Let’s Talk N_2Ohhh

4R Senior Industrial Research Chair

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Senior Industrial Research Chair 4R Nutrient Management

Manitoba Potato Days
January 25, 2023

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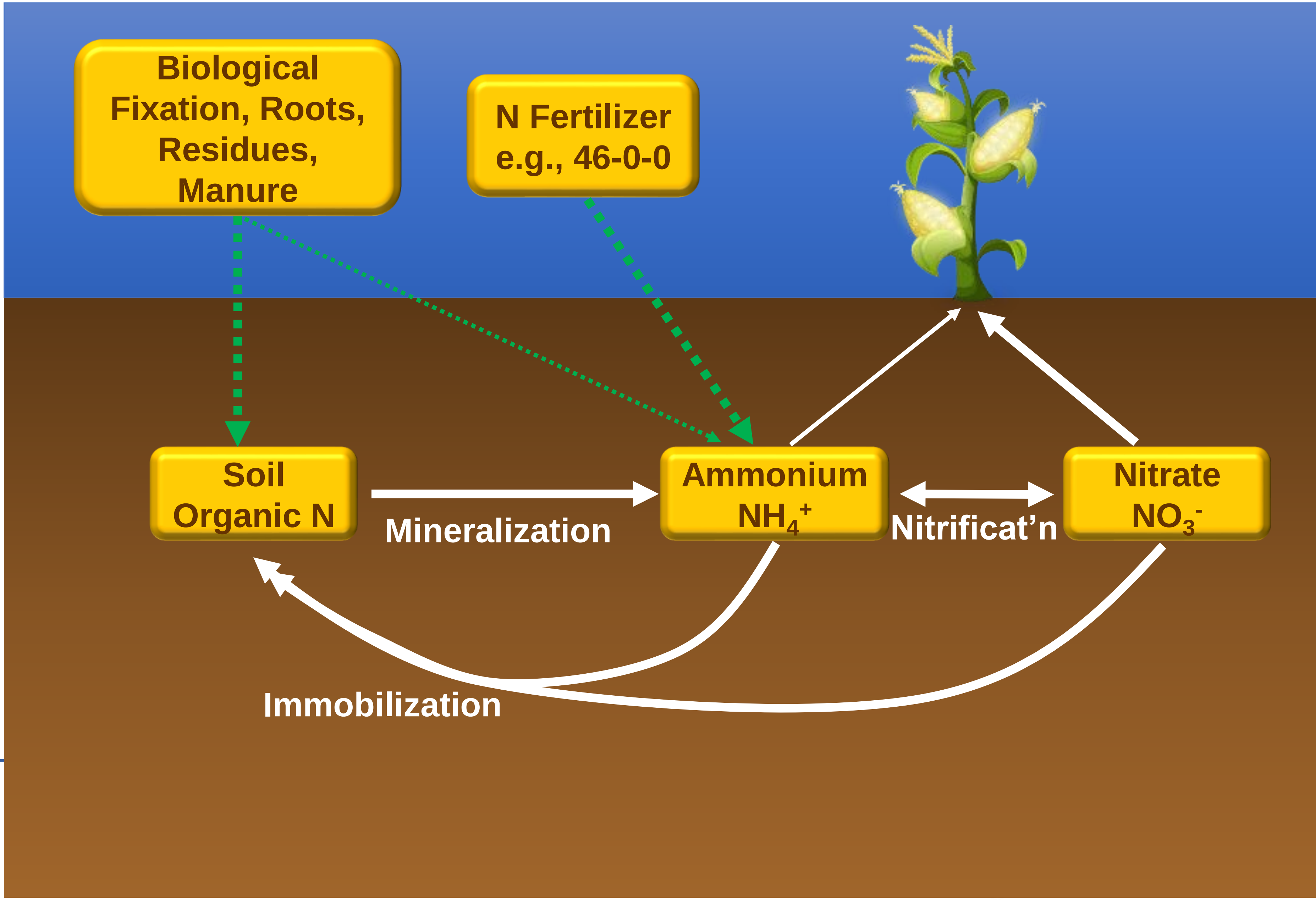
1772 Joseph Priestley

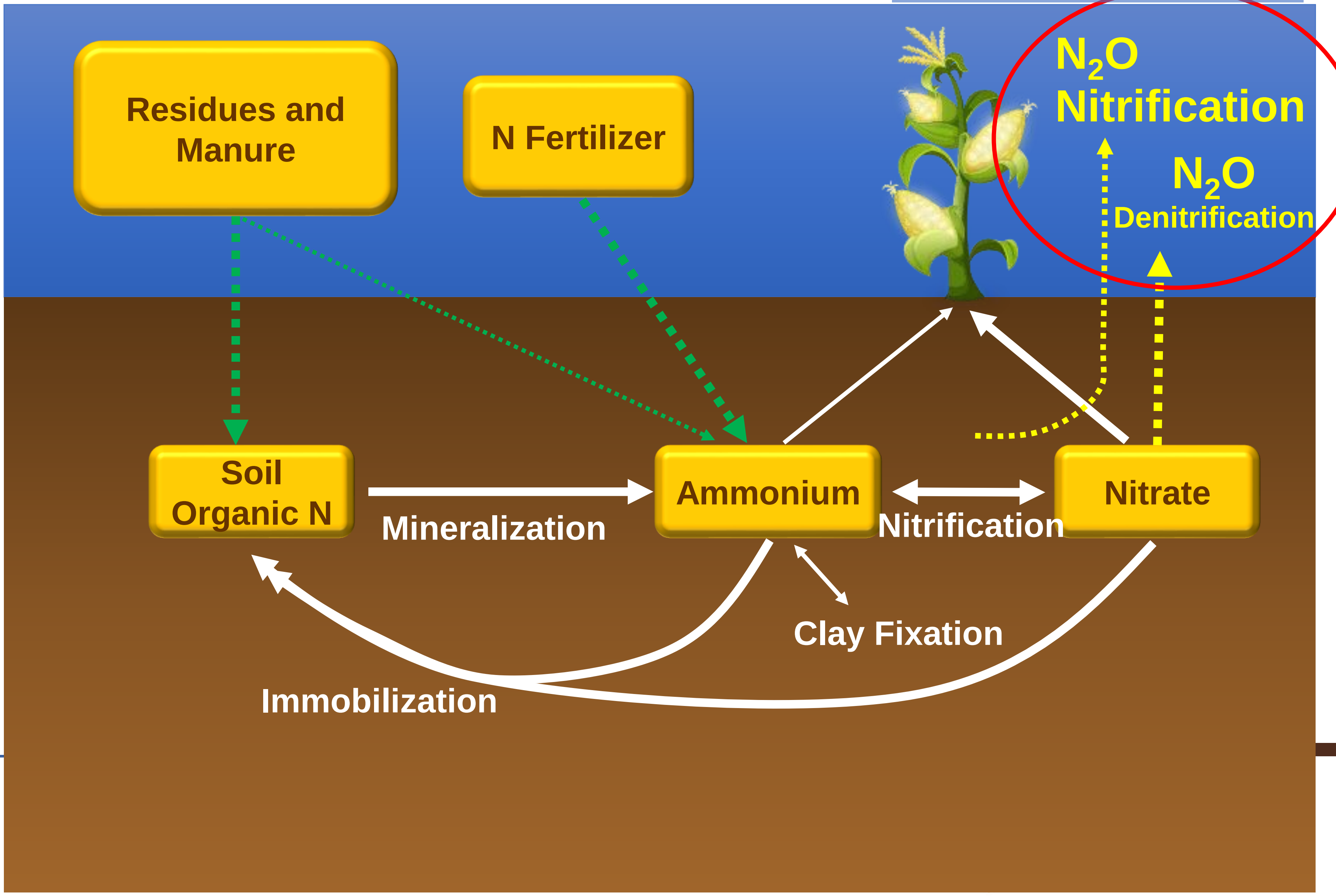
Sources: http://www.sedationdentistry4u.com/nitrous-oxide-chemistry.gif
http://www.prestige-dental-care.com.my/blog/wp-content/uploads/2011/02/DSC_0003-Copy.jpg
http://s1168.photobucket.com/user/alc0nzy/media/IPD_VO
VO_C30_NOS_TANKS.jpg.html
http://www.seattleweekly.com/2010-07-07/news/the-gas-peddle-the-nitrous-mafia-spreads-widespread-panic-at-summer-music-festivals/
http://www.consumerqueen.com/wp-content/uploads/2013/07/reddi_wip.png

Nitrogen Cycle



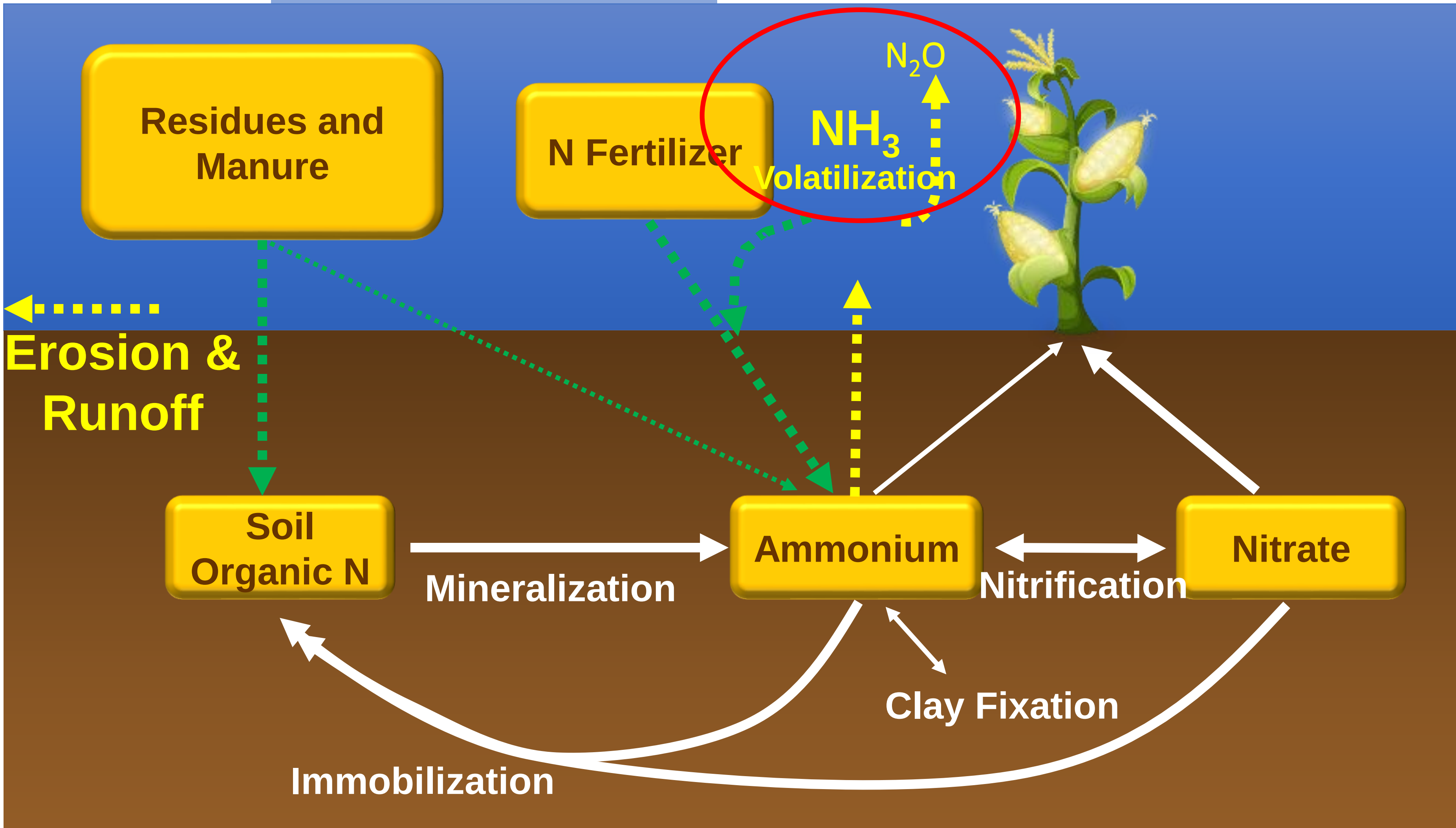
Direct Emission of N_2O

up to 3% of fertilizer lost as N_2O



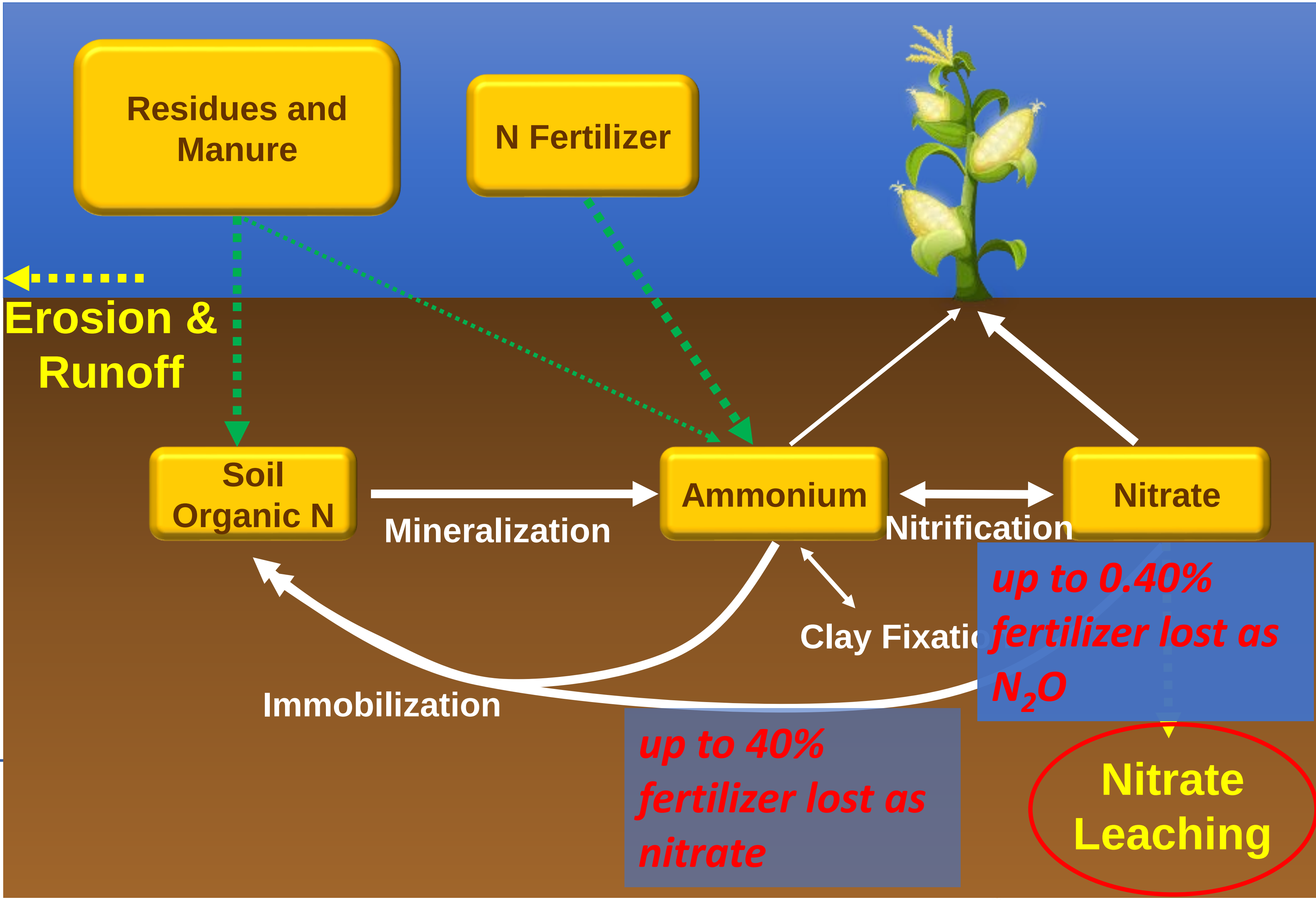
up to 20% fertilizer lost as NH_3

up to 0.2% fertilizer lost as N_2O



Indirect Losses of N_2O - Ammonia

Indirect Loss of N_2O – Nitrate Leaching



Recap: Sources of N_2O

Direct Sources

Green manure ploughdown
Animal manure storage and addition
Nitrogen Fertilizer addition
Crop residues

N_2O from
nitrification and denitrification in soil

In-direct Sources

Ammonia volatilization
Nitrate leaching

N_2O from
ammonia in upper atmosphere
denitrification of nitrate in waters

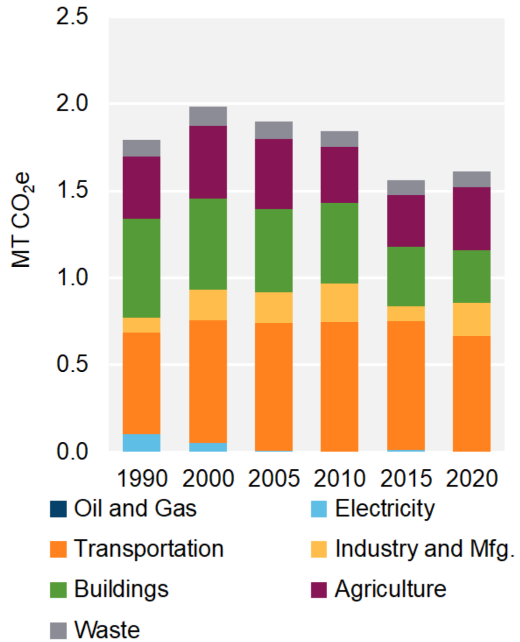
Perspectives on N Losses

- Annual emission of N_2O from fields vary from 0.5 to 4 kg N/ha/year – N_2O 300x more powerful than CO_2 to warm the atmosphere thus ***environmentally but not agronomically important***

- Depending on soil, climate and practices- leaching, volatilization and denitrification losses 10-60 kg N/ha/year – ***agronomically & environmentally important***

So What is All the Huff About N_2O?

PEI GHG by Sector



Emissions in PEI Agriculture

Source	CO_2	CH_4	N_2O
Enteric Fermentation		110	
Manure		18	20
Soils			
Direct			110
Indirect			50
Burning		0.20	0.05
Liming, Fertilization	7		

Commitment to reduce GHG emissions by 1/3 in 2030

Commitment to be GHG neutral by 2050

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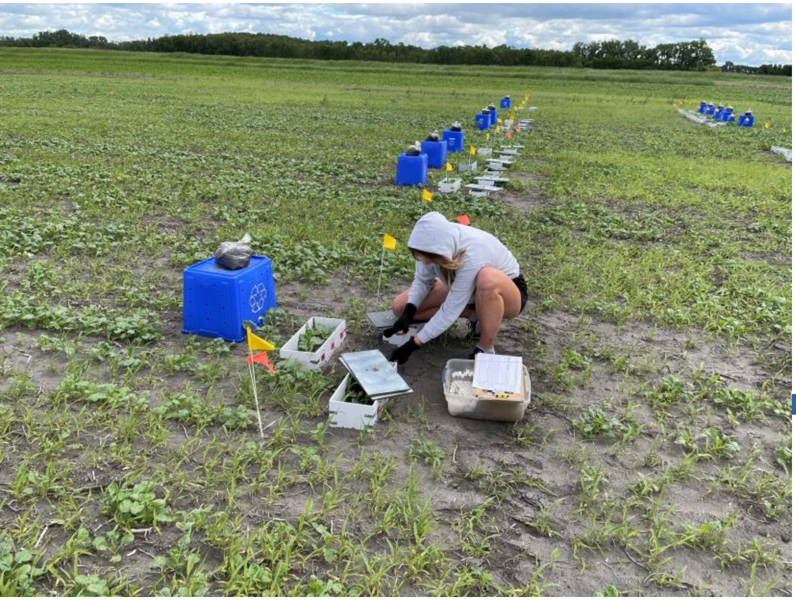
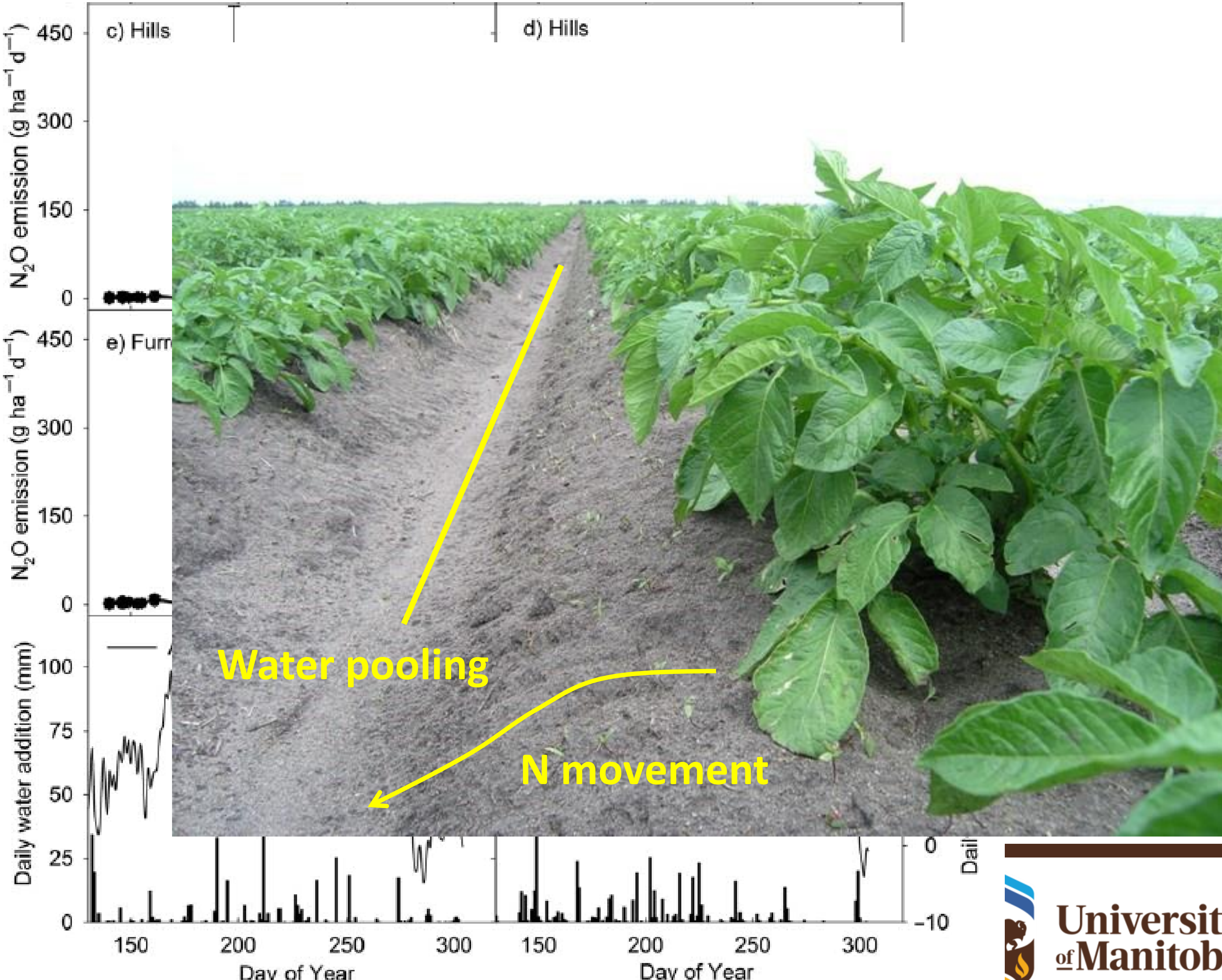
How We Study N_2Ohhh



2009 2010



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4R nutrient stewardship

Rate

- Not more than needed to prevent yield limitation
- Credit soil nitrate/mineralization
- Tailor to crop, variety and hybrid
- Treat fields individually
- Consider field properties

Source

- Mainly ammonium-based fertilizers
- Enhanced Efficiency Fertilizers to limit losses

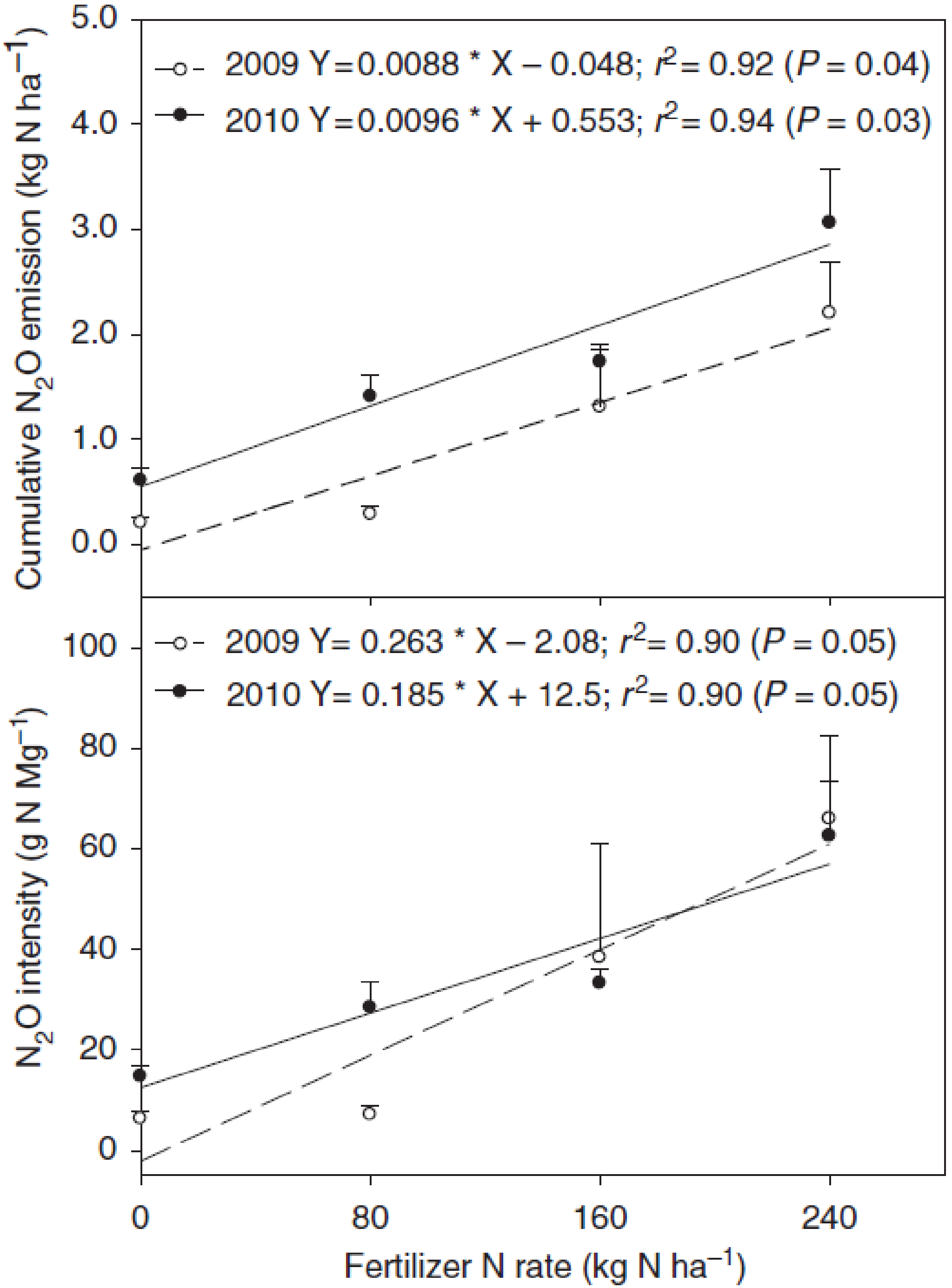
Placement

- Incorporated, banded or injected
- Split applications for long season crops
- Appropriate for crop growth stage & soil conditions

Timing

- Meets time of crop demand
- Late fall application
- No winter application

Emissions Go Up with N Rate



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Some Points

- Emissions are going to happen with N additions
- N additions to potato are large, thus large emissions compared to field crops
- Irrigation is important, increase emissions
- Fertigation is an opportunity to throttle N additions

Enhanced Efficiency (EEF) N Fertilizers

- **Stabilized N**
  - Urease inhibitor
  - Nitrification inhibitor
  - Double inhibitor

- **Controlled Release**
  - Polymer Coated Urea

- **Slow Release**
  - Sulfur-coated Urea, Methylene Urea, Isobuylidene Diurea, Urea Formaldehyde, Urea Triazone

Some N Stabilizers in the Market

Urease inhibitor

Nitrolizer N
NITRAIN 2.0
ECLIPSE-N NITROGEN STABILIZER 26.7%
ANVOL
AGROTAIN
N-YIELD NITROGEN STABILIZER
Limus Nitrogen Management
ARM U

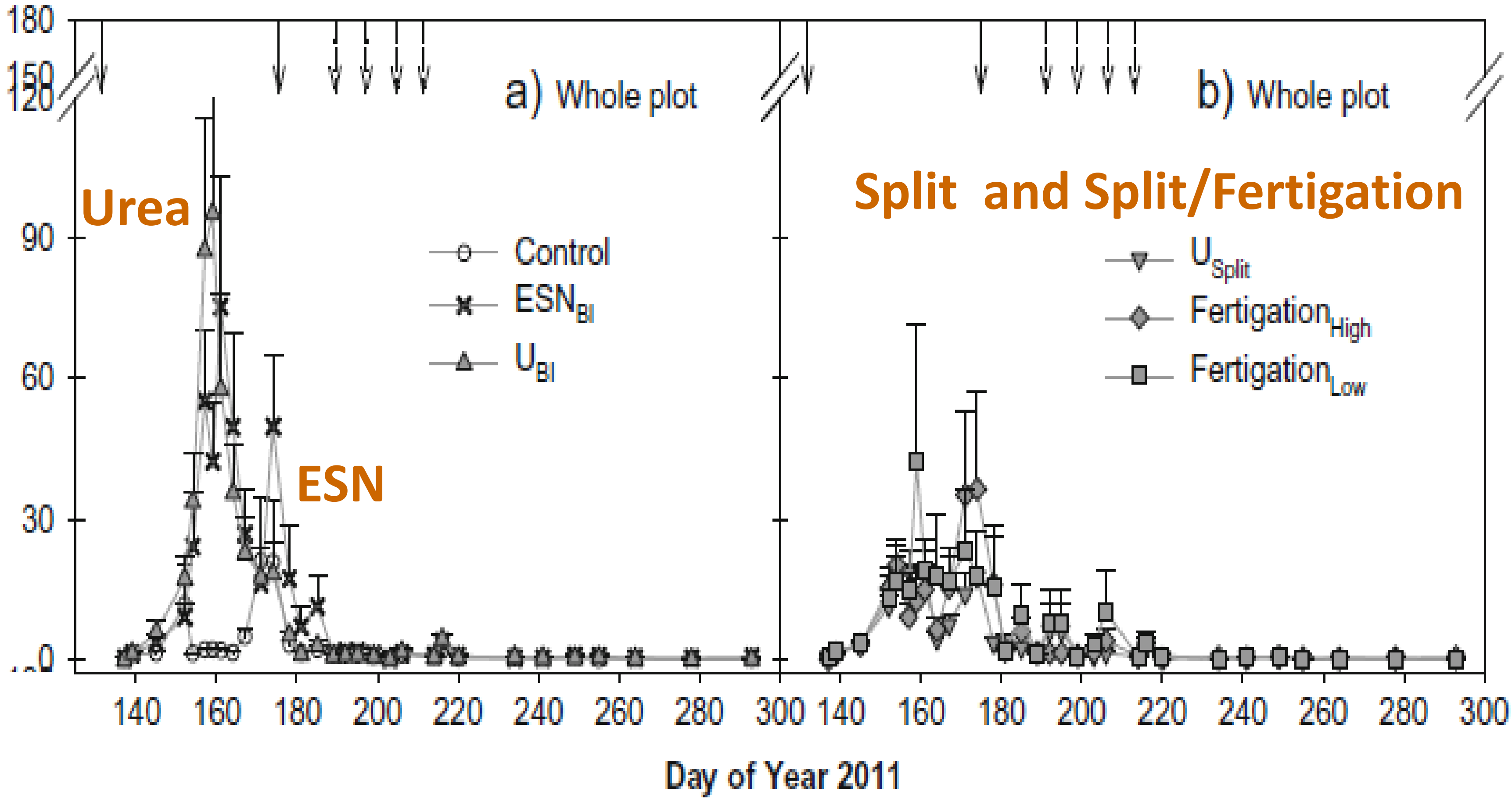
Nitrification inhibitor

ECLIPSE-D NITRIFICATION INHIBITOR NITROGEN STABILIZER
ENTEC
N-Serve NITROGEN STABILIZER
eNtrench NITROGEN STABILISER
N-BOUND NITROGEN STABILIZER
CENTURO
DRIVE-N™ For Anhydrous Ammonia

Double inhibitor

SUPERU
ARM U ADVANCED Intelligent Nitrogen Stabilizer
NEON AIR
AGROTAIN PLUS SC
TRIBUNE
N Protect

Fertilizer Type and Timing on Emissions 2011 Manitoba



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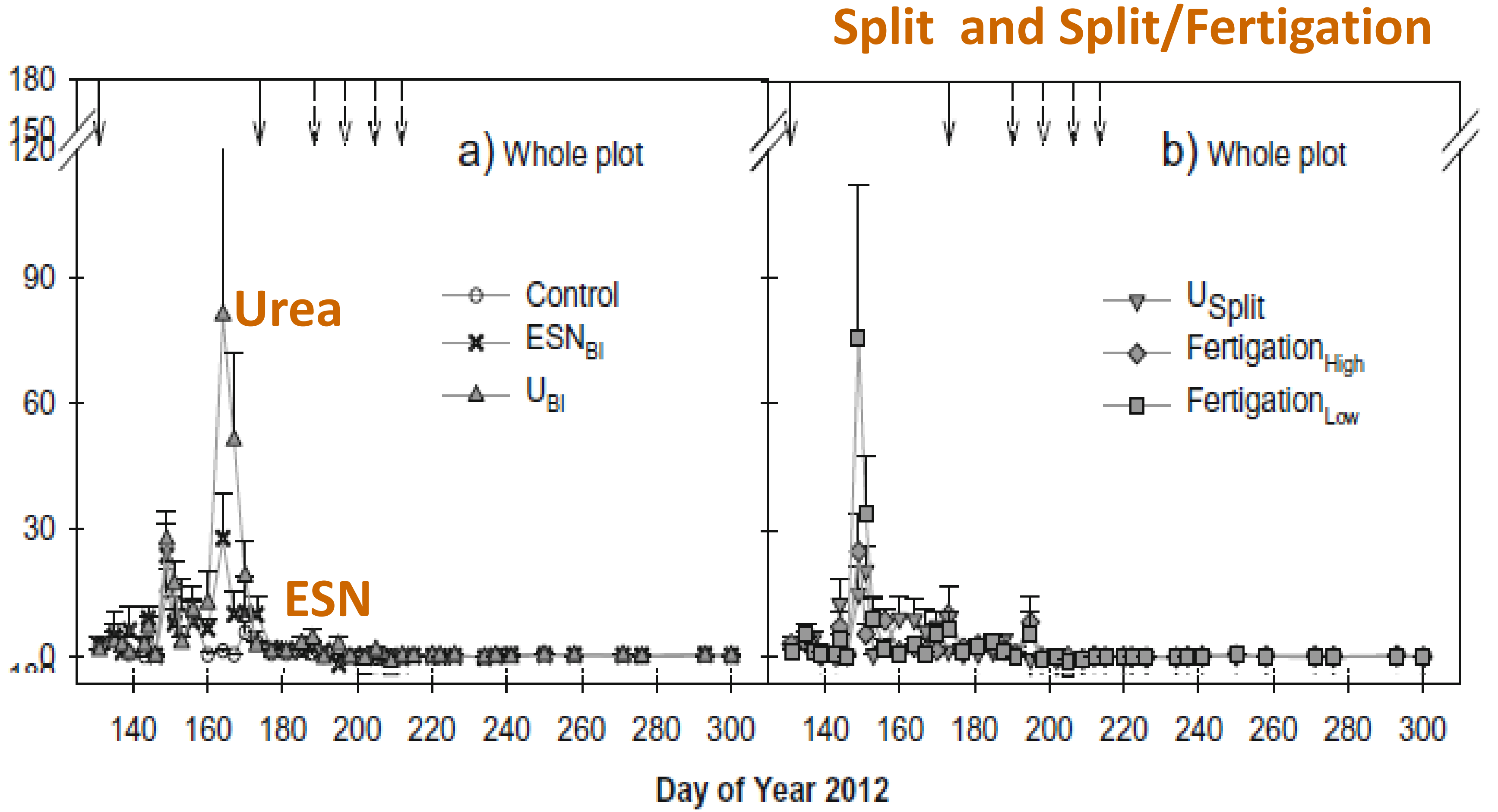
Fertilizer Type and Timing on Emissions 2012 Manitoba



Emission Summary: ESN and Banding

	N_2O (kg N ha^{-1})	EF (%)	EI (g N Mg^{-1})
Experiment 1			
Year			
2011	2.07 A	0.95 A	57.0 A
2012	0.58 B	0.31 B	16.8 B
Treatment			
Control	0.46 c	-	14.4 d
$ESN_{100\text{-}Bl}$	1.33 ab	0.88	32.7 c
$ESN_{100\text{-}Bd}$	1.04 b	0.59	25.8 c
$ESN_{200\text{-}Bl}$	1.87 a	0.71	52.4 a
$ESN_{200\text{-}Bd}$	1.28 b	0.41	35.8 bc
$U_{200\text{-}Bl}$	1.72 ab	0.63	45.0 abc
$U_{200\text{-}Bd}$	1.56 ab	0.55	51.9 ab

Difference in Year

ESN
Lower Emissions

Banding Less than Incorporation

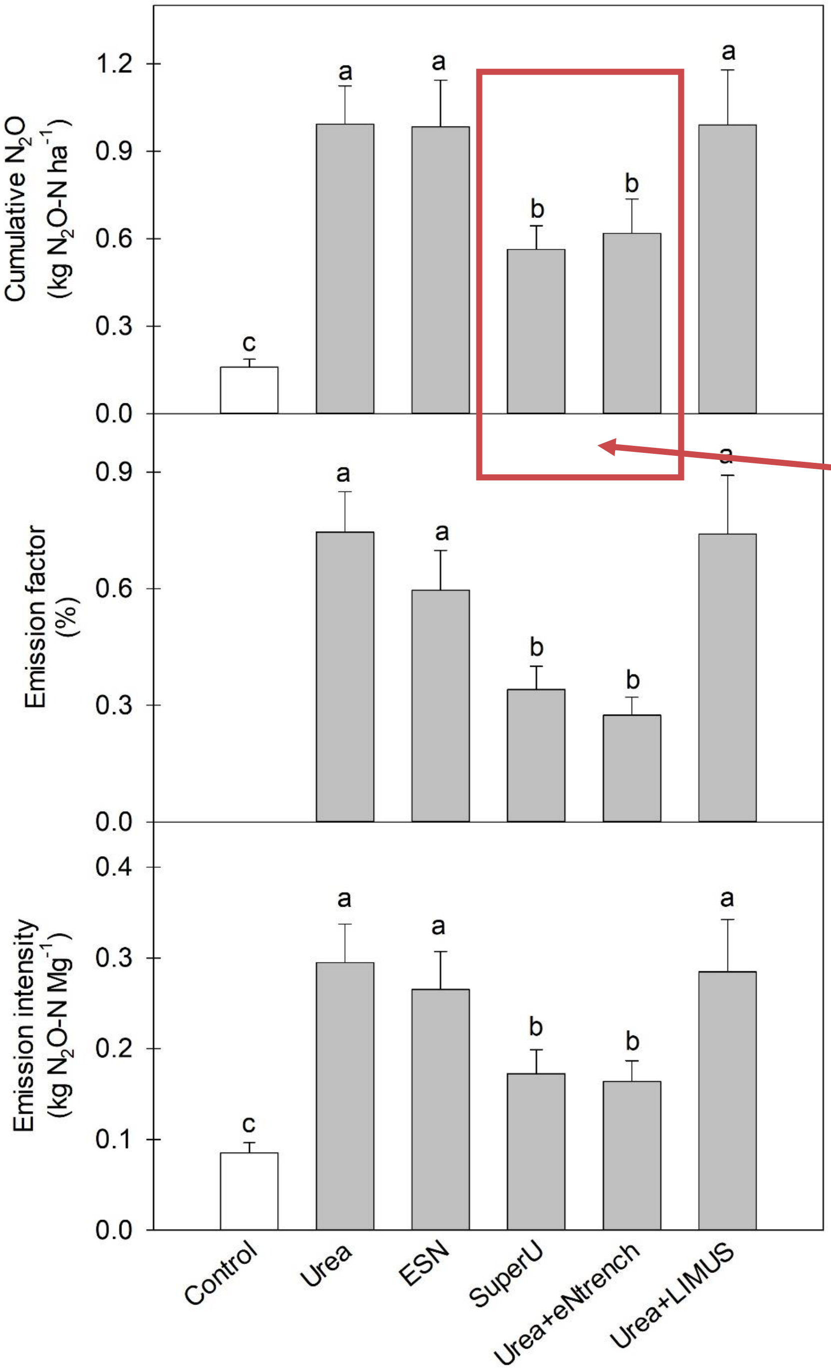
Emission Summary: ESN, Split and Fertigation

	N_2O (kg N ha^{-1})	EF (%)	EI (g N Mg^{-1})
Experiment 2			
Year			
2011	0.78 A	0.31 A	23.8 A
2012	0.40 B	0.12 B	11.4 B
Treatment			
Control	0.26 d	-	11.1
U_{BI}	0.96 a	0.39 a	26.6
ESN_{BI}	0.82 ab	0.31 ab	23.7
U_{Split}	0.39 cd	0.07 b	11.3
$Fertigation_{Low}$	0.60 abc	0.19 ab	20.2
$Fertigation_{High}$	0.49 bc	0.13 b	12.6

Difference in Year

Split and Split/Fertigation Lower Emissions

N_2O Emission Indicators – Manitoba Spring Wheat



SuperU and eNtrench Lower Emissions

40-60% reductions across indicators for nitrification inhibitors

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Many 4R Practices Significantly Reduce N_2O Emissions but Don't Change Yield

Management Practice	Site Years	N_2O Reduction %*	Yield Reduction %
Nitrification Inhibitors	22	32	1
Polymer Coated Urea (ESN)	21	27	increase 2
Deep Banding	16	3	1
N Fixing Legumes	15	61	NA
Split N Application	13	48	increase 3
Fall Application	7	increase 36	increase 1
Shallow Banding	6	increase 89	5
Cover Crops	4	1	
Organic Production	2	17	32

Summary of Field Studies by the 4R Chair Program from 2010-present

4R N Processing Yield Study

Treatments	Total N applied	Pre-plant broadcast incorporation		At-plant banding		At hilling incorporation		Fertigation		
		Rate	Source	Rate	Source	Rate	Source	Rate	Rate per week*	Source
Control	0	–	–	–	–	–	–	–	–	–
U_{BI}	100	100	urea	–	–	–	–	–	–	–
$U_{Split\text{-}BI}$	100	40	urea	–	–	60	urea	–	–	–
$U_{Split\text{-}Bd}$	100	–	–	40	urea	60	urea	–	–	–
$SU_{Split\text{-}BI}$	100	40	SuperU	–	–	60	SuperU	–	–	–
$SU_{Split\text{-}Bd}$	100	–	–	40	SuperU	60	SuperU	–	–	–
ESN_{BI}	100	100	ESN	–	–	–	–	–	–	–
$(ESN + U)_{BI}$	100	50 + 50	ESN + urea	–	–	–	–	–	–	–
Fertigation-A	100	60	urea	–	–	–	–	40	17, 13, 10, 0	UAN
Fertigation-B	100	40	urea	–	–	–	–	60	20,17, 13, 10	UAN
Fertigation-C	100	30 + 30	ESN + urea	–	–	–	–	40	17, 13, 10, 0	UAN

Values are percentage (%) of total N fertilizer added

*In-season fertigation was conducted 8, 9, 10, and 11 weeks, respectively

Fertilizer Type: Urea, SuperU, ESN, UAN

Placement: Incorporation, Banded

Fertigation Scheduling: High, Low

Marketable Yield Summary

	2013		2014		2015	Mean
	Carberry Mg ha^{-1}	Carman	Carberry	Carman	Carberry	
Control	47.9	31.1	20.7	39.1	33.1	34.4
U_{BI}	54.3 a	52.0 a	40.9 ab	57.4 a	46.1 a	50.1
$U_{Split\text{-}BI}$	51.8 a	53.2 a	48.3 ab	58.6 a	50.6 a	52.5
$U_{Split\text{-}Bd}$	55.7 a	48.8 a	49.5 ab	59.4 a	49.1 a	52.5
$SU_{Split\text{-}BI}$	56.1 a	48.0 a	51.0 a	56.8 a	49.7 a	52.3
$SU_{Split\text{-}Bd}$	54.3 a	50.3 a	46.2 ab	57.5 a	50.0 a	51.7
ESN_{BI}	58.2 a	54.5 a	46.9 ab	53.8 a	48.9 a	52.5
$(ESN + U)_{BI}$	51.4 a	53.3 a	41.0 ab	52.6 a	50.3 a	49.7
Fertigation-A	57.9 a	54.2 a	41.5 ab	57.2 a	52.0 a	52.6
Fertigation-B	56.4 a	50.8 a	39.7 b	54.7 a	51.6 a	50.6
Fertigation-C	58.0 a	47.8 a	45.7 ab	54.9 a	53.1 a	51.9
Mean	54.7 A	49.5 B	42.9 C	54.7 A	48.6 B	

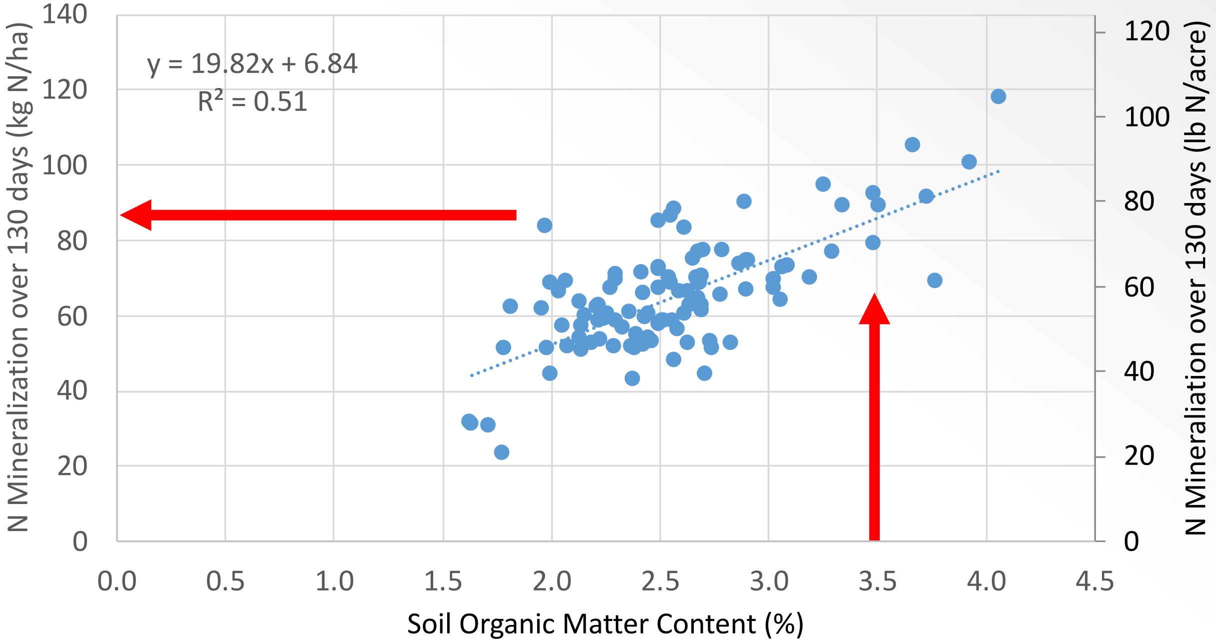
No Consistent Effect of Treatments

Urea and Up Front N applications Performed Well

Credit for N Mineralization from Soil Organic Matter

Step 5: Credit soil organic matter content (S)

Soil organic matter greater than or equal to 3.5%	15
Soil organic matter less than 3.5%	0
S in kg N/ha = (enter appropriate value from above) = _________	(5)



Source: Dr. David Burton

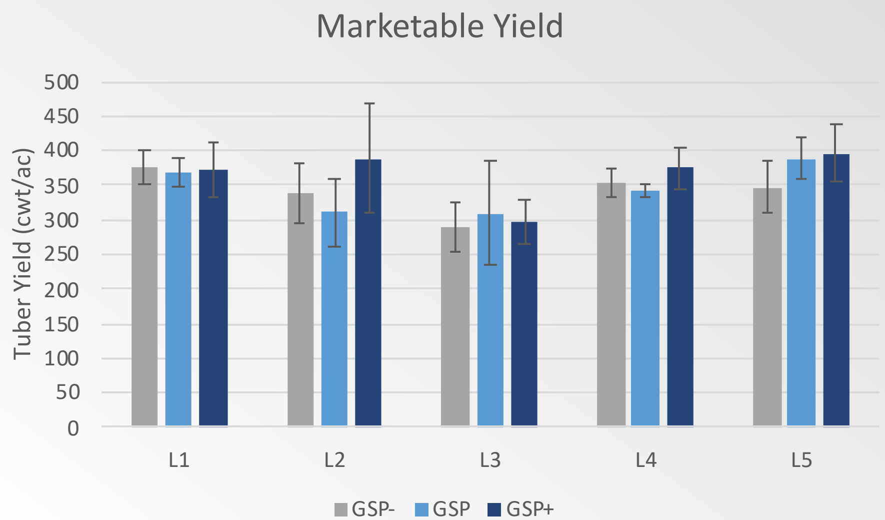
2021 Trial PEI

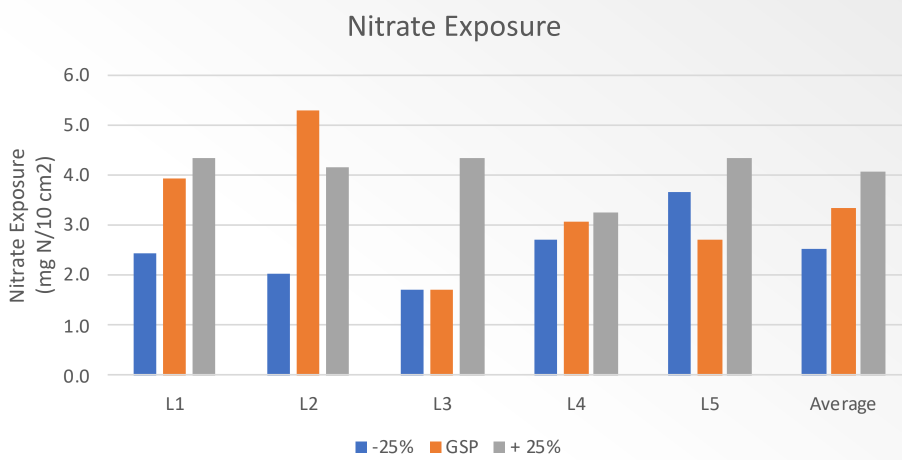
In 2021 compared the

- Grower Standard Practice (GSP)
- GSP + 25%
- GSP - 25%

Object to generate N response curve and see if BNA predicted where there would be a yield response.

- No yield response to N!
- But there was increased N_2O emissions with increased N rate.





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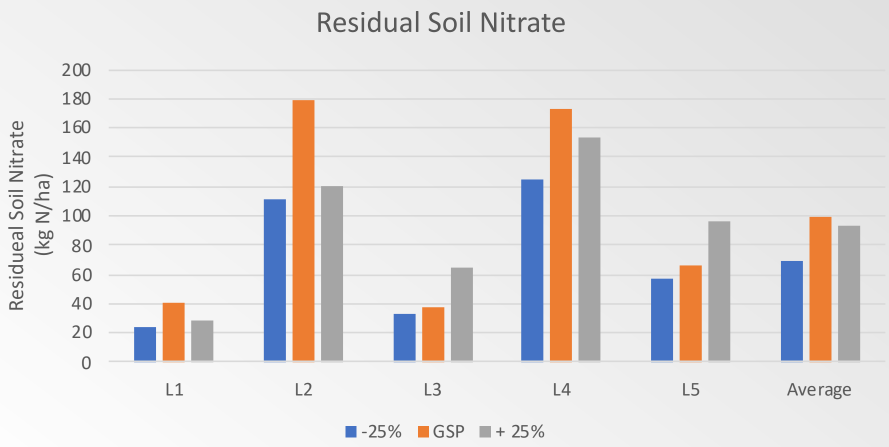
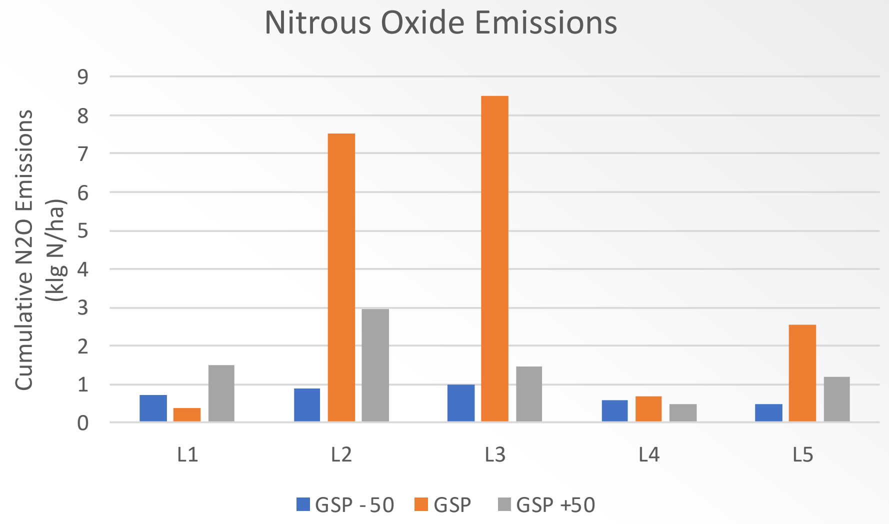


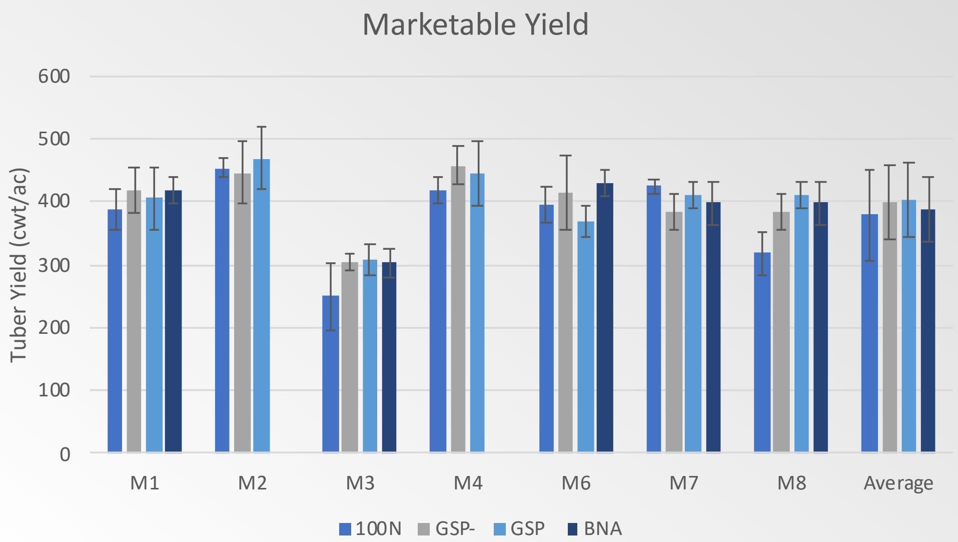


Source: Dr. David Burton

2022 PEI Trial

In 2022 compared the

- Grower Standard Practice (GSP)
- Rate adjusting GSP based on BNA
- GSP - 25%
- 100 lbs N/acre

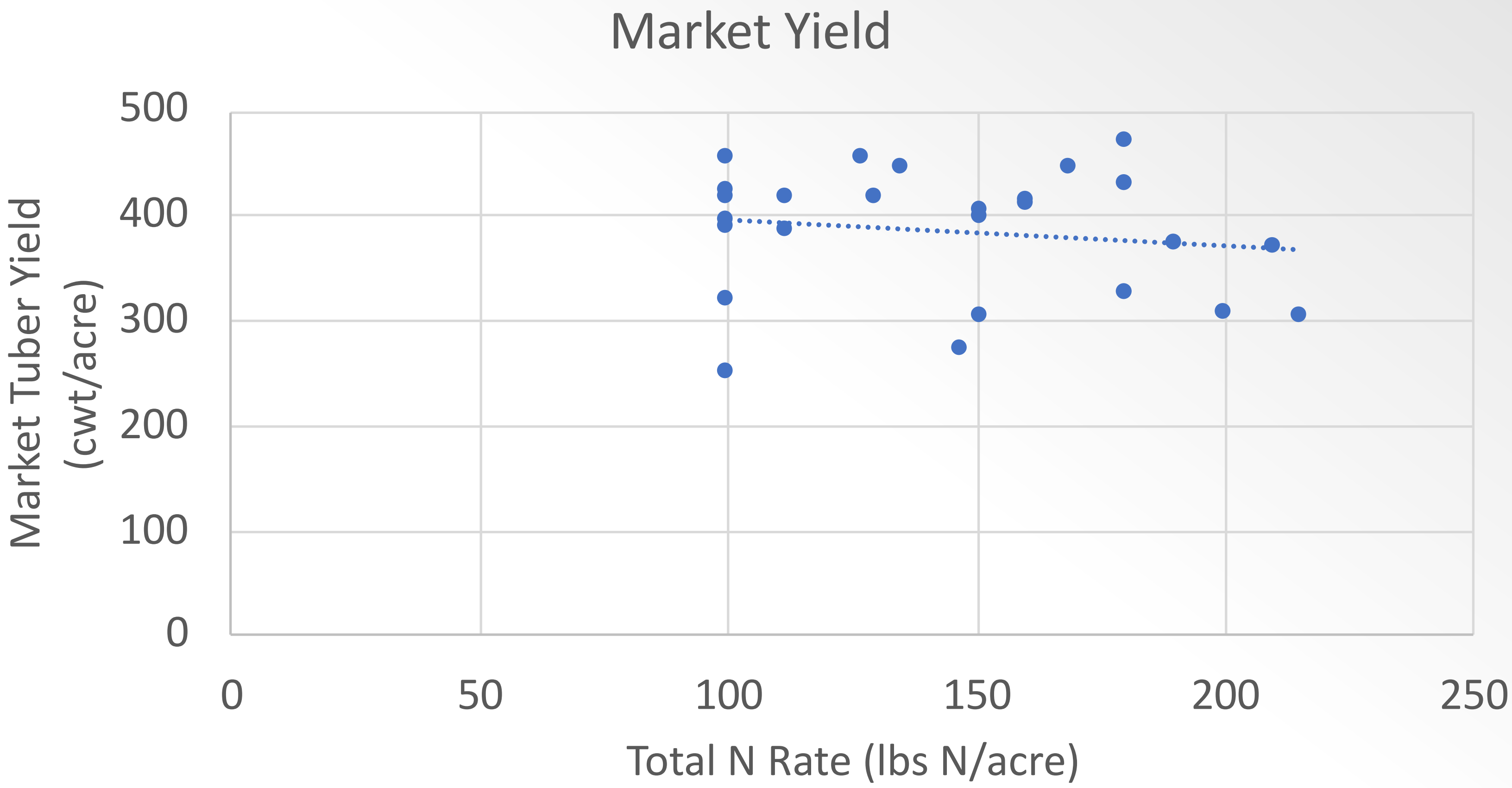


Object again was to generate N response curve and see if BNA predicted where there would be a yield response.

- Still no yield response to N!
- But again there was increased N_2O emissions with increased N rate.

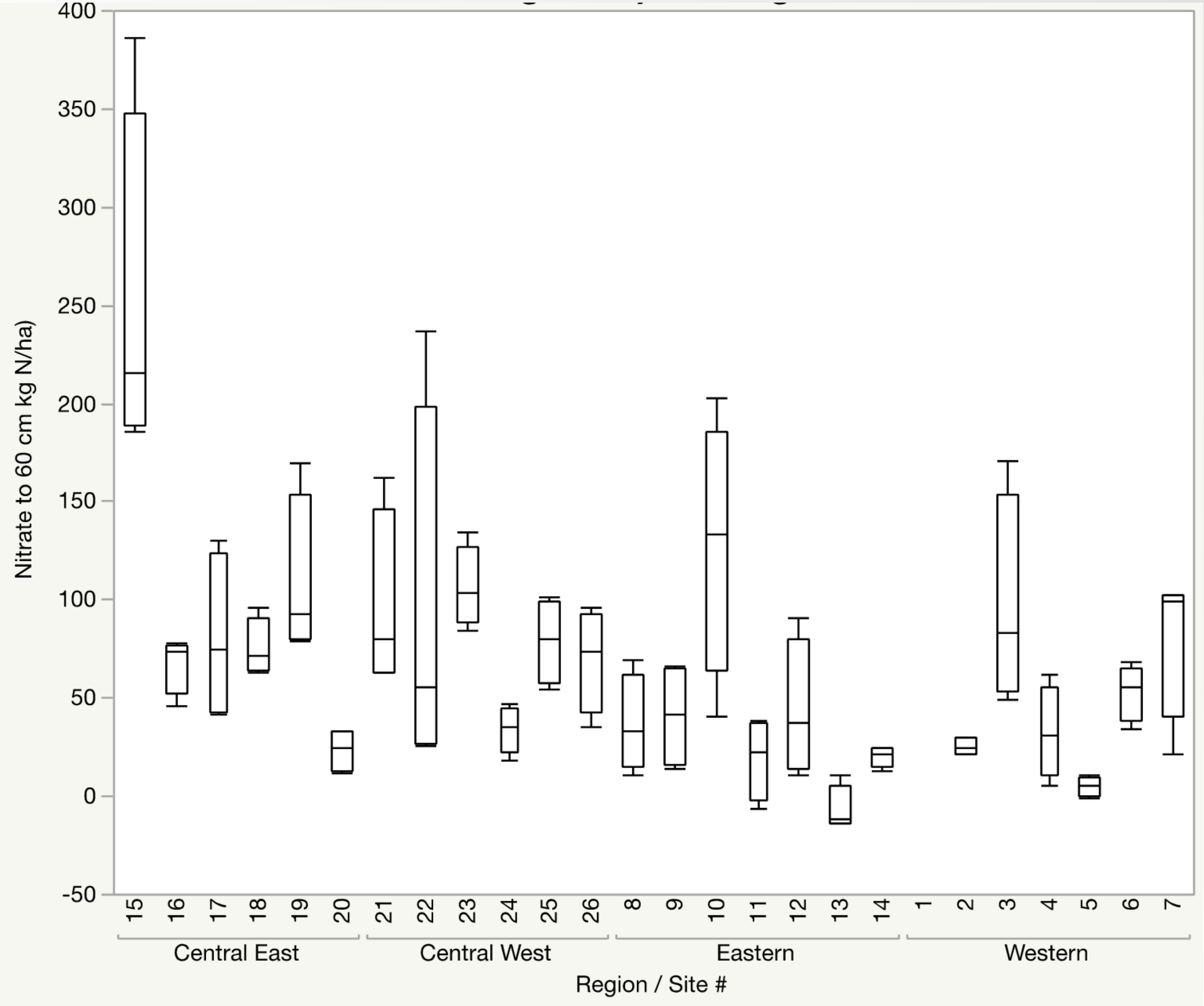
Source: Dr. David Burton

Not seeing a yield response to added nitrogen!



Source: Dr. David Burton

Left-over Nitrate in the Soil Profile



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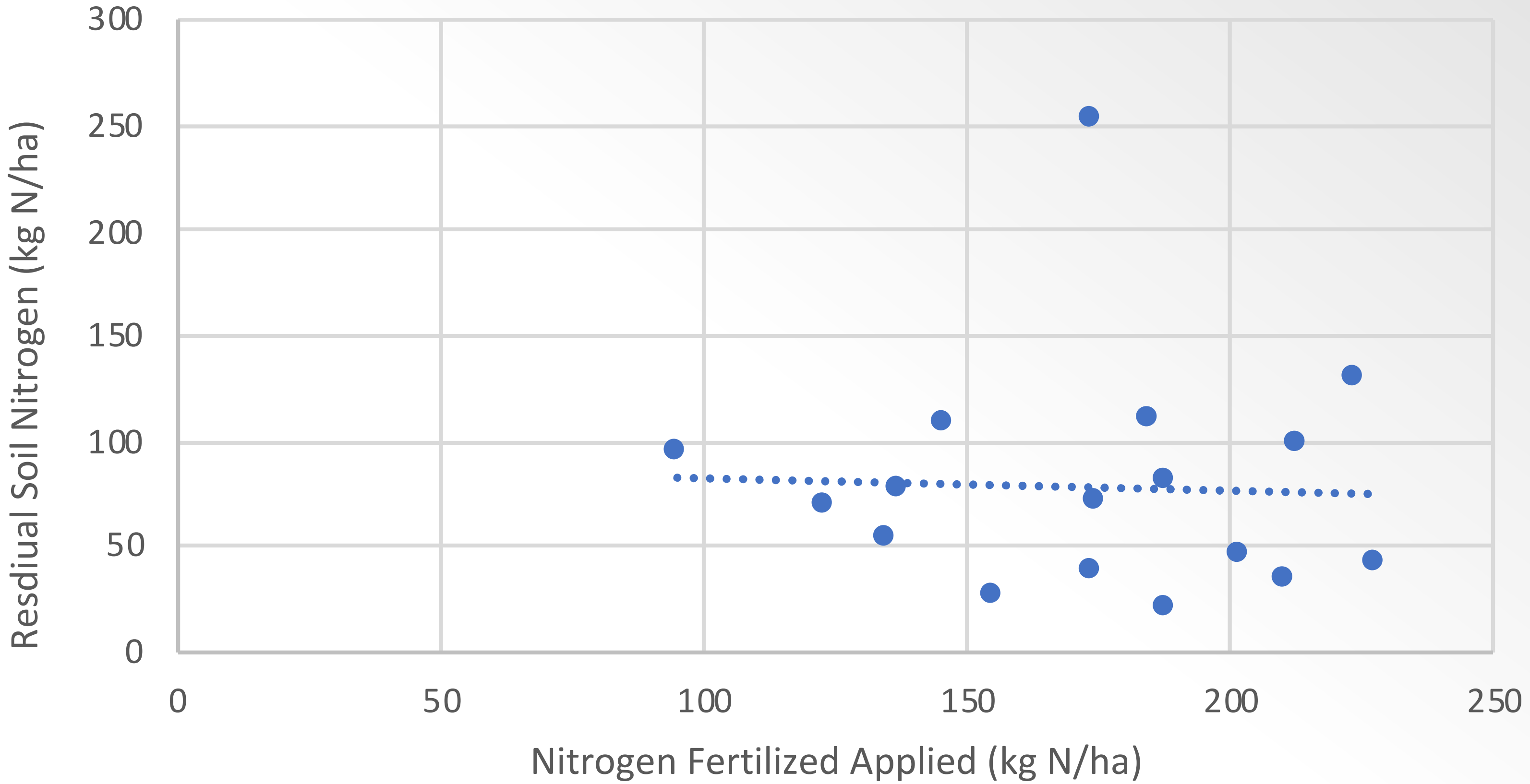
Source: Dr. David Burton

Left-over nitrate not a function of N application…



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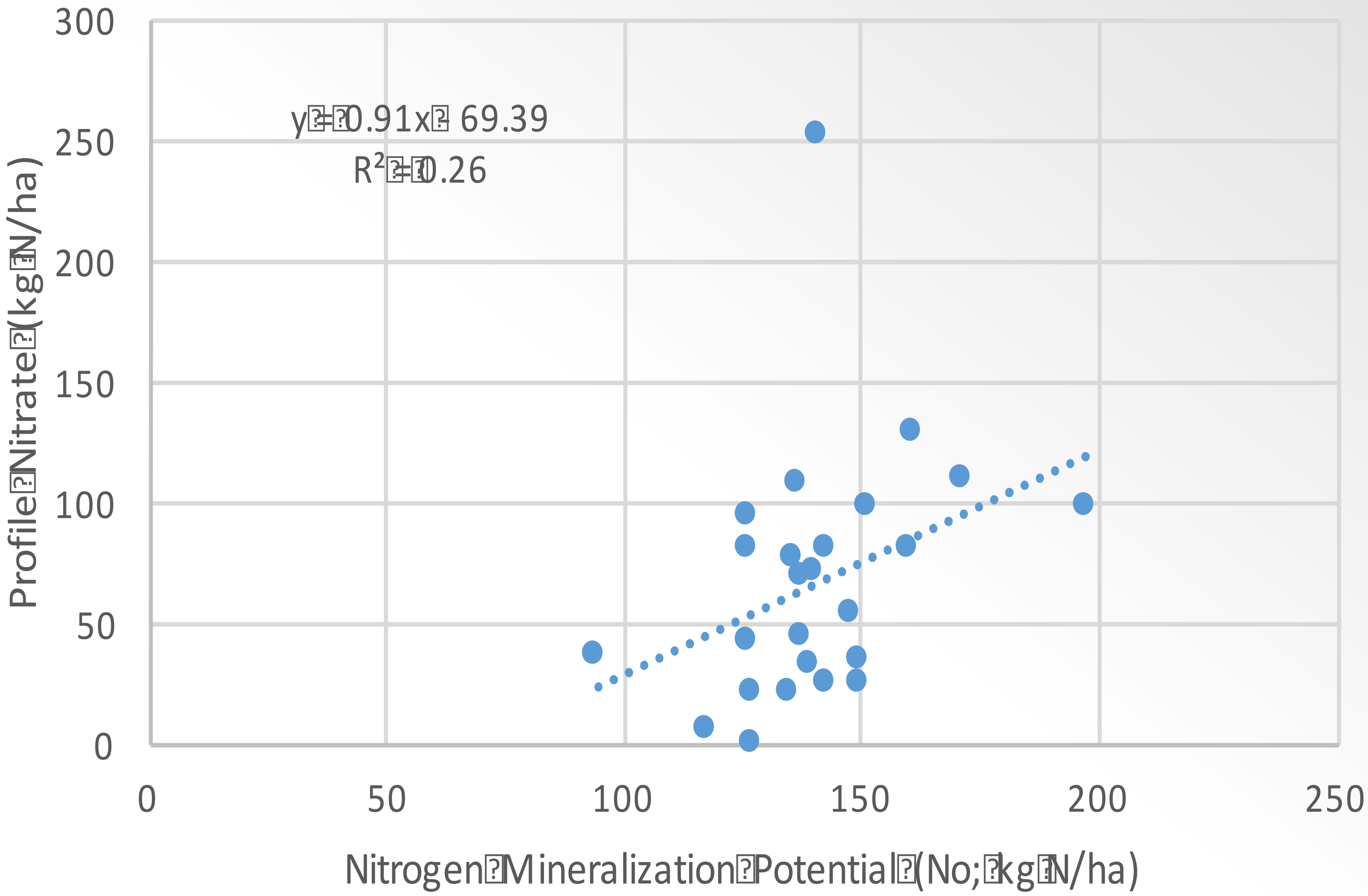
Source: Dr. David Burton

Profile nitrate and N mineralization potential



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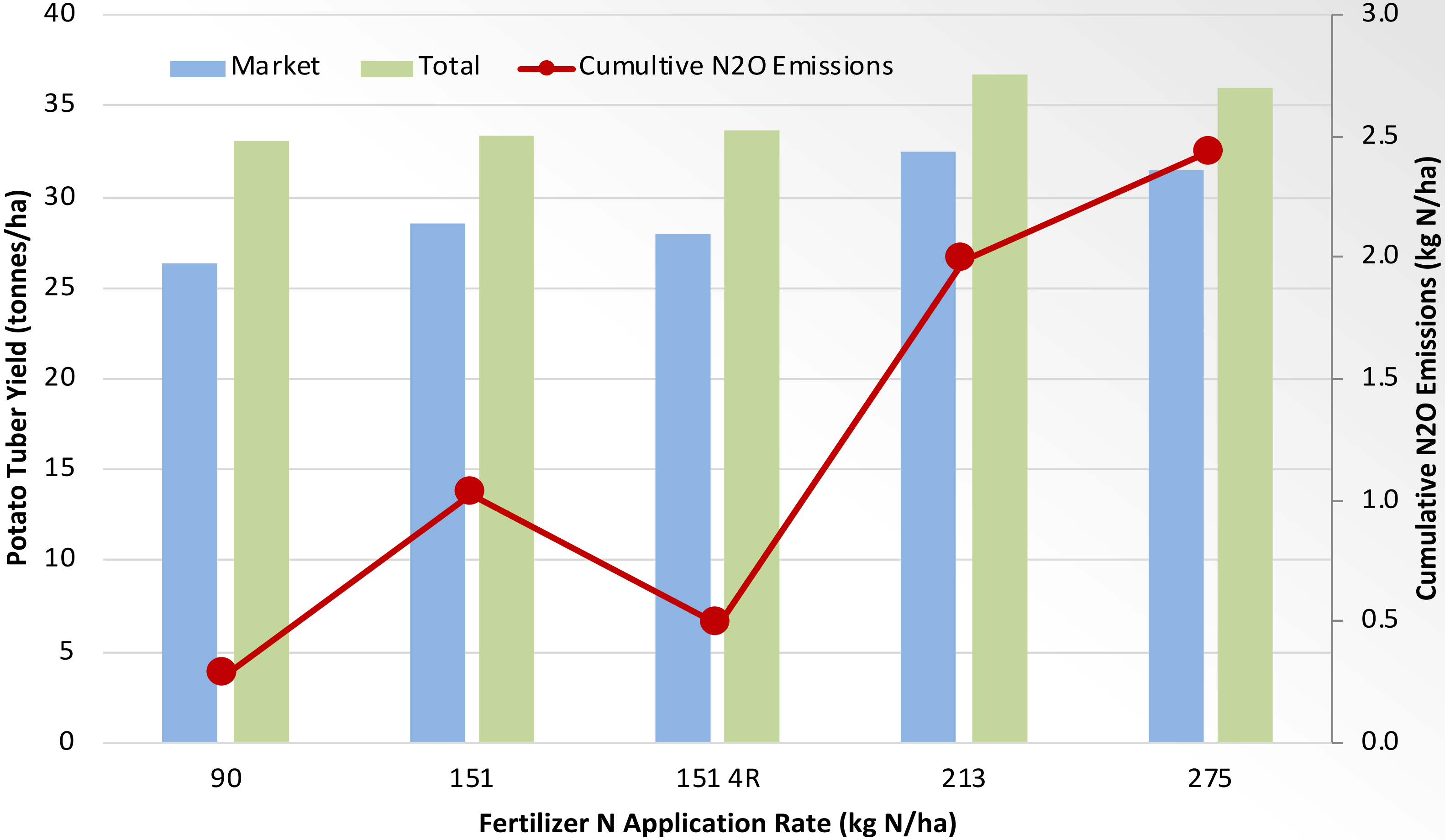
Source: Dr. David Burton

Does 4R work?

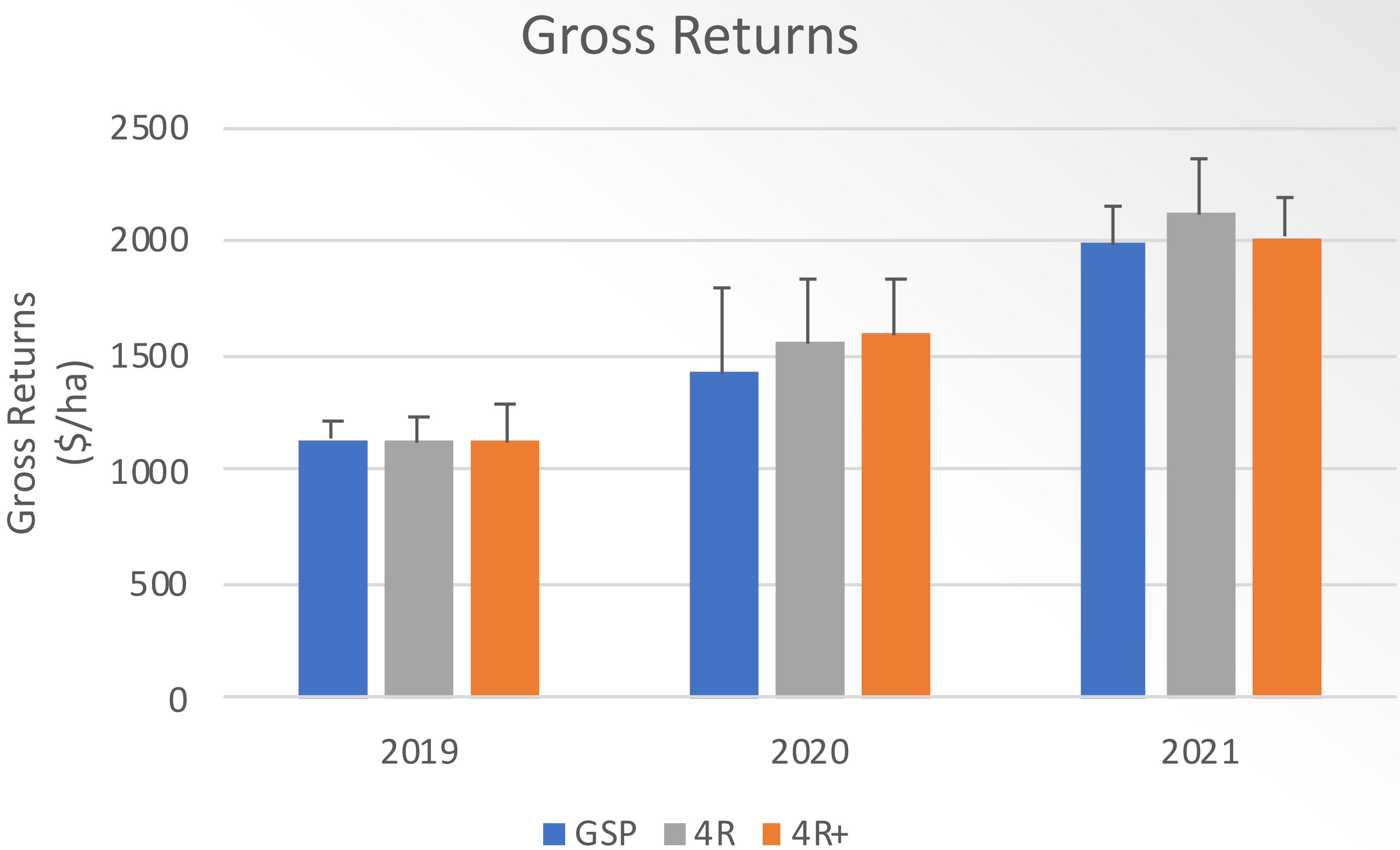
2020



Source: Dr. David Burton

Does 4R work?

Living Labs
Side-by-Side Trials



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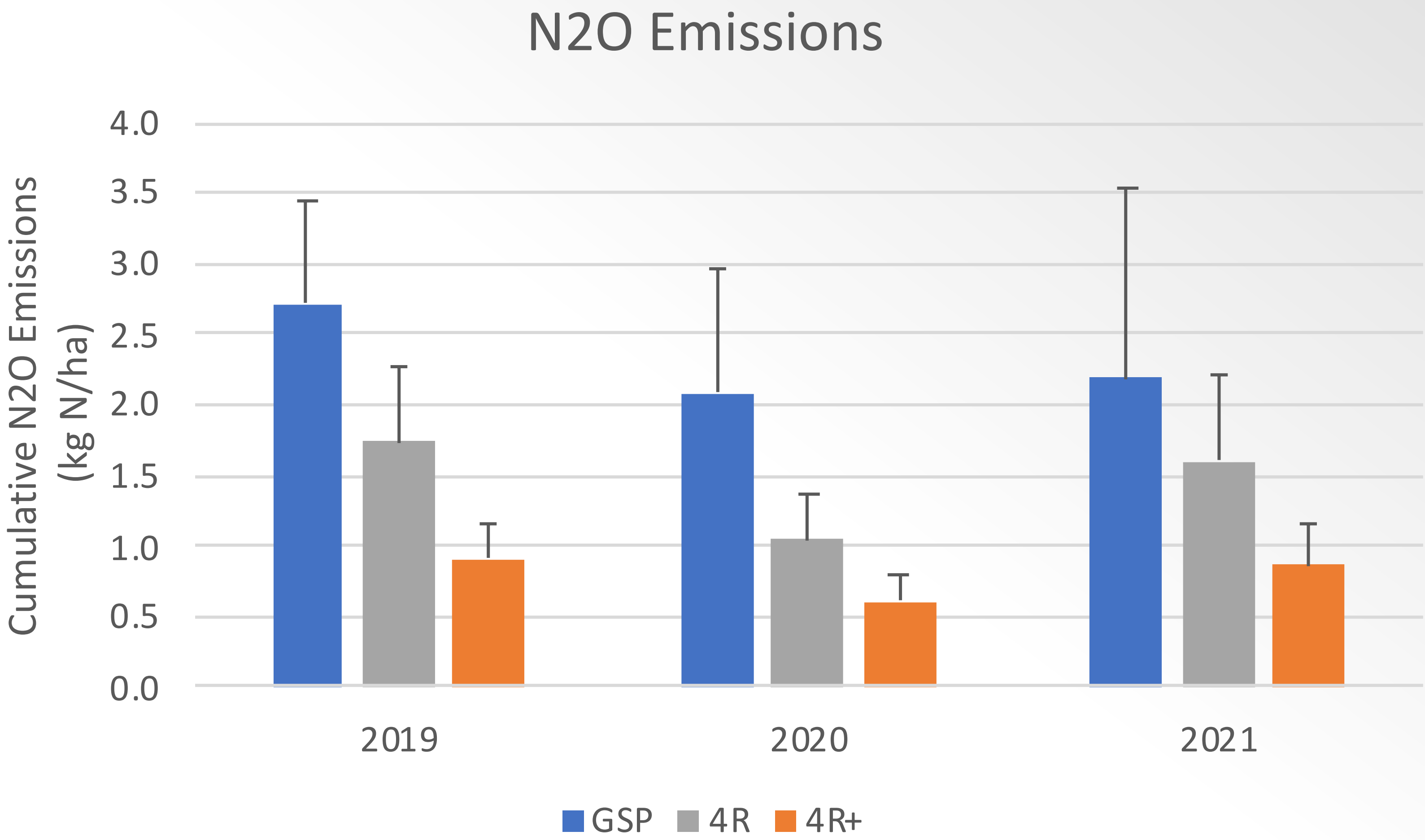

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Source: Dr. David Burton

Break Even Point (BEP) Analysis for Potato Manitoba

Potato $15/cwt
Assume rate 134 lb N/ac
Assume 30% N_2O reduction with EEF
Assume 2.5% N_2O-N kg/kg N

Product	$/lb N	$/ac	cwt BEP ↑	lb N/ac BEP ↓	$/t CO_2 BEP ↑	PEIFA acres
Urea (46-0-0)	1.58	212	-	-	-	-
Urease Urea (46-0-0)	1.66	223	0.7	127	-	7000
Nitrification Inhibitor (46-0-0)	1.70	228	1.1	124	69	4600
Double Inhibitor Urea (46-0-0)	1.71	229	1.2	123	74	4300
Polymer Coated Urea (44-0-0)	1.74	233	1.4	120	92	3500

Tenuta, M. current analysis

IMPROVING NITROGEN MANAGEMENT

NITROGEN MANAGEMENT BMP

- Max $75K over two years
- Polymer coated urea
- Nitrification and urease inhibited fertilizer
- N management plans
- Soil testing
- Soil mapping
- Adding legumes to a crop rotation
- Application equipment
- Split application
- Organic N sources

https://peifa.ca/wp-content/uploads/2022/09/PEIFA_OFCAF_Program-guidelines_V3_2022-2023.pdf

Proposed Potato Cluster Project

Benefits of Improved N Use Efficient Varieties and Enhanced Efficiency Fertilizers

Thoughts

- N_2O reductions achievable with 4Rs
- Inhibitors work to reduce direct and indirect emissions
- Placement works to reduce emissions
- Splitting applications and fertigation work to reduce emissions
- Benefit to yield not as apparent
- Missing understanding of rate effects in combinations with 4Rs
- Missing understanding of 4Rs and indirect N_2O emissions
- Missing integration of broad Canadian network of research, particularly AAFC, ECCC, academia, farmers and industry together: Potato Cluster
- N rates keep going up so imperative to tackle emission reductions to not handcuff production

Important Thoughts

- Use good practices such as 4Rs and N_2O will decrease without hurting yield
- Cost of 4Rs can be offset by reduce N rates because of lower losses (more of a sure thing)
- Cost of 4Rs can be offset by higher yields (not clear a sure thing)
- Cost of 4Rs can be offset by OFCAF cost share programs
- As time goes on return on 4Rs to reduce N_2O should improve from a C market
- N management is more challenging in potatoes (tuber set, vine/tuber growth, tuber quality) -

Thank You to

- AAFC, NSERC, Manitoba Agriculture, KPPA, Simplot, McCain, MCDC, Nutrien, KOCH
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- Many farmer co-operators in Manitoba

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