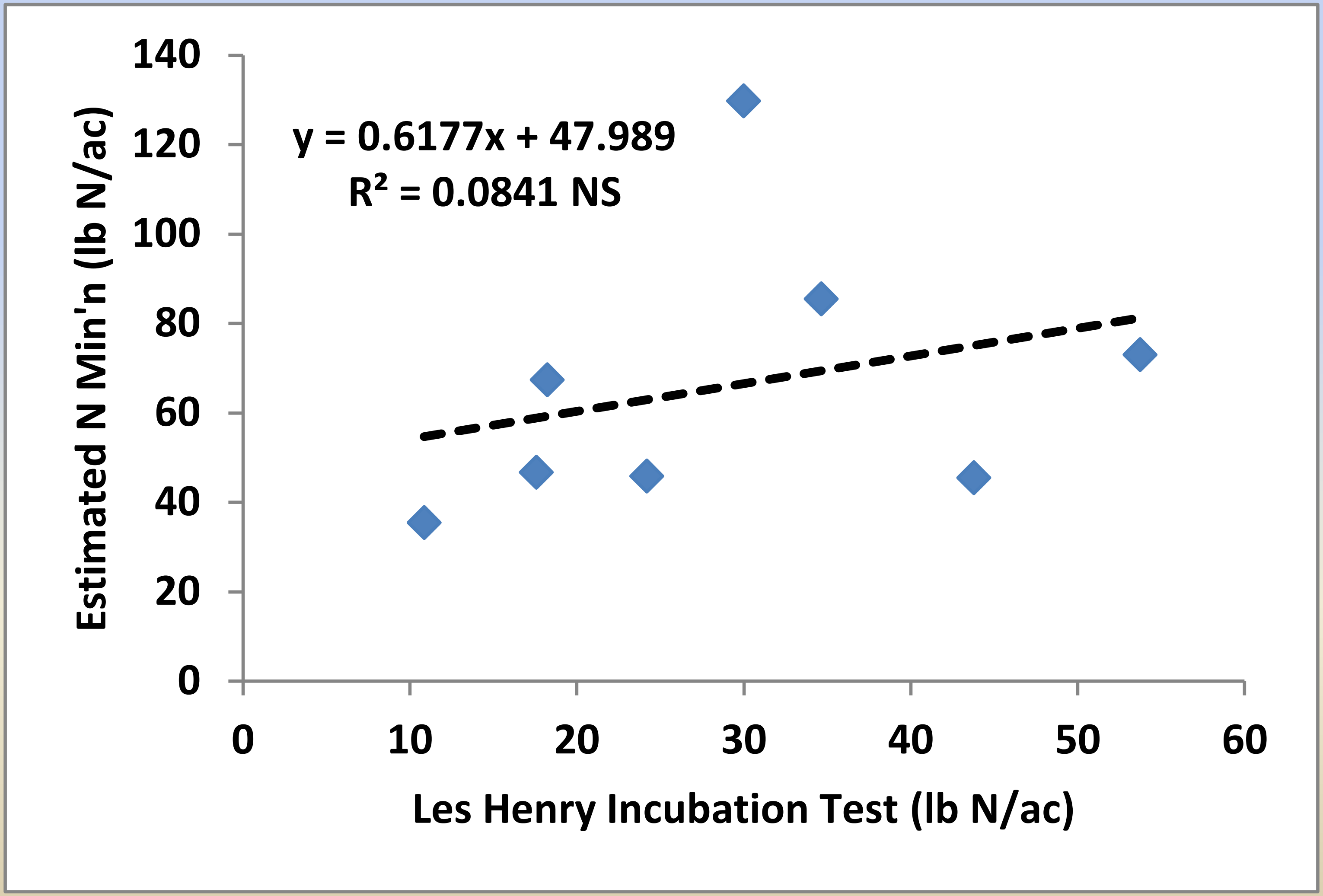
Predicting N Mineralization in Wheat N Study Using Les Henry Incubation Test



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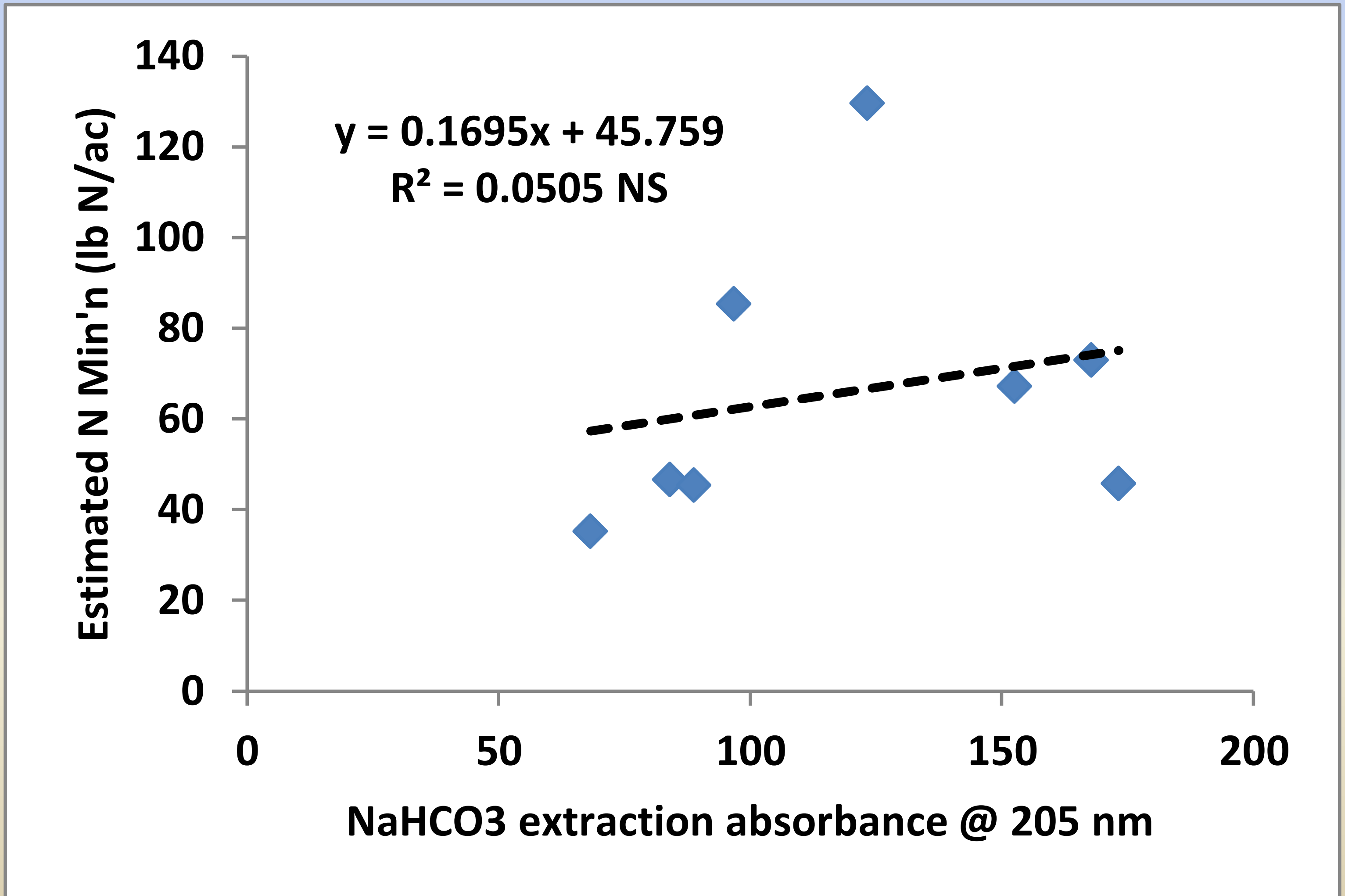
Predicting N Mineralization in Wheat N Study Using $NaHCO_3$ Extraction Absorbance at 205 nm



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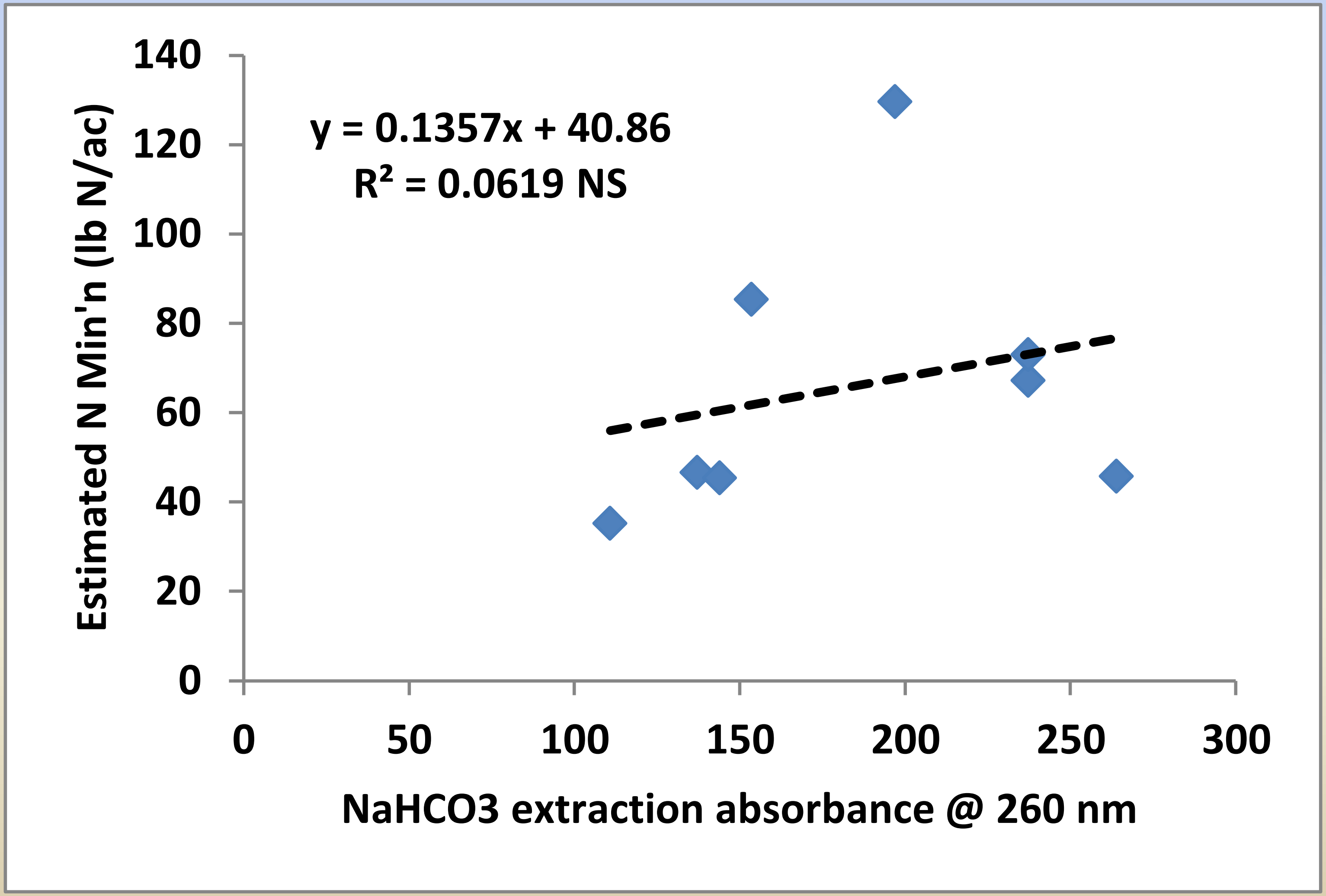
Predicting N Mineralization in Wheat N Study Using $NaHCO_3$ Extraction Absorbance at 260 nm



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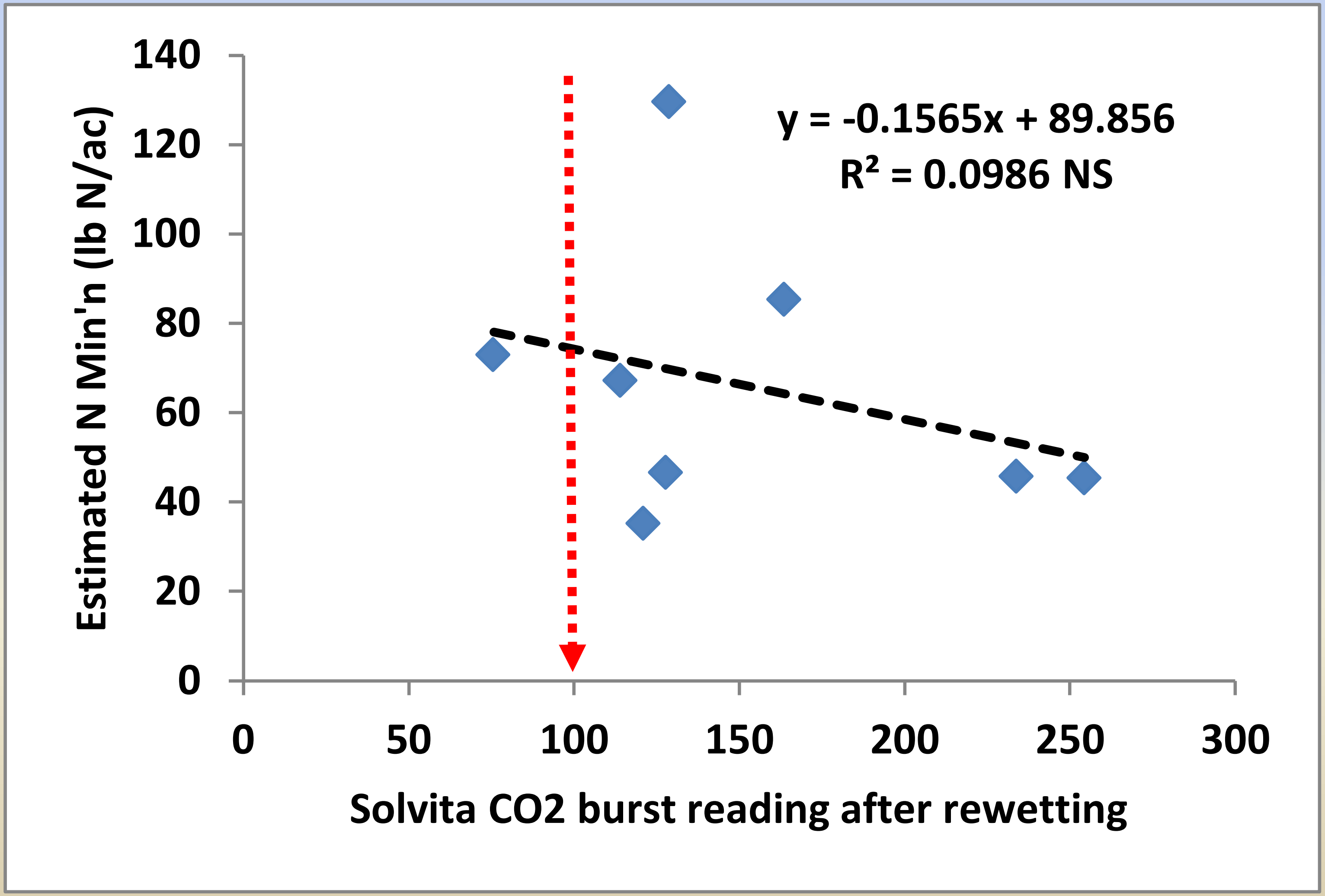
Predicting N Mineralization in Wheat N Study Using Solvita CO_2 Burst After Rewetting



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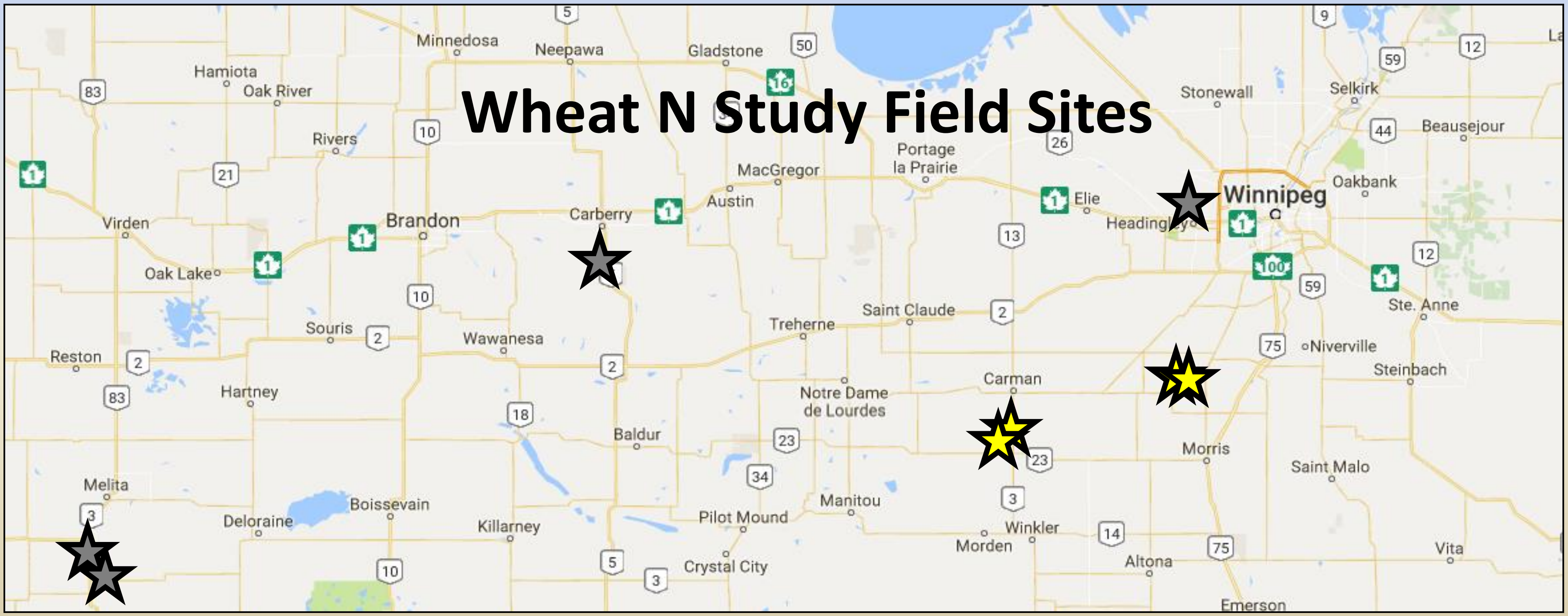
Site and Year Effects on N Mineralization

- **N mineralization varies substantially from one field to another and one year to the next**
- **Current tools for estimating N mineralization in fields are not reliable**



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Summary Thoughts ...

- Applying synthetic fertilizer & livestock manure builds reserves of organic N that release large amounts of mineralized N in later years
- The rate and amount of N mineralized varies with nutrient management history, current and historical cropping management practices
- Temporal & spatial variability (eg. site & year) will probably mess up any lab-based methods for estimating N mineralization for next year’s crop in a field
- Many of these factors will also vary the amount of N mineralized within different areas of fields as a function of landscape position, etc.

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Summary Thoughts, cont'd.

- We need better tools and strategies to apply the right rate of N, eg:
  - Apply decent base rates of N at or near planting; then use on-the-go, real time leaf reflectance measurements and other agronomic measurements that account for spatial and temporal variability in N supply/demand to determine midseason N applications
  - Validate N "budgets" for individual fields and management zones, with end of season "audits" using residual NO_3-N immediately after harvest (ie. a validated "virtual soil test")
- In the meantime, use and follow annual fall residual NO_3 tests, to keep from getting too far off track

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Acknowledgments

- Manitoba Wheat and Barley Growers Association
- Manitoba Corn Growers Association
- Manitoba Pork Council
- Dairy Farmers of Manitoba
- Manitoba Livestock Manure Mgmt. Initiative
- Canada/Manitoba Growing Forward 2 Program
- John Heard and colleagues in Manitoba Agriculture
- Crop Diversification Centres (WADO, CMCDC, PESAI)
- U of MB Ian Morrison Research Station at Carman
- U of MB Glenlea Research Station
- U of MB National Centre for Livestock and the Environment
- David Laudin
- Antara Agronomy
- Koch Fertilizer
- Agrium/Nutrien
- AGVISE Laboratories
- Farmers Edge Laboratory
- Monsanto-Dekalb
- Richardson Pioneer, Kelburn Farm
- Anthony Buckley, casual support staff and many summer students

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