Predicting Crop Responses to Fertilizer: Not as Simple as Some People Think

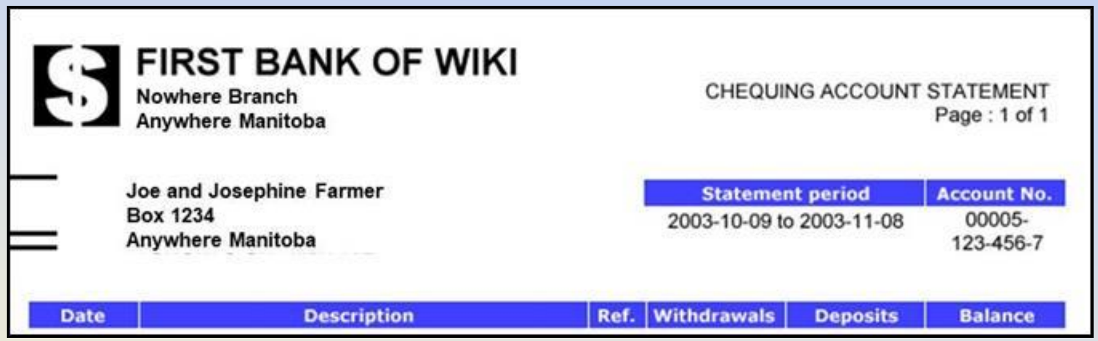
Don Flaten, Professor Emeritus, University of Manitoba

AGVISE Soil Fertility Seminar, March 2024

Last slide …

Annual soil testing is a <u>useful</u> fertilizer planning tool (like a financial budget)

… and an <u>excellent</u> fertilizer program auditing tool (like a bank statement)



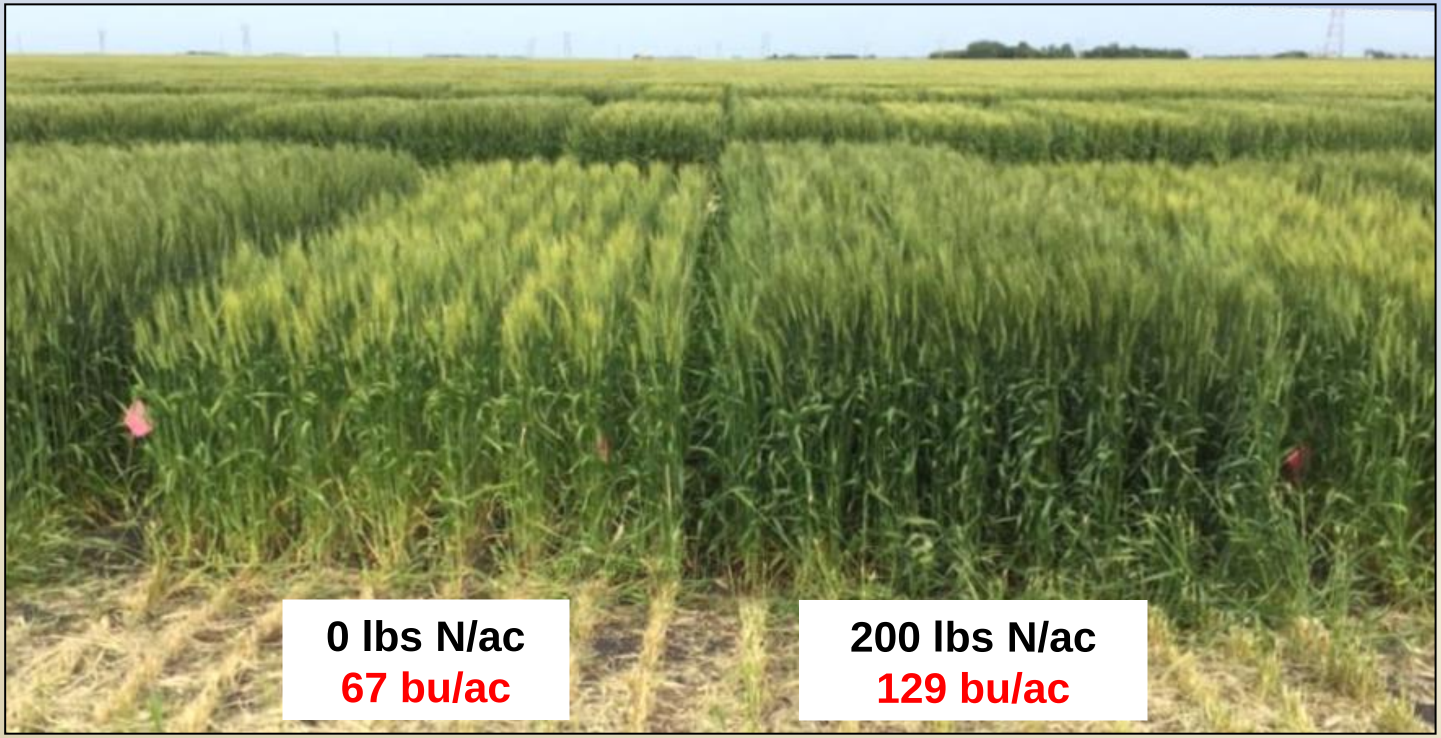
University of Manitoba

Factors affecting agronomic crop response to fertilizer:

i) crop's nutrient requirements, considering crop species & variety or hybrid, yield potential, soil, weather, etc.

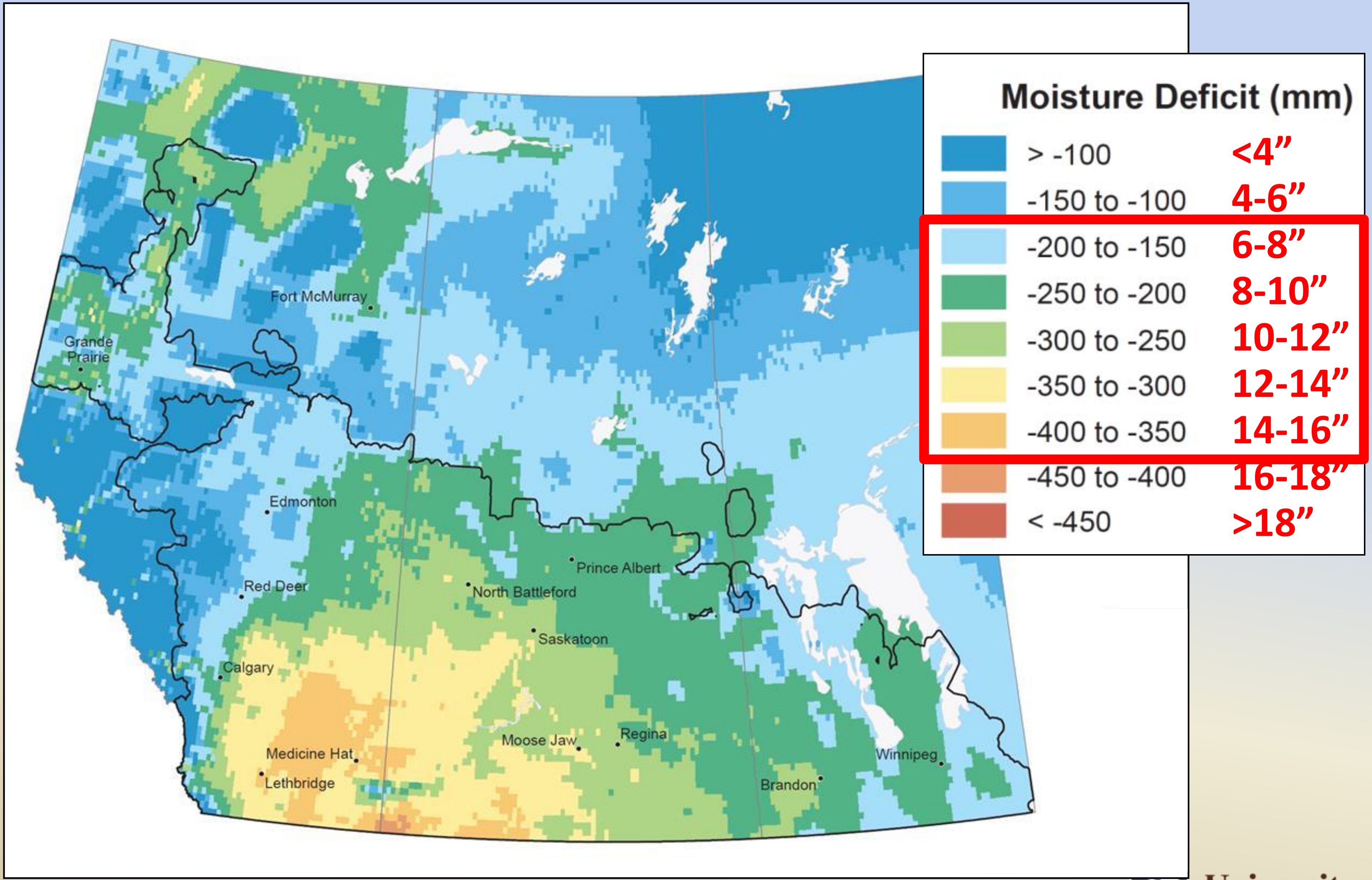
ii) crop's ability to use soil's nutrient supply

iii) fertilizer use efficiency for different sources, timings & placements



University of Manitoba

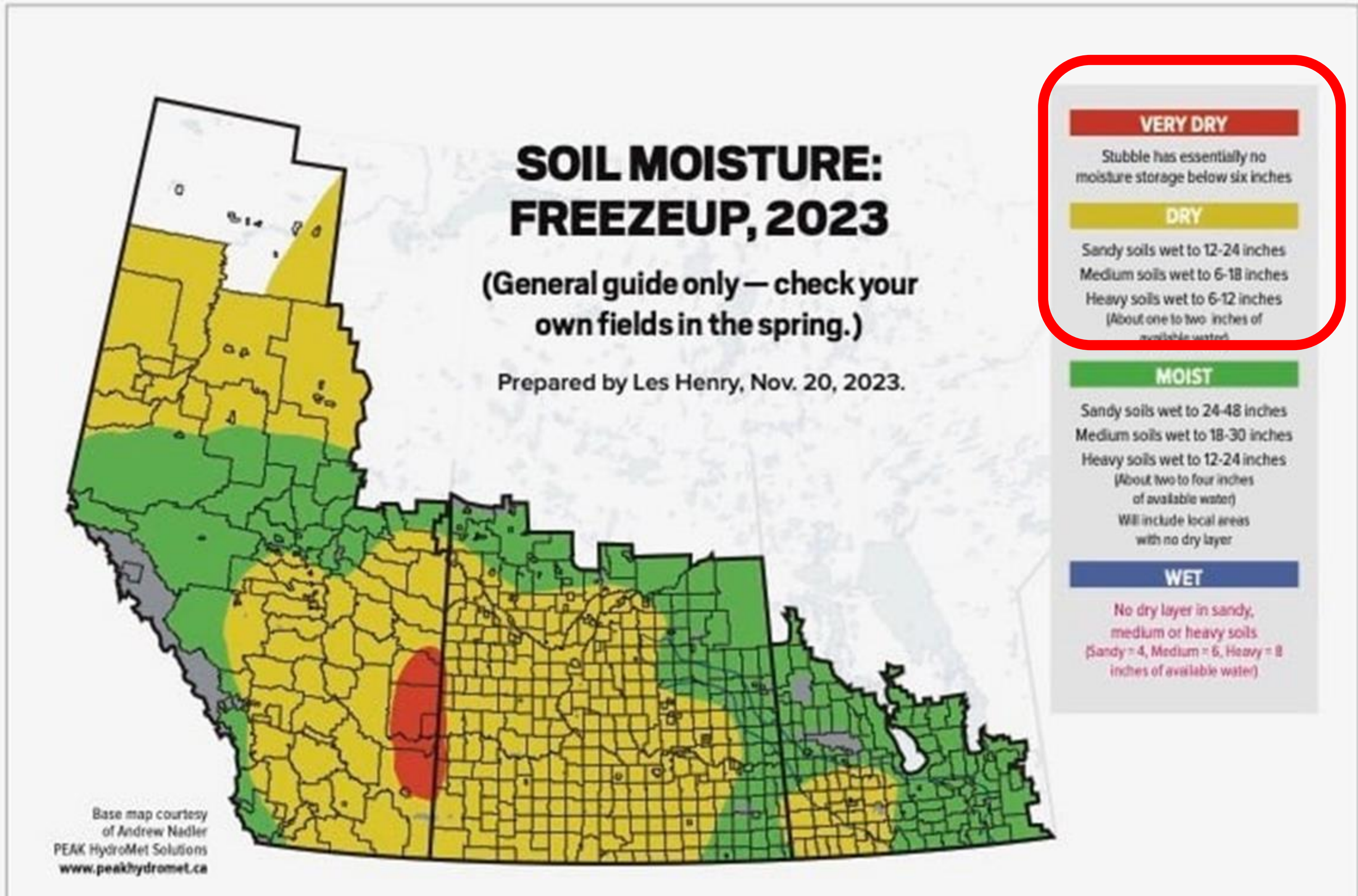
Long term regional variability in growing season moisture deficits



Moisture deficits were accumulated from seeding date, until estimated crop maturity for spring wheat
Source: AAFC https://publications.gc.ca/collections/collection_2018/aac-aafc/A59-63-2010-eng.pdf

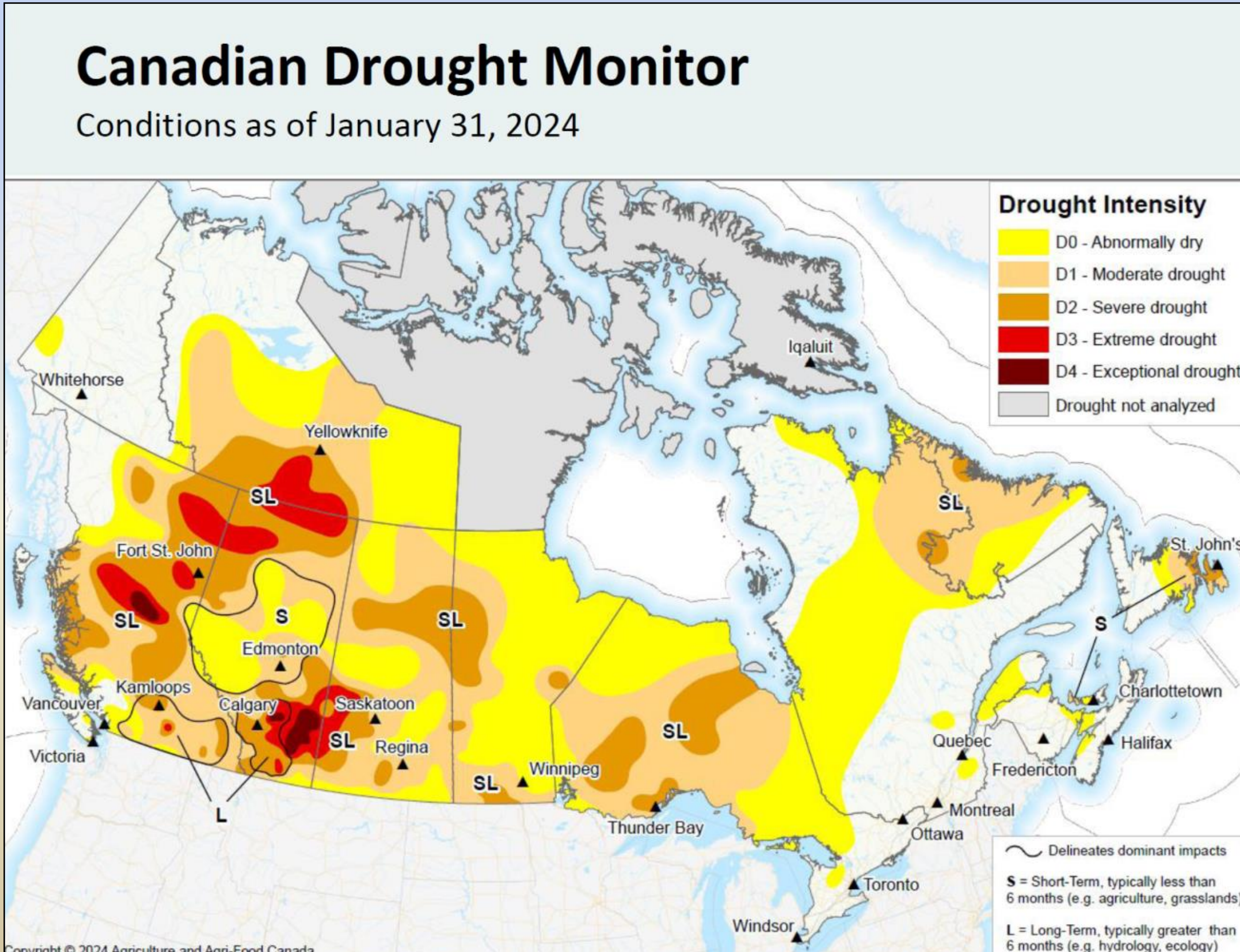
University of Manitoba

Plus short term spatial and temporal variability in precipitation …
e.g. Low reserves of soil moisture in fall 2023



https://www.grainews.ca/columns/a-new-year-a-new-soil-moisture-map/

plus low snowfall in winter 2023-2024 = High risk of drought

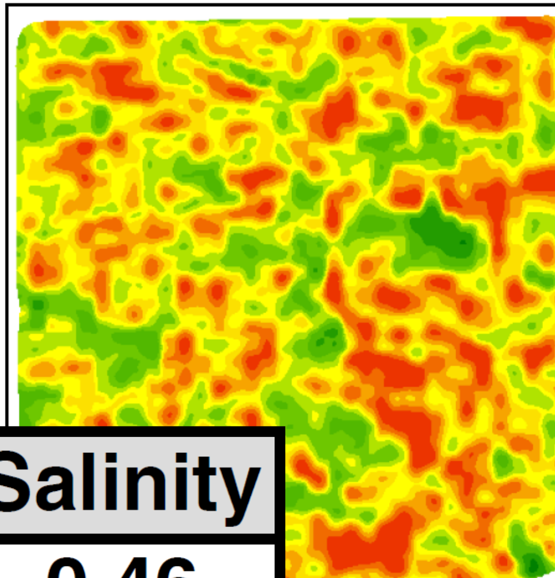


Yield potential also varies substantially within most fields … due to variation in moisture, nutrients, salinity, etc.

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022

Zone	Acres	YieldGoal (bu/ac)	Canola	MAP	Urea	Crystal Green	Actual Fertility Rates
1	10.5	30					- 0 - 0 + 3Mg
2	18.2	35					- 0 - 0 + 3Mg
3	25.6	40					- 0 - 0 + 3Mg
4	27.8	45					- 0 - 0 + 3Mg
5	28.3	50					- 0 - 0 + 3Mg
6	24.9	50					- 0 - 0 + 3Mg
7	15.6	50					- 0 - 0 + 2Mg
8	7	40					- 0 - 0 + 2Mg
9	2.5	30					- 0 - 0 + 1Mg
10	1.2	15					- 0 - 0 + 1Mg
	Average:	43.6					- 0 - 0



Notes: Low P in zones … in zones 1-2. Light sali… …gh in zones 9-10.

Field Area	% Field	…	K	S	Cl	Zn	…	Salinity	CMPT Date
zone 1,2	18		249	27	11	0.4		0.46	May 05, 2021
zone 3,4	33		253	45	8	0.5		0.45	May 05, 2021
zone 5,6	33		335	59	19	1.1		0.70	May 05, 2021
zone 7,8	14		400	160	24	1.2		1.36	May 05, 2021
zone 9,10	2		304	160	60	0.8		4.85	May 05, 2021

CropPro SWAT map prov…

YieldGoal

Zone	Acres		(bu/ac)
1	10.5	High	30
2	18.2		35
3	25.6		40
4	27.8		45
5	28.3		50
6	24.9		50
7	15.6		50
8	7		40
9	2.5		30
10	1.2	Low	15
	Average:		43.6

Salinity
0.46
0.45
0.70
1.36
4.85

University of Manitoba

Factors affecting agronomic crop response to fertilizer:

i) crop's nutrient <u>requirements</u>, considering crop species & variety, yield potential, soil, weather, etc.

ii) crop's ability to use <u>soil's nutrient supply</u>

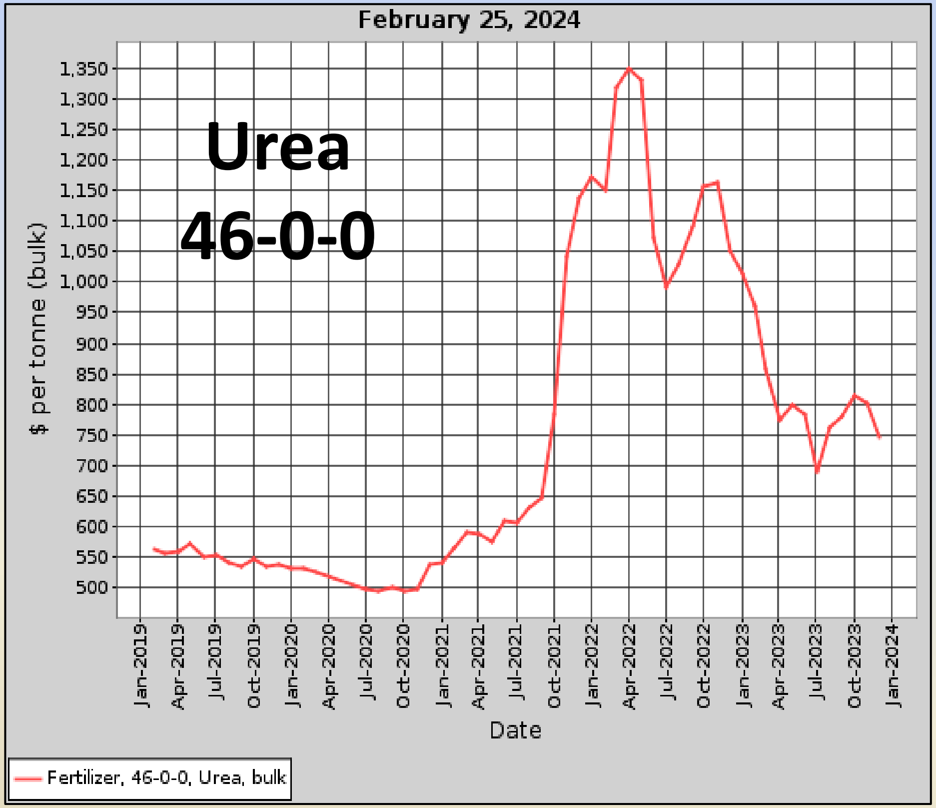
- soil's power to supply nutrients over growing season
    - chemical extractants or ion exchange membranes provide rapid analysis that imitates plant extraction of nutrients
    - net release of additional nutrients during the growing season … e.g., N mineralization from more decomposition than formation of soil org. matter
- crop's ability to extract nutrients from soil … which varies with species and cultivar, especially for P and K

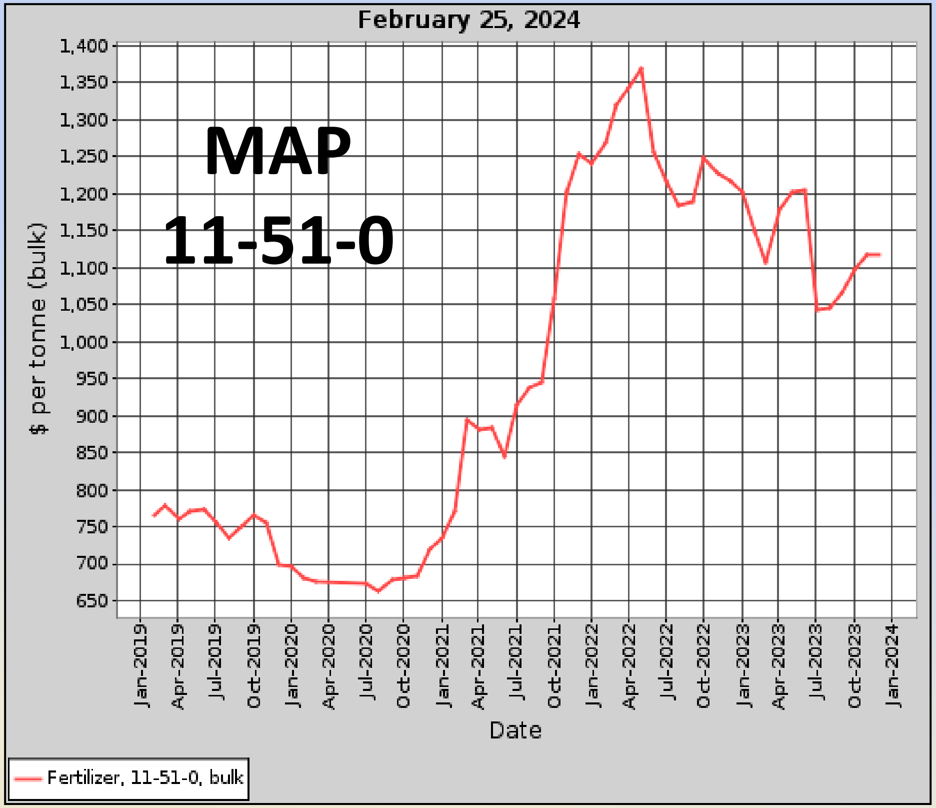
iii) fertilizer use <u>efficiency</u> for different sources, timings & placements

But what about the <u>economic</u> response?

University of Manitoba

Unstable prices for fertilizer
Jan 2019 - Jan 2024

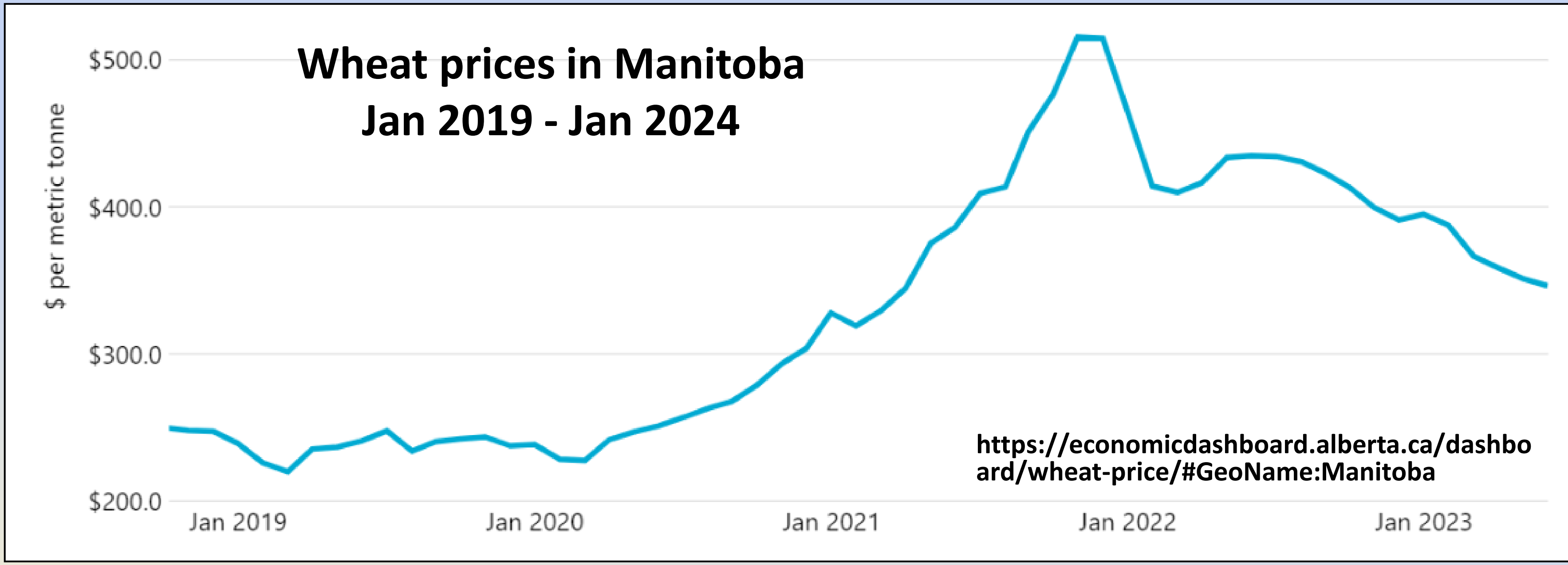


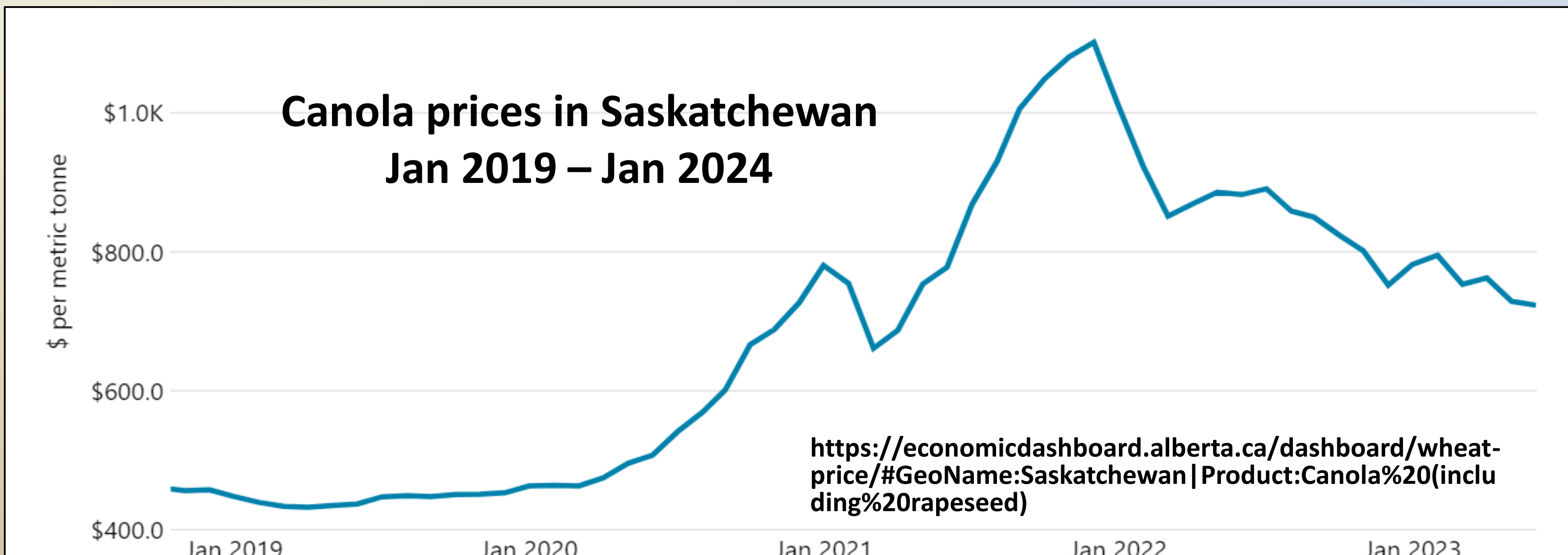


Source: Alberta Agriculture and Irrigation, Farm Input Prices as of Dec. 31, 2023 https://www.agric.gov.ab.ca/app21/farminputprices

University of Manitoba

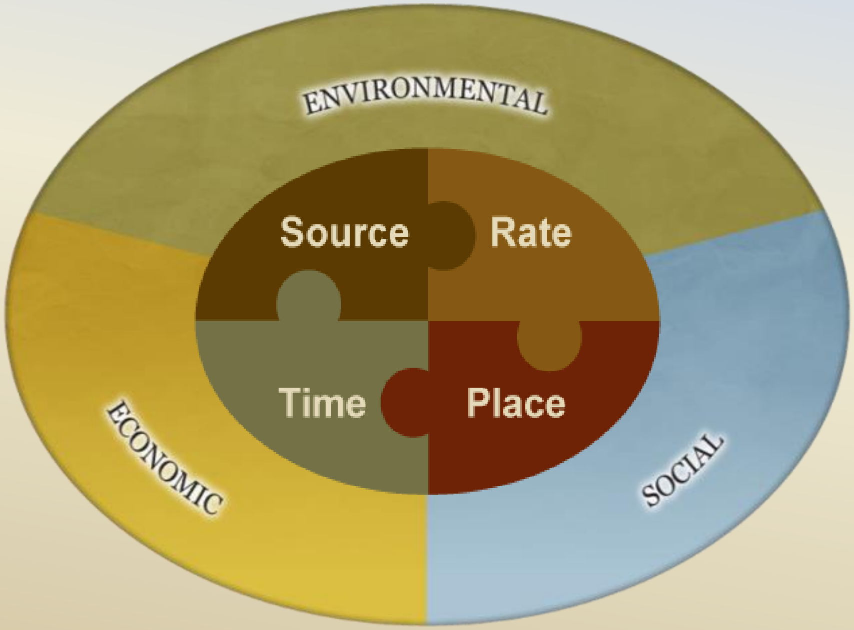
Unstable and falling prices for crops





At the high stakes poker table …

Unstable prices for fertilizer and falling prices for crops … plus low reserves of soil moisture … have increased the financial risks from over- or under-fertilizing … so determining the "Right Rate" is extremely important

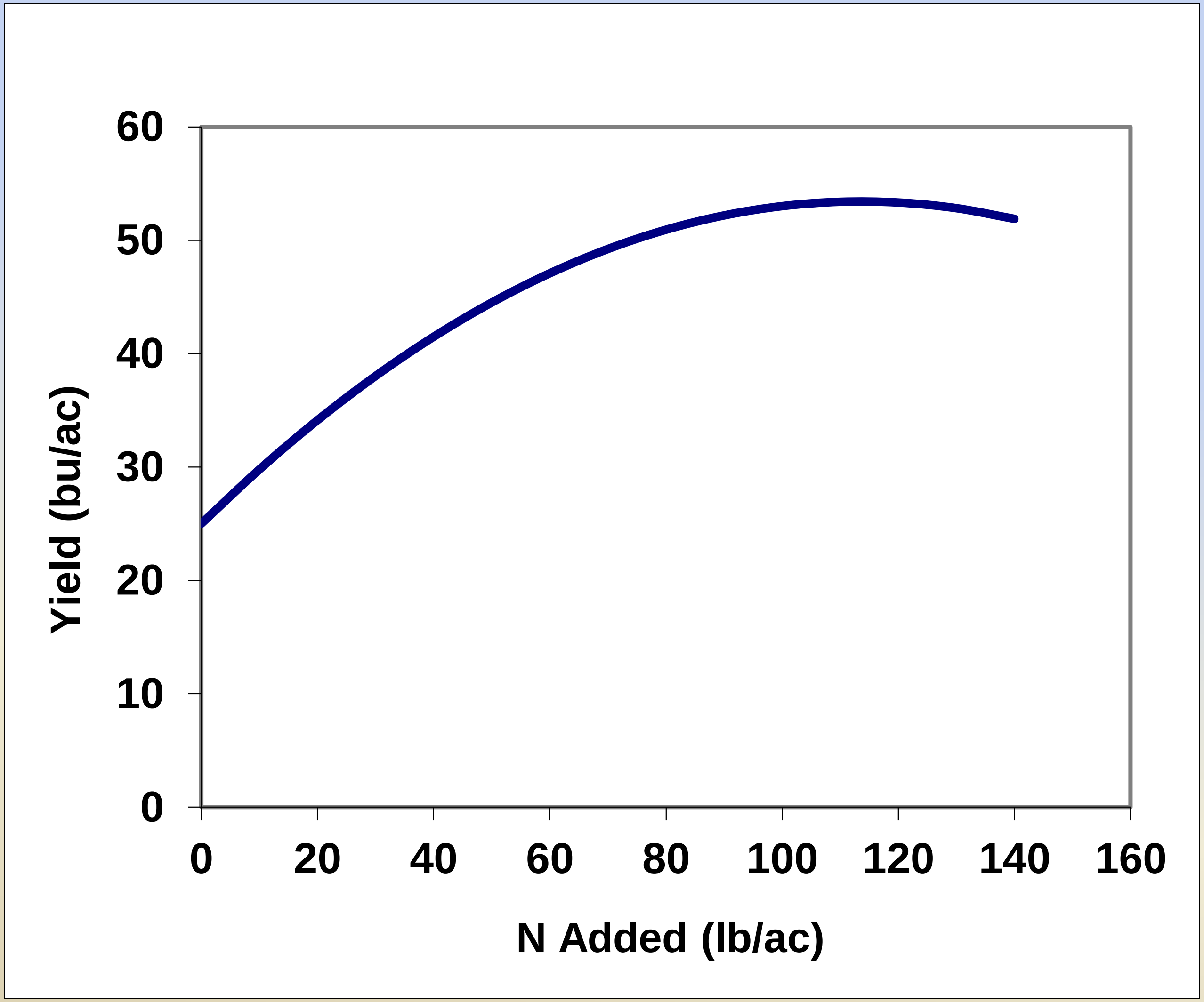


University of Manitoba

N Dealing with variability in crop response to N fertilizer and N fertility

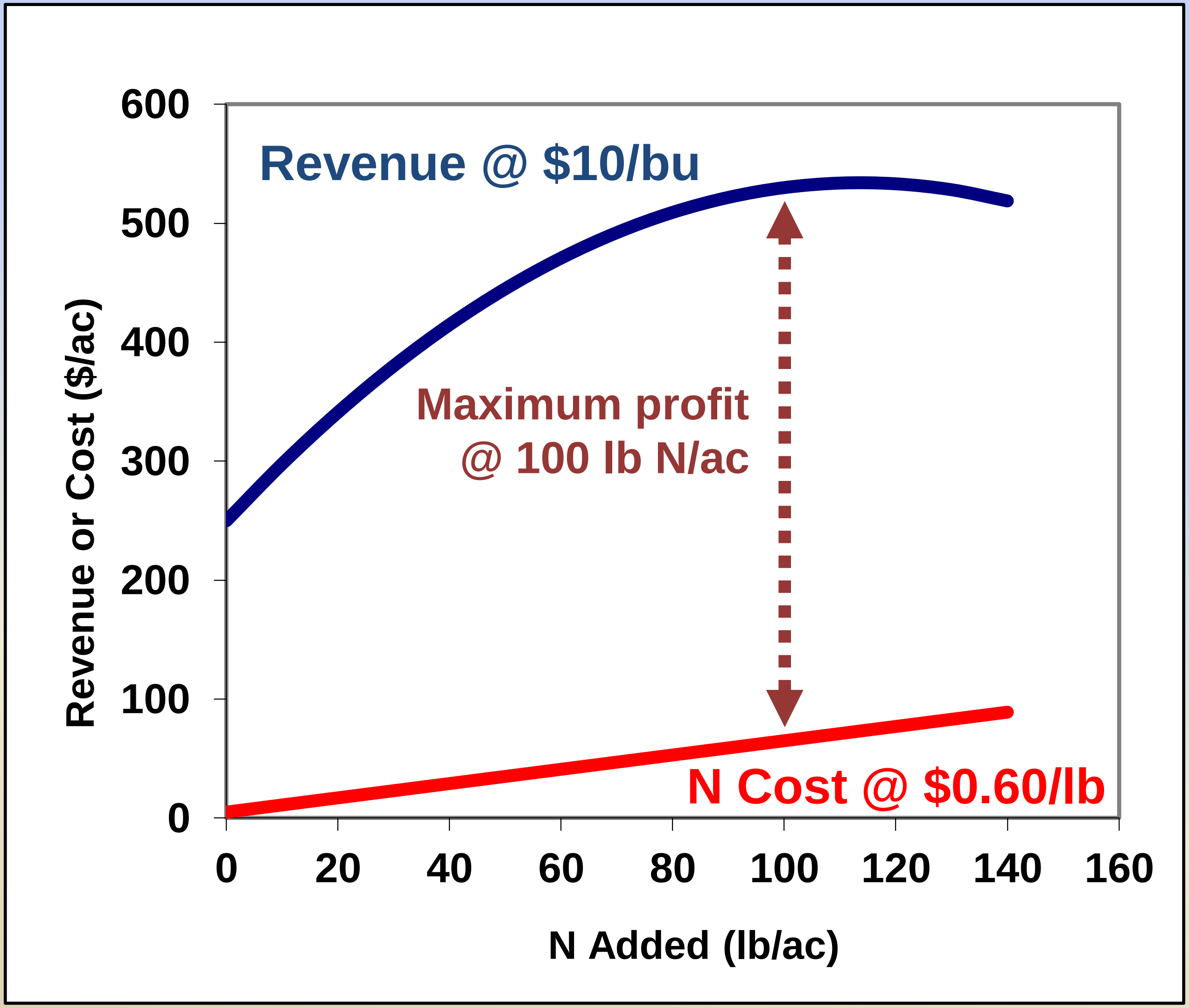
University of Manitoba

Conceptual Overview of Effect of N Fertilizer Rate on Canola Yield



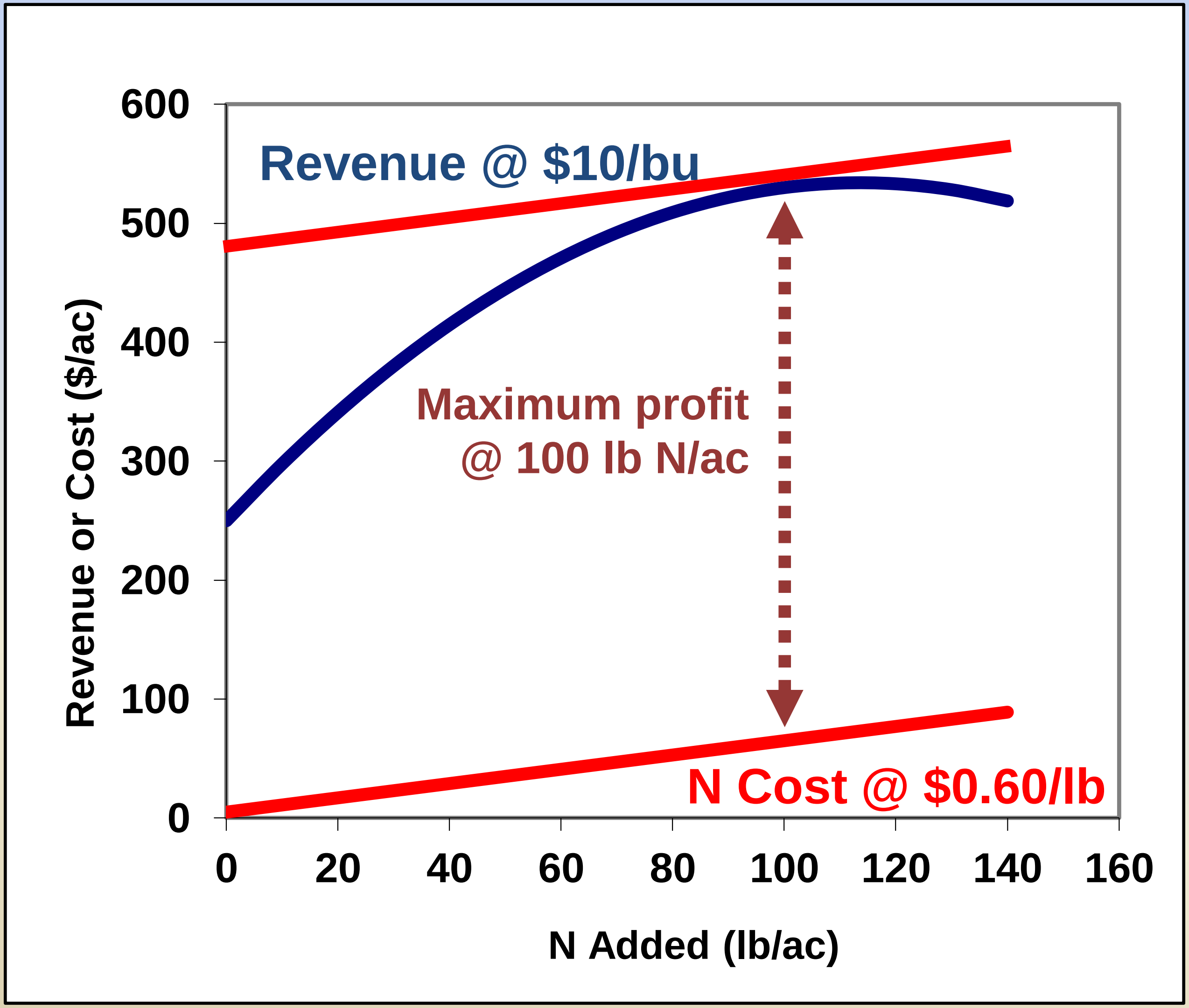
University of Manitoba

Conceptual Overview of Effect of N Fertilizer Rate on Canola Revenue and Fertilizer Cost



University of Manitoba

Conceptual Overview of Effect of N Fertilizer Rate on Canola Revenue and Fertilizer Cost



All you need to know is exactly what your yield response will be … along with fertilizer and crop prices

University of Manitoba

Economic optimum rates of fertilizer vary with fertilizer & crop prices … e.g., Manitoba N Rate Calculator for wheat, barley & canola … note the blue & red cells indicating +/- $0.50 & $1/acre returns

Nitrogen $ Rate of Return Calculator

Manitoba (All)

Return to Canola (hybrid) as variable Go to Marginal Return Chart Return to Data Entry

Crop/Fertilizer N data	
Crop	CANOLA
$/bushel	$9.00
Fertilizer N increment	10
Fertilizer price increment, $	$100.00
Soil test N (0-24") lb N/acre	33

		Expected N Fertilizer Price						
		$400	$500	$600	$700	$800	$900	$1,000
	Yield Increase	Net Return ($/ac.)**						
N Rate	from 0 lb. N*	Canola:N Price Ratio						
(lb./acre)	(bu./ac.)	22.8	18.2	15.2	13.0	11.4	10.1	9.1
100	14.9	$94.3	$84.4	$74.5	$64.7	$54.8	$44.9	$35.0
110	15.8	$98.8	$87.9	$77.0	$66.2	$55.3	$44.4	$33.6
120	16.6	$102.4	$90.5	$78.6	$66.8	$54.9	$43.1	$31.2
130	17.4	$105.0	$92.2	$79.4	$66.5	$53.7	$40.8	$28.0
Current N Rate➔ 140	18.0	$106.8	$93.0	$79.2	$65.3	$51.5	$37.7	$23.8
150	18.6	$107.7	$92.9	$78.1	$63.2	$48.4	$33.6	$18.8
160	19.0	$107.7	$91.9	$76.1	$60.3	$44.4	$28.6	$12.8
170	19.3	$106.8	$90.0	$73.2	$56.4	$39.6	$22.8	$6.0
180	19.6	$104.9	$87.2	$69.4	$51.6	$33.8	$16.0	($1.8)

*Yield responses are averages from 34-site years
Current N rate from your soil test report or common practice
**Net Return = canola price x yield increase) - (N price x N rate)
Net return in blue represents maximum ± $0.50 for the Canola:N Price Ratio range in this table and in Orange within $1.00 of maximum

Barley (Moist) Fertilizer | Barley (Dry) Fertilizer | Barley (Arid) Fertilizer | Canola Fertilizer | Canola (hybrid) Fertilizer

https://www.gov.mb.ca/agriculture/crops/soil-fertility/nitrogen-rate-calculator.html

University of Manitoba

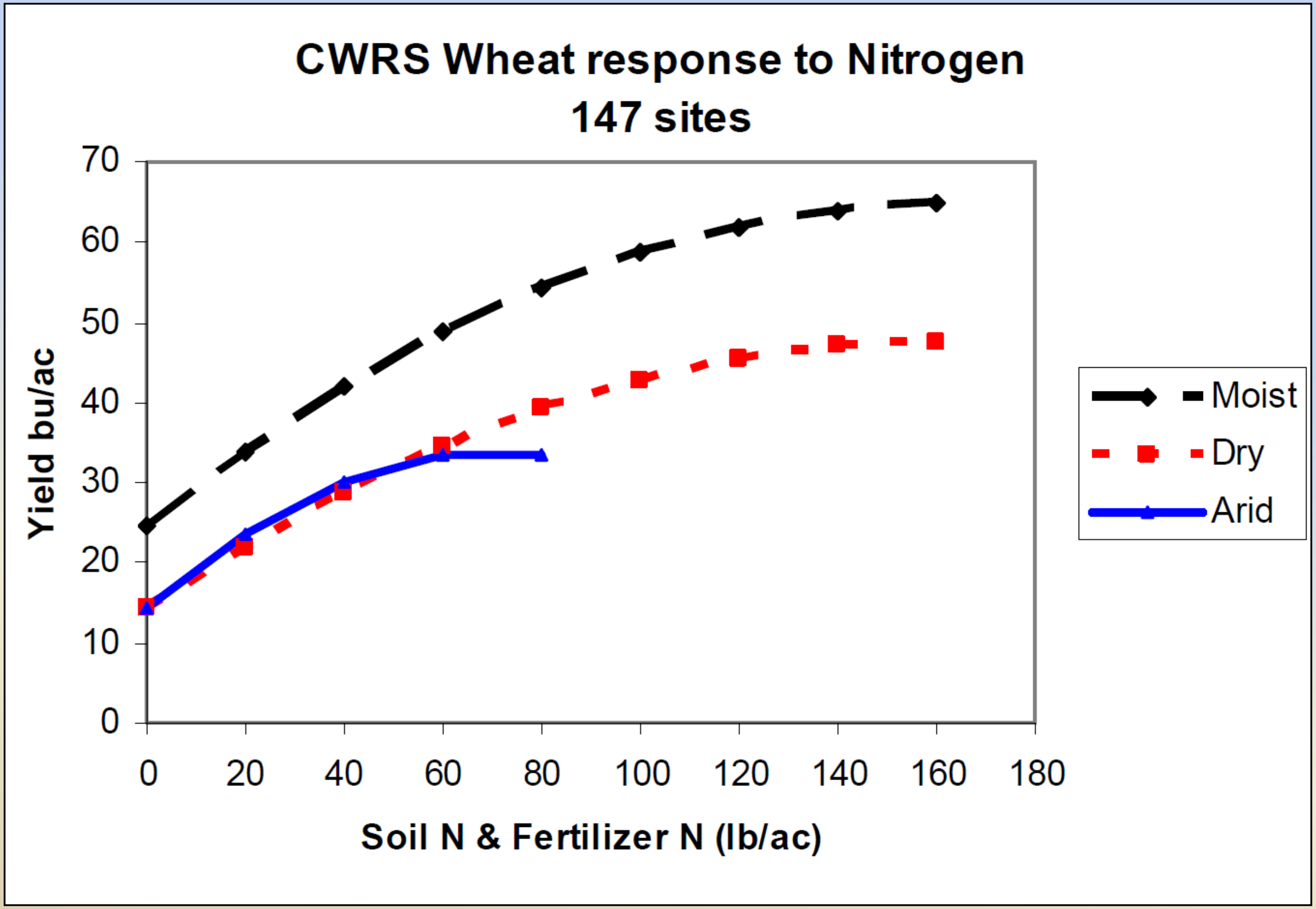
Fertilizer & crop price scenarios for MB N Rate Calculator for wheat, based on 147 Westco field trials and 30 lb residual N soil test

Spring Wheat Scenarios	Urea Price $/Tonne	Wheat Price $/bu	Optimum N Rate lb N/ac	Crop Yield bu/ac	Net Return to N $/ac
Jan 2022 fertilizer & crop prices - moist	$ 1,300	$ 13.50	100	63	$ 209
Jan 2024 fertilizer & crop prices - moist	$ 800	$ 9.50	110	64	$ 159
Jan 2024 fertilizer & low crop prices - moist	$ 800	$ 7.50	100	63	$ 109
Jan 2024 fertilizer & crop prices - dry	$ 800	$ 9.50	90	45	$ 78

Optimum rates of N are relatively stable across a range of fertilizer and crop prices … and moisture supplies

University of Manitoba

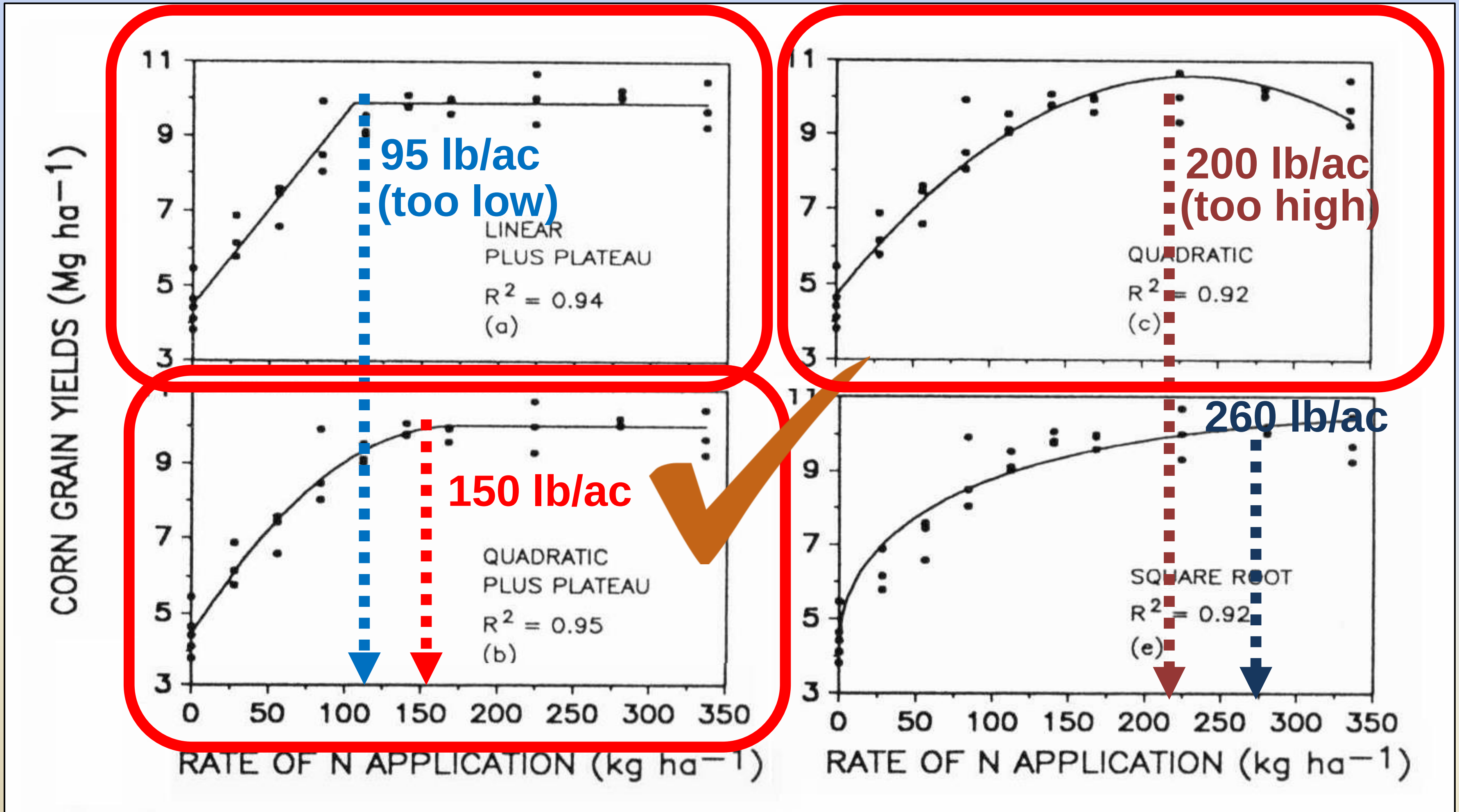
The MB N Rate Calculator uses “quadratic” equations to describe response to soil plus fertilizer N, based on data from Westco’s field trials in MB and Eastern SK



Moist environment (25 sites), $Y = 24.75 + 0.4902x - 0.0015x^2$ $R^2 = 0.9927$
Dry environment (67 sites), $Y = 14.22 + 0.4159x - 0.0013x^2$ $R^2 = 0.9436$
Arid environment (55 sites), $Y = 14.22 + 0.5464x - 0.0038x^2$ $R^2 = 0.8175$

University of Manitoba

The choice of N response curve makes a huge difference to the estimate for optimum economic N rate and quadratic equations often over-estimate the optimum rate of N … e.g. corn for 1 site-year in Iowa



Cerrato and Blackmer Agron. J. 82:138-143 (1990)

University of Manitoba

Received: 28 January 2022 | Accepted: 9 April 2022

DOI: 10.1002/ael2.20075

Agricultural & Environmental Letters OPEN ACCESS

RESEARCH LETTER

How can we estimate optimum fertilizer rates with accuracy and precision?

"We fitted the LP and QP models and chose the best-fitting of these two according to their Akaike Information Criterion (AIC) values."

Fernando E. Miguez[1] | **Hanna Poffenbarger**[2]

[1]Dep. of Agronomy, Iowa State Univ., 716 Farm House Ln., Ames, IA 50011, USA

[2]Dep. of Plant and Soil Sciences, Univ. of Kentucky, 1100 Nicholasville Rd., Lexington, KY 40506, USA

Correspondence

Fernando E. Miguez, Dep. of Agronomy, Iowa State Univ., 716 Farm House Ln., Ames, IA 50011, USA.

Email: femiguez@iastate.edu

Assigned to Associate Editor Matthew Ruark.

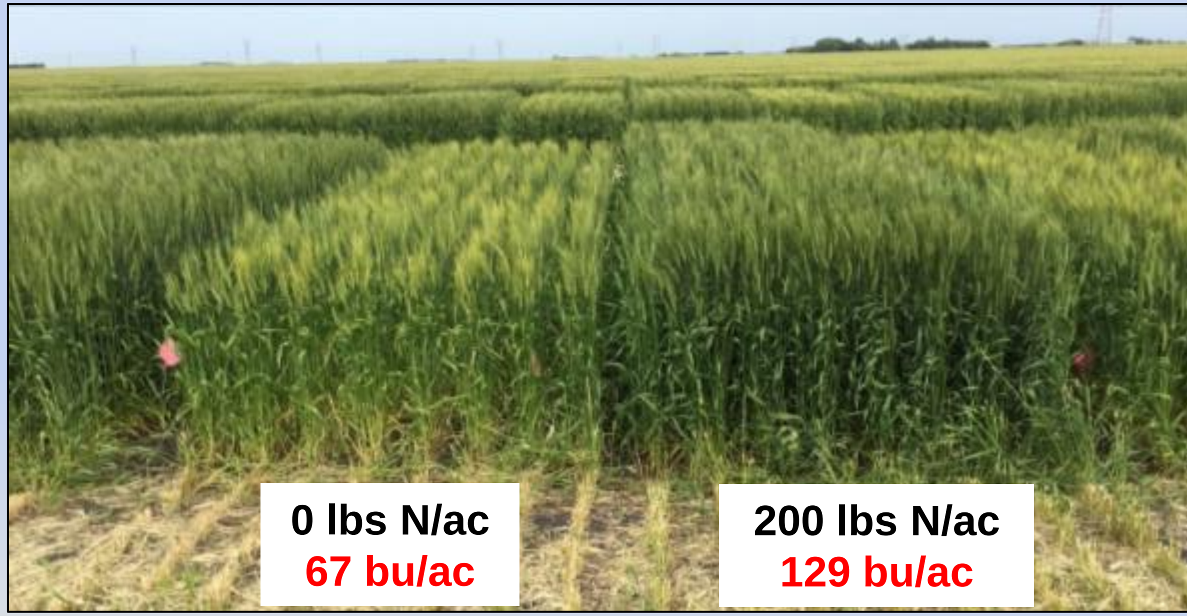
Abstract

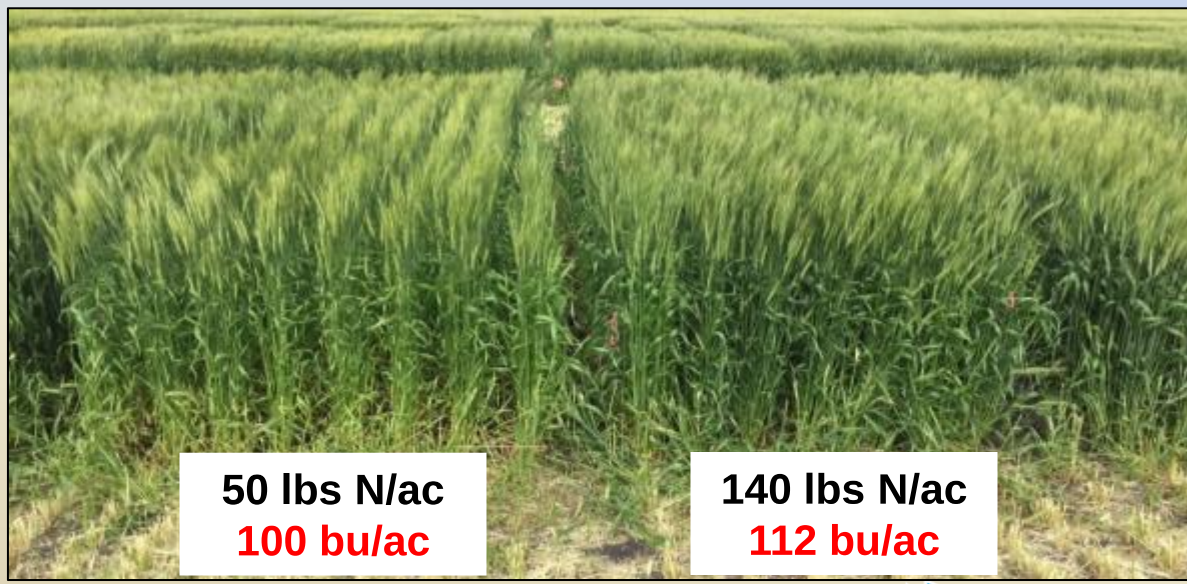
For decades, agronomists have invested time and resources to identify the optimum nitrogen (N) rates for cereal crops. The most common method for estimating the agronomic optimum N rate (AONR) is to design a field experiment with several N

will demand an increase in the number of N rates and replications. Finally, we propose that using either the best-fitting model or a weighted model is preferable to always choosing either the linear-plateau (negative bias) or quadratic-plateau (positive bias) models.

Finally, we propose that using either the best-fitting model or a weighted model is preferable to always choosing either the linear-plateau (negative bias) or quadratic-plateau (positive bias) models

Nitrogen Management for High-Yielding Wheat in Manitoba





Prosper spring wheat plots at Brunkild 2017

University of Manitoba

Most Accurate N Response Curves for "Hind-Casting" High-Yielding Wheat in Manitoba (Mangin et al. 2018)*

Site-Year	Wheat Variety	Statistical Model for N Response Curve				
		Linear - Plateau	Linear - Linear	Quadratic - Plateau	Quadratic	Linear
Brunkild 2016	Brandon	Best				
	Prosper		Best			
Carman 2016	Brandon					Best
	Prosper					Best
Brunkild 2017	Brandon				Best	
	Prosper		Best			
Carman 2017	Brandon					Best
	Prosper		Best			
Melita 2016	Brandon				Best	
	Prosper	Best				
Carberry 2016	Brandon					Best
	Prosper					Best
Melita 2017	Brandon					Best
	Prosper					Best
Grosse Isle 2017	Brandon	Best				
	Prosper				Best	

*Accuracy determined using Akaike Information Criterion (AIC) values for each model and site-year

Optimum N Rate for Brandon CWRS Wheat in Manitoba (Determined using top-ranked means group, Mangin & Flaten 2018)

Site-year	Economic Optimum Fert. N Rate*	Yield at Optimum Fert. N Rate	Total Nitrogen Supply per bushel	Grain Protein at Optimum Fert. N Rate
	lbs. N/ac	bu/ac	lbs. N/bu	%
~~Carman 2016~~	~~170~~	~~65~~ Hail Damaged	~~3.3~~	~~14.8~~
Brunkild 2016	170	73	2.9	13.0
Carman 2017	170	99	2.2	14.8
Brunkild 2017	170	115	1.9	12.5
Melita 2016	125	66	2.6	14.7
Carberry 2016	110	98	2.0	13.7
Melita 2017	155	77	2.1	12.1
Grosse Isle 2017	140	75	2.7	13.6

Optimum soil test N + Fertilizer N = 2.25 lb N/bu @ 13.5% protein

http://www.mbwheatandbarley.ca/wp-content/uploads/2018/05/Mangin-Flaten-N-mgmt-for-HY-wheat-project-revised-technical-report-2018-03-31.pdf

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

University of Manitoba

Low protein is a useful indicator of N deficiency in wheat*

"The yield curve in wheat flattens out at a certain point. And that point is 13.5 percent. So there are areas in that field with 11.5 percent (protein) that still had yield potential, that might have reached 100 bu. per acre."

– Rick Rutherford, Innovation Farms, Grosse Isle, MB

Farmer experiments with protein monitor

By Robert Arnason

Western Producer - August 17, 2023

Reading Time: 3 minutes

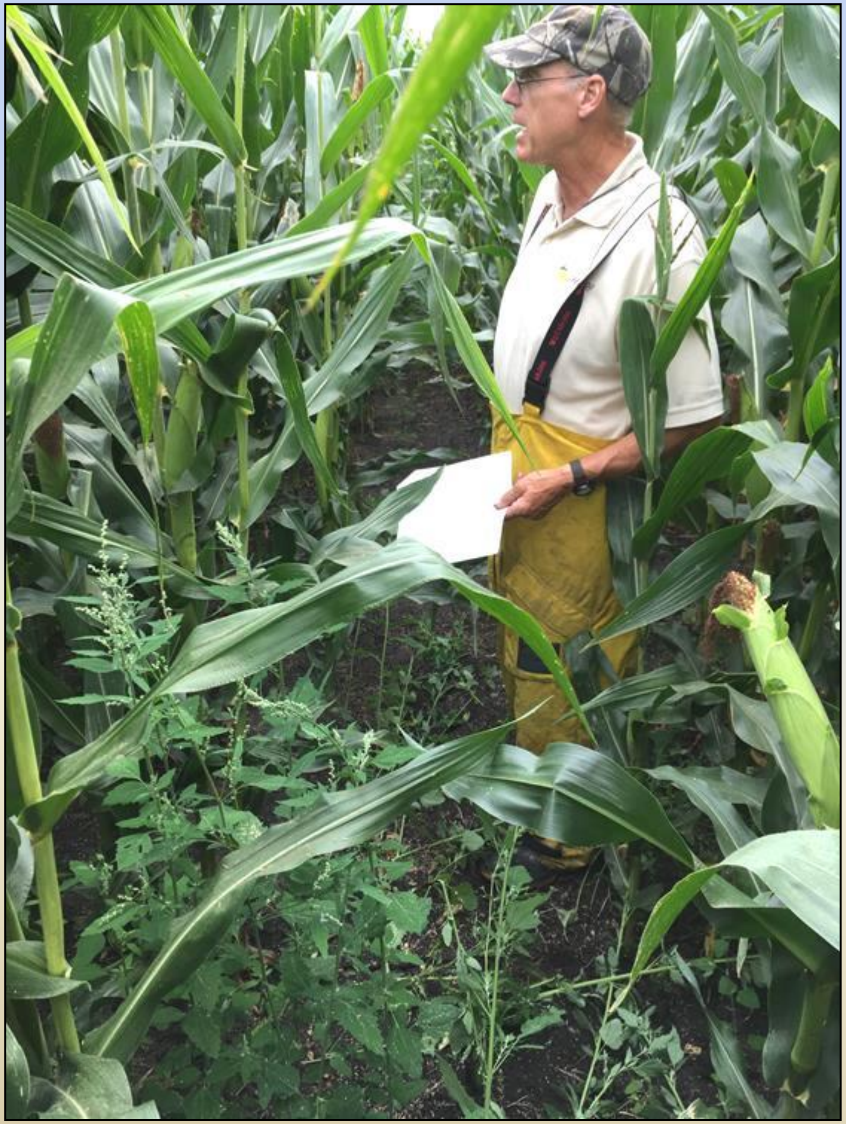
Published: August 17, 2023

Crops, Machinery, News

Rick Rutherford could be one of the first producers in Manitoba to experiment with a protein monitor in his combine. | File photo

*e.g., see Jay Goos et al. Agronomy Journal (1982) … based on 1977-1980 research in Colorado

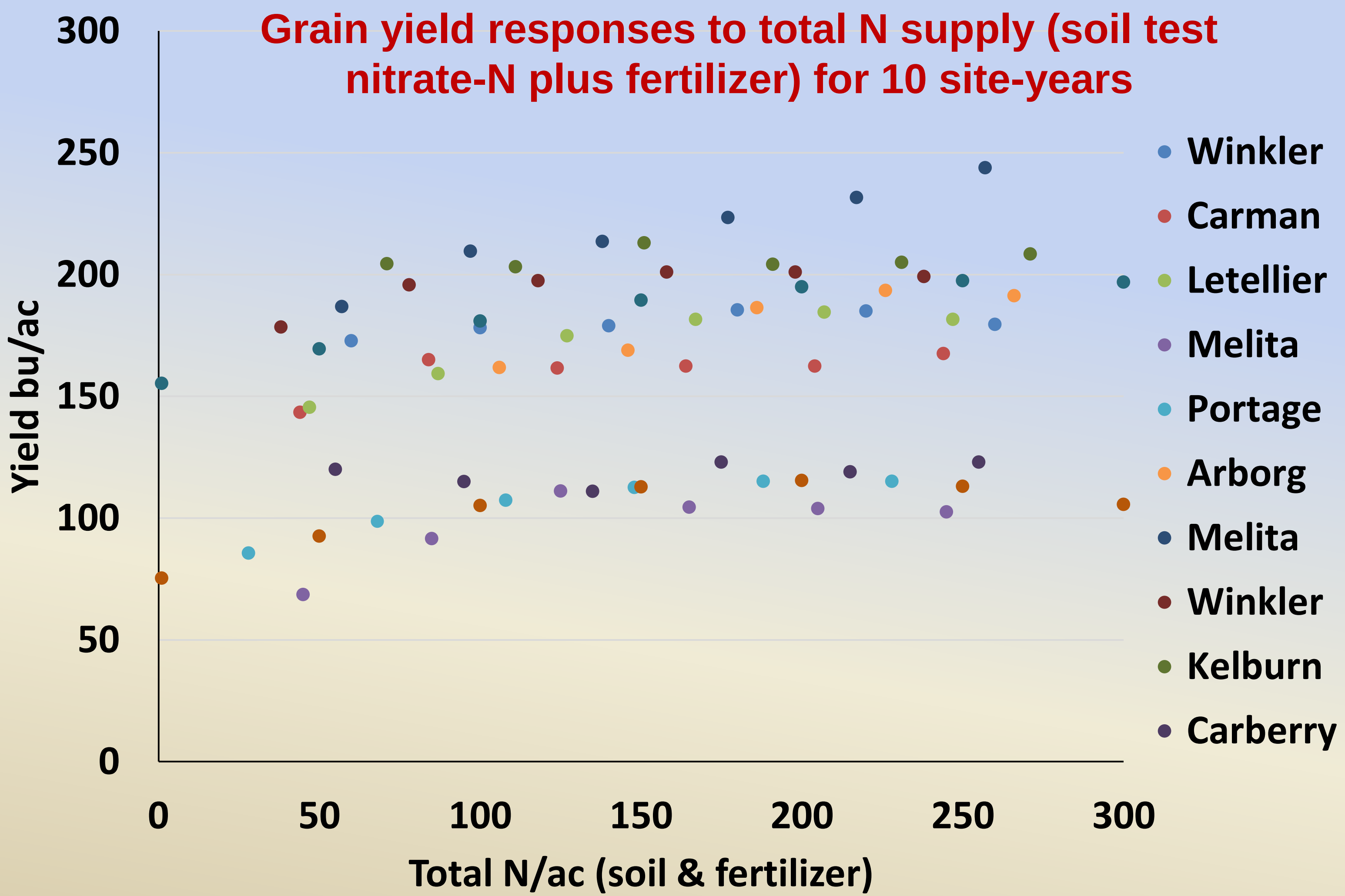
Nitrogen Fertilization for Corn
2016-2017 Manitoba Agriculture Field Trials



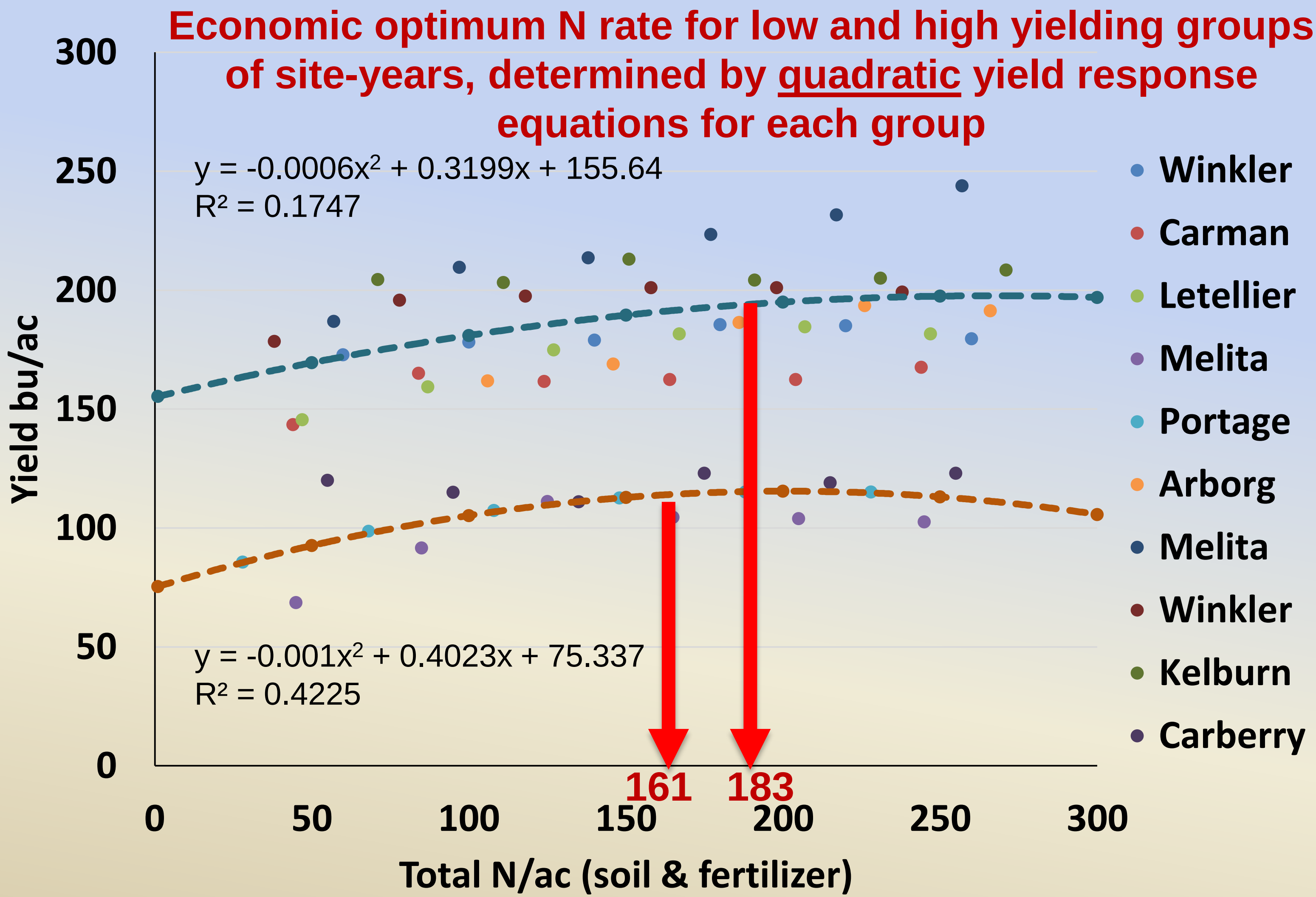
**John Heard,
Manitoba
Agriculture**

University of Manitoba

Most economic rate of N @ $4/bu corn and $0.40/lb N

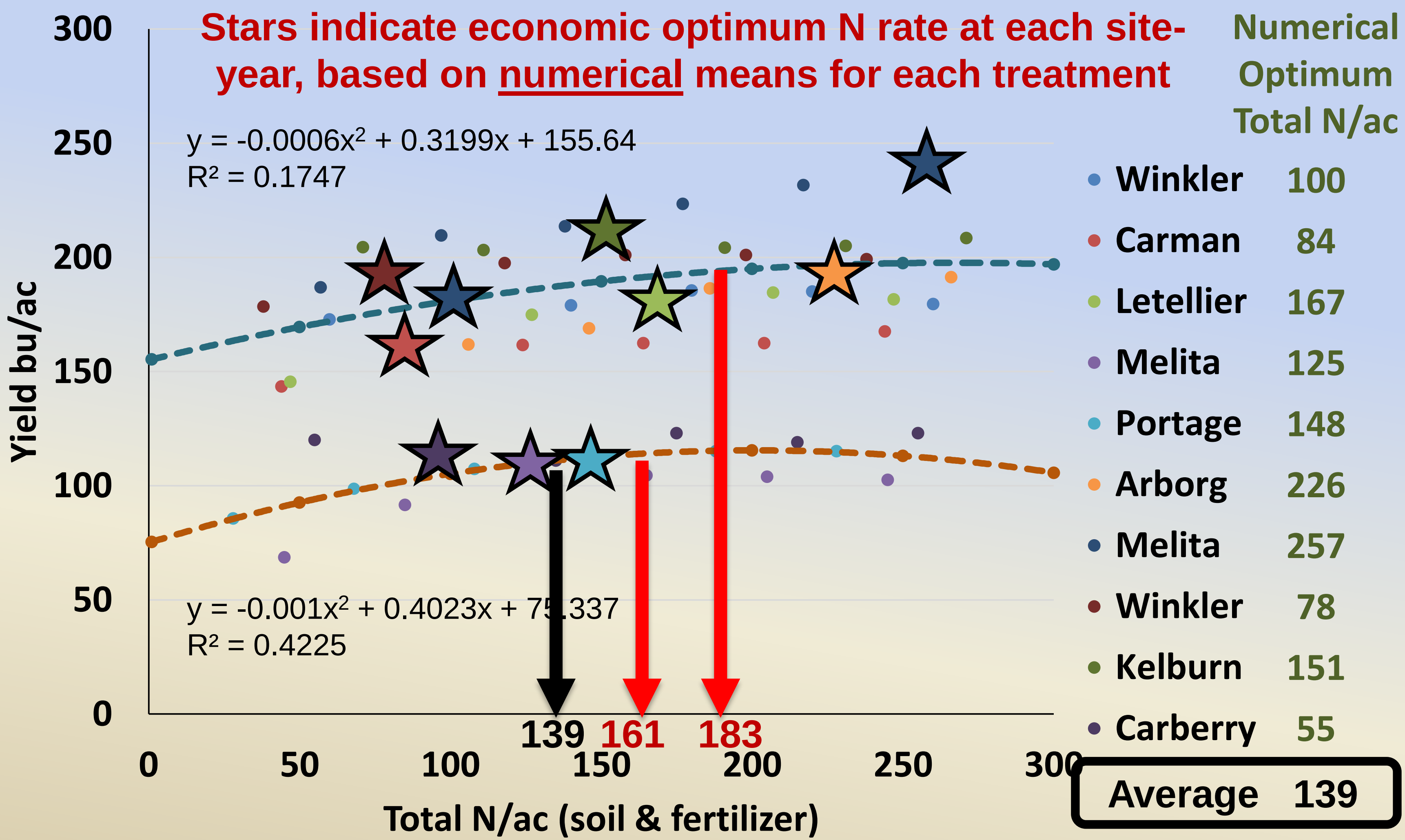


Most economic rate of N @ $4/bu corn and $0.40/lb N



University of Manitoba

Most economic rate of N @ $4/bu corn and $0.40/lb N



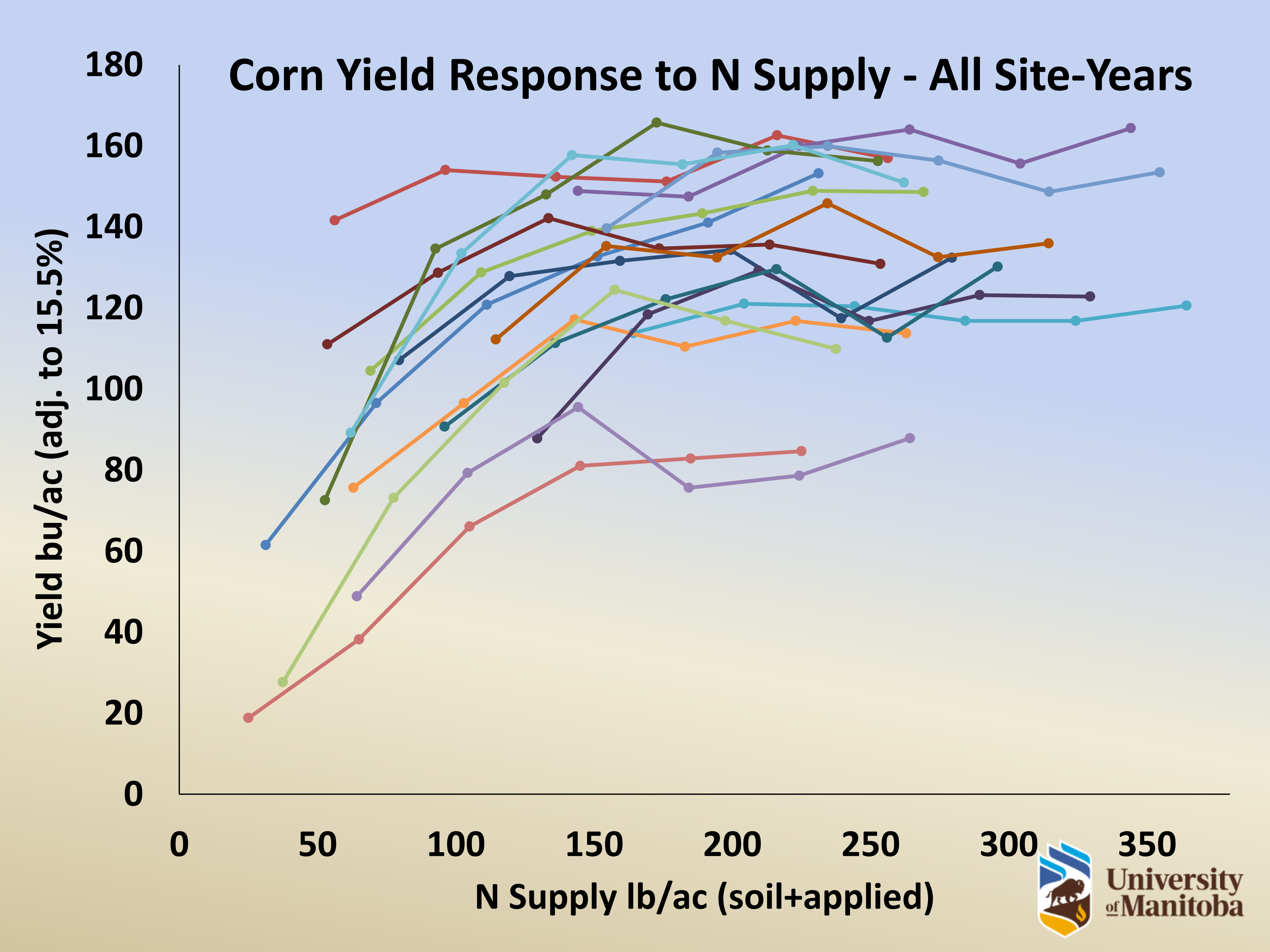
University of Manitoba

Nitrogen Fertilization for Modern Corn Hybrids 2018-2019 University of Manitoba Field Trials

Lanny Gardiner

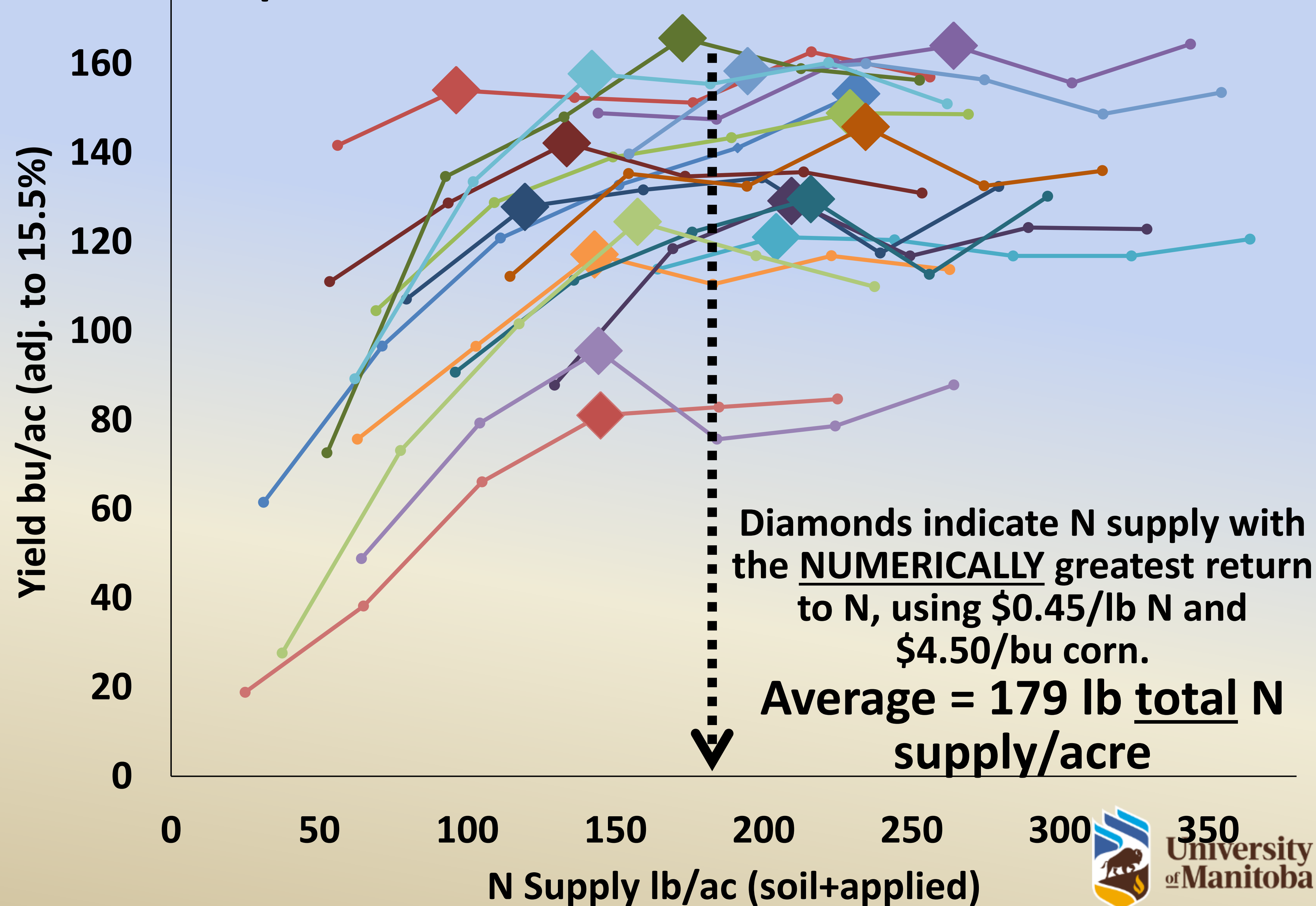
Dept. of Soil Science, University of Manitoba

University of Manitoba



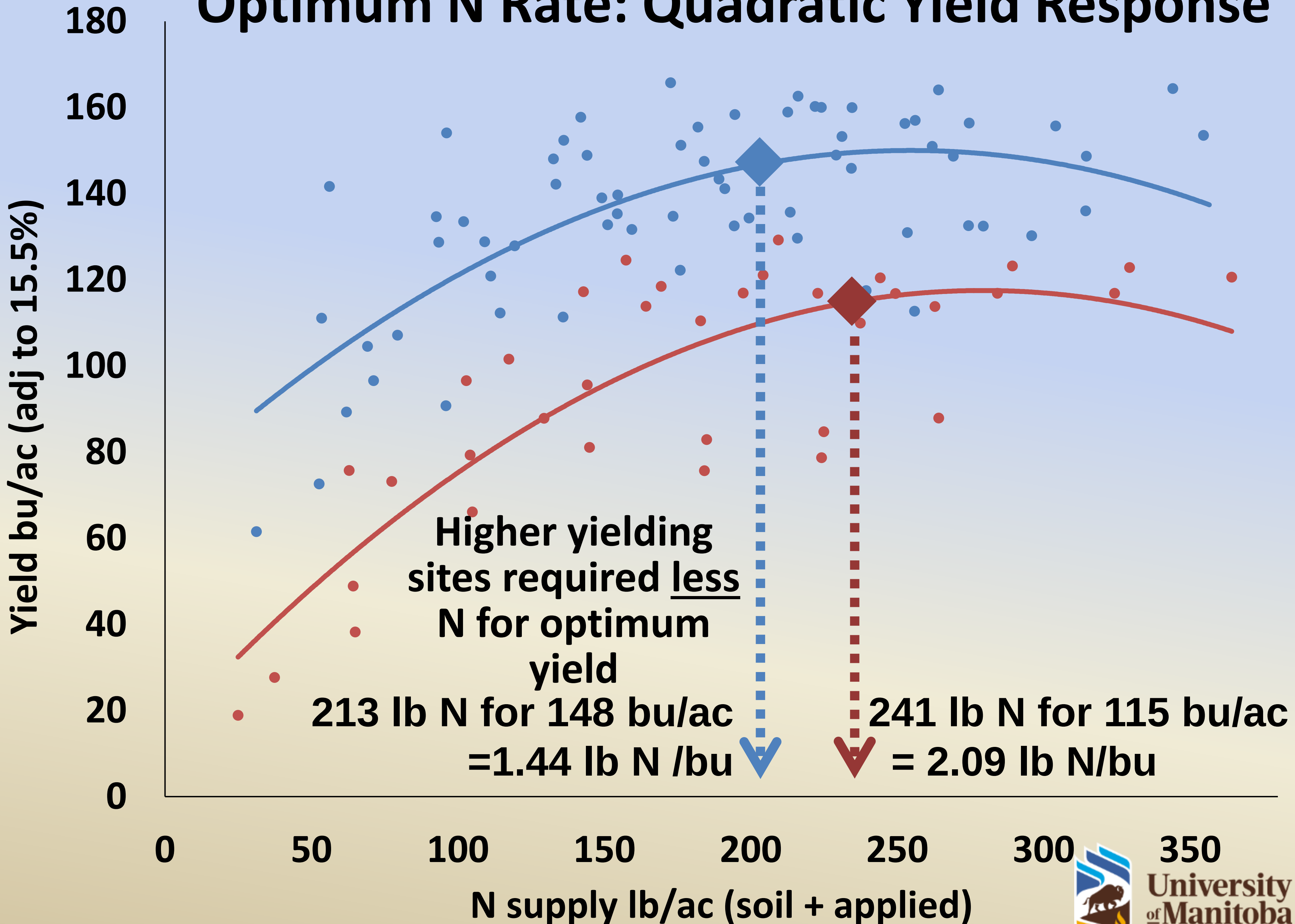
Corn Yield Response to N Supply - All Site-Years
Yield bu/ac (adj. to 15.5%)
N Supply lb/ac (soil+applied)
0
20
40
60
80
100
120
140
160
180
0
50
100
150
200
250
300
350
University of Manitoba

Optimum N Rate: Numerical Max. Returns to N



University of Manitoba

Optimum N Rate: Quadratic Yield Response



University of Manitoba

Economic Optimum Total N Supply* Summary

Method of Analysis	Average for site-years yielding less than 130 bu/ac	Average for site-years yielding more than 130 bu/ac
Numerical Maximum Return	167 lb N for 111 bu = 1.5 lb N/bu	185 lb N for 150 bu = 1.2 lb N/bu
Individual Quadratic Responses for Each Site-Year	188 lb N for 107 bu = 1.8 lb N/bu	189 lb N for 147 bu = 1.3 lb N/bu
One Quadratic Response for Each Yield Group	241 lb N for 115 bu = 2.1 lb N/bu	213 lb N for 148 bu = 1.4 lb N/bu
Estimated N Mineralization	30 lb N/ac	63 lb N/ac

*Total N Supply = Pre-Plant Soil Test Nitrate-N + Fertilizer N

University of Manitoba

Factors affecting crop response to fertilizer:

i) crop's nutrient requirements, considering crop species & variety or hybrid, environment, yield potential, etc.

ii) crop's ability to use soil's nutrient supply

- soil's power to supply nutrients over growing season
  - chemical extractants or ion exchange membranes provide rapid analysis that imitates plant extraction of nutrients … e.g., soil test nitrate-N
  - net release of additional nutrients during the growing season … e.g., N mineralization from more decomposition than formation of soil org. matter

University of Manitoba

Variation in Field-Estimated Measurements of N Mineralization in Wheat and Corn N Field Trials in Manitoba

Effect of Site and Year on Estimated N Mineralization During the Spring Wheat Growing Season (Mangin & Flaten 2018)

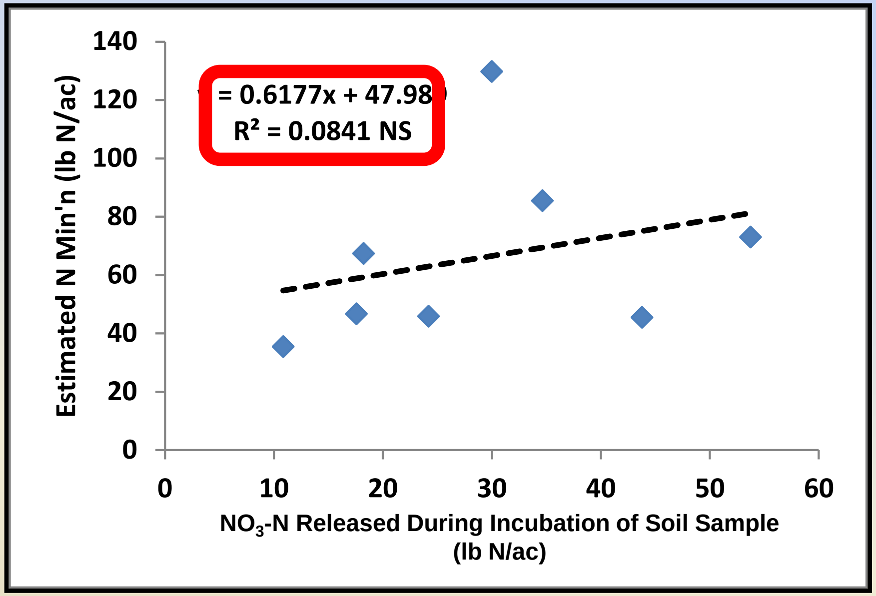
Site-Year	Estimated N mineralization (lb N/ac)
Carman 2016	67
Brunkild 2016	35
Melita 2016	47
Carberry 2016	130
Carman 2017	73
Brunkild 2017	45
Melita 2017	85
Grosse Isle 2017	46
Mean	66
Range	35-130

Effect of Site and Year on Estimated N Mineralization During the Grain Corn Growing Season (Gardiner & Flaten 2020)

Site-Year	Estimated N mineralization (lb N/ac)
CarmanWest 2018	89
Graysville 2018	58
Macgregor 2018	51
Rosebank 2018	92
Stephenfield 2018	12
CarmanNorth 2019	47
CarmanSouth 2019	95
Clearwater 2019	43
Elgin 2019	59
Graysville 2019	67
Morris 2019	17
Rosebank 2019	22
StClaude 2019	32
Mean	53
Range	12-95

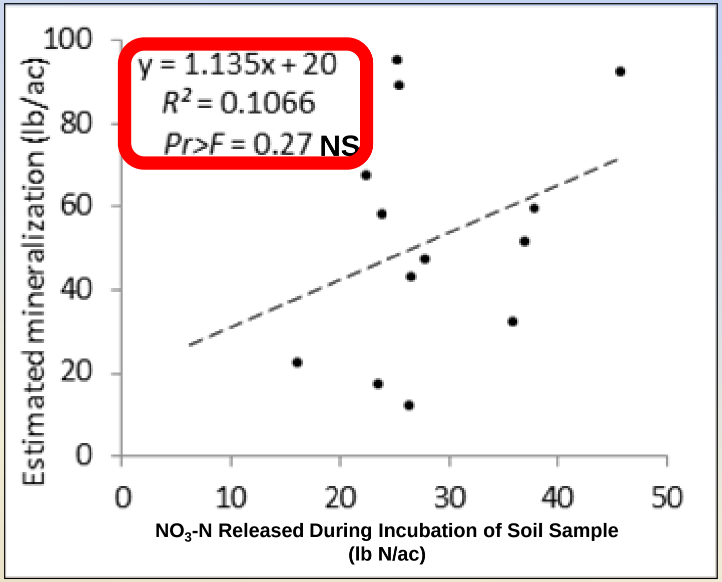
Soil sample incubation tests* did not predict N mineralization in the field … due to differences in environmental conditions and management

Incubation Test for Estimating N Mineralization for High Yielding Spring Wheat in the Field for 8 Site-Years



Mangin et al. 2018

Incubation Test for Estimating N Mineralization for Corn in the Field for 13 Site-Years



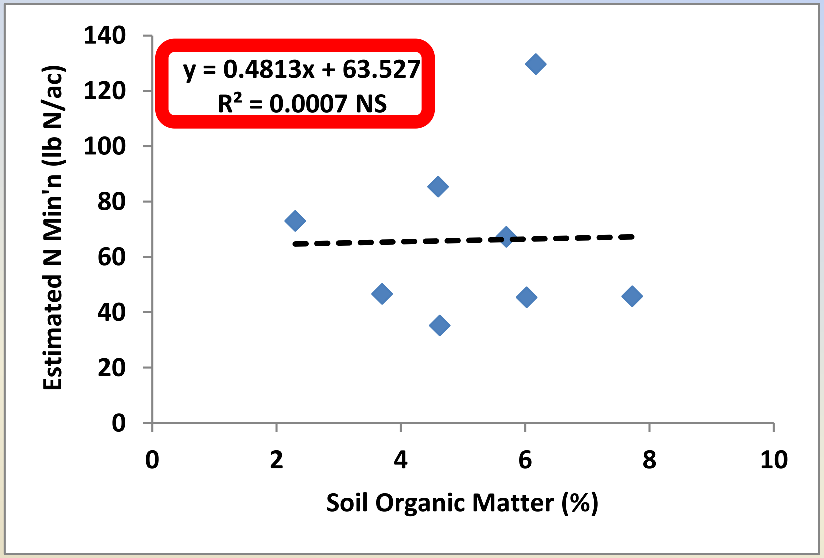
Gardiner and Flaten 2020

*** Field moist soil incubated at room temperature for 4 weeks after sampling, compared to soil dried & analyzed quickly after sampling**

University of Manitoba

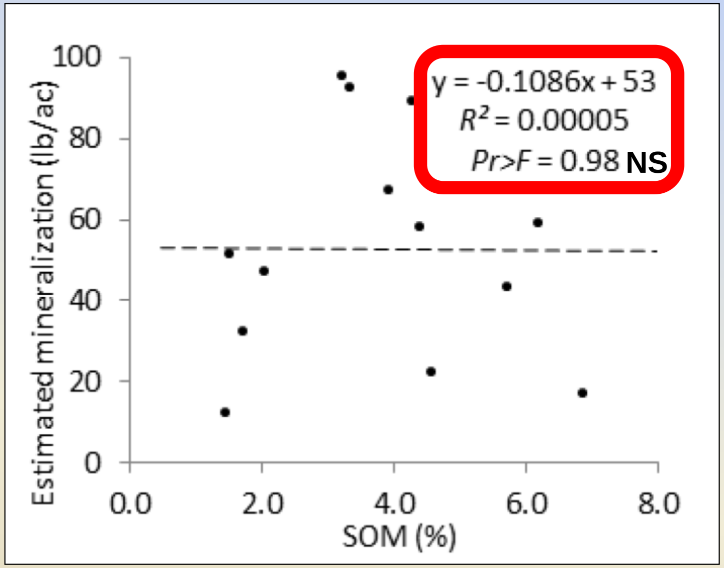
% Soil Organic Matter did not predict N mineralization in the field … due to differences in organic matter composition, environmental conditions and agronomic management

% Soil Organic Matter for Estimating N Mineralization for High Yielding Spring Wheat in the Field for 8 Site-Years



Mangin et al. 2018

% Soil Organic Matter for Estimating N Mineralization for Corn in the Field for 13 Site-Years

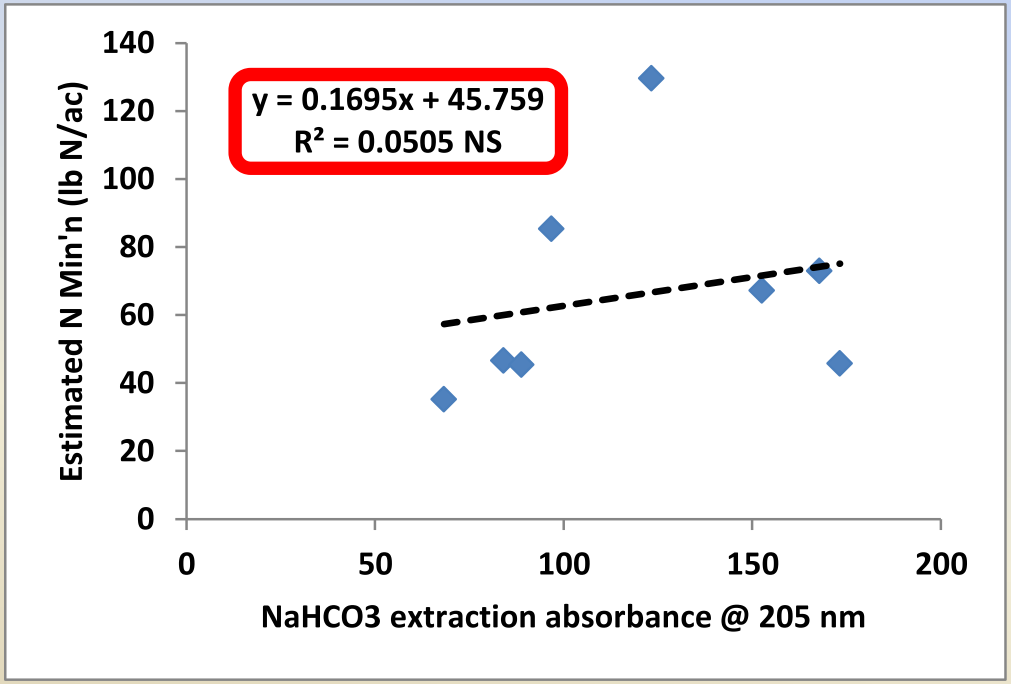


Gardiner and Flaten 2020

University of Manitoba

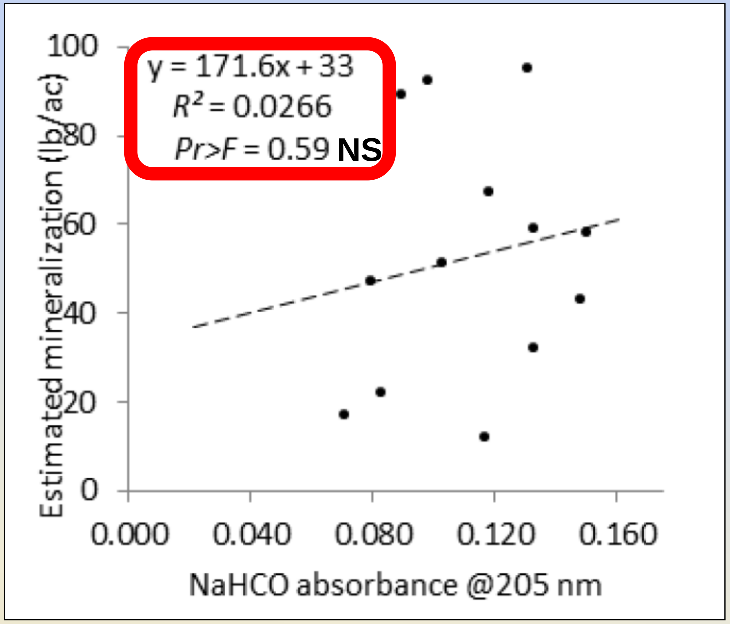
Sodium bicarbonate test did not predict N mineralization in the field … due to differences in environmental conditions and management

$NaHCO_3$ Extraction Absorbance Soil Test (205 nm) for Estimating N Mineralization for High Yielding Spring Wheat in the Field for 8 Site-Years



Mangin et al. 2018

$NaHCO_3$ Absorbance Soil Test (205 nm) for Estimating N Mineralization for Corn in the Field for 13 Site-Years



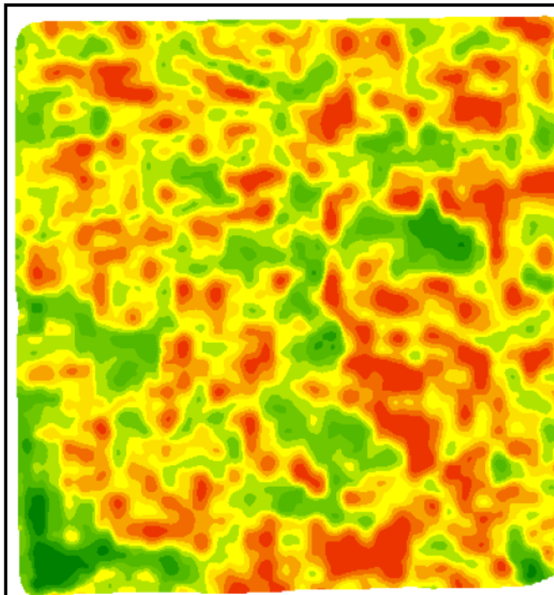
Gardiner and Flaten 2020

N fertility is often variable within fields, eg. due to landscape

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022

Zone	Acres	YieldGoal (bu/ac)	Canola Layer 1	MAP Layer 2	Urea Layer 3	Crystal Green Layer 4	Layer 5	Actual Fertility Rates	
1	10.5	30	5.3	30	160	60		82 - 39 - 0 - 0	+ 3Mg
2	18.2	35	5.1	30	170	60		86 - 39 - 0 - 0	+ 3Mg
3	25.6	40	4.9	35	180	50		91 - 38 - 0 - 0	+ 3Mg
4	27.8	45	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
5	28.3	50	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
6	24.9	50	4.8	35	190	50		95 - 38 - 0 - 0	+ 3Mg
7	15.6	50	4.8	30	190	40		93 - 32 - 0 - 0	+ 2Mg
8	7	40	5.1	20	170	30		82 - 22 - 0 - 0	+ 2Mg
9	2.5	30	5.3	15	100	15		49 - 14 - 0 - 0	+ 1Mg
10	1.2	15	4	15	50	15		26 - 14 - 0 - 0	+ 1Mg
Average:		43.6	4.9	32.5	177.4	49.1		89 - 36 - 0 - 0	



Notes: Low P in zones 1-6. Low chloride in zones 1-4. Low zinc in zones 1-2. Light salinity in zones 7-8, very high in zones 9-10.

Field Area	% Field	N(20)	N(21)	OM %	pH	P	K	S	Cl	Zn	Cu	B	Texture	Salinity	CMPT Date
														0.46	May 05, 2021
														0.45	May 05, 2021
														0.70	May 05, 2021
														1.36	May 05, 2021
														4.85	May 05, 2021

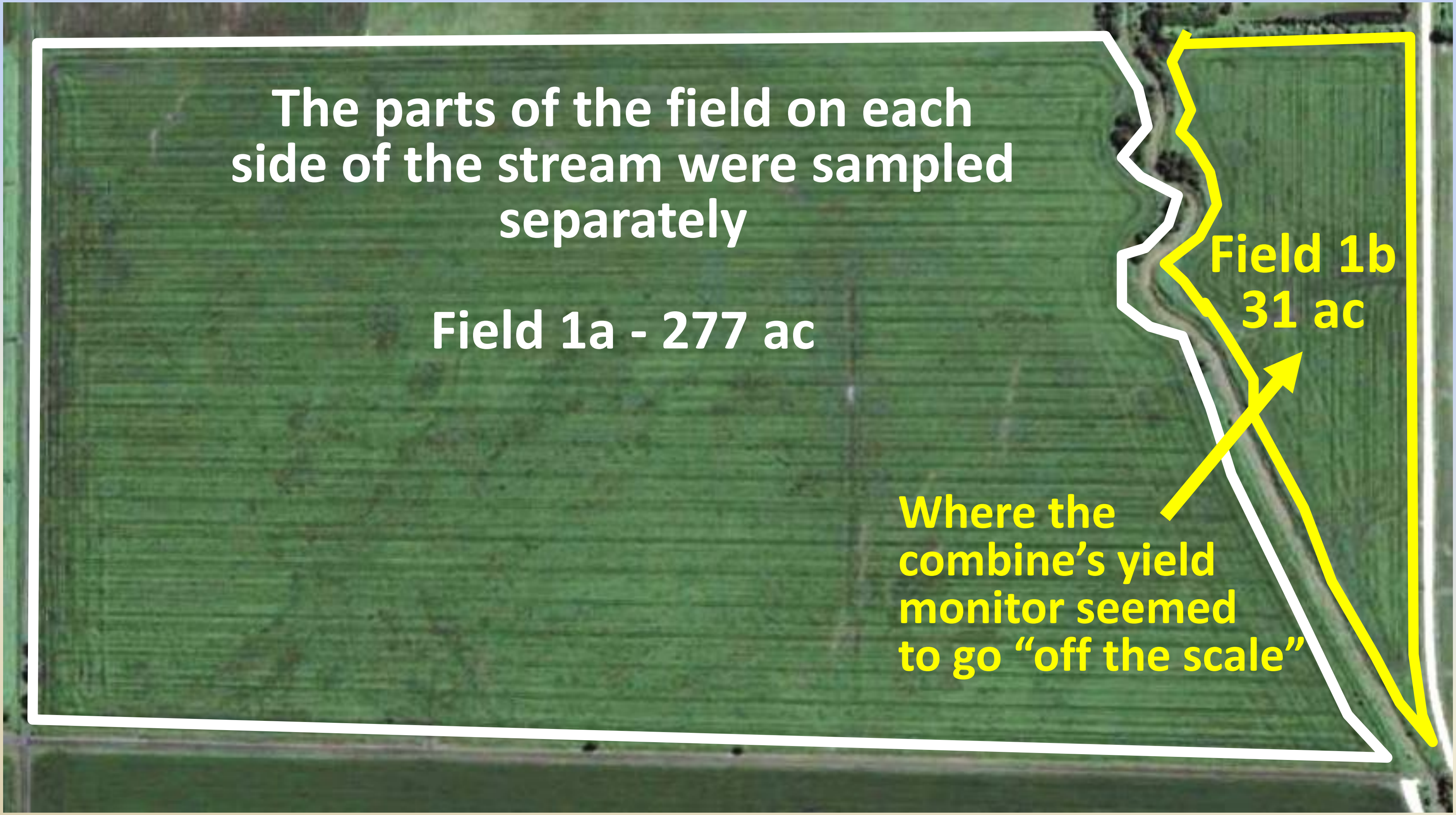
Cr

Field Area	% Field	N(20)	N(21)
zone 1,2	18	24	35
zone 3,4	33	21	33
zone 5,6	33	28	41
zone 7,8	14	17	20
zone 9,10	2	75	63

University of Manitoba

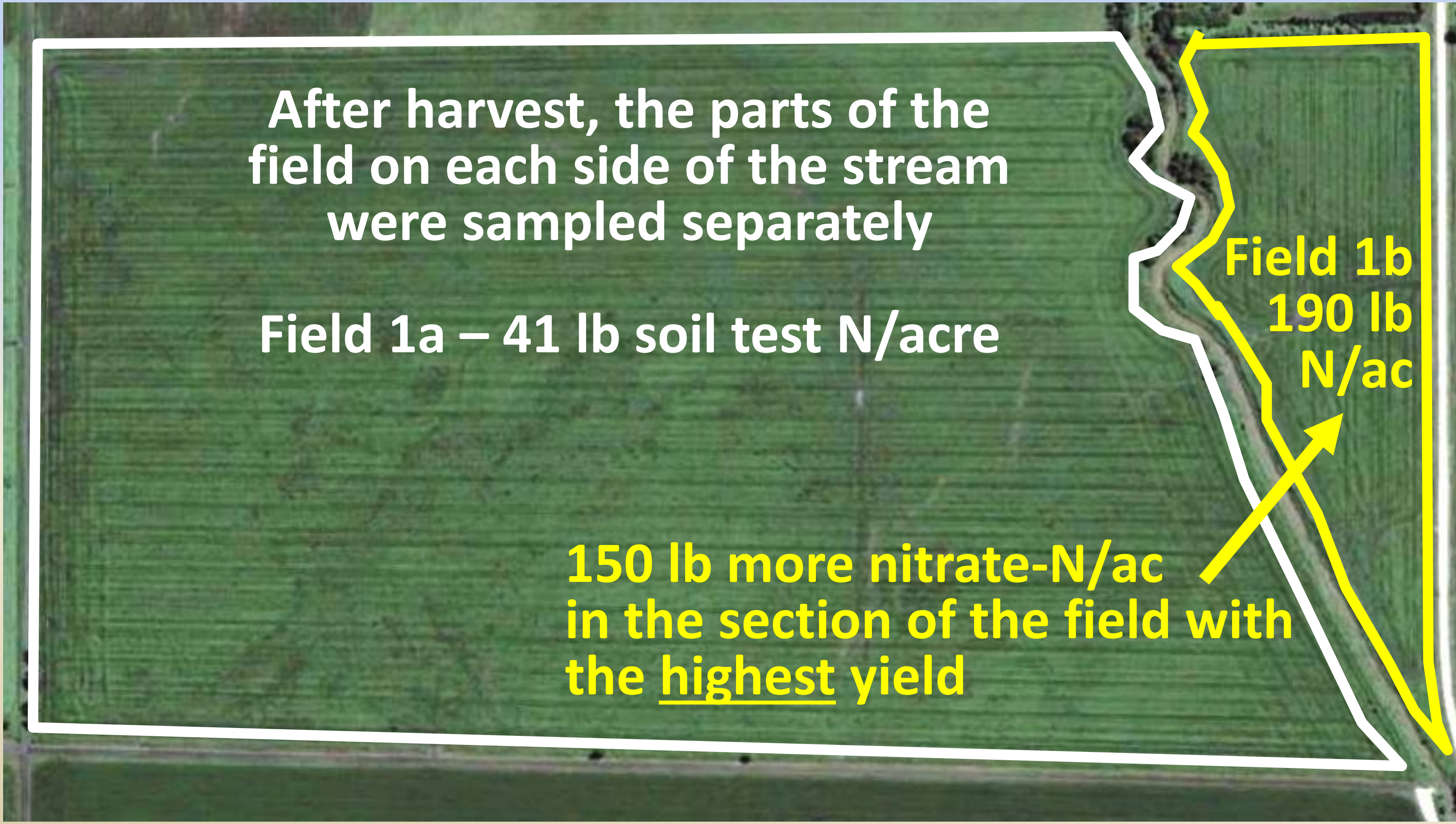
Soil test N variability due to historical management within a nearly level field of clay soil near Winnipeg

Soil test N variability due to historical management within a nearly level field of clay soil near Winnipeg



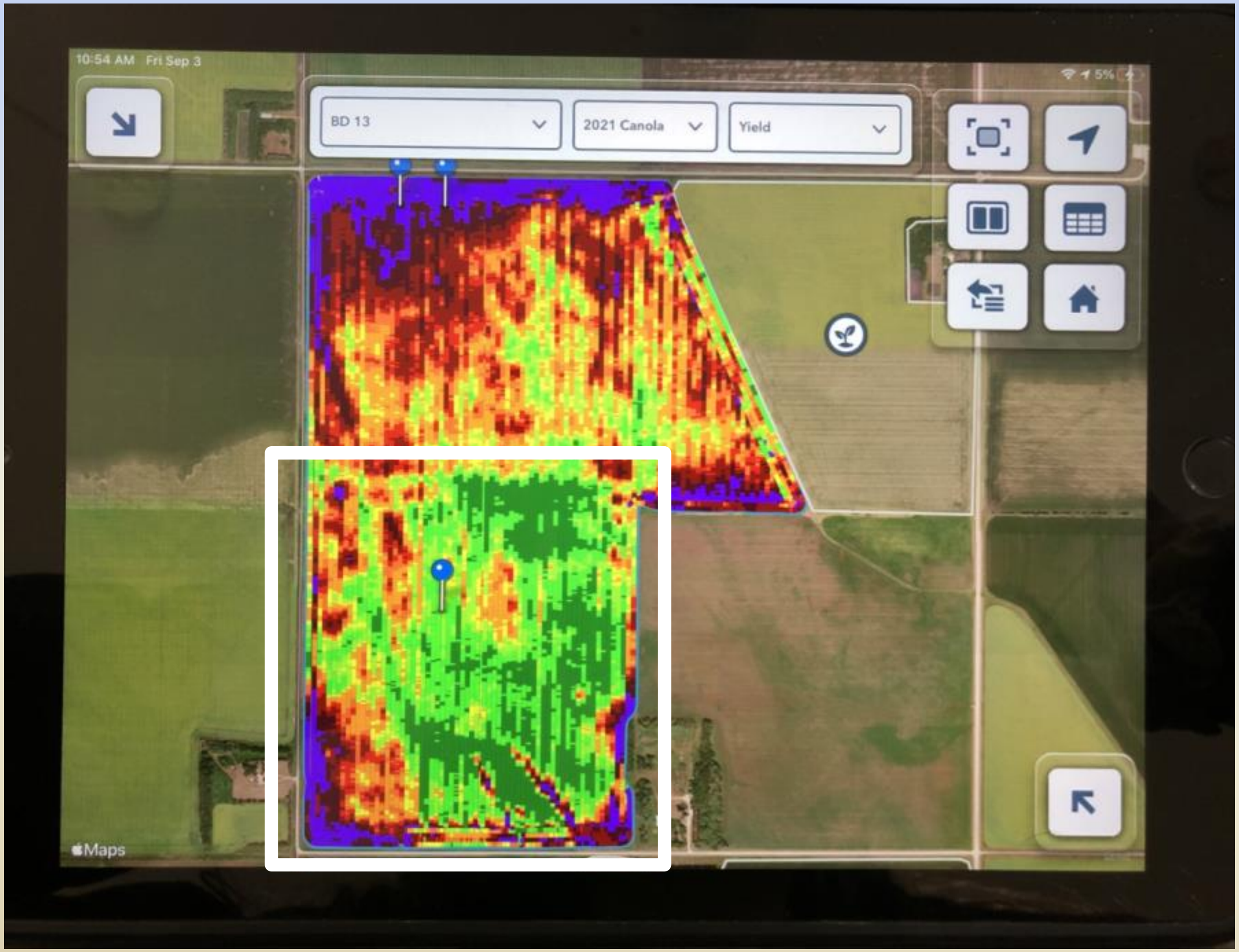
University of Manitoba

Soil test N variability due to <u>historical management</u> within a nearly level field of clay soil near Winnipeg



University of Manitoba

Variable N supply in field due to historical applications of pig manure >20 years ago at the Jochum farm near St. Francois Xavier, MB



Fiona
@fionajochum

Seeing some interesting things on our @FieldViewCanada yield maps. Not related to variety or applications. Ex: the S quarter had 🐷💩 until we sold out in the 90's! #OurFieldViewFarm #KnowMoreGrowMore @Bayer4CropsCA …now to find some more 💩🤑

5:06 PM · Sep 29, 2021 · Twitter for iPhone

3 Retweets 17 Likes

University of Manitoba

Effect of 8 years of annual applications of fertilizer* and manure** on estimated N mineralization measured at the National Centre for Livestock and the Environment long term field trials near Winnipeg***

Historic Fertility Treatments	Wheat 2016	Canola 2017	Average
	-------- lb N/acre --------		
Control - no fertilizer or manure since 2007	22	32	27
Discontinued synthetic fertilizer in 2016	68	65	67
Discontinued liquid pig manure in 2016	103	66	84
Discontinued solid pig manure in 2016	99	85	92
Discontinued solid dairy manure in 2016	141	93	117

* Fertilizer applied acc. to rec. from MB Soil Fertility Guide
** N-based rates using MB's standard formulas for manure N availability
*** Annual crop rotation

an additional
40 to 90 lb N/acre
per year compared to long term control

Adapted from Fraser and Flaten 2018 Final Report to MLMMI

University of Manitoba

Factors affecting crop response to fertilizer:

i) crop's nutrient requirements, considering crop species & variety or hybrid, environment, yield potential, etc.

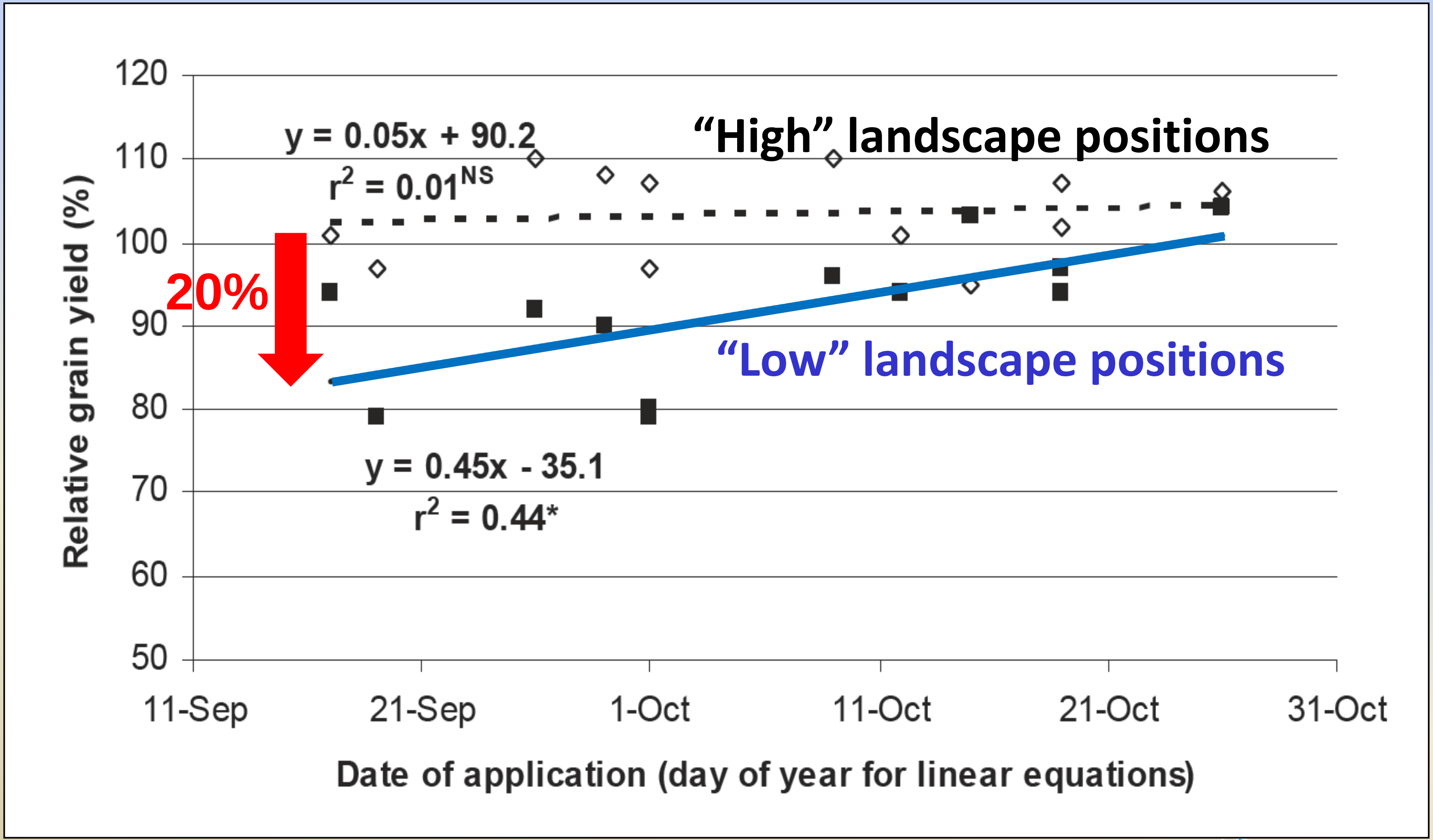
ii) crop's ability to use soil's nutrient supply

- soil's power to supply nutrients over growing season
  - chemical extractants or ion exchange membranes provide rapid analysis that imitates plant extraction of nutrients, e.g., soil test nitrate-N
  - net release of additional nutrients during the growing season … e.g., N mineralization from more decomposition than formation of soil org. matter
- **crop's ability to extract nutrients from soil … which varies with species and cultivar (especially for P & K)**

iii) fertilizer use efficiency for different sources, timings & placements

University of Manitoba

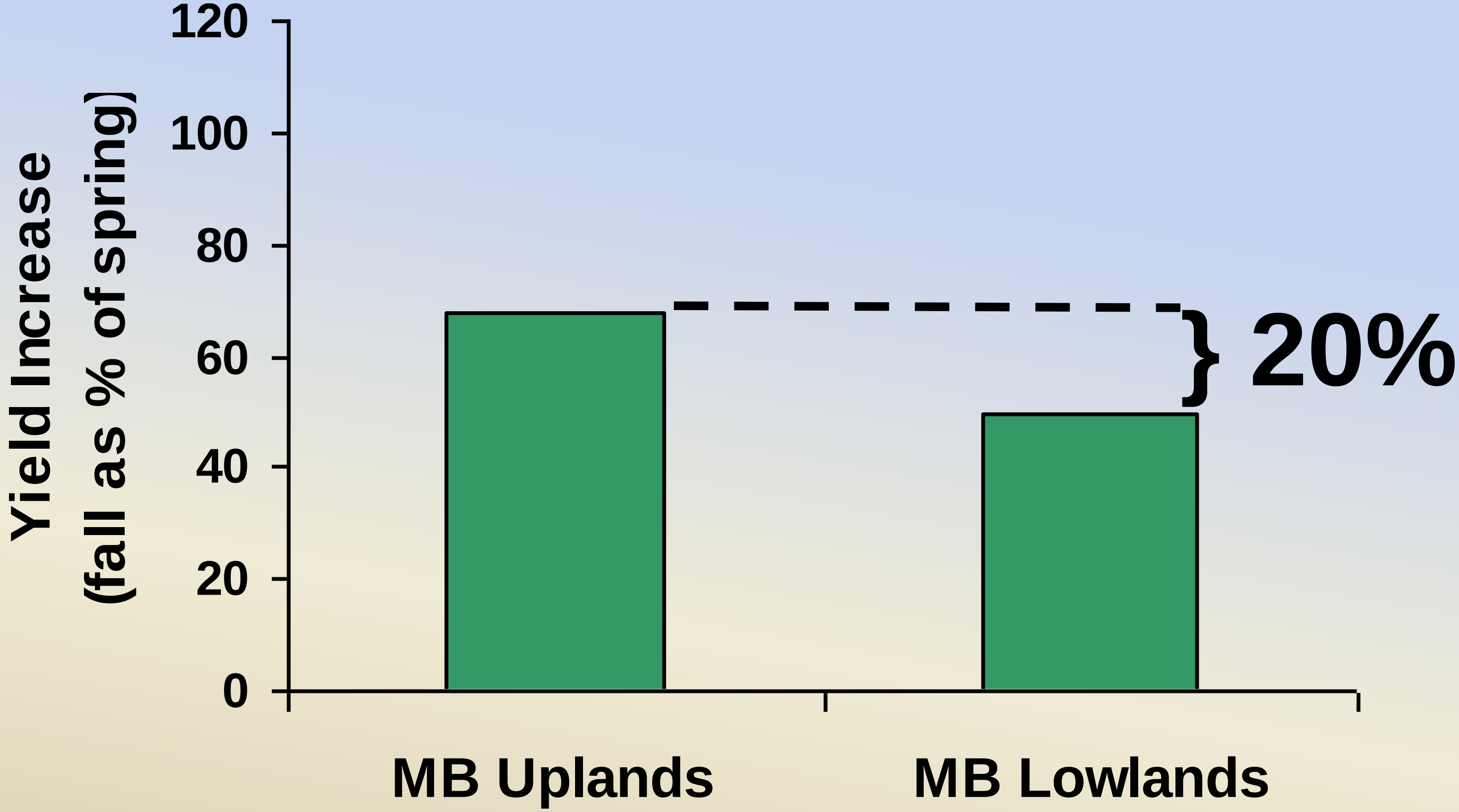
<u>Within the same fields</u>, fall-banded urea on "low" landscape positions was less efficient than spring-banded urea … especially if N was applied early in fall



Tiessen et al., Agron. J. 2008

University of Manitoba

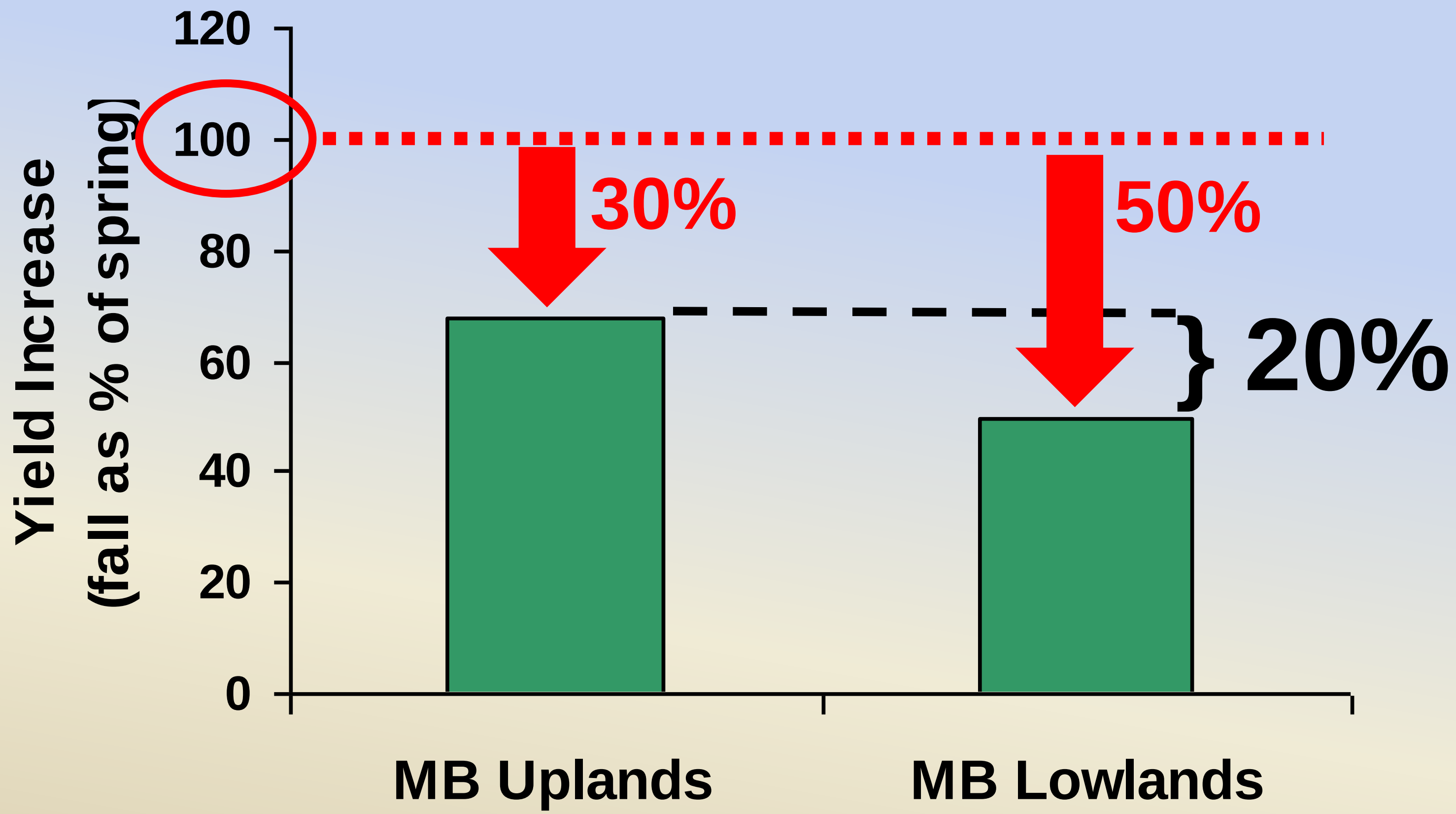
Research in the 1970s showed that barley yield increase from fall vs spring broadcast/incorporated N in Manitoba was 20% lower in the Red River Valley than in Western MB



Avg of 22 b'cast N expts. reported by Ridley MSSS 1975

Research in the 1970s showed that barley yield increase from fall vs spring broadcast/incorporated N in Manitoba was 20% lower in the Red River Valley than in Western MB

... but fall was much poorer than spring broadcast in both regions



Avg of 22 b'cast N expts. reported by Ridley MSSS 1975

University of Manitoba

Tools to Deal with Variable Crop Response to N

- Use in-field check & N-rich strips or plots to monitor N responses
- In situations where mid-season rainfall is likely, consider in-season evaluation of crop yield potential and N status to determine if midseason N applications are likely to be beneficial
- Use annual fall residual soil nitrate tests to provide:
  - a decent forecast of typical crop responses to fertilizer N … and to keep from getting too far off track with N applications for the next crop (e.g., similar to a financial budget or plan)
  - an excellent update/audit on your N “budgets” for individual fields and management zones (e.g., similar to a bank account statement)

FIRST BANK OF WIKI
Nowhere Branch
Anywhere Manitoba

CHEQUING ACCOUNT STATEMENT
Page : 1 of 1

Joe and Josephine Farmer
Box 1234
Anywhere Manitoba

Statement period	Account No.
2003-10-09 to 2003-11-08	00005-123-456-7

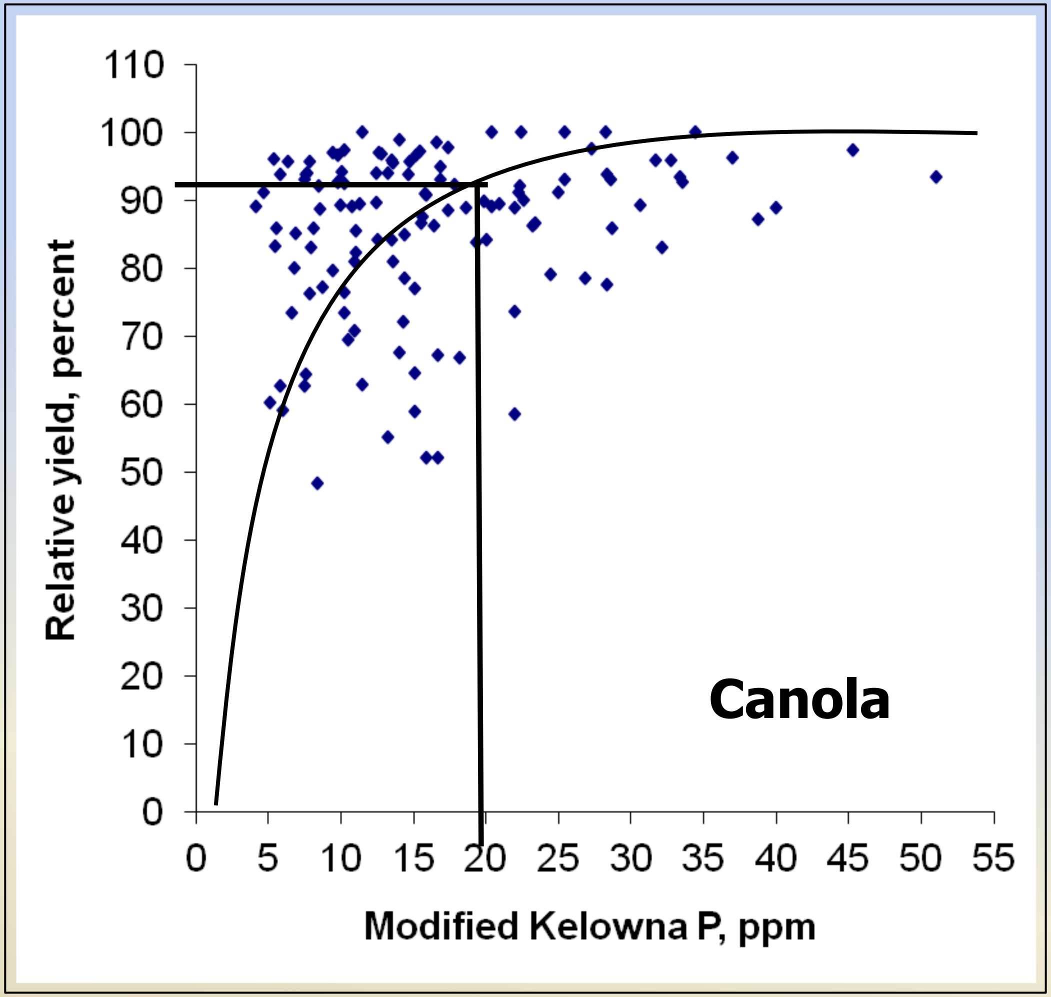
Date	Description	Ref.	Withdrawals	Deposits	Balance

P Dealing with variability in crop response to P fertilizer and P fertility

University of Manitoba

P fertilizer responses and critical soil test P thresholds under field conditions are not precise

- Alberta data show a critical level of 20-25 ppm STP for <u>average</u> of 10% increase in yield
- Above this level, only maintenance (crop removal) application would be required

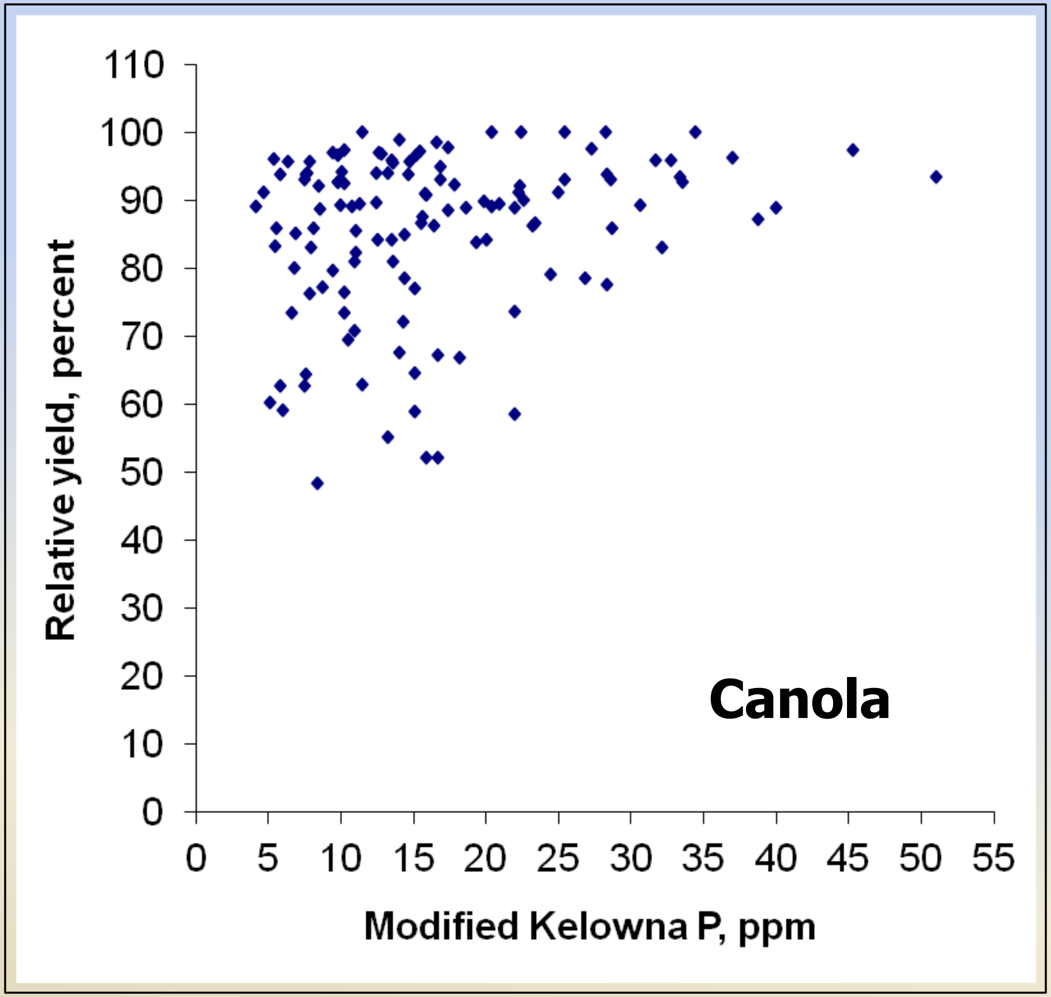


Ross McKenzie, Alberta Agric.

University of Manitoba

P fertilizer responses and critical soil test P thresholds under field conditions are not precise

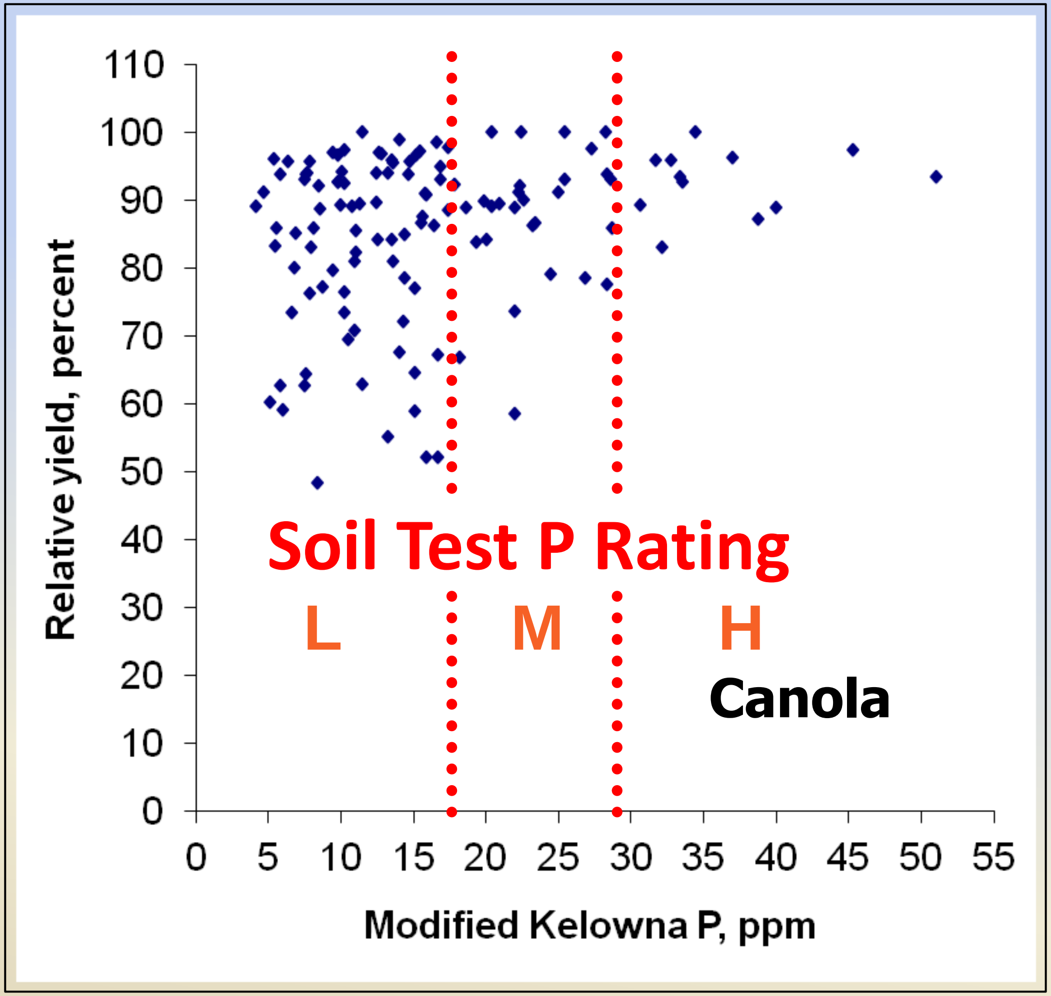
- **Alberta data show a critical level of 20-25 ppm STP for <u>average</u> of 10% increase in yield**
- **Above this level, only maintenance (crop removal) application would be required**
- **But the variability was large, even for the same crop**



Ross McKenzie, Alberta Agric.

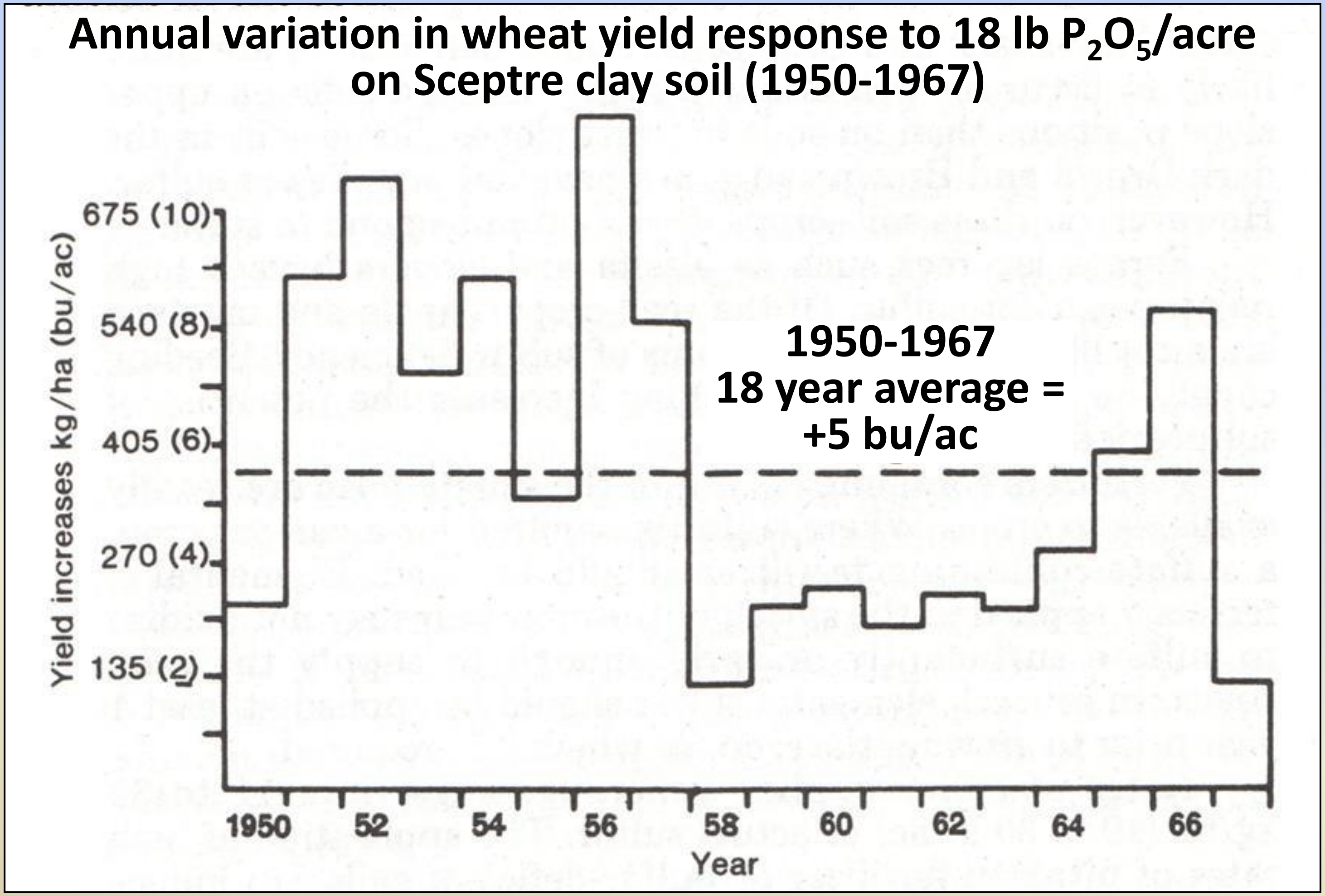
P fertilizer responses and critical soil test P thresholds under field conditions are not precise

- Given the large variability, a <u>probability</u> approach may be more realistic than a "<u>response curve</u>" … ie. soil test P rated at low, medium, or high … based upon high, medium, and low probability of a response to P



Ross McKenzie, Alberta Agric.

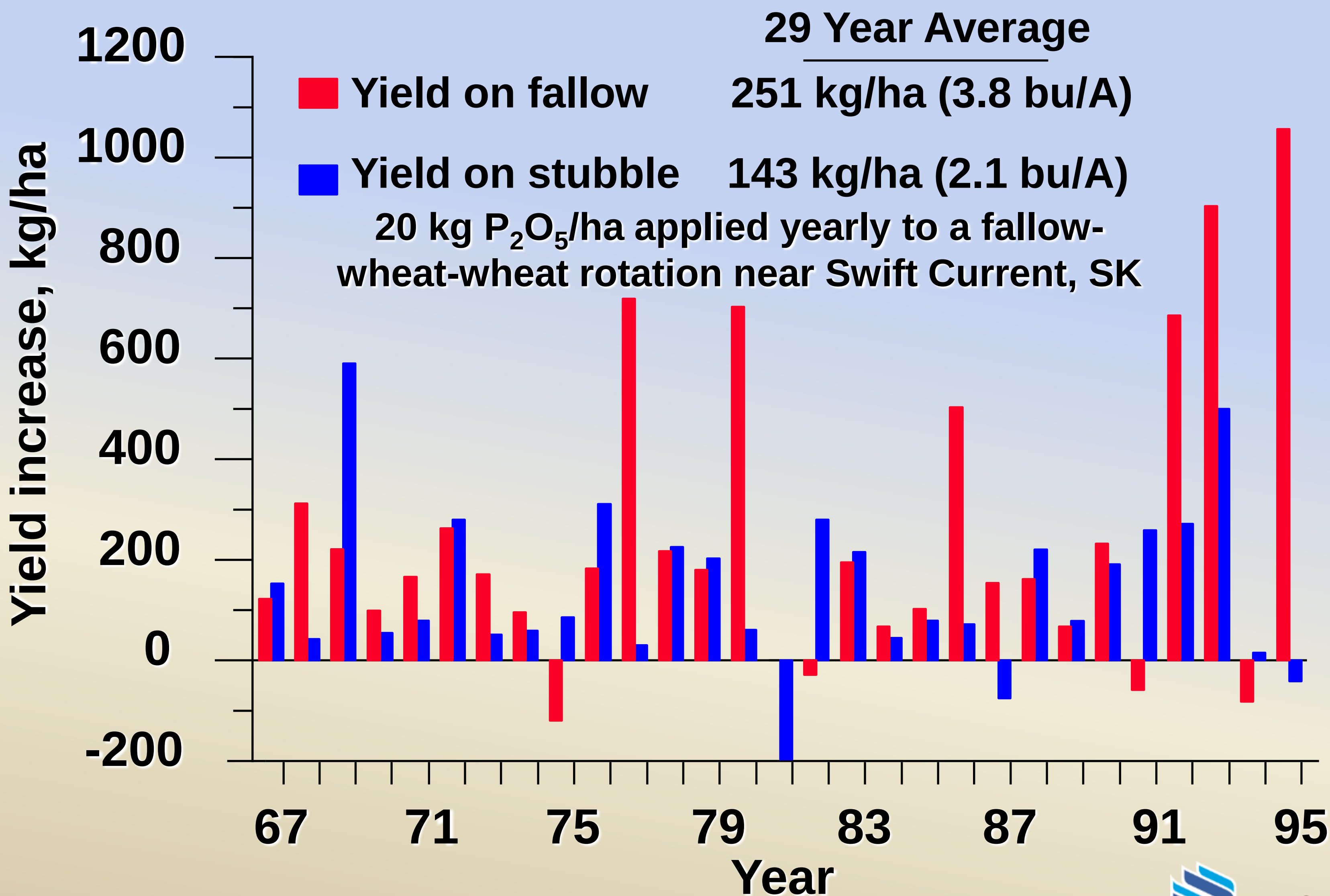
Year to year differences in moisture and temperature conditions result in highly variable response to P … even in the same soil



Guide to Farm Practice in Saskatchewan 1987

University of Manitoba

Yield response to P is highly variable from year to year ... and from one crop phase to another ... in the same soil



Adapted from Campbell, C. A., Zentner, R. P., Selles, F., Jefferson, P. G., McConkey, B. G., Lemke R. and Blomert, B. J. 2005. Long-term effect of cropping system and nitrogen and phosphorus fertilizer on production and nitrogen economy of grain crops in a Brown Chernozem. Can. J. Plant Sci. 85: 81–93.

University of Manitoba

Probability of cereal crop response to fertilizer P drops below 50% at Olsen soil test P levels greater than ~ 15 ppm

Manitoba P Response Probabilities for Cereals and Hay Crops

Available P (ppm Olsen)		Number of Experiments	% Responding to Fertilizer P
0-5	V. Low	15	100
5-12	Low-Med	50	62
12-18	Med-High	16	56
>18	High-VH	14	29
Overall		95	63

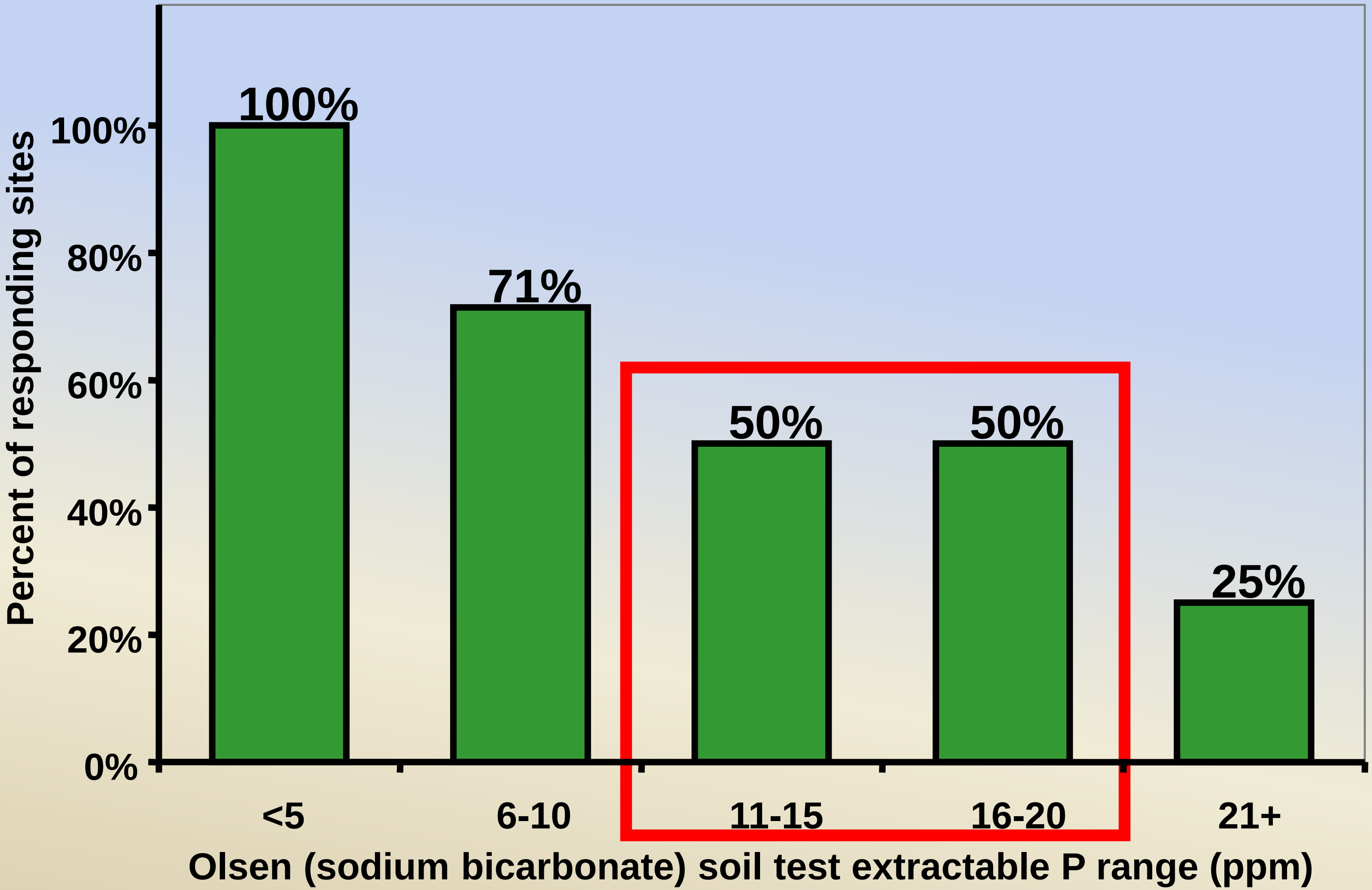
Hedlin, U of M,

Saskatchewan P Response Probabilities

Soil Test P 0-6 inch (ppm)	(lb/A)	Recommended Fertilizer Rate (lb P_2O_5/A)	Probability of Yield Response (%)
0-5	0-10	35-40	>75
5-10	11-20	30-35	50-75
10-15	21-30	25-30	50
15-30	31-60	15-20	25-50
>30	>60	0-15	less than 25

University of Manitoba

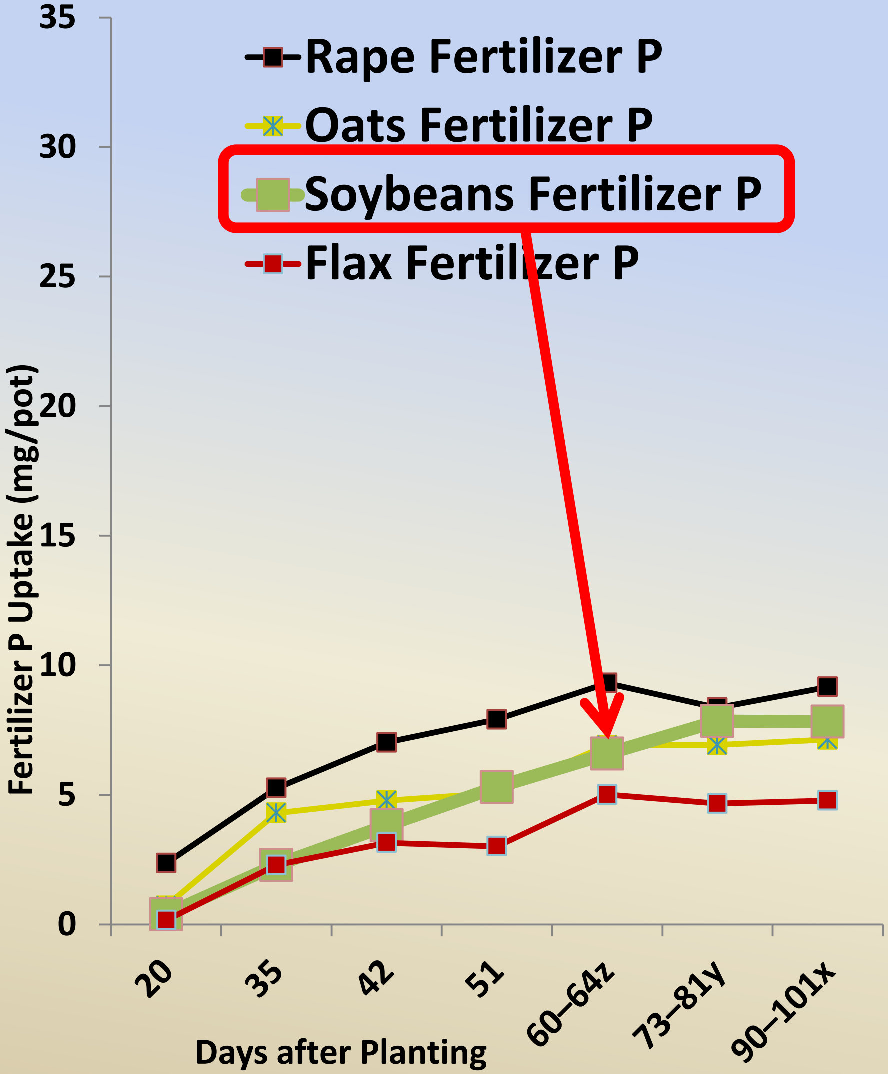
P Response Probabilities for Westco Studies with Spring Wheat in AB, SK and MB 1988-1995

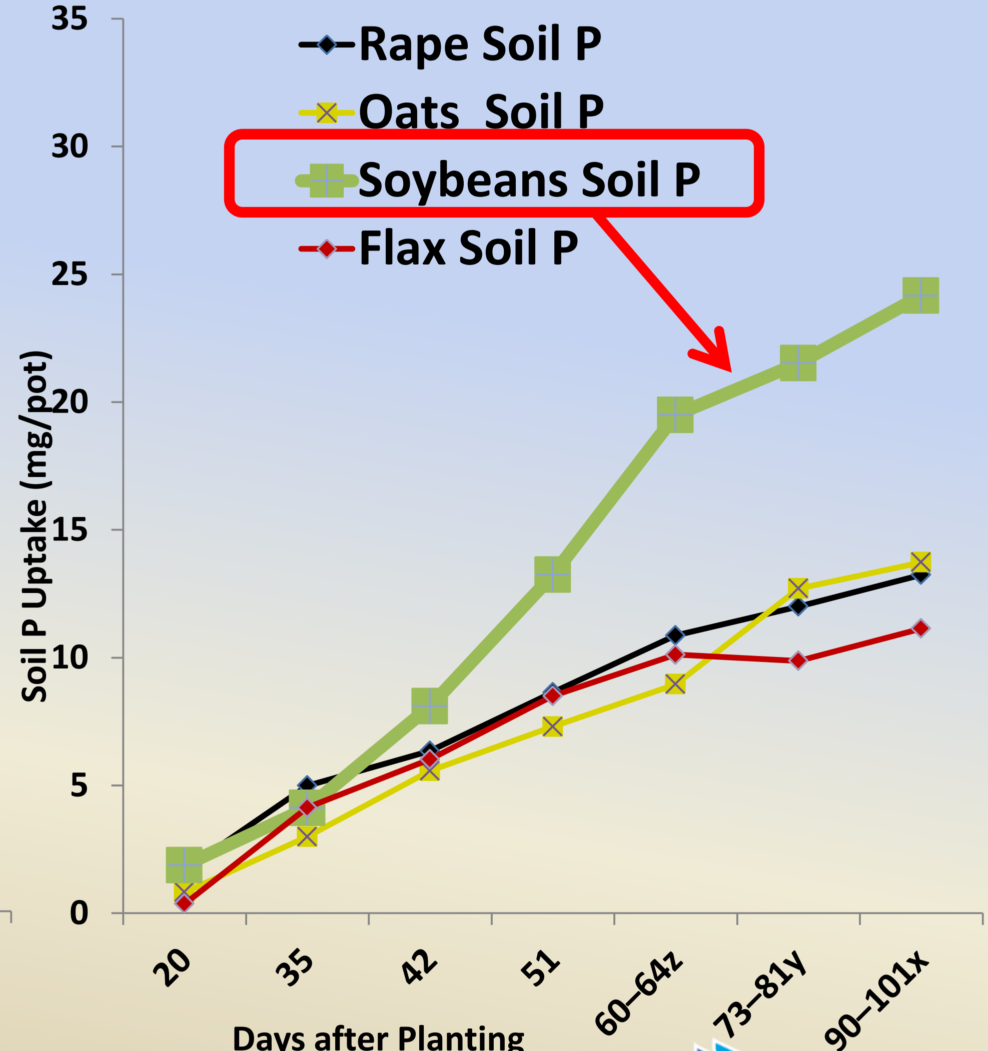


Karamanos et al., 47 site years in AB, SK, MB 1989-1995
CJPS 90:265

University of Manitoba

P response also varies with crop species – e.g. soybeans are more efficient than other crops for feeding on <u>soil</u> P

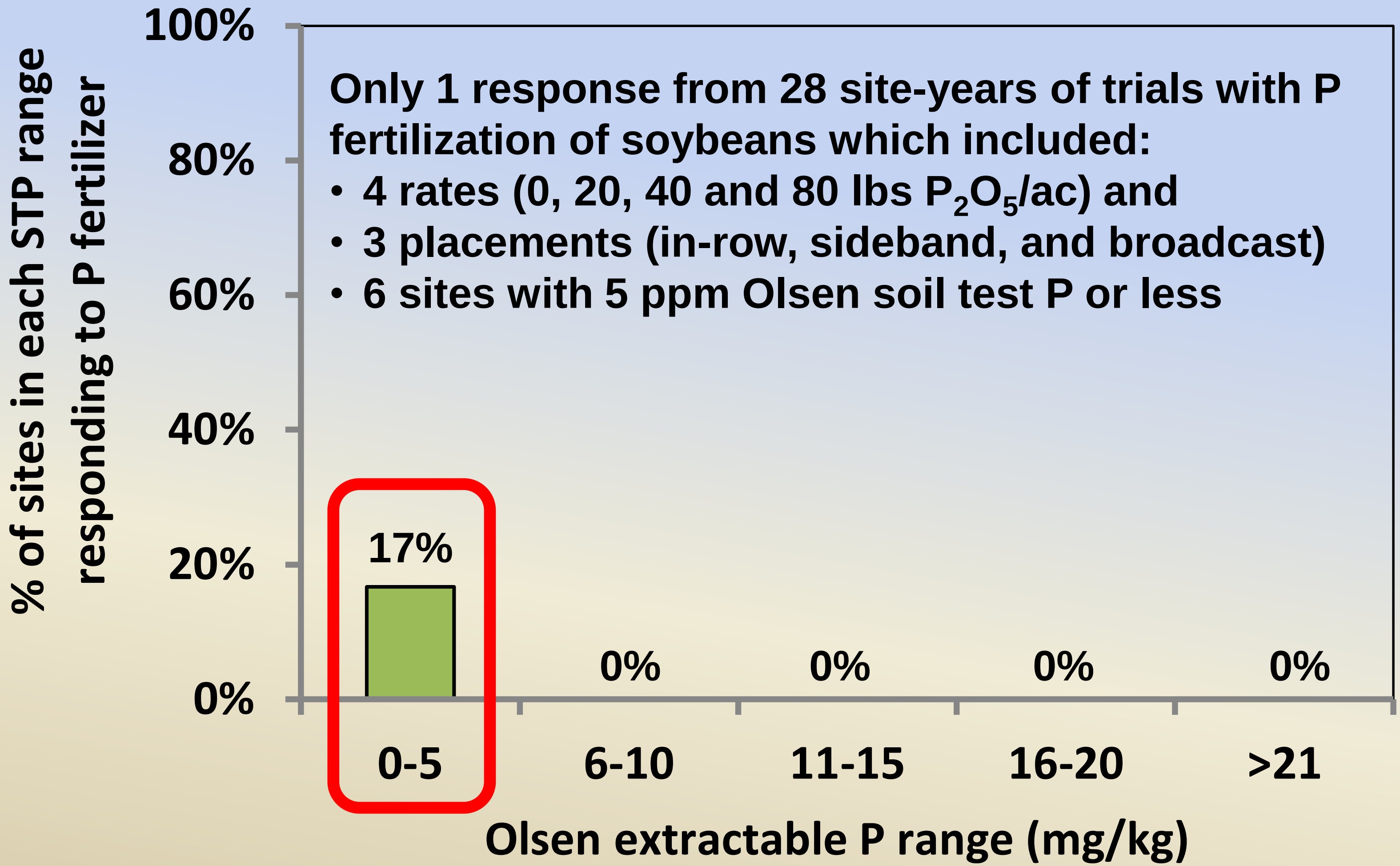




(Kalra and Soper 1968)

University of Manitoba

P response probabilities were very low for U of MB studies with soybeans in Manitoba (2013-2015)

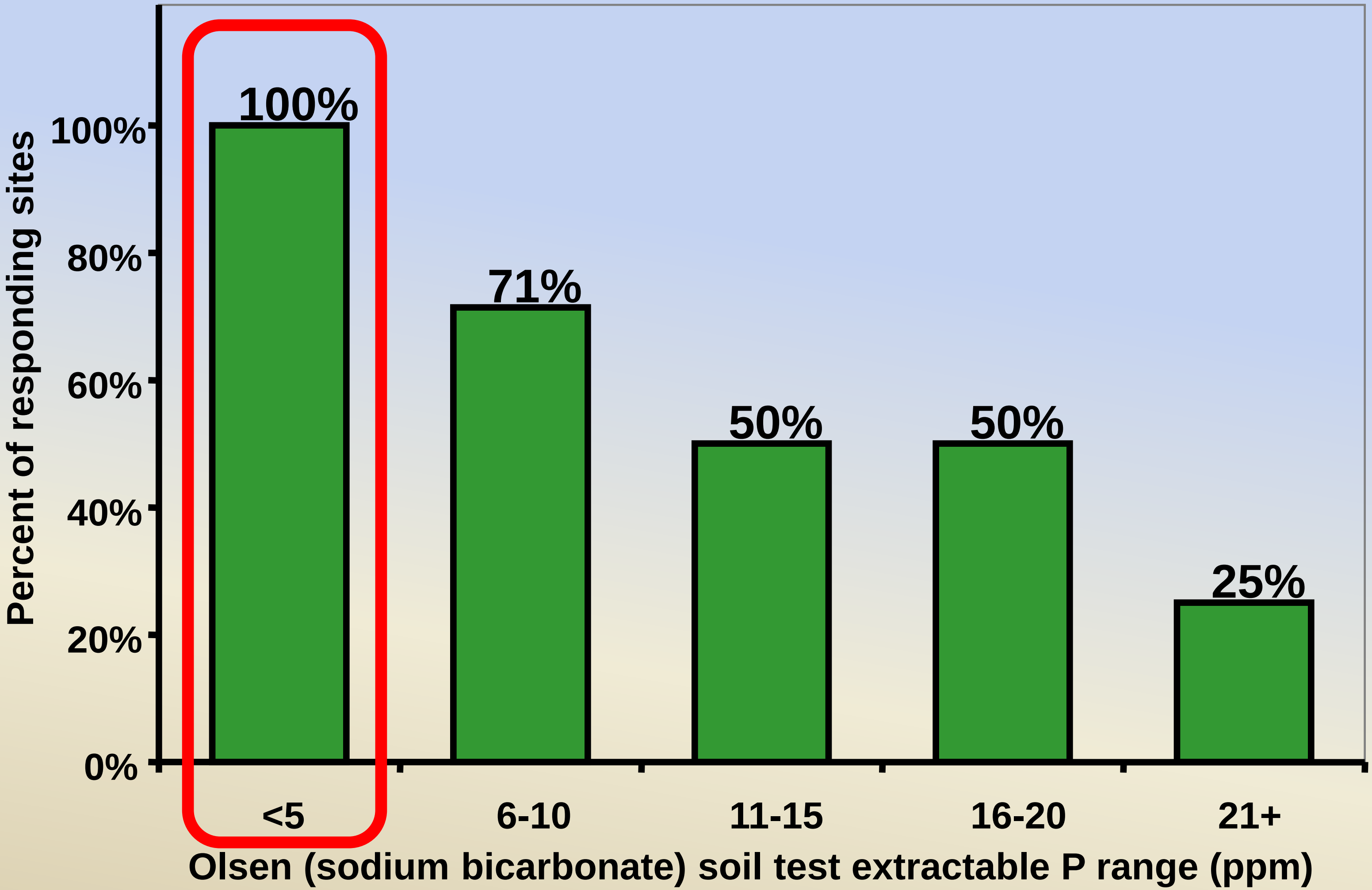


Gustavo Bardella 2016, U of MB MSc Thesis

https://mspace.lib.umanitoba.ca/handle/1993/31688

University of Manitoba

P Response Probabilities for Westco Studies with Spring Wheat in AB, SK and MB 1988-1995



Karamanos et al., 47 site years in AB, SK, MB 1989-1995
CJPS 90:265

University of Manitoba

P response to side-banded starter P in corn can be large (Magda Rogalsky 2017, U of MB M.Sc. Thesis)

⬆ 2 x Early Season Biomass

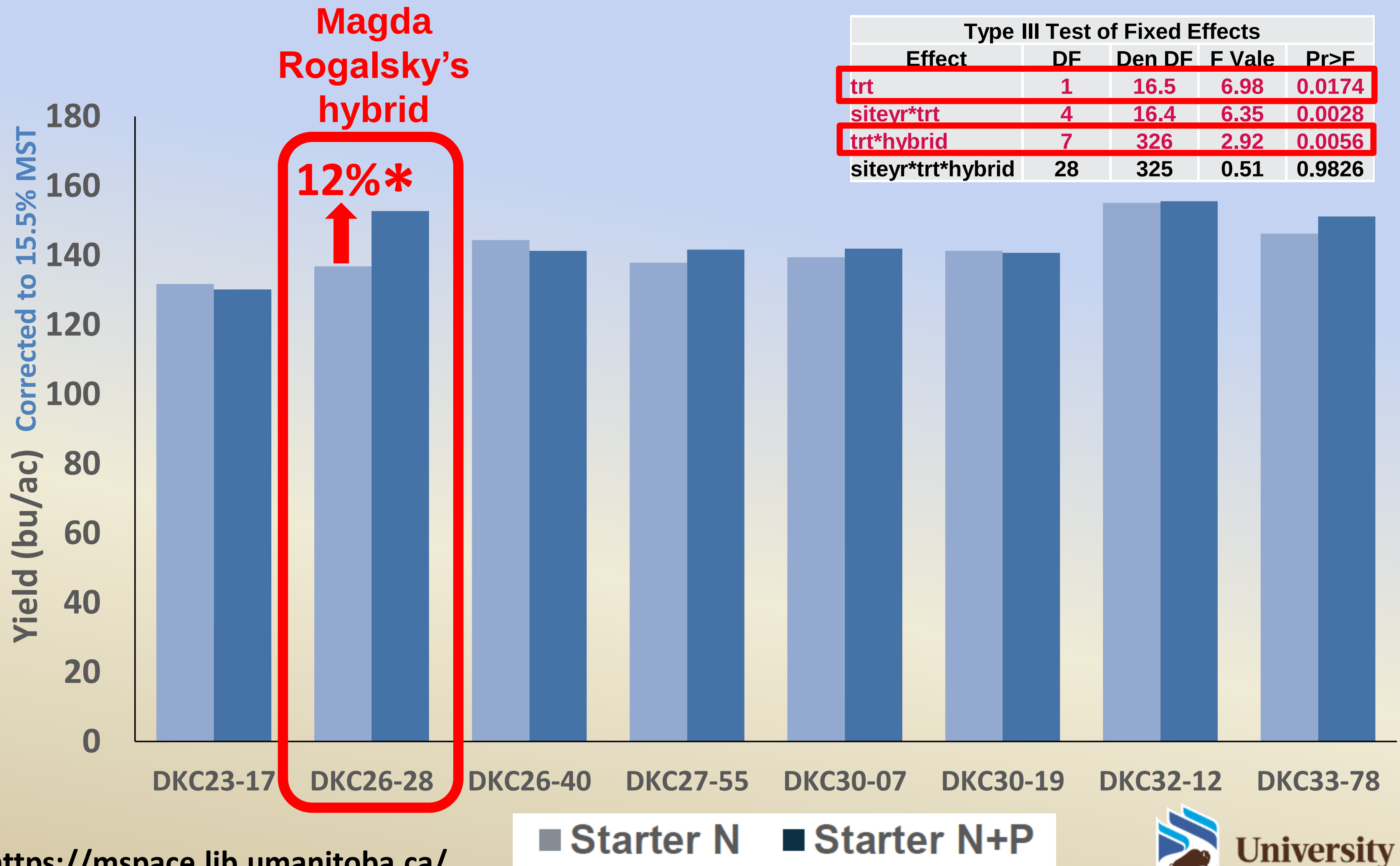
⬆ Up to 1 Week Accelerated Maturity

⬇ 2-3% Grain moisture
⬆ 10% Grain Yield

https://mspace.lib.umanitoba.ca/handle/1993/32462

University of Manitoba

… but even though starter P is beneficial for corn, overall response varies among hybrids (Tran, U of M M.Sc. thesis)

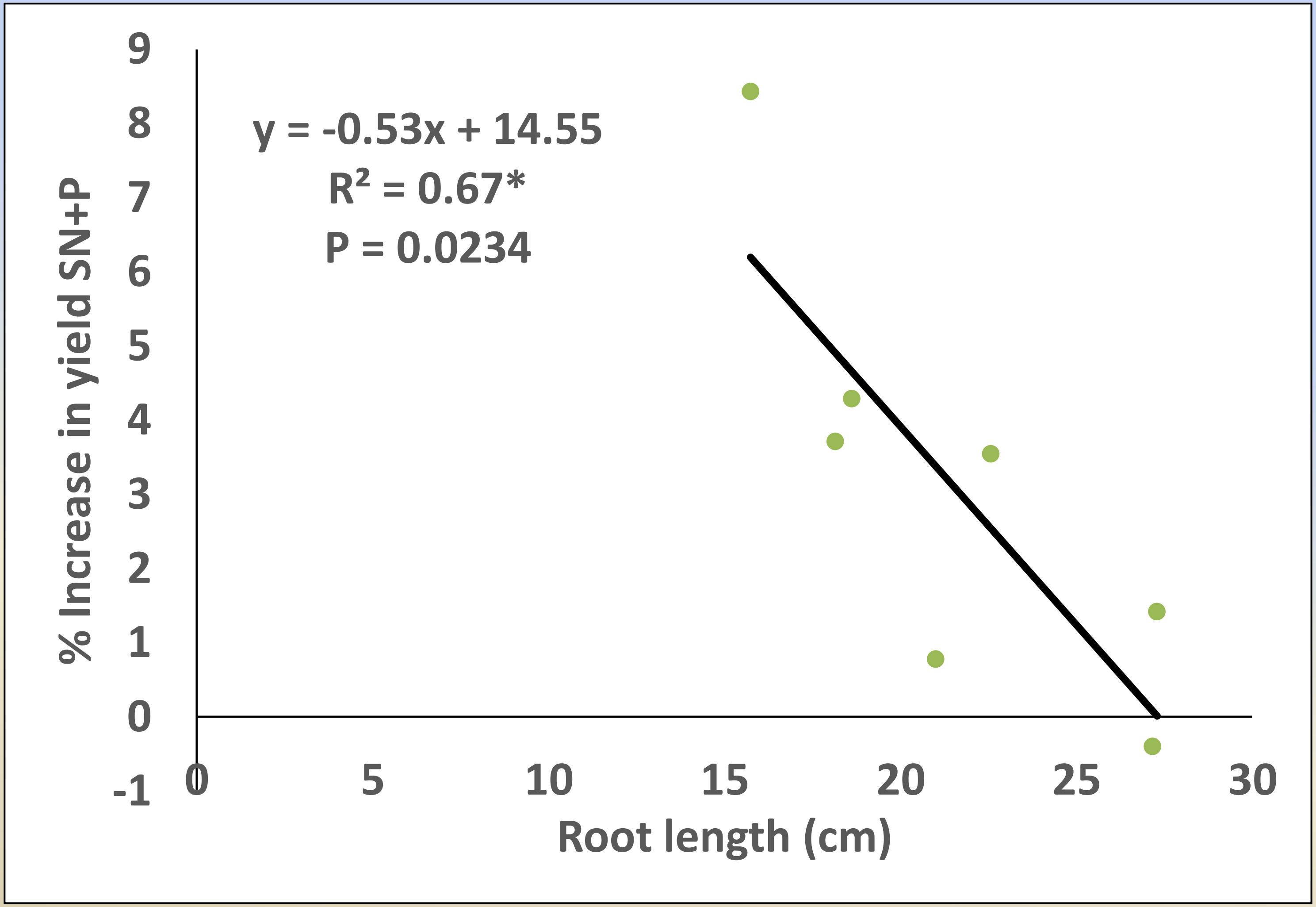


Type III Test of Fixed Effects				
Effect	DF	Den DF	F Vale	Pr>F
trt	1	16.5	6.98	0.0174
siteyr*trt	4	16.4	6.35	0.0028
trt*hybrid	7	326	2.92	0.0056
siteyr*trt*hybrid	28	325	0.51	0.9826

https://mspace.lib.umanitoba.ca/handle/1993/36850

University of Manitoba

Corn hybrid seedlings with greater root length are less likely to respond to 10-34-0 starter fertilizer



Dickson Tran. MSc Thesis, Univ. of Manitoba

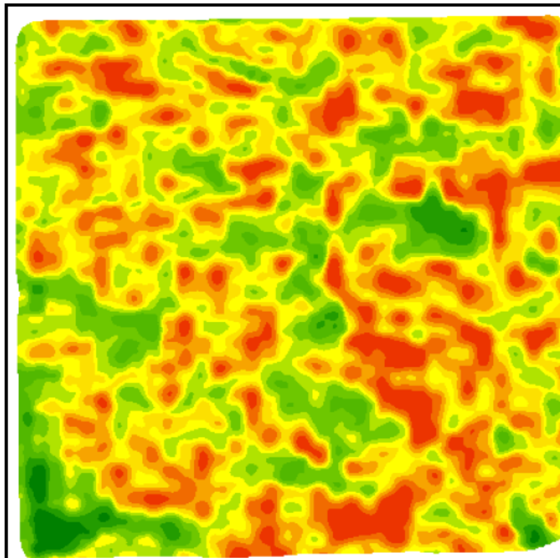
University of Manitoba

P fertility is often variable within fields

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022

Zone	Acres	YieldGoal (bu/ac)	Canola Layer 1	MAP Layer 2	Urea Layer 3	Crystal Green Layer 4	Layer 5	Actual Fertility Rates	
1	10.5	30	5.3	30	160	60		82 - 39 - 0 - 0	+ 3Mg
2	18.2	35	5.1	30	170	60		86 - 39 - 0 - 0	+ 3Mg
3	25.6	40	4.9	35	180	50		91 - 38 - 0 - 0	+ 3Mg
4	27.8	45	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
5	28.3	50	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
6	24.9	50	4.8	35	190	50		95 - 38 - 0 - 0	+ 3Mg
7	15.6	50	4.8	30	190	40		93 - 32 - 0 - 0	+ 2Mg
8	7	40	5.1	20	170	30		82 - 22 - 0 - 0	+ 2Mg
9	2.5	30	5.3	15	100	15		49 - 14 - 0 - 0	+ 1Mg
10	1.2	15	4	15	50	15		26 - 14 - 0 - 0	+ 1Mg
	Average:	43.6	4.9	32.5	177.4	49.1		89 - 36 - 0 - 0	



Notes: Low P in zones 1-6. Low chloride in zones 1-4. Low zinc in zones 1-2. Light salinity in zones 7-8, very high in zones 9-10.

Field Area	% Field	N(20)	N(21)	OM %	pH	P
zone 1,2	18	24	35	4.0	7.9	8 (Olsen)
zone 3,4	33	21	33	4.3	7.8	11 (Olsen)
zone 5,6	33	28	41	5.5	7.7	12 (Olsen)
zone 7,8	14	17	20	6.2	7.8	27 (Olsen)
zone 9,10	2	75	63	5.4	8.0	45 (Olsen)

Field Area		% Field	P
zone 1,2	High area	18	8 (Olsen)
zone 3,4		33	11 (Olsen)
zone 5,6		33	12 (Olsen)
zone 7,8		14	27 (Olsen)
zone 9,10	Low area	2	45 (Olsen)

CropPro SWAT map provided by Dwight

University of Manitoba

Tools to Deal with Variable Crop Response to P

Soil test for P every year to estimate needs & monitor trends … then use one of two P management strategies:

Short-Term Sufficiency

- Choose a rate based on typical economic yield response in the year of application only, eg. typical Provincial rec'ns that seed-place a low rate of P … often less than crop removal … so P fertility declines over the long term
- Suitable for short-term land tenure and when P costs are high relative to crop prices

Long-Term Sustainability

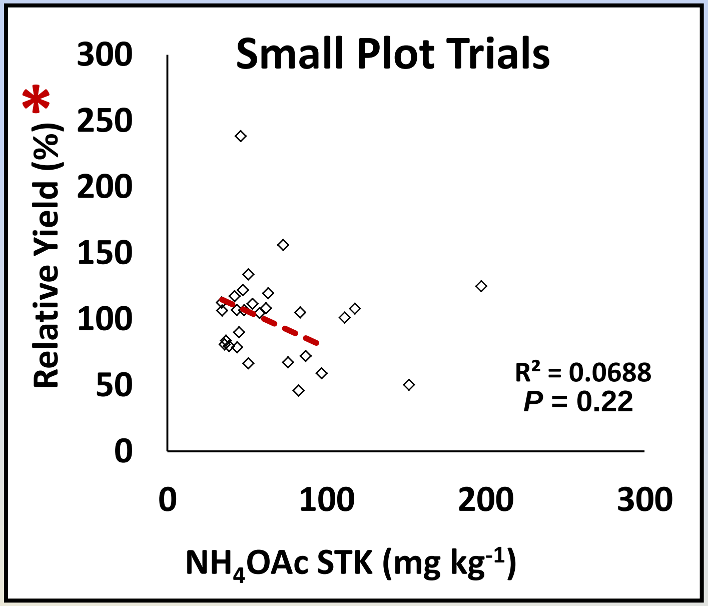
- Long-term economics considers residual P value for P fertility
- Aim P applications to reach and maintain soil test P target range (e.g., 10-20 ppm Olsen P):
  - Build on low-P soils
  - Deplete on high-P soils
- Suitable for long-term land tenure and when P costs are low relative to crop prices

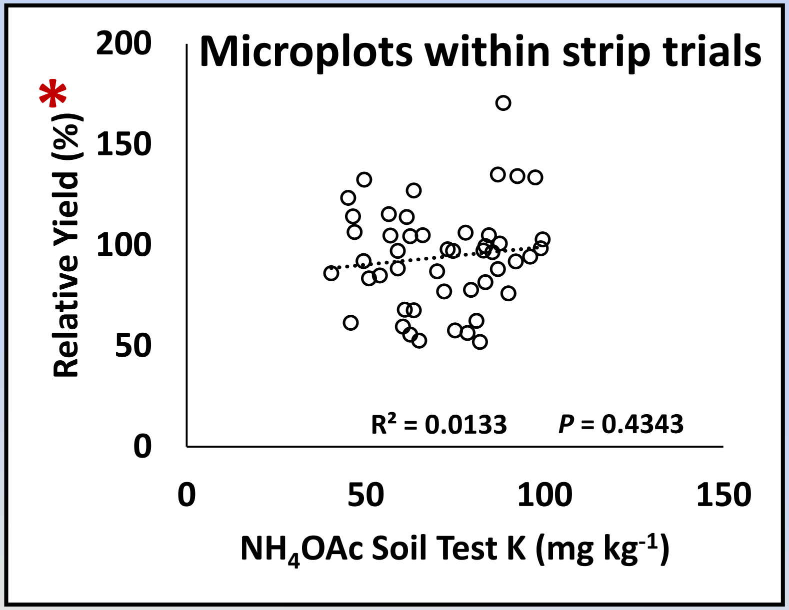
University of Manitoba

K Dealing with variability in crop response to K fertilizer and K fertility

University of Manitoba

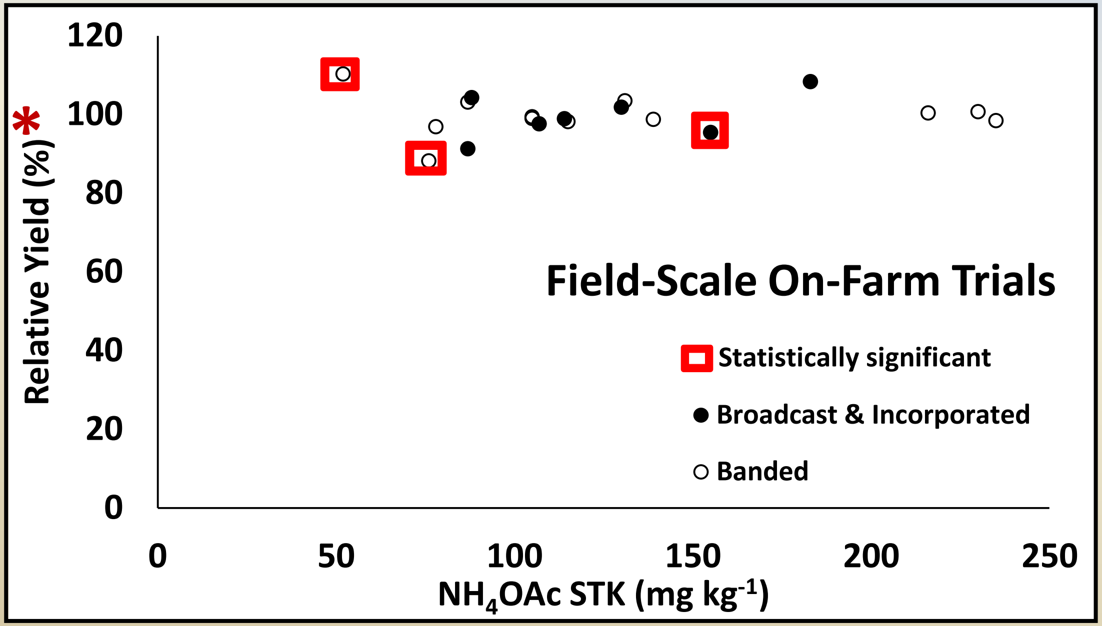
K response varies with crop species … e.g., no evidence of soybean yield response to K fertilization at STK < 100 ppm





* Relative yield for check vs fertilized plots, in percent

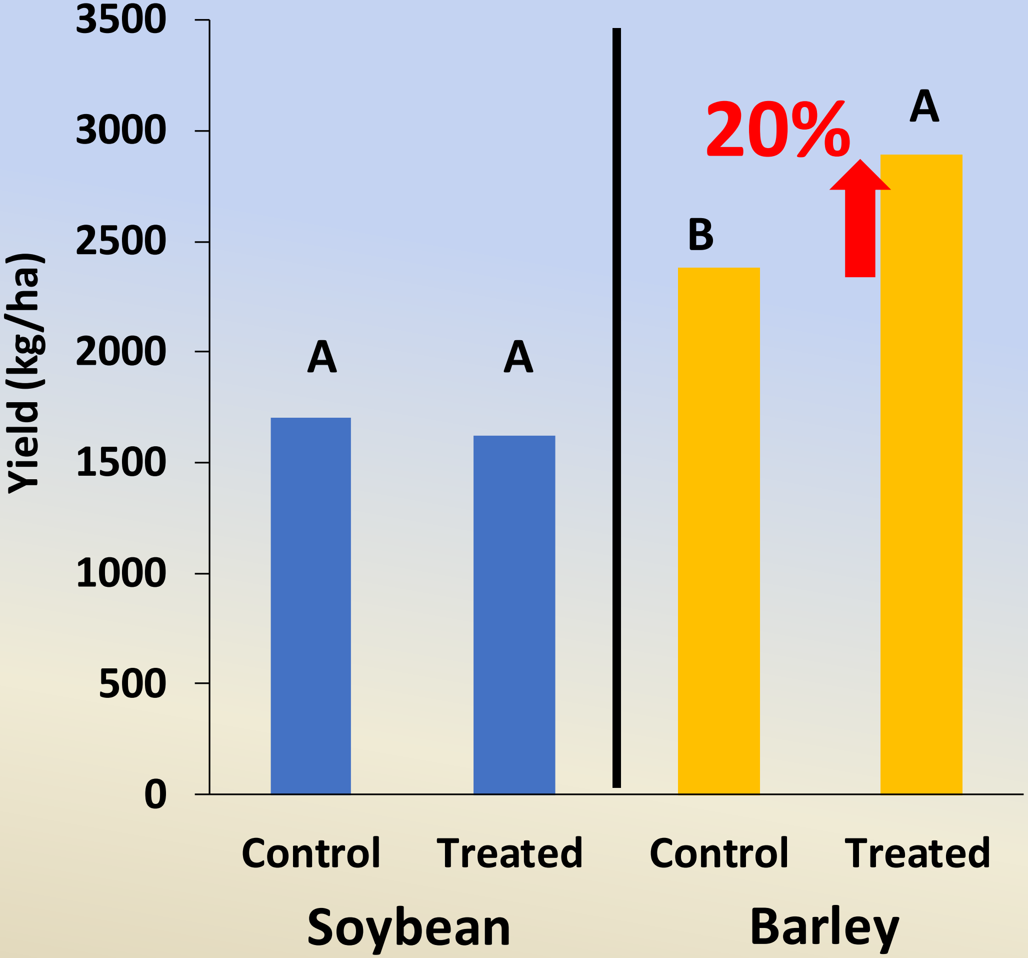
Data from Megan Bourns' MSc thesis



University of Manitoba

K Fertilization for Soybeans vs. Barley
Megan Bourns, M.Sc. Project

- Barley/soybean K response study conducted in 2018 at same sites as soybean fertilization study
- K fertilization increased barley yields by 20%, but no response in soybean at the same sites
- Current recommend'ns, based on soil test K worked well for barley, but not for soybean



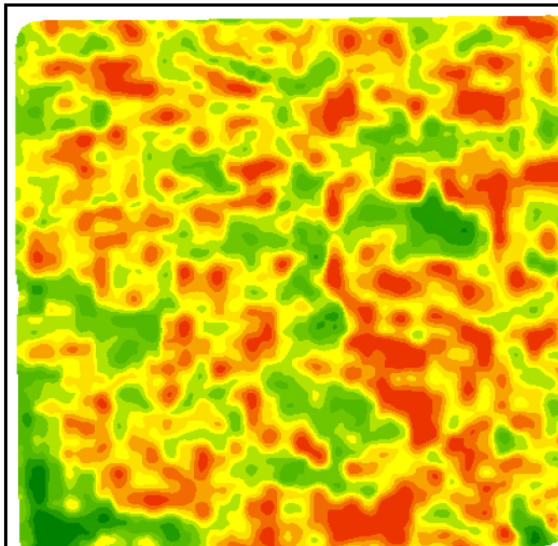
University of Manitoba

K fertility is often patchy within fields

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022

Zone	Acres	YieldGoal (bu/ac)	Canola Layer 1	MAP Layer 2	Urea Layer 3	Crystal Green Layer 4	Layer 5	Actual Fertility Rates	
1	10.5	30	5.3	30	160	60		82 - 39 - 0 - 0	+ 3Mg
2	18.2	35	5.1	30	170	60		86 - 39 - 0 - 0	+ 3Mg
3	25.6	40	4.9	35	180	50		91 - 38 - 0 - 0	+ 3Mg
4	27.8	45	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
5	28.3	50	4.8	35	180	50		91 - 38 - 0 - 0	+ 3Mg
6	24.9	50	4.8	35	190	50		95 - 38 - 0 - 0	+ 3Mg
7	15.6	50	4.8	30	190	40		93 - 32 - 0 - 0	+ 2Mg
8	7	40	5.1	20	170	30		82 - 22 - 0 - 0	+ 2Mg
9	2.5	30	5.3	15	100	15		49 - 14 - 0 - 0	+ 1Mg
10	1.2	15	4	15	50	15		26 - 14 - 0 - 0	+ 1Mg
	Average:	43.6	4.9	32.5	177.4	49.1		89 - 36 - 0 - 0	



Notes: Low P in zones 1-6. Low chloride in zones 1-4. Low zinc in zon

Field Area	% Field	N(20)	N(21)	OM %	pH	P	K
zone 1,2	18	24	35	4.0	7.9	8 (Olsen)	249
zone 3,4	33	21	33	4.3	7.8	11 (Olsen)	253
zone 5,6	33	28	41	5.5	7.7	12 (Olsen)	335
zone 7,8	14	17	20	6.2	7.8	27 (Olsen)	400
zone 9,10	2	75	63	5.4	8.0	45 (Olsen)	304

Field Area		% Field	K
zone 1,2	High area	18	249
zone 3,4		33	253
zone 5,6		33	335
zone 7,8		14	400
zone 9,10	Low area	2	304

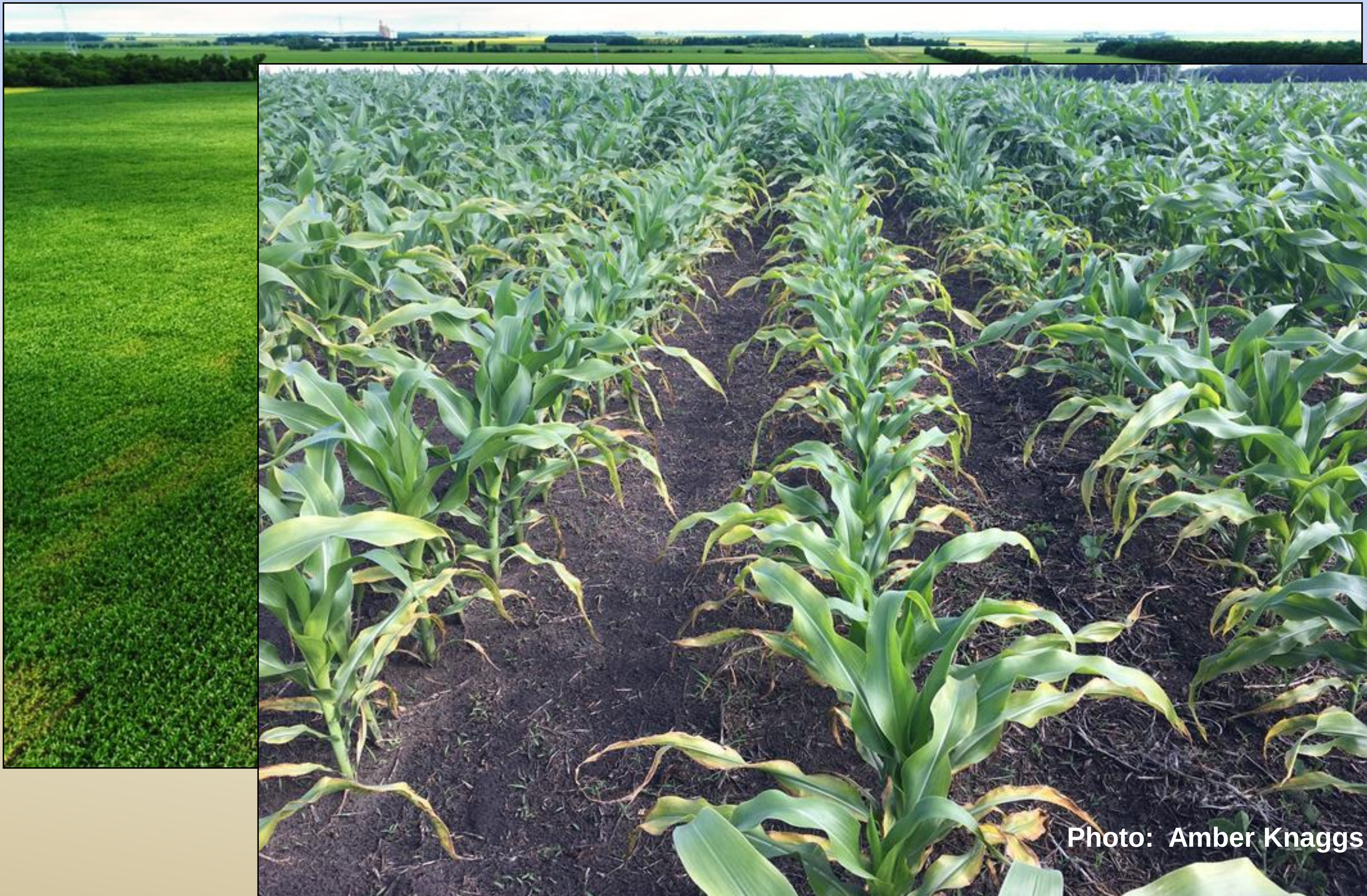
CropPro SWAT map provided by Dwight Oe

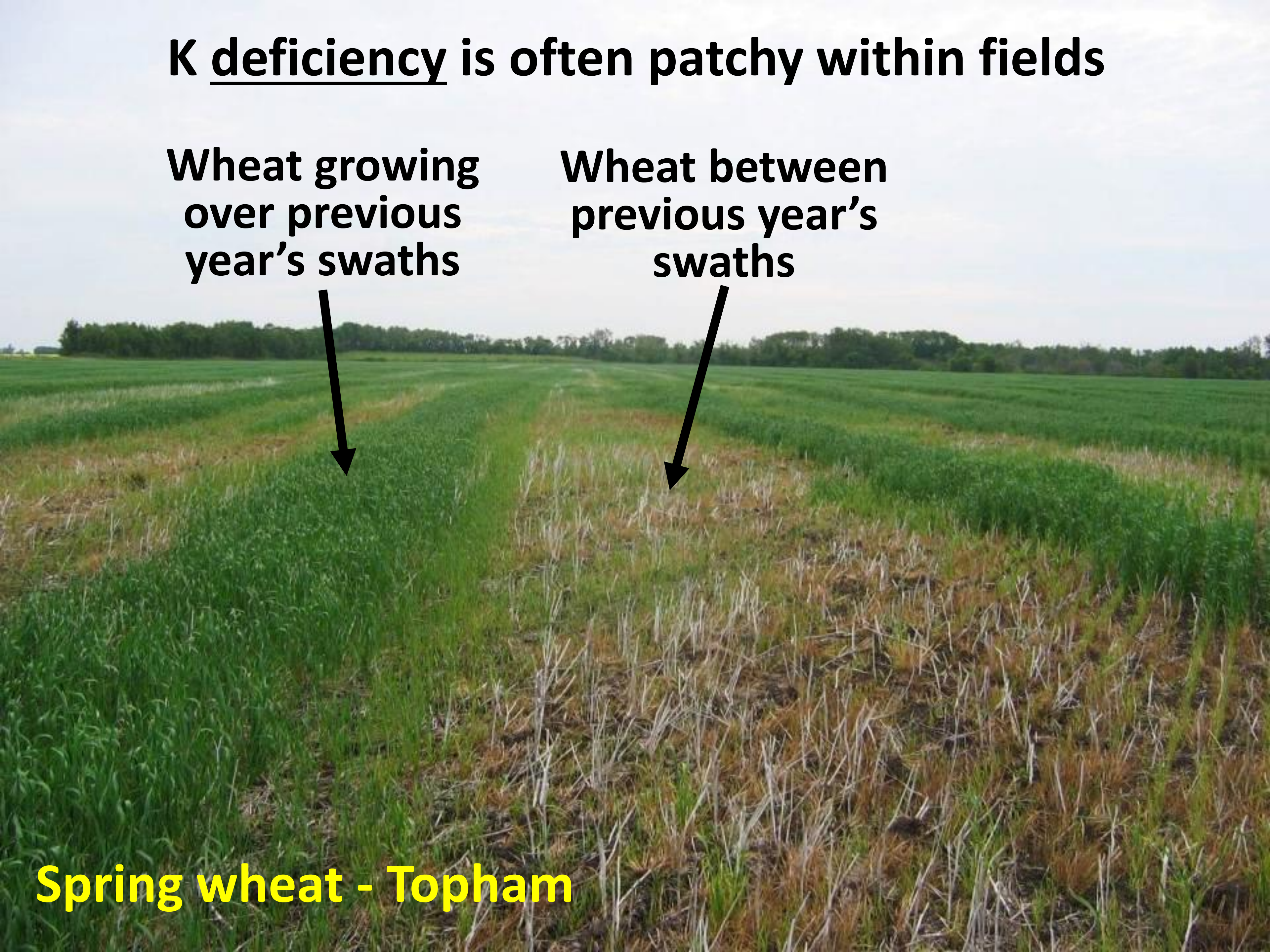
University of Manitoba

K deficiency is often patchy within fields

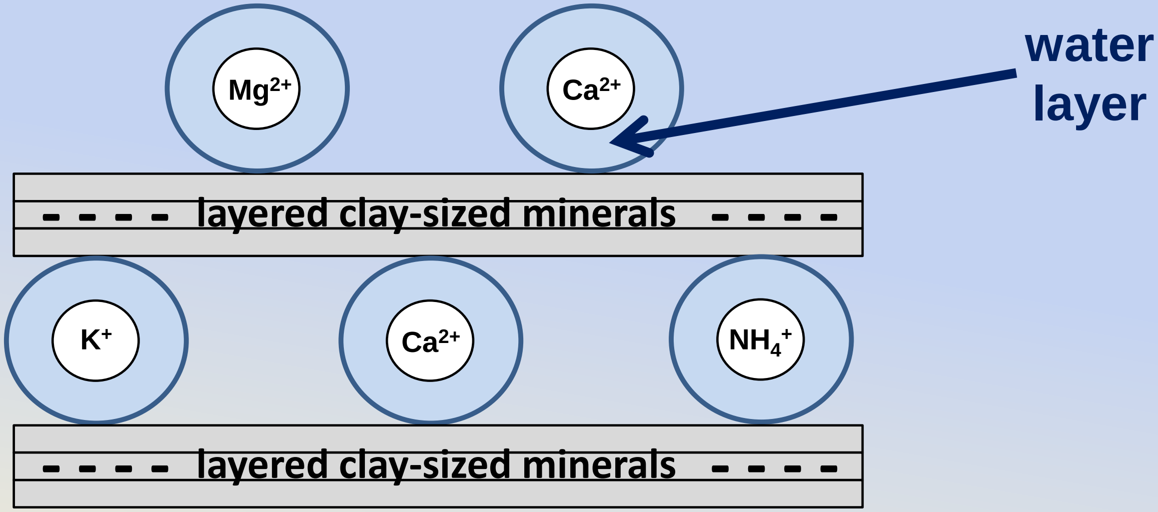
Megan Bourns, U of M M.Sc. Project

K deficiency is often patchy within fields

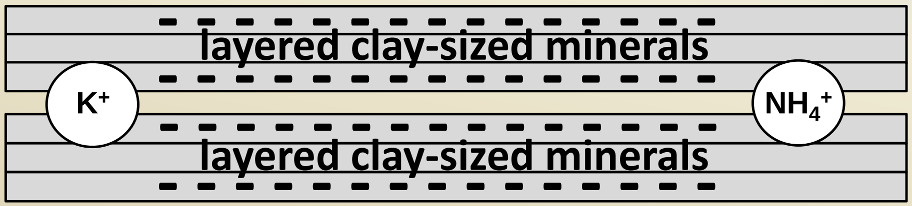



K deficiency is often patchy within fields
Wheat growing over previous year's swaths
Wheat between previous year's swaths
Spring wheat - Topham

K retention & release in soil varies with types of soil minerals, affecting interpretation of soil test K e.g. John Breker's MSc research at NDSU



exchangeable adsorption of hydrated ions



non-exchangeable adsorption of dehydrated ions

Tools to Deal with Variable Crop Response to K

- **Use in-field K-check & K-rich strips to monitor K responses across fields**
- **Use annual fall soil K tests to track trends in soil test K, especially on sandy soils**

University of Manitoba

S Dealing with variability in crop response to S fertilizer and S fertility

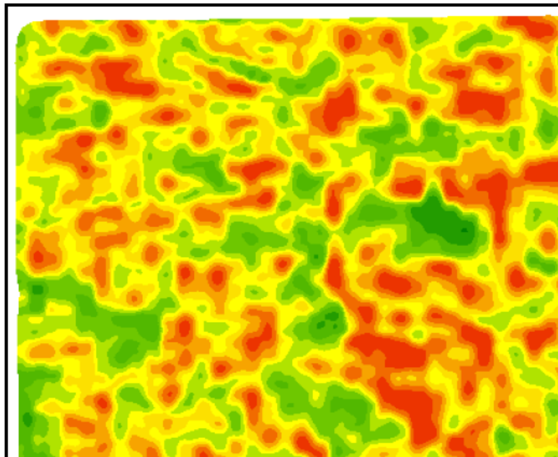
University of Manitoba

S fertility is often patchy within fields

Crop: Canola
Last Crop: Barley-Malt
Yield Goal (bu/ac) 43.6

Machine Controller: X30
Prescription File: D1MervinCanola2022

Zone	Acres	YieldGoal (bu/ac)	Canola Layer 1	MAP Layer 2	Urea Layer 3	Crystal Green Layer 4	Layer 5	Actual Fertility Rates
1	10.5	30	5.3	30	160	60		82 - 39 - 0 - 0 + 3Mg
2	18.2	35	5.1	30	170	60		86 - 39 - 0 - 0 + 3Mg
3	25.6	40	4.9	35	180	50		91 - 38 - 0 - 0 + 3Mg
4	27.8	45	4.8	35	180	50		91 - 38 - 0 - 0 + 3Mg
5	28.3	50	4.8	35	180	50		91 - 38 - 0 - 0 + 3Mg
6	24.9	50	4.8	35	190	50		95 - 38 - 0 - 0 + 3Mg
7	15.6	50	4.8	30	190	40		93 - 32 - 0 - 0 + 2Mg
8	7	40	5.1	20	170	30		82 - 22 - 0 - 0 + 2Mg
9	2.5	30	5.3	15	100	15		49 - 14 - 0 - 0 + 1Mg
10	1.2	15	4	15	50	15		26 - 14 - 0 - 0
Average:		43.6	4.9	32.5	177.4	49.1		89 - 36 - 0 - 0



Notes: Low P in zones 1-6. Low chloride in zones 1-4. Low zinc in zones 1-2. L

Field Area	% Field	N(20)	N(21)	OM %	pH	P	K	S
zone 1,2	18	24	35	4.0	7.9	8 (Olsen)	249	27
zone 3,4	33	21	33	4.3	7.8	11 (Olsen)	253	45
zone 5,6	33	28	41	5.5	7.7	12 (Olsen)	335	59
zone 7,8	14	17	20	6.2	7.8	27 (Olsen)	400	160
zone 9,10	2	75	63	5.4	8.0	45 (Olsen)	304	160

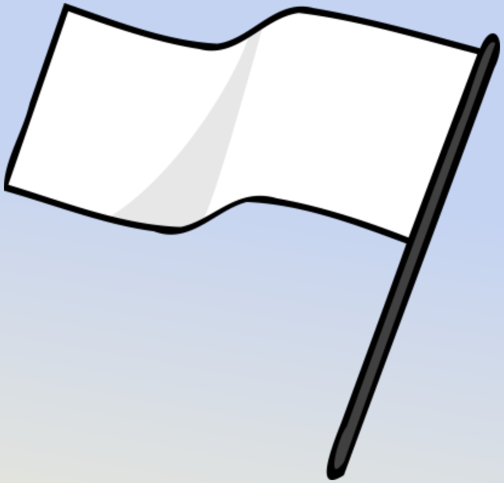
Field Area	S
zone 1,2	27
zone 3,4	45
zone 5,6	59
zone 7,8	160
zone 9,10	160

CropPro SWAT map provided by Dwight Odelei

Saline areas might have 30,000 lbs S/acre

University of Manitoba

Tools to Deal with Variable Crop Response to S



- Most of us have given up on relying soil testing for S recommendations and we simply recommend applying S across most fields for sensitive crops such as canola because of:
  - substantial, fine-scale variability in S fertility within fields
  - the potential for catastrophic yield loss associated with S deficiency
  - the relatively low cost of S fertilization

University of Manitoba

Summary

Crop response to fertilizer varies greatly across space and time because many factors affect crop response, e.g.

i) crop's nutrient requirements, considering crop species & variety or hybrid, yield potential, soil, weather, etc.

ii) crop's ability to use soil's nutrient supply

- soil's power to supply nutrients over growing season
    - chemical extractants or ion exchange membranes provide rapid analysis that imitates plant extraction of nutrients
    - net release of additional nutrients during the growing season … e.g., N mineralization from more decomposition than formation of soil org. matter
- crop's ability to extract nutrients from soil … which varies with species and cultivar, especially for P and K

iii) fertilizer use efficiency for different sources, timings & placements

University of Manitoba

Summary, cont'd.

- **Soil test every field/mgmt zone, every year, to:**

1. **<u>Predict</u> "typical" fertilizer and/or manure requirements for next year's crop, based on existing reserves in soil and long term "average" responses**

2. **<u>Evaluate/audit</u> your nutrient management planning for last year's crop … e.g., look for signs of overfertilization or more N mineralization than expected and reduce rates for that field or zone accordingly for next year's crop**

3. **<u>Monitor</u> for long term upward or downward trends in soil fertility and soil health … e.g., excess residual N or decreasing soil test P**

University of Manitoba

Summary, cont'd.

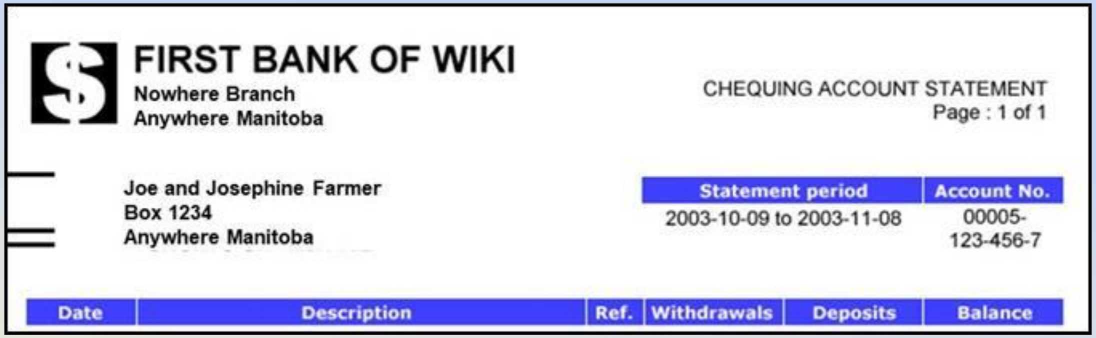
- Use fertilizer curves or models with caution:
  - better suited to explore general concepts than for precisely predicting next year's crop response
  - for N, beware of "quadratic" response curves which often over-estimate N requirements
  - for P and K, remember that variability in these responses is large … so better suited to probabilities than response curves and be prepared for variable responses from year to year and crop to crop on the same field (e.g., 47 years of P trials in SK)
  - for S, we probably need to keep adding S on a whole field basis for sensitive crops such as canola
- Establish and monitor check and/or high fertility plots/strips … and keep vigilant for "unusualities" in fields
  - in-season "two-eyed seeing", tissue testing, canopy reflectance
  - yield monitor and/or scaled grain cart at harvest
  - post-harvest soil testing

University of Manitoba

Summary, cont'd.

Annual soil testing is a <u>useful</u> fertilizer planning tool (like a financial budget)

… and an <u>excellent</u> fertilizer program auditing tool (like a bank statement)



Thank you for your attention!

University of Manitoba