THE POWER TO MAKE THINGS GROW

Fertilizers and Soil Amendments to Maximize Crop Production

KOCH

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In times of change, learners inherit the Earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists

Eric Hoffer

So… what has changed?

Cell phone then and now

Computers then and now

Urea 1
Urea 2
Urea 3
Urea 4
Urea 5
Urea 5d
.
Urea 6
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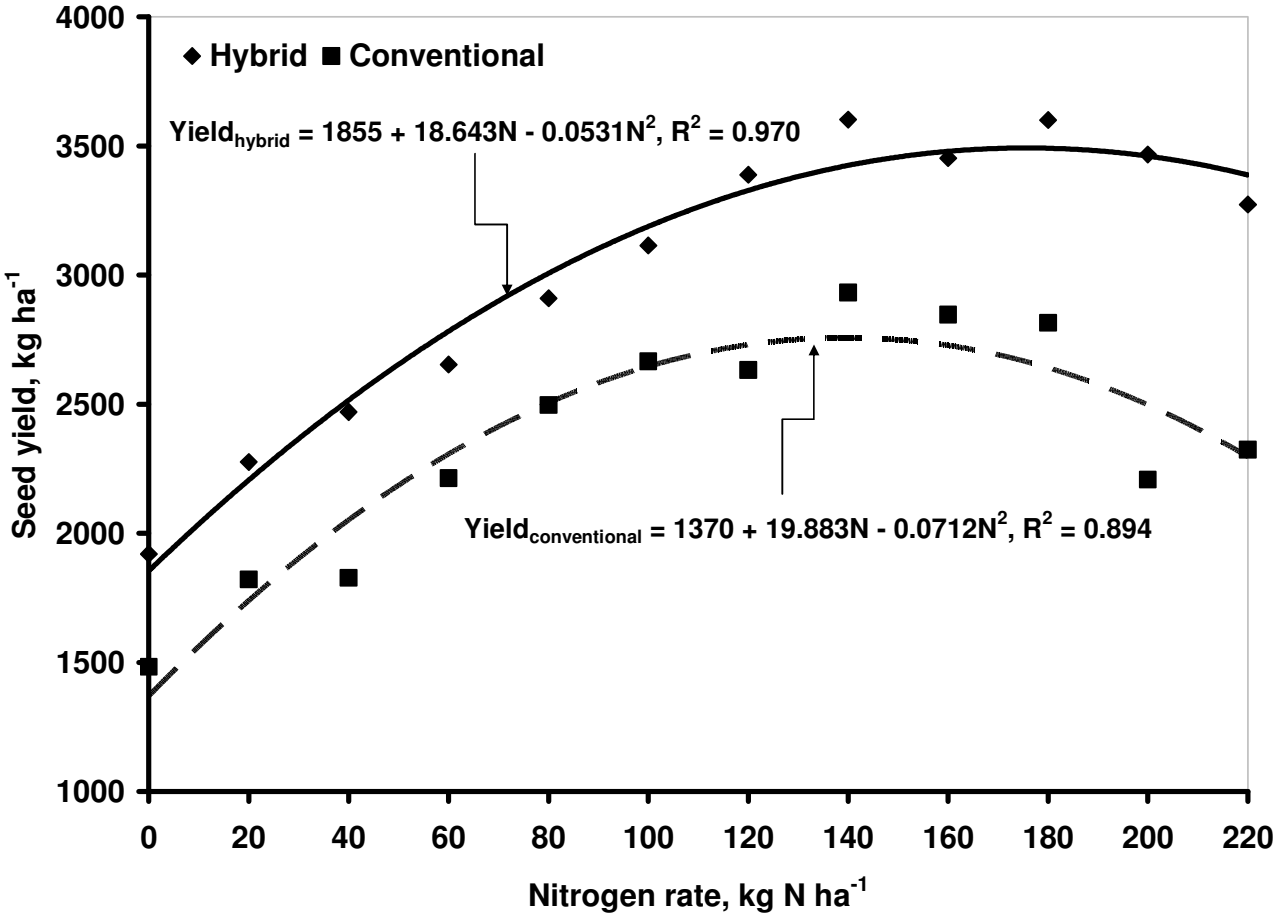
Maximum crop production cannot be achieved with fertilizers and amendments alone – We need to answer first:

- What Crop Yields Are Possible?
- What fertility and moisture is required to get there?
  - Crops exhibit different water use efficiency in every part of the prairies and the Red River valley is not an exception.
  - Water use efficiency is also weather dependent and when combined with best management practices for fertilizers and desirable crop genetics leads to maximum yields.
- Fertility products that work and those that don't.

What determines Maximum Yield?

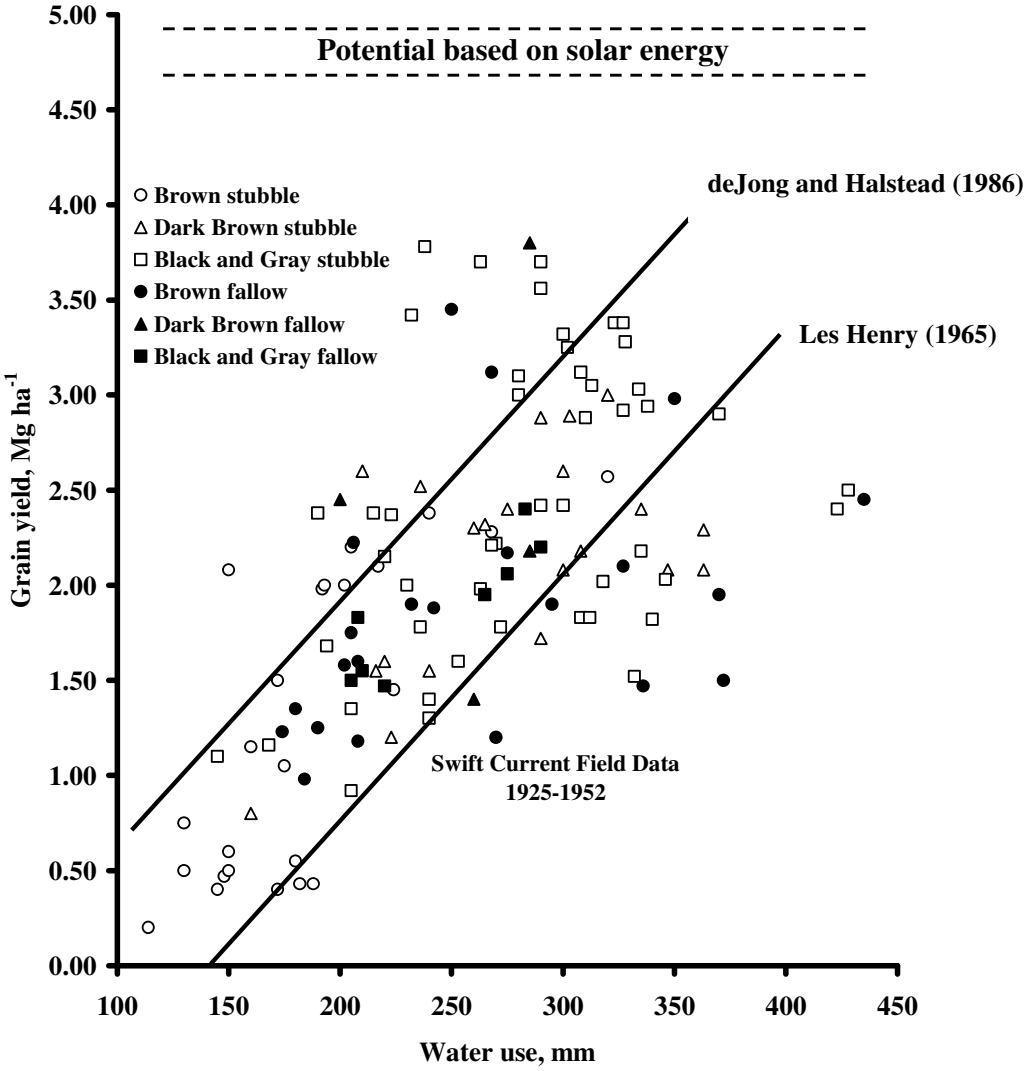
- Crop genetics
- Solar radiation
- WATER
- Nutrients

Canola hybrids



Karamanos et al. (2005)

HRS Wheat

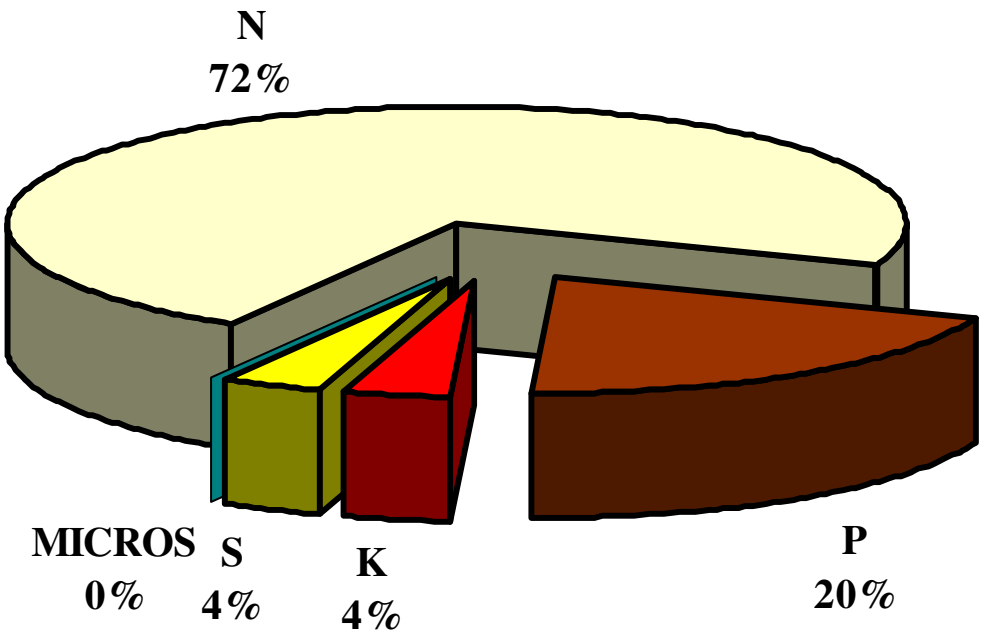

Potential based on solar energy
Brown stubble
Dark Brown stubble
Black and Gray stubble
Brown fallow
Dark Brown fallow
Black and Gray fallow
deJong and Halstead (1986)
Les Henry (1965)
Swift Current Field Data
1925-1952
Grain yield, Mg ha-1
Water use, mm
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
100
150
200
250
300
350
400
450

What determines Maximum Yield?

- **Nutrients**

Nitrogen is the single most important nutrient and provides a response almost always when a soil is Nitrogen deficient.

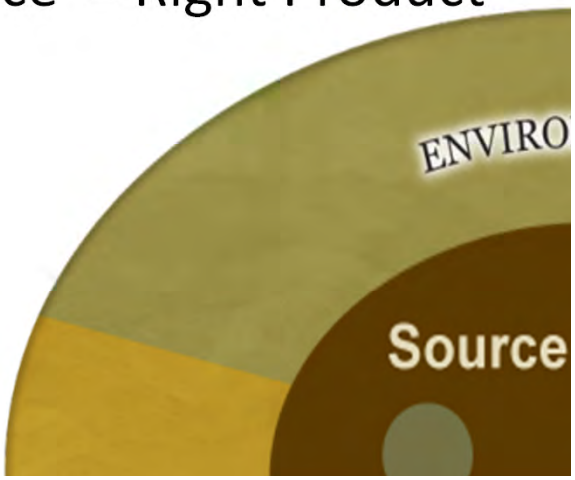
Relative Nutrient Response
Barley average 19 site-years
(1990-1998)



J.T. Harapiak and R.E. Karamanos and A. Johnston 2000. Better Crops, 84 (1): 14-45.

4R Nutrient Stewardship

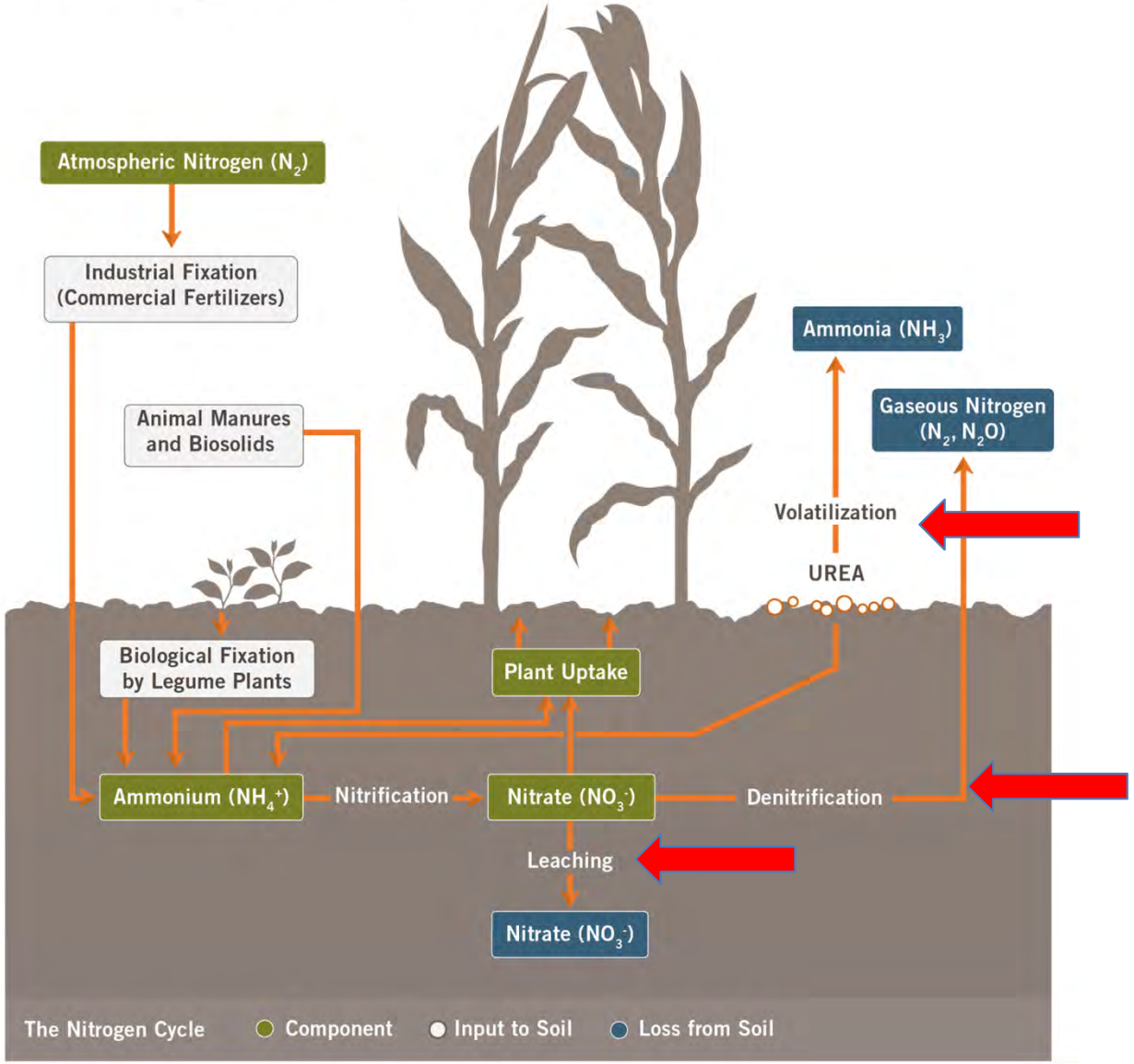
- Right Source = Right Product



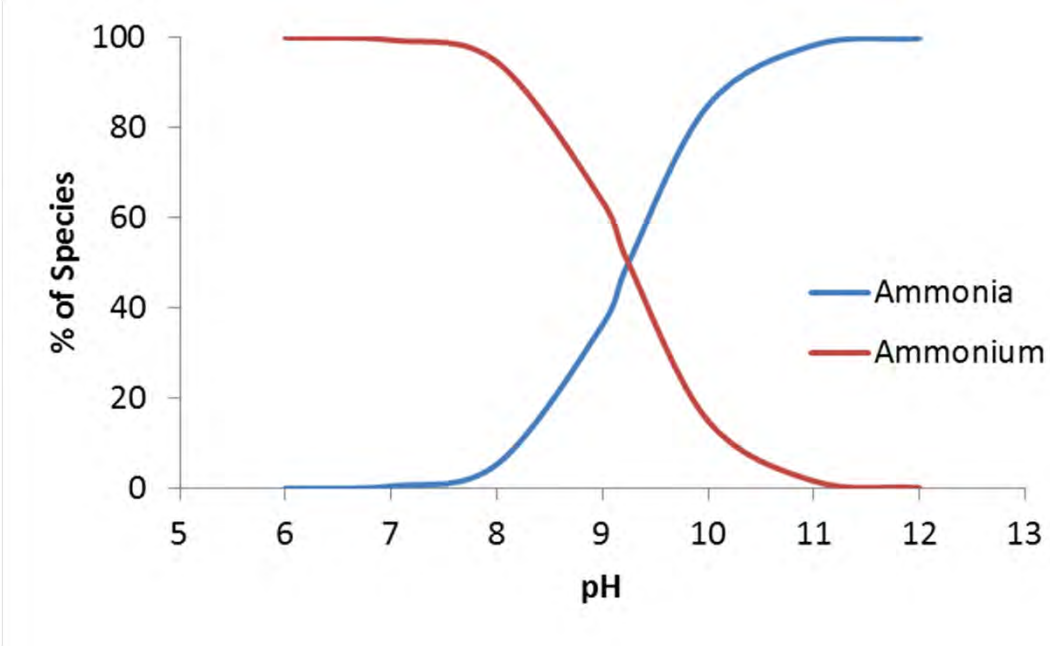
Nitrogen

Courtesy IPNI

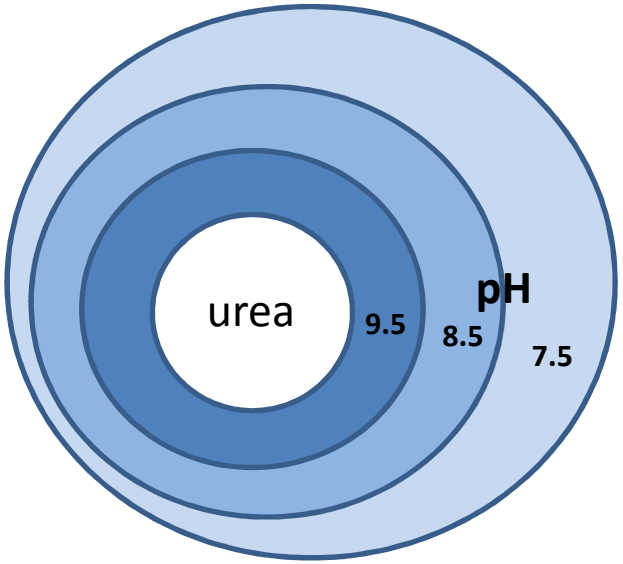
Losses during N cycling



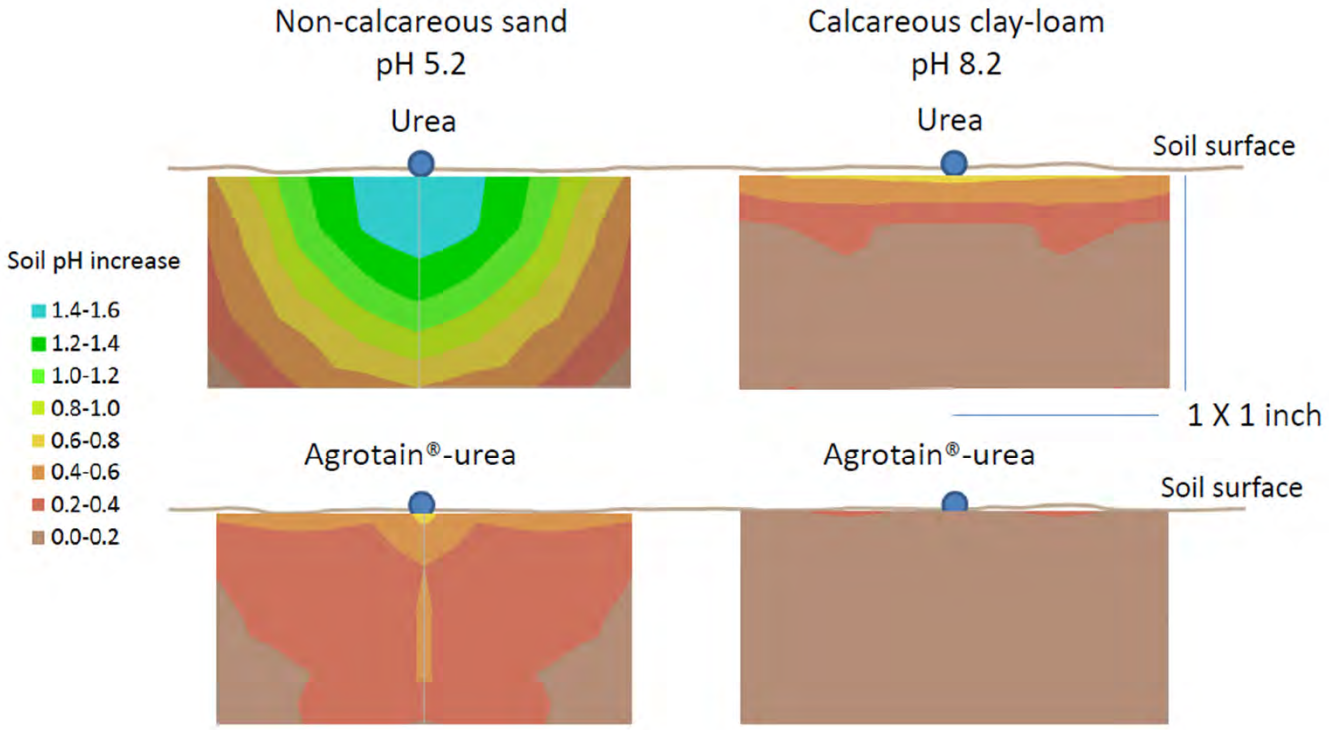
Nitrogen Loss: Ammonia Volatilization occurs due to rapid rise in pH around unprotected urea prill. The high pH results in more ammonia.



$NH_4^+ \longleftrightarrow NH_3 + H^+$



Volatilization results from soil pH change surrounding urea granule



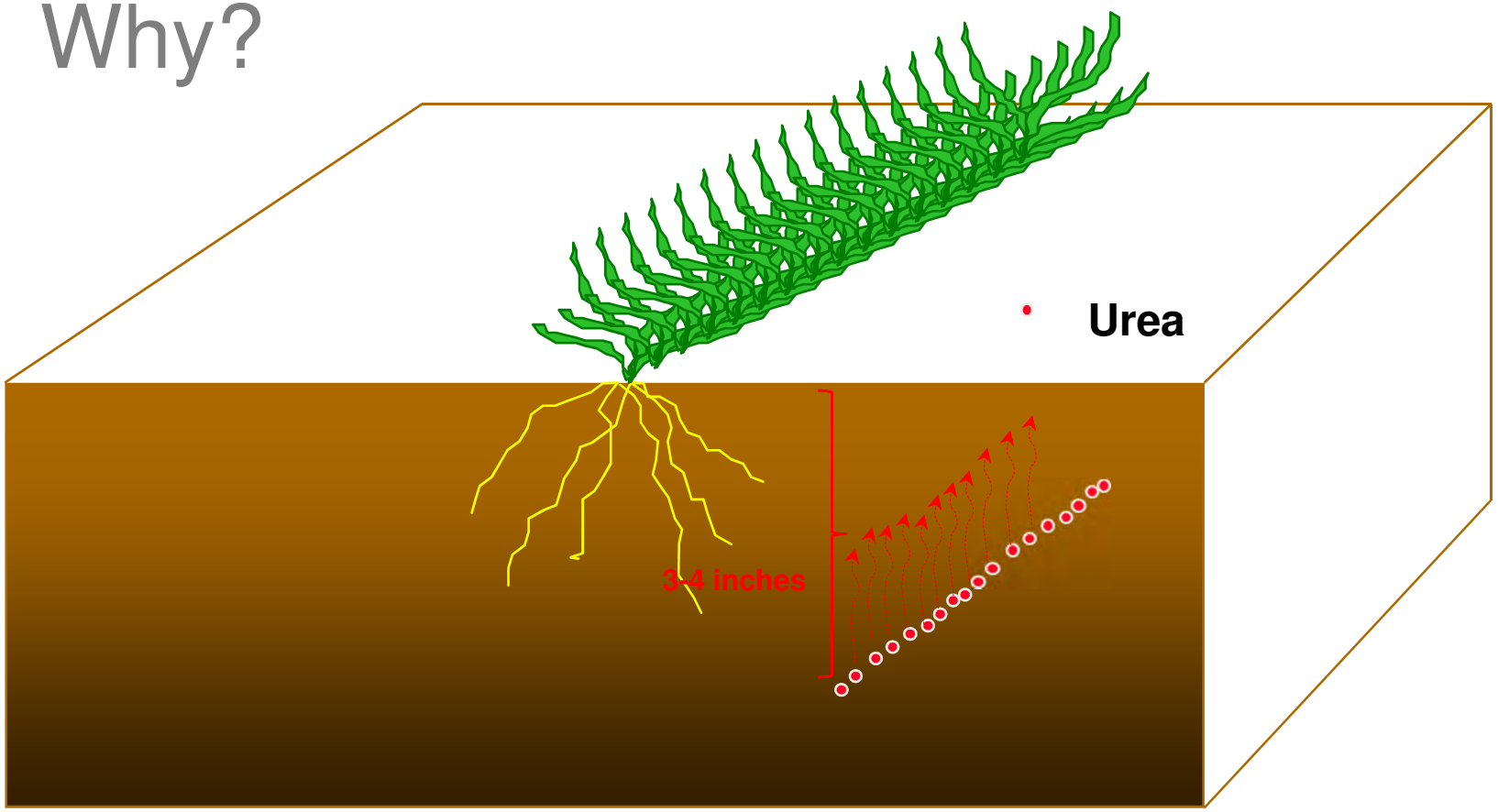
Change in soil pH from the original pH by distance and depth 6 days after urea with and without Agrotain® is placed on soil surface. Adapted from Christianson et al. 1993.

Used with permission of Dr. Clain Jones, Montana State University

Recommended practices to lower volatilization

- Use of urease inhibitors (Watson,1990)
- Slow-release forms (Rao, 1987), and,
- Irrigation shortly after application (Holcomb et al., 2011)
- **However, the most common practice has been the incorporation of the fertilizer into the soil.**

Why?

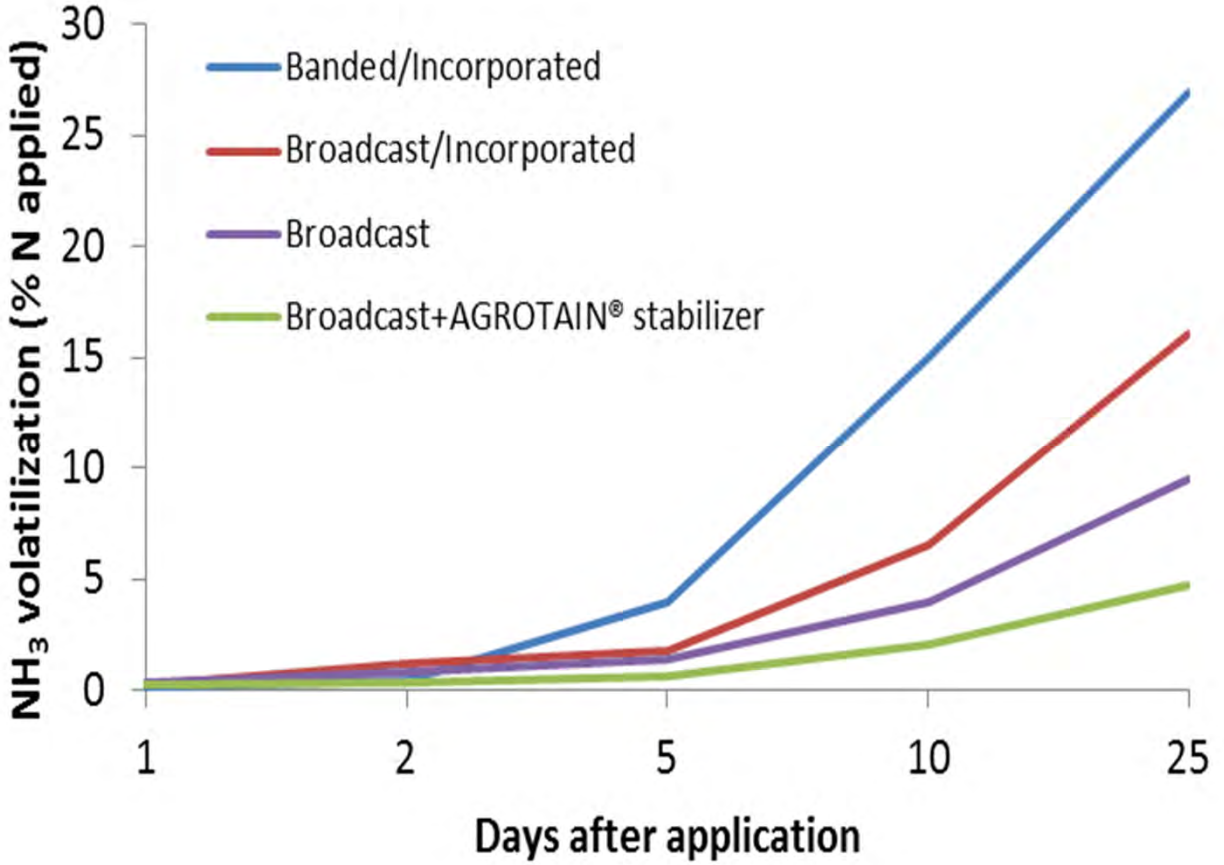


Because of increased resistance to the upward diffusion of ammoniacal N in the liquid and gaseous phases and **the retention of NH_4^+–N on soil** when urea is placed at depth (Sommer et al., 2004)

So, what is new now?

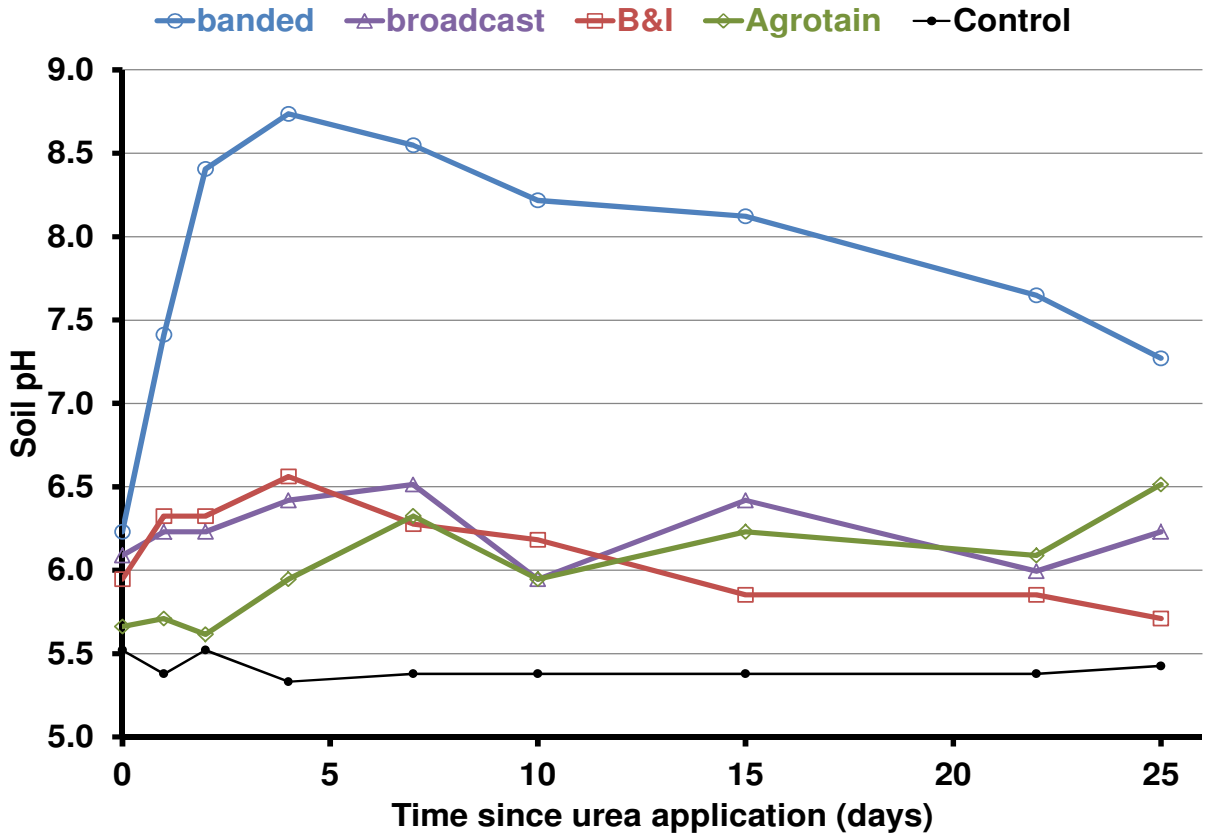
- Today, for example, in zero till fields where all the fertilizer is being applied at time of seeding, the urea or UAN bands are seldom more than 1 1/2" - 2" deep.
- This shallower placement of nitrogen may be causing greater losses than we suspect.
- Our belief that if "it's in the soil it's safe" may be misguided.
- New research is indicating that shallow banded urea and UAN are susceptible to volatilization losses.

How did it all start?



- Field study. Average study temperature: 5 °C
- Le Bras clay loam soil; pH 5.5
- Nitrogen rate of 125 lbs N/acre
- Urea incorporated 2 inches deep
- AGROTAIN® applied at label rate
- Source: Rochette et al., 2009. Agriculture and Agri-Food Canada.

Change in soil pH at 0 - 4 cm (0 – 1.5”) depth



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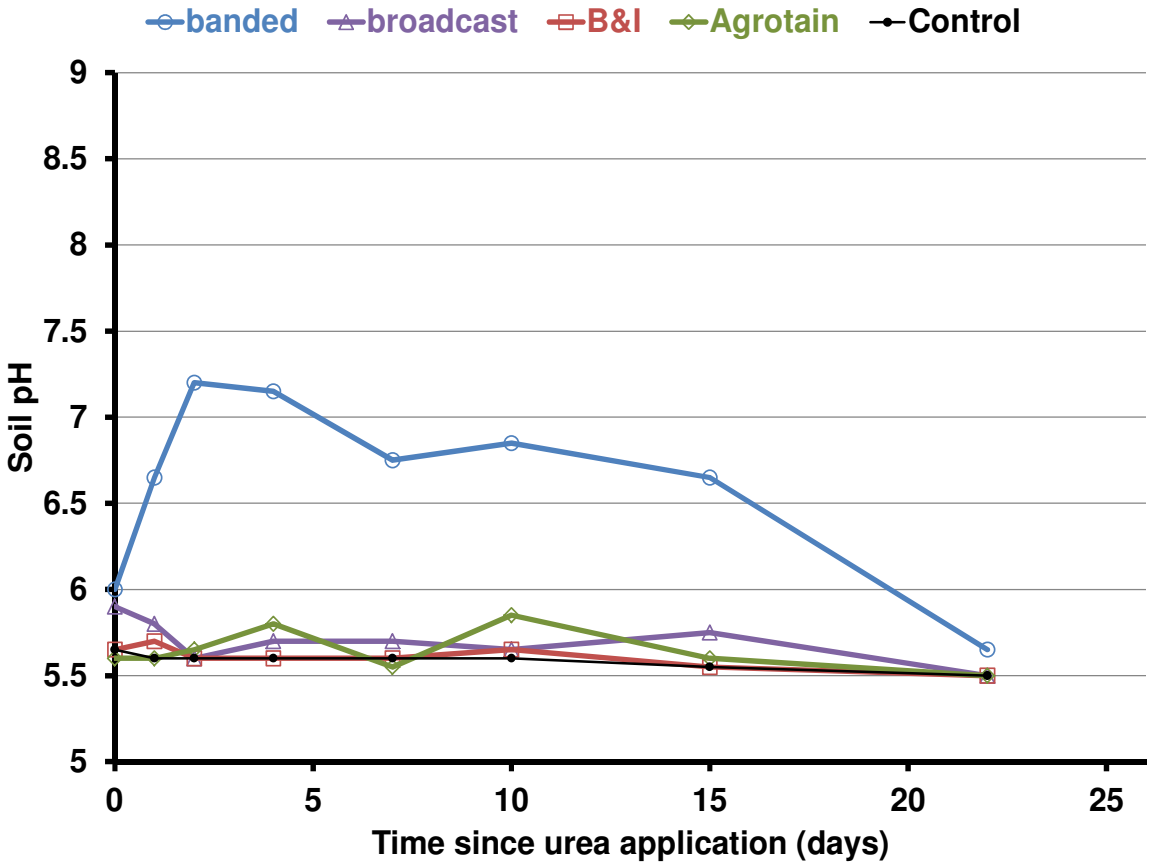
Change in soil pH at 4 - 8 cm (1.5 – 3”) depth



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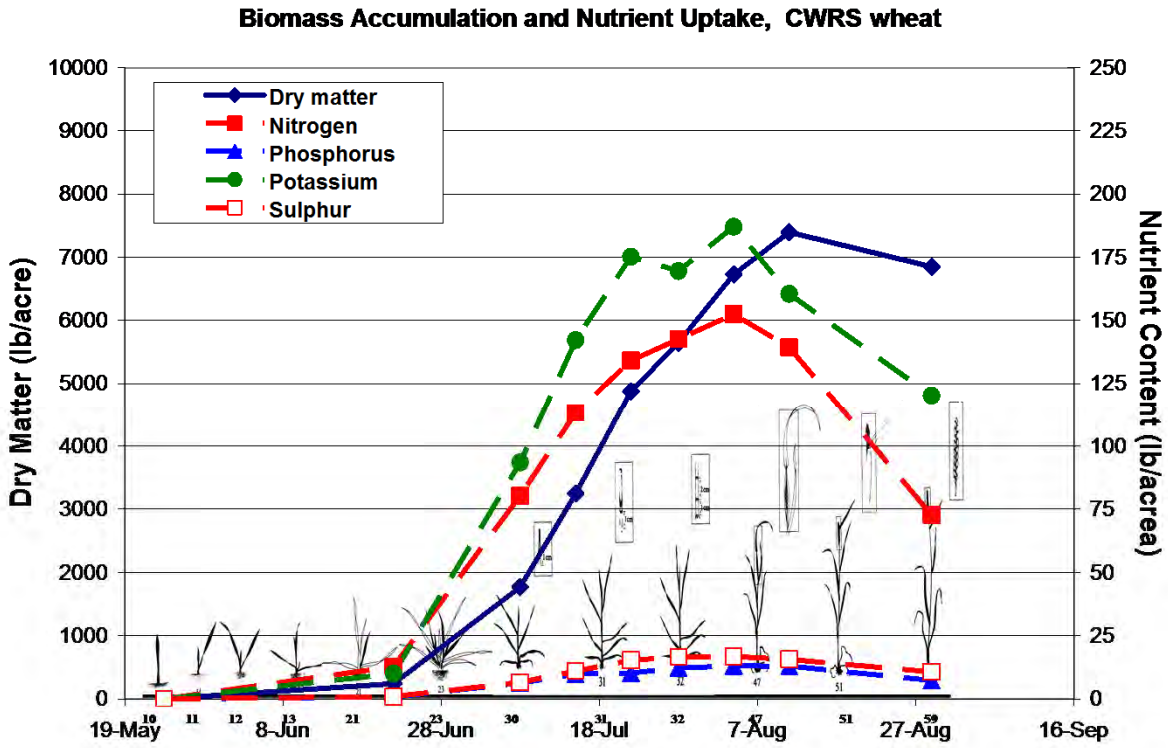
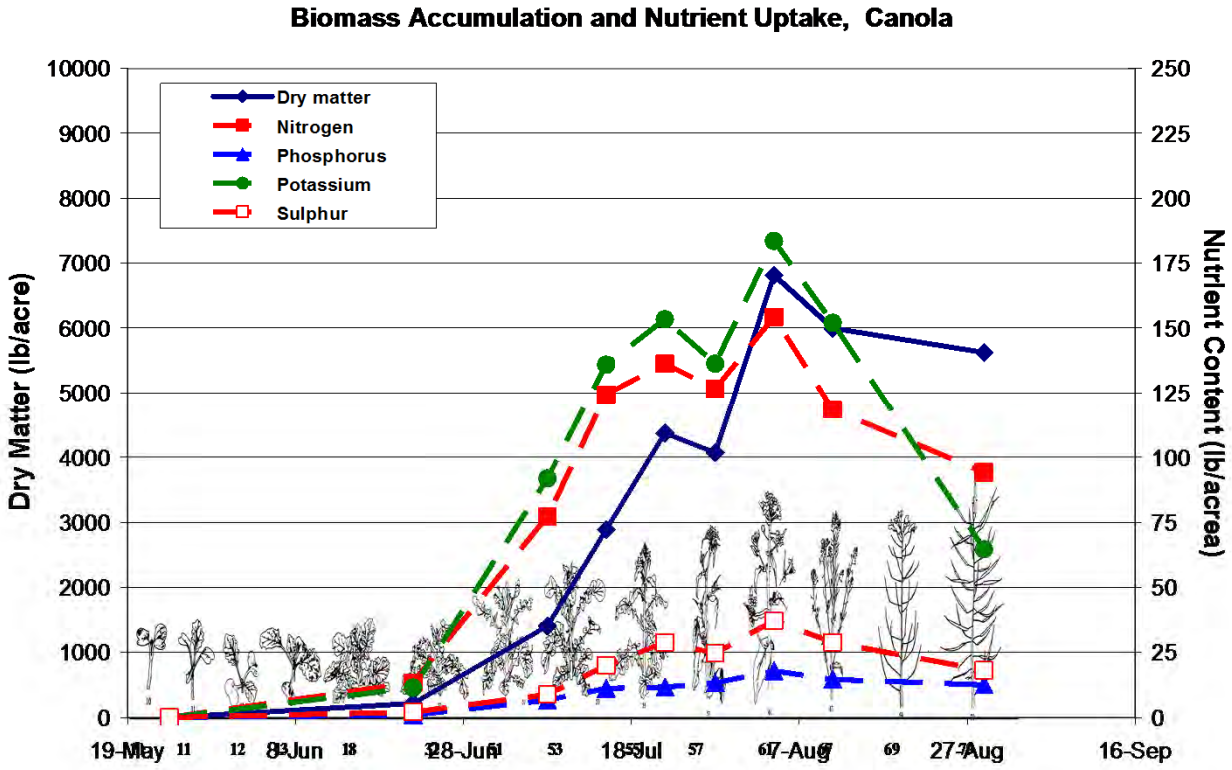
Plant biomass and nutrient accumulation in wheat



Karamanos, R.E. 2014. Prairie Soils and Crops, 6: 52-63, http://www.prairiesoilsandcrops.ca/table_of_contents.html

Plant biomass and nutrient accumulation in canola



Karamanos, R.E. 2014. Prairie Soils and Crops, 6: 52-63, http://www.prairiesoilsandcrops.ca/table_of_contents.html

Cor3-2011 - Rethinking Nitrogen Losses – 2011

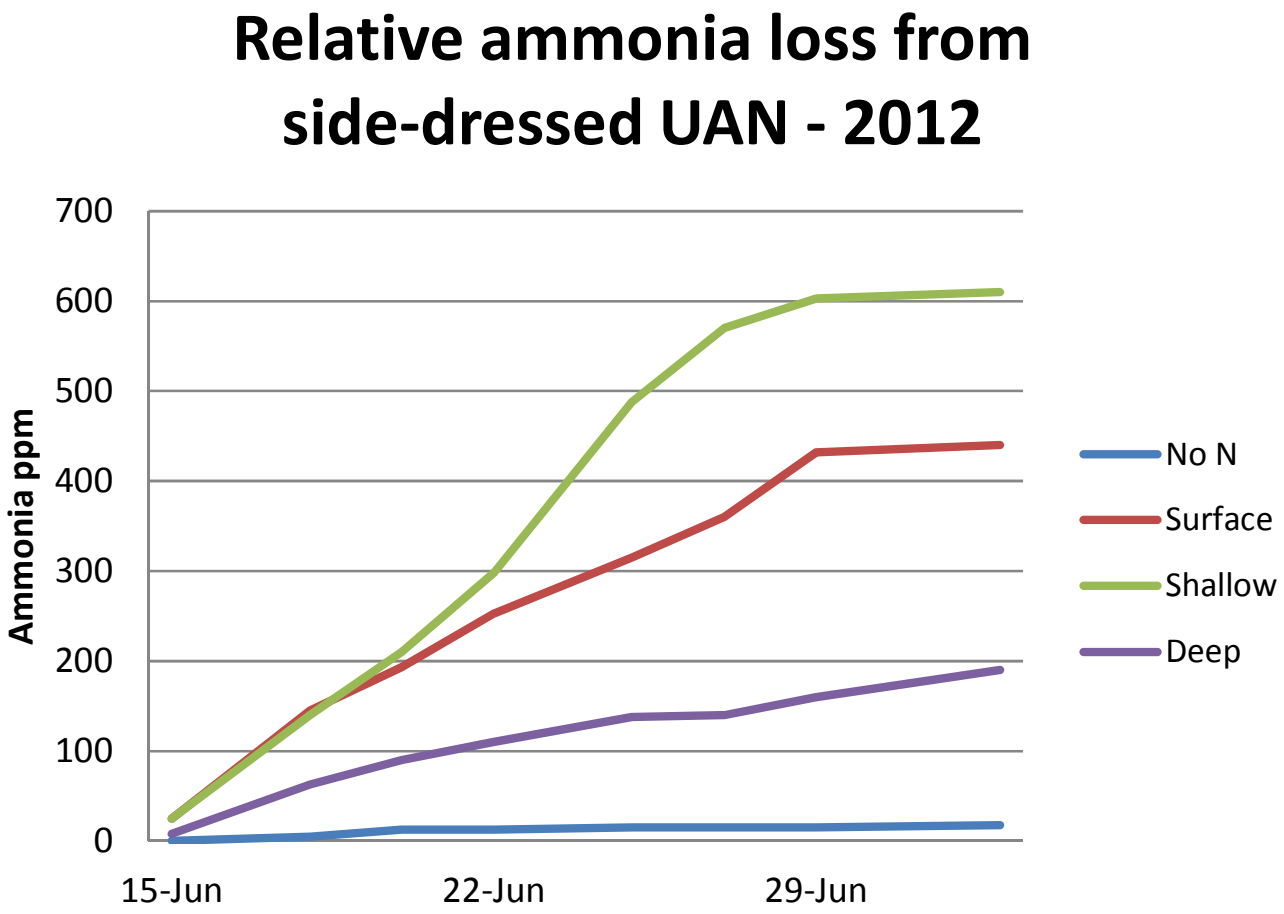
http://www.ontariosoilcrop.org/cropadvances.htm

Table 1. Ammonia volatilization related nitrogen loss response for different UAN side-dressing methods in June 2010 in Ridgetown and Winchester, Ontario

Side-dress Method	N-Loss Index (%)
UAN Side-dress surface	100
UAN Side-dress Shallow (1")	112
UAN Side-dress Standard (3-4")	6

Demonstration in Manitoba

Demonstration in Manitoba



- Demonstration
- Ammonia dosimeter tube readings
- Source: John Heard, Manitoba Agriculture and Food.

Leaching and denitrification: Losses that occur due to nitrate

urea

urease

Ammonium (NH_4^+)

Nitrosomonas

Nitrite (NO_2^-)

Nitrobacter

Nitrate (NO_3^-)

(Ammonia mono-oxygenase)

(N_2O and N_2)

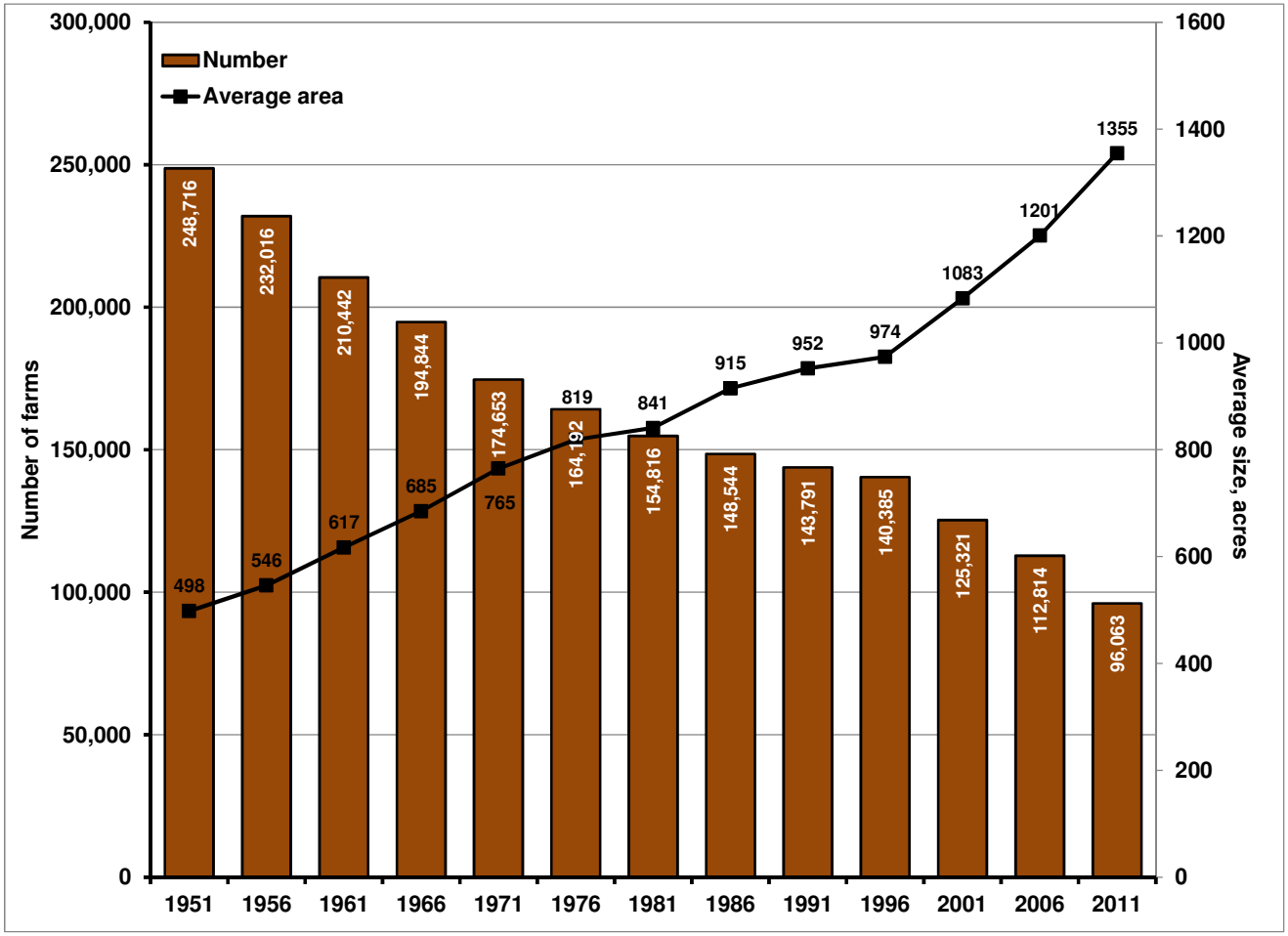
nitrate and nitrite reductase

Leaching

NITROGEN MANAGEMENT

- Nitrogen fertilizer management is receiving considerable attention due to:
  - Fluctuating prices of nitrogen fertilizer and crops
  - Efforts to reduce NH_3 and N_2O emissions, and nutrient leaching and run-off
- Key is to manage nitrogen availability for plants by reducing losses
  - Long periods from application to crop demand
  - Susceptible to loss
- Enhanced Efficiency Fertilizers can play a role

Number and size of farms on the prairies*



*** Statistics Canada:**
http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=0010010&pattern=summerfallow&tabMode=dataTable&srchLan=-1&p1=1&p2=33

What is an Enhanced Efficiency Fertilizer?

- T-70 Enhanced Efficiency is a term describing fertilizer products with characteristics that allow increased plant uptake and reduce the potential of nutrient losses to the environment, such as gaseous losses, leaching or runoff, as compared to an appropriate reference product.
- Adopted from AAPFCO (2008)*

*Association of American Plant Food Control Officials

Types of EEF Products

- Uncoated slowly available fertilizers containing N
  - e.g., urea-aldehyde condensation products (e.g., urea-formaldehyde reaction products, IBDU), triazines, etc.
- Physical coating or barrier around soluble N fertilizer
  - e.g., SCU, PCU, combination products
- Stabilized materials
  - e.g., nitrification and urease inhibitors

Polymer coated urea

- N release controlled by diffusion
- Major factors affecting release
  - coating thickness
  - temperature
  - moisture

ESN Fertilizer Technology Development

Collaborative 4 year study 2008-2012:

- **ARD**
  - **ESD (Land Use)**
  - **RIAD (Food & Bio-Industrial Crops)**
- **AAFC – Lacombe, Beaverlodge**
- **Agrium**
- **ACIDF**

Slide courtesy of Len Kryzanowski, ABAG

"5th R" – Right Economics

Yield and economic response of the ESN treatments (2008 – 2010)

Crop	Year	Yield Response			Economic Response	
		Positive	Percent Positive	Negative	Number of Treatments	Percent Economic
Barley	2008	87	60.4%	59	70	48.6%
	2009	73	50.7%	71	66	45.8%
	2010	72	56.3%	56	61	47.7%
	Total	232	55.8%	186	197	47.4%
Canola	2008	98	68.1%	46	90	62.5%
	2009	93	64.6%	51	87	60.4%
	2010	73	65.2%	38	67	59.8%
	Total	264	65.9%	135	244	60.9%
Wheat	2008	76	52.8%	68	64	44.4%
	2009	88	61.1%	56	67	46.5%
	2010	70	54.7%	57	61	47.7%
	Total	234	56.2%	181	192	46.2%

Economic response proportion of ESN application (2008 – 2010)

Crop	Fall Banded ESN	Spring Banded ESN	Seed placed ESN	Seed placed Blend
Barley	38.0%	39.8%	48.1%	56.5%
Canola	44.4%	46.3%	65.7%	72.2%
Wheat	35.2%	35.2%	54.6%	58.3%

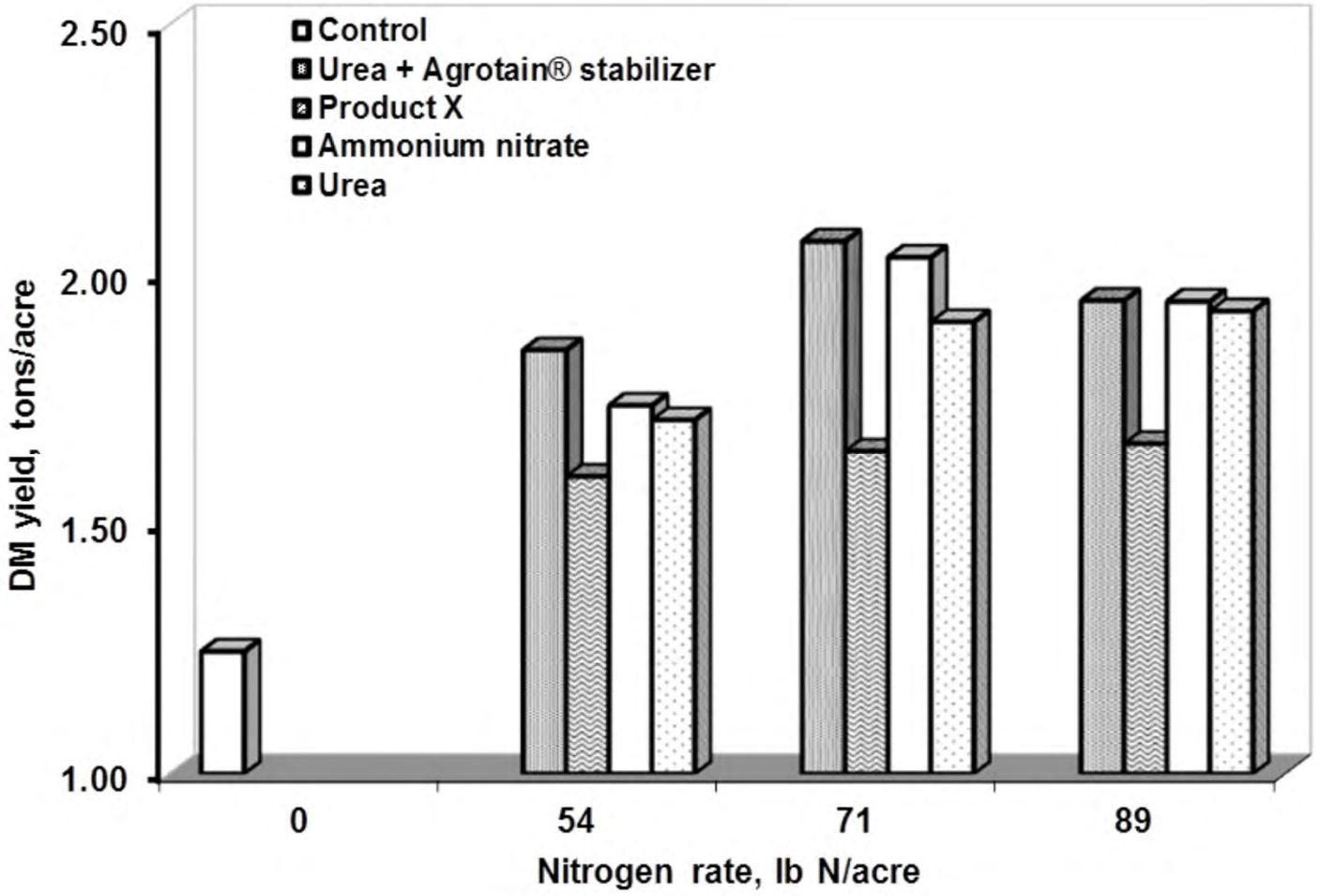
Slide courtesy of Len Kryzanowski, ABAG

Polymer Coated Fertilizers & Inhibitors– When can you expect them to work?

- When N fertilizers are applied in a high volatilization environment
- Seed row safeners

Stabilized Products

Forage Production (5 site-years)



Karamanos, R.E. and F. C. Stevenson, 2013. Canadian Journal Plant Science, 93: 151-160

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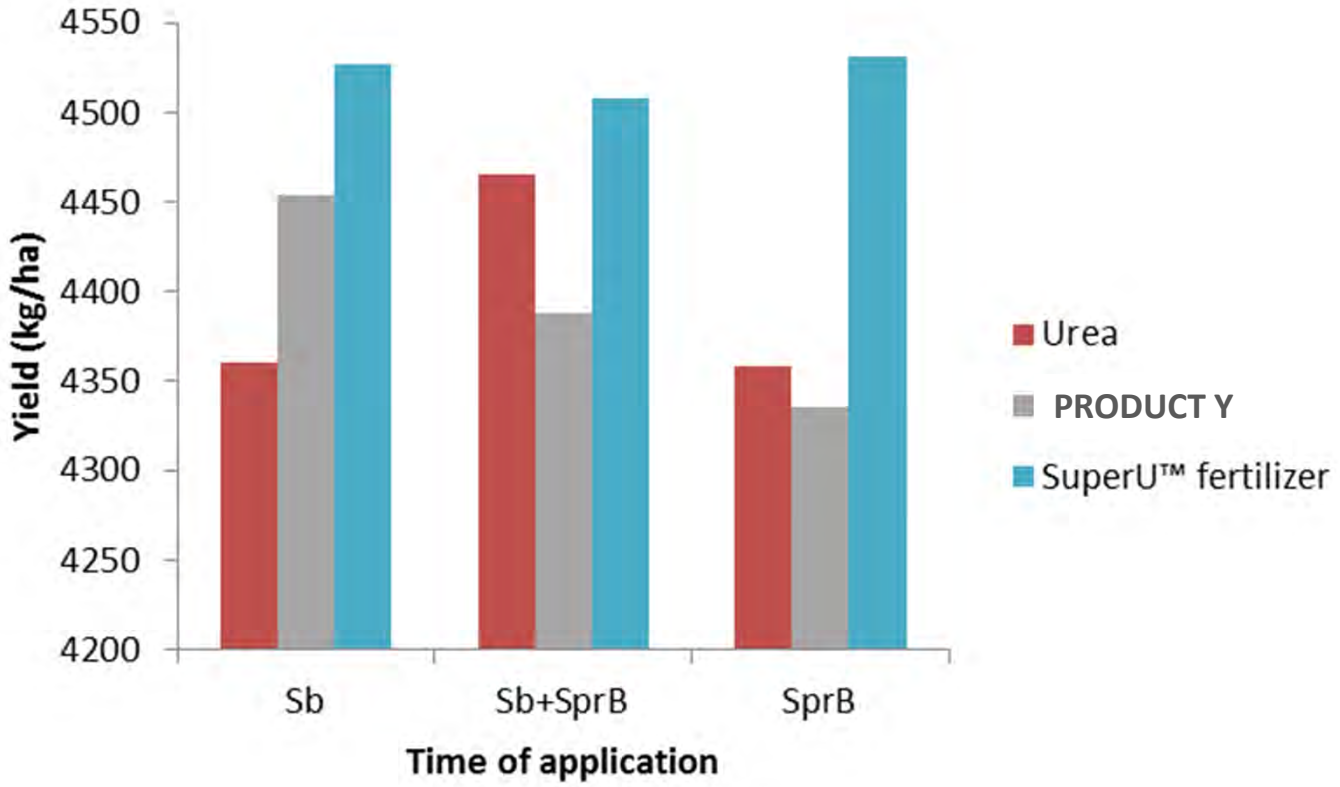
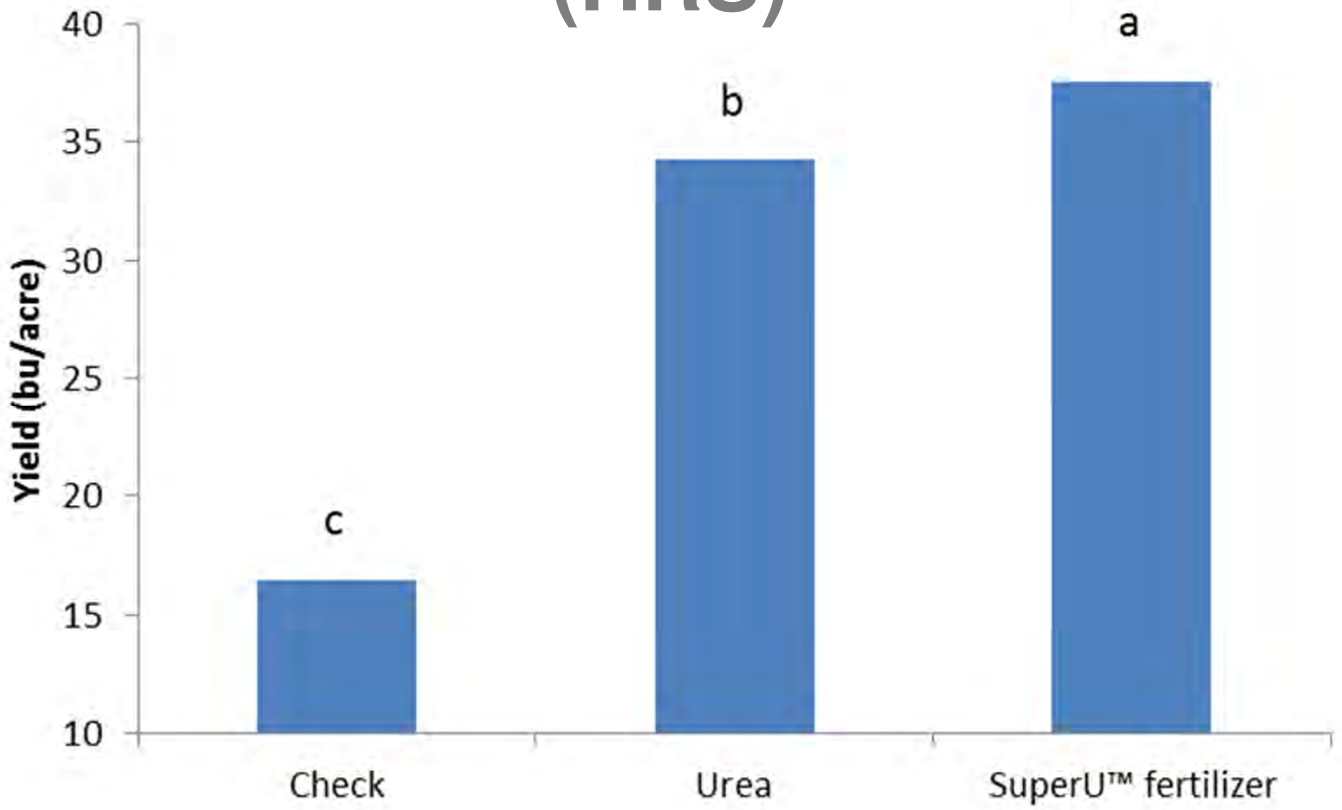
Agriculture and Agri-Food Canada – Canada Western Red Winter Wheat



- Average results across six sites and two years of study (AB, SK, and MB)
- N rate 80% of recommended for each site
- Sb-all sidebanded at time of seeding
- Sb+SprB-1/2x sideband; 1/2x broadcast in spring
- SprB-all broadcast in early spring
- Source: Beres et al., 2009

Wheatland Conservation Area – Wheat (HRS)



- Nitrogen rate of 50 lbs N/acre
- Treatments were band-incorporated to a depth of 1.5 inches
- Swinton silt loam soil
- Bars followed by the same letter are not statistically different
- Source: Nybo, 2010.

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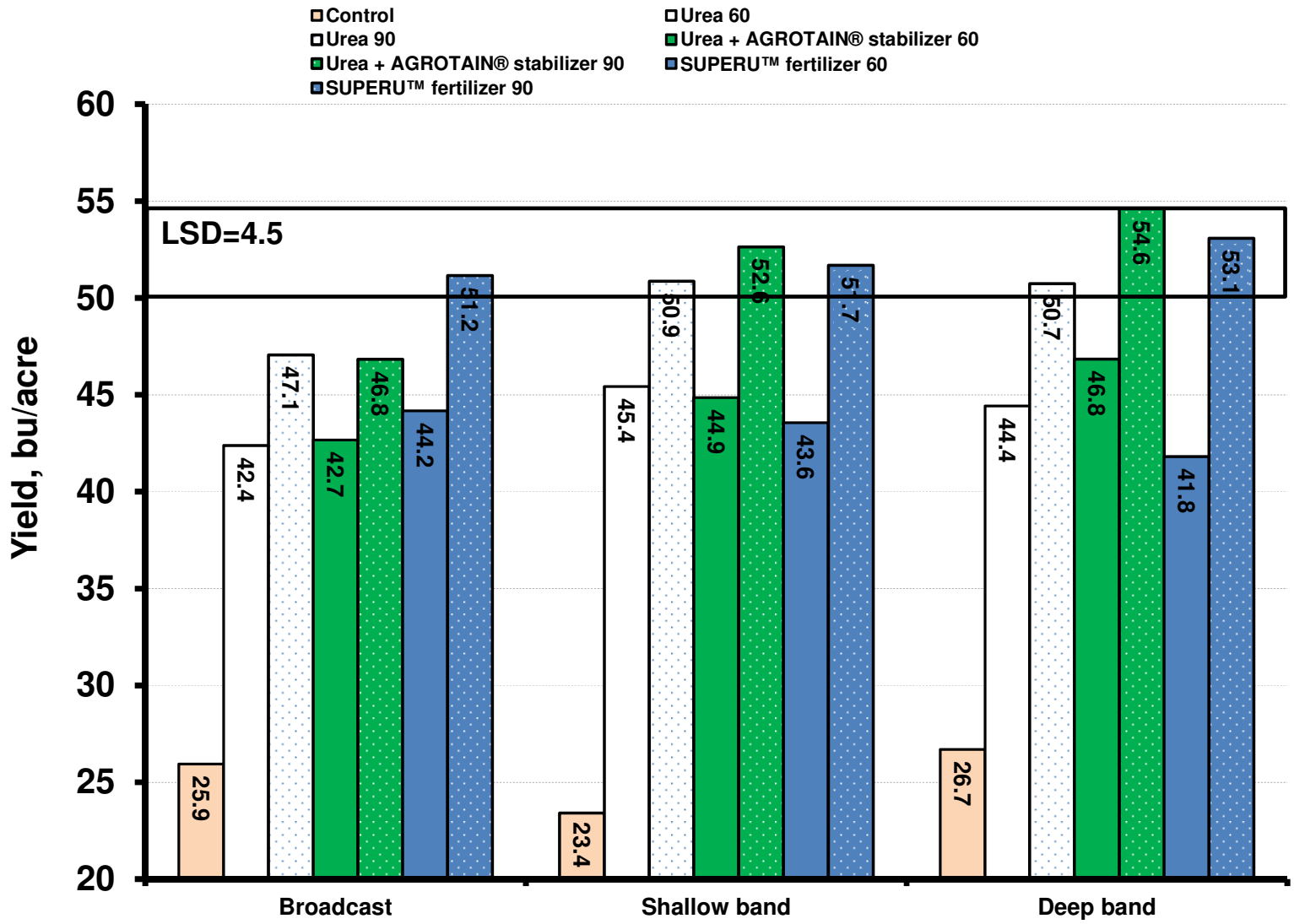
IHARF - Overall Effect of Product and Ra



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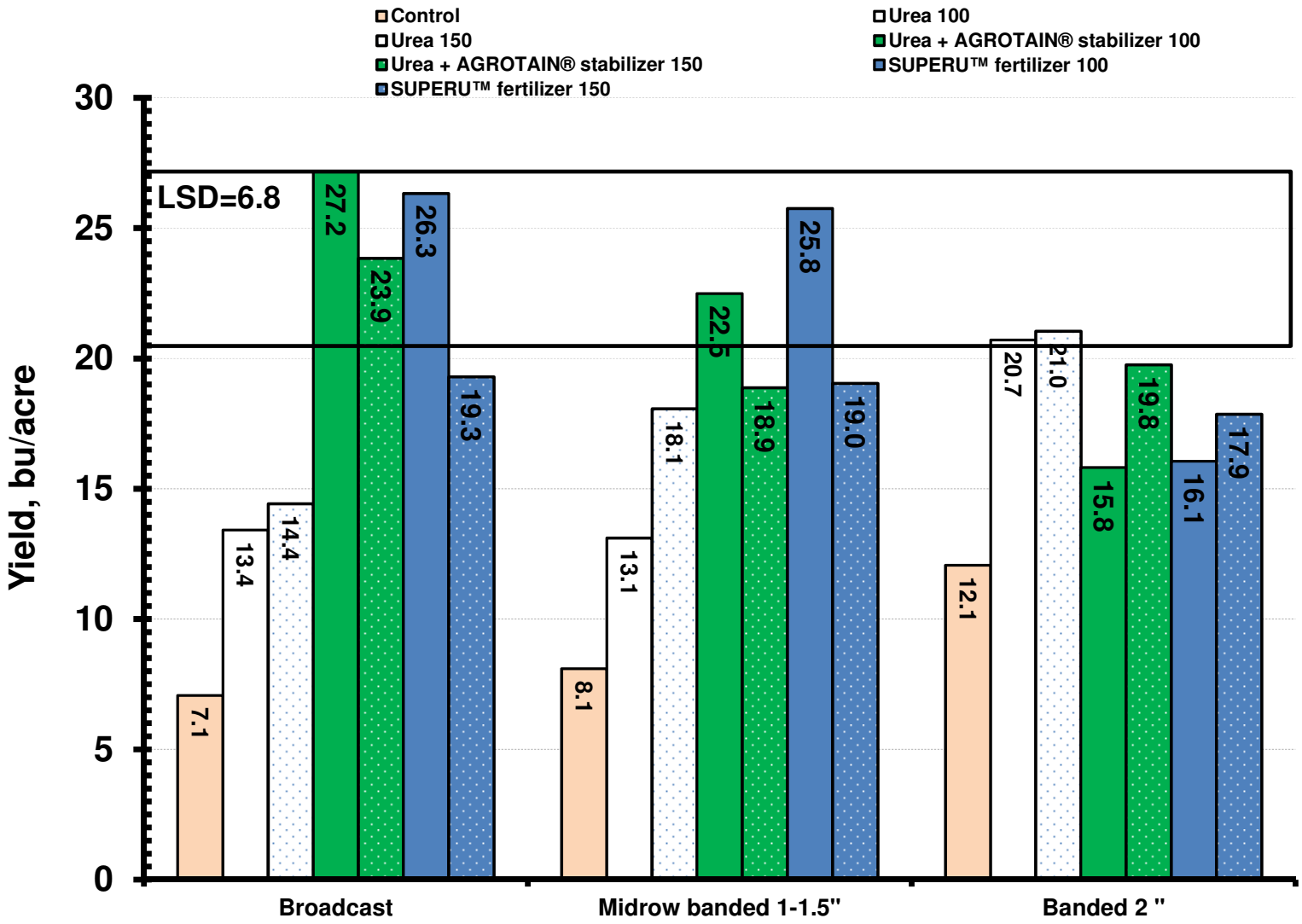
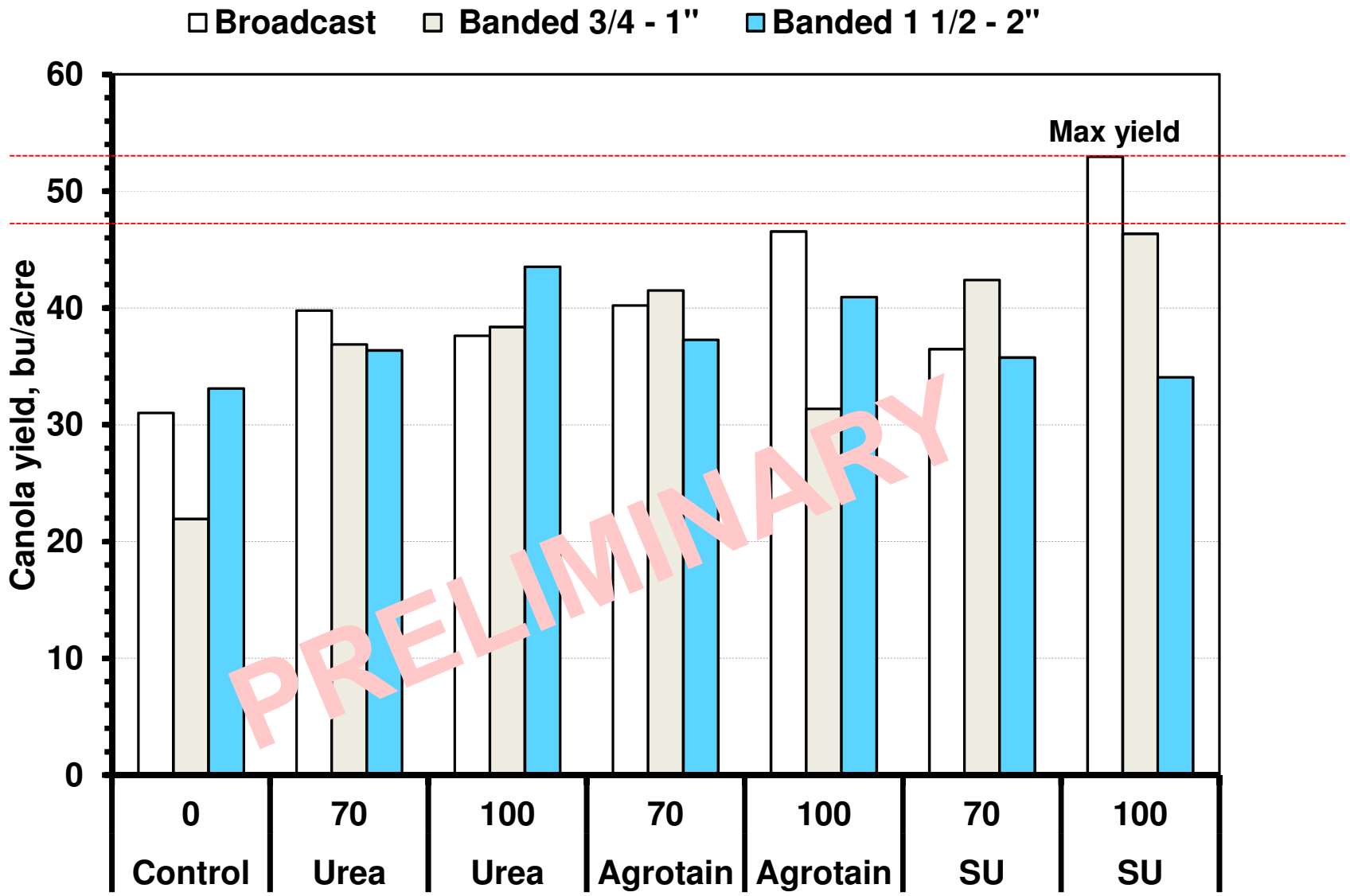
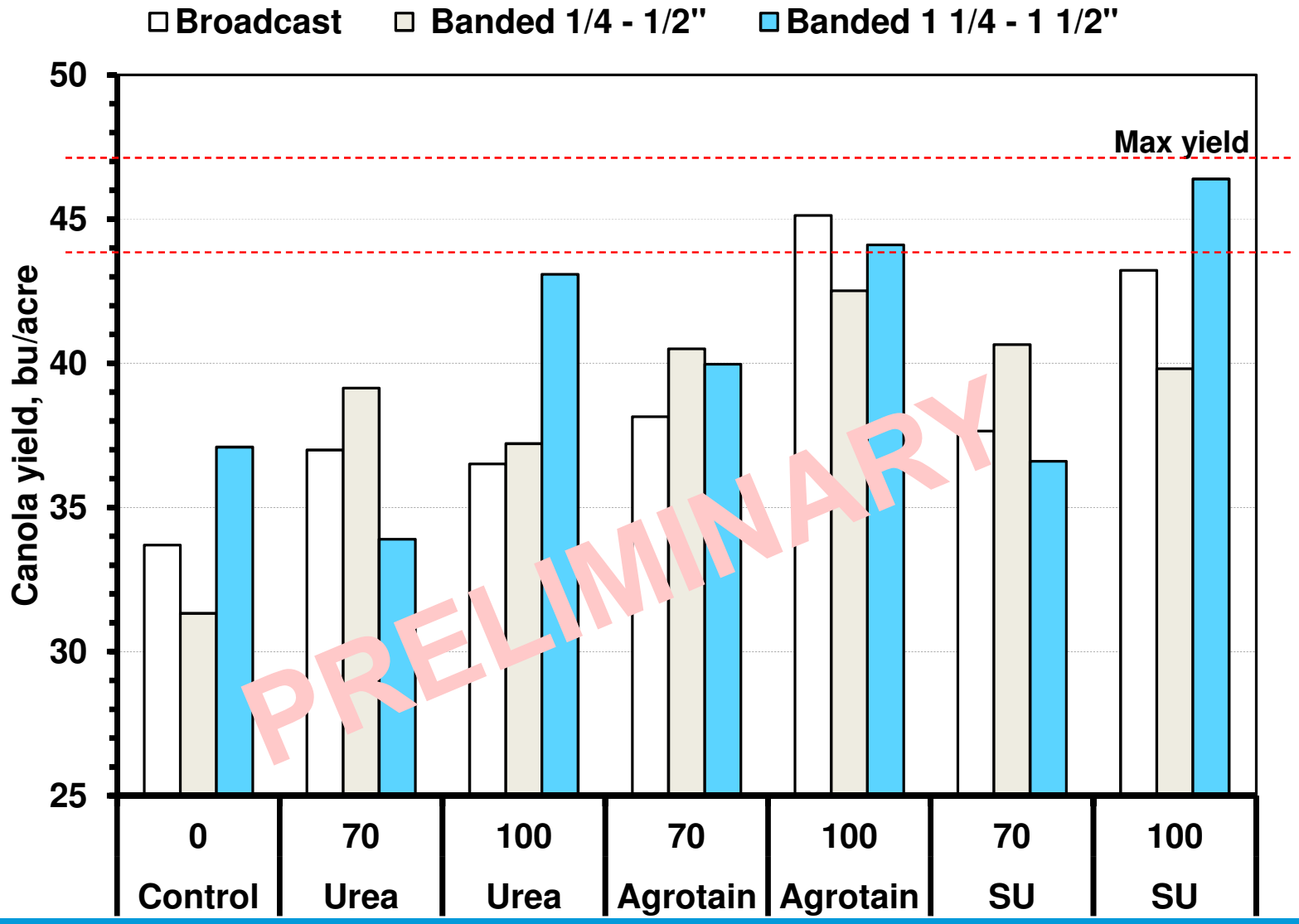
Breton - Overall Effect of Product and



Carman, MB

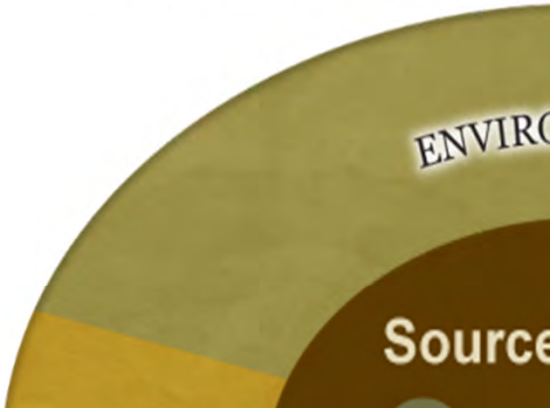

Broadcast
Banded 3/4 - 1"
Banded 1 1/2 - 2"
Canola yield, bu/acre
60
50
40
30
20
10
0
Max yield
PRELIMINARY
0 Control
70 Urea
100 Urea
70 Agrotain
100 Agrotain
70 SU
100 SU

Kelburn Farm, MB



4R Nutrient Stewardship

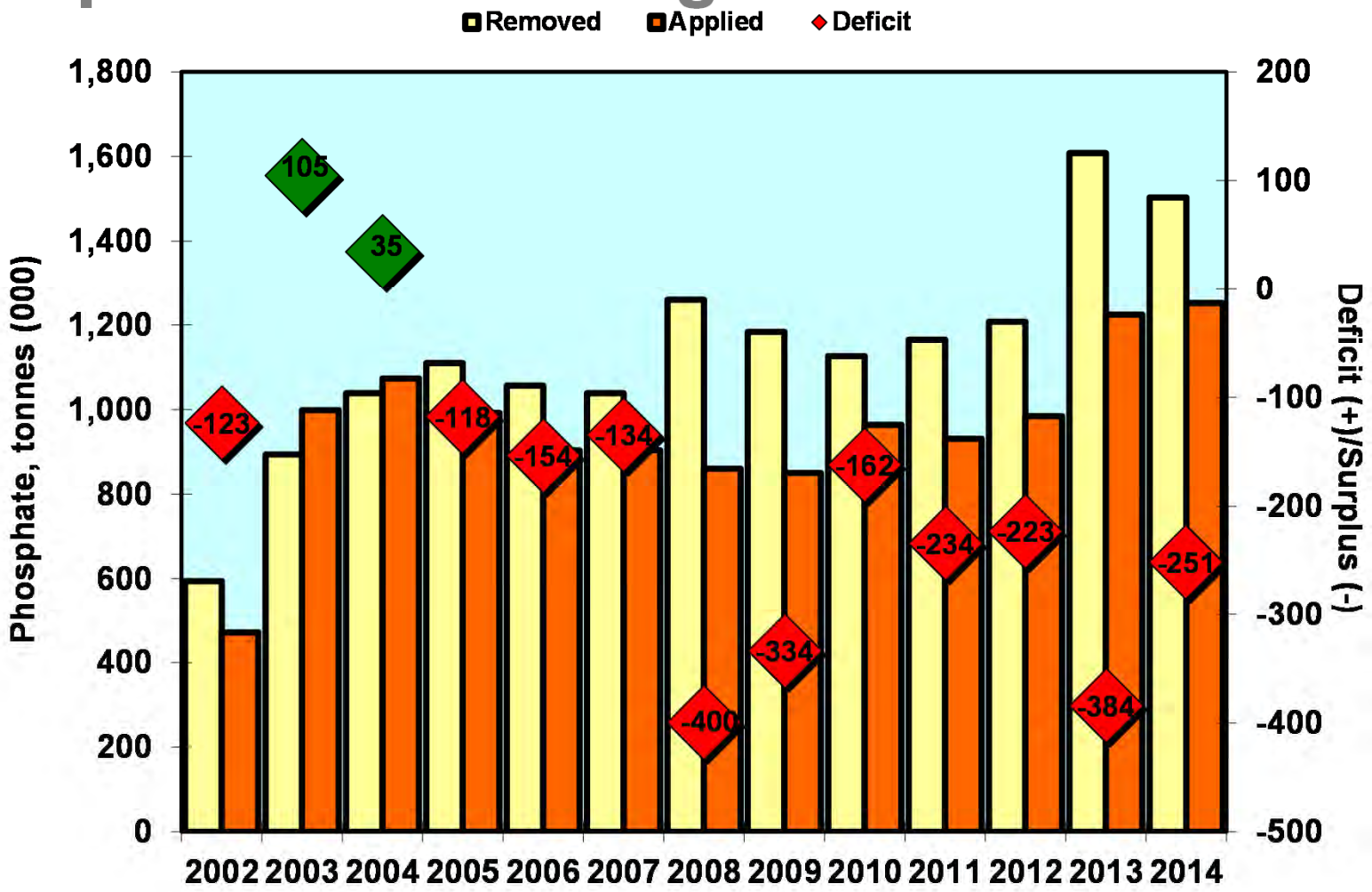
- Right Source = Right Product



Phosphorus

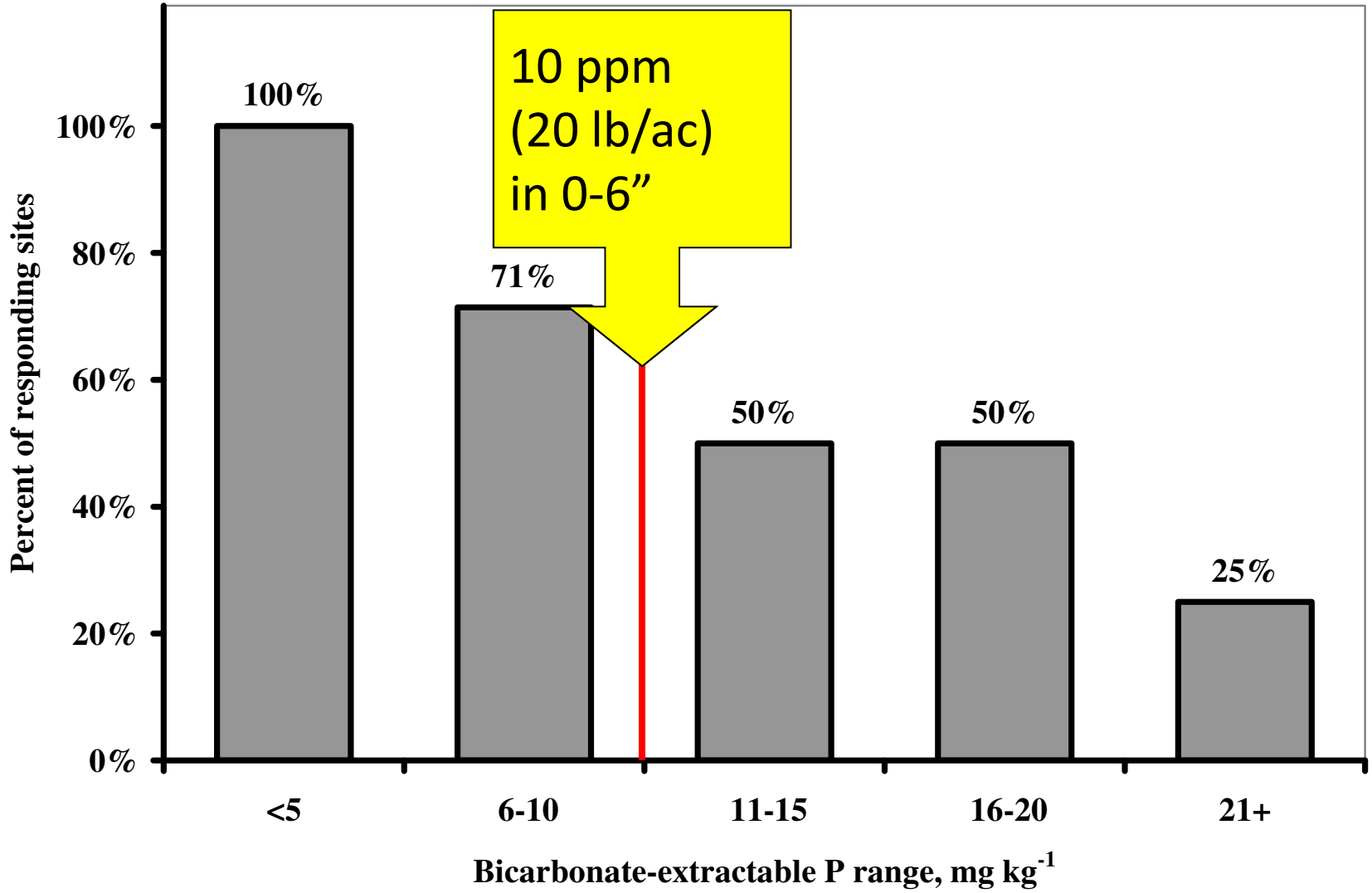
Courtesy IPNI

Phosphorus – The forgotten macronutrient?



*Canadian Fertilizer Institute: http://www.cfi.ca/publications.cfm, or
International Plant Nutrient Institute: http://www.ipni.net/article/IPNI-3296

Percentage of wheat responding sites to application of P as a function of soil test P



Karamanos, R. E., Flore, N. A. and Harapiak, J. T. 2010. Can. J. Plant Sci. 90:265 277, 47 site years in AB, SK, MB 1988-1995

Phosphorus fertilizers

- Monoammonium Phosphate
- Diammonium phosphate
- Triple super phosphate
- Orthophosphate
- Polyphosphate

Phosphorus Products

- Is a lb of P_2O_5 is a lb of P_2O_5?

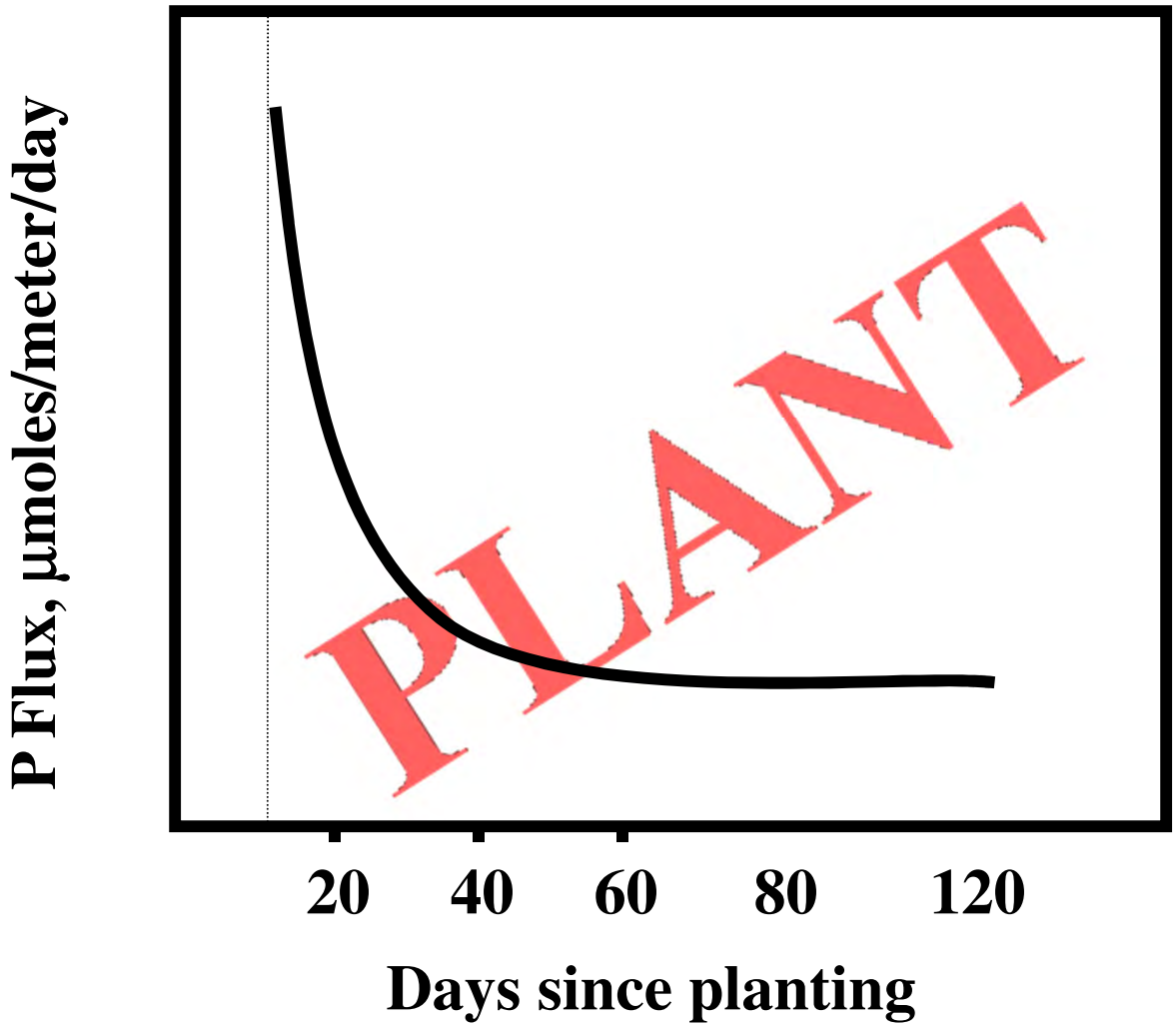
Major factors that make products different or… the same!

- **Product chemical make-up**
- **Soil chemistry**
- **Plants**
- **Combination of all of the above**

Soil solution P

- **Two forms (orthophosphates)**
- **Monovalent ($H_2PO_4^-$) dominates in acid soils while divalent (HPO_4^{2-}) dominates in alkaline soils**

Plants Also Influence Utilization of Available Phosphorus



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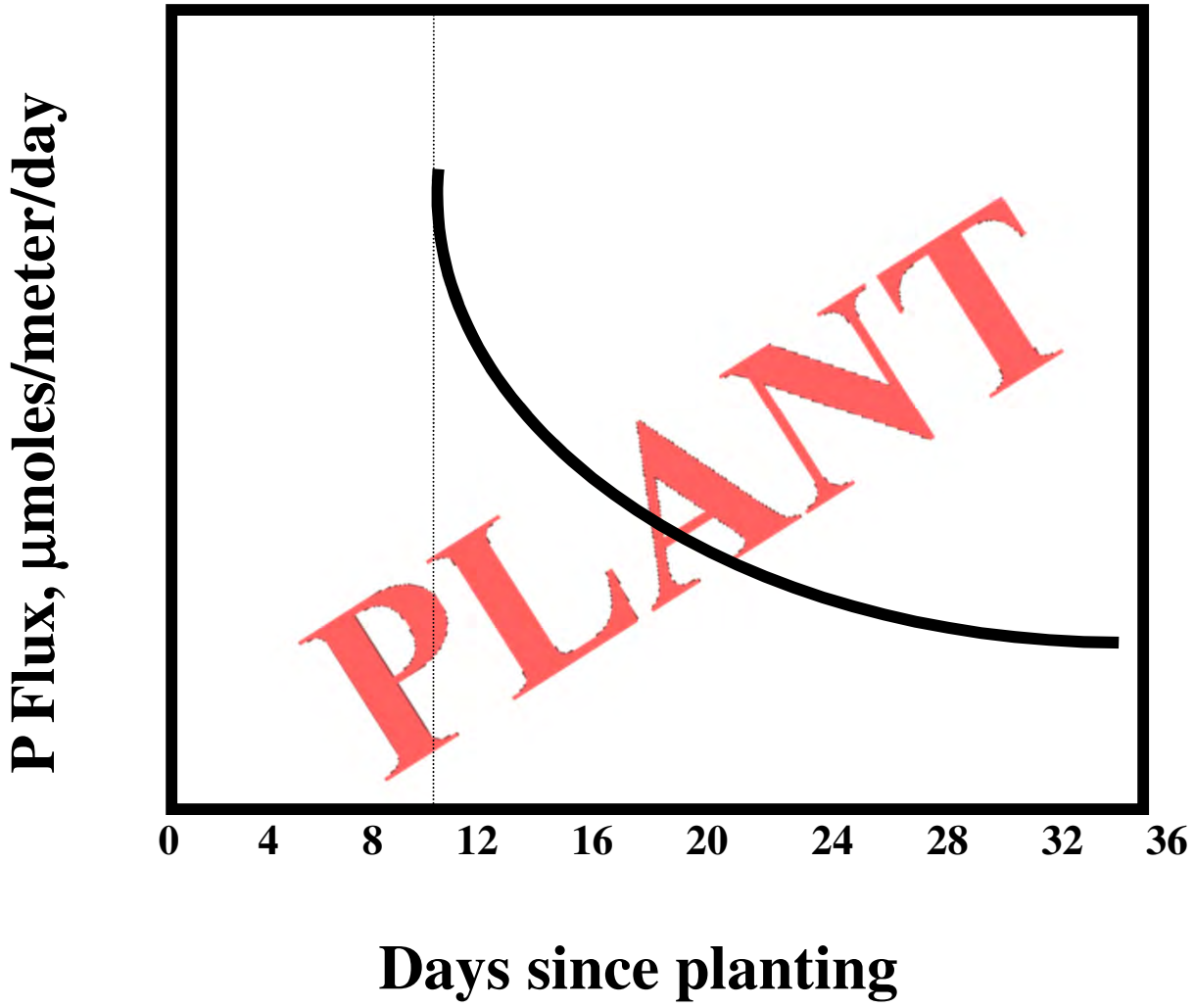
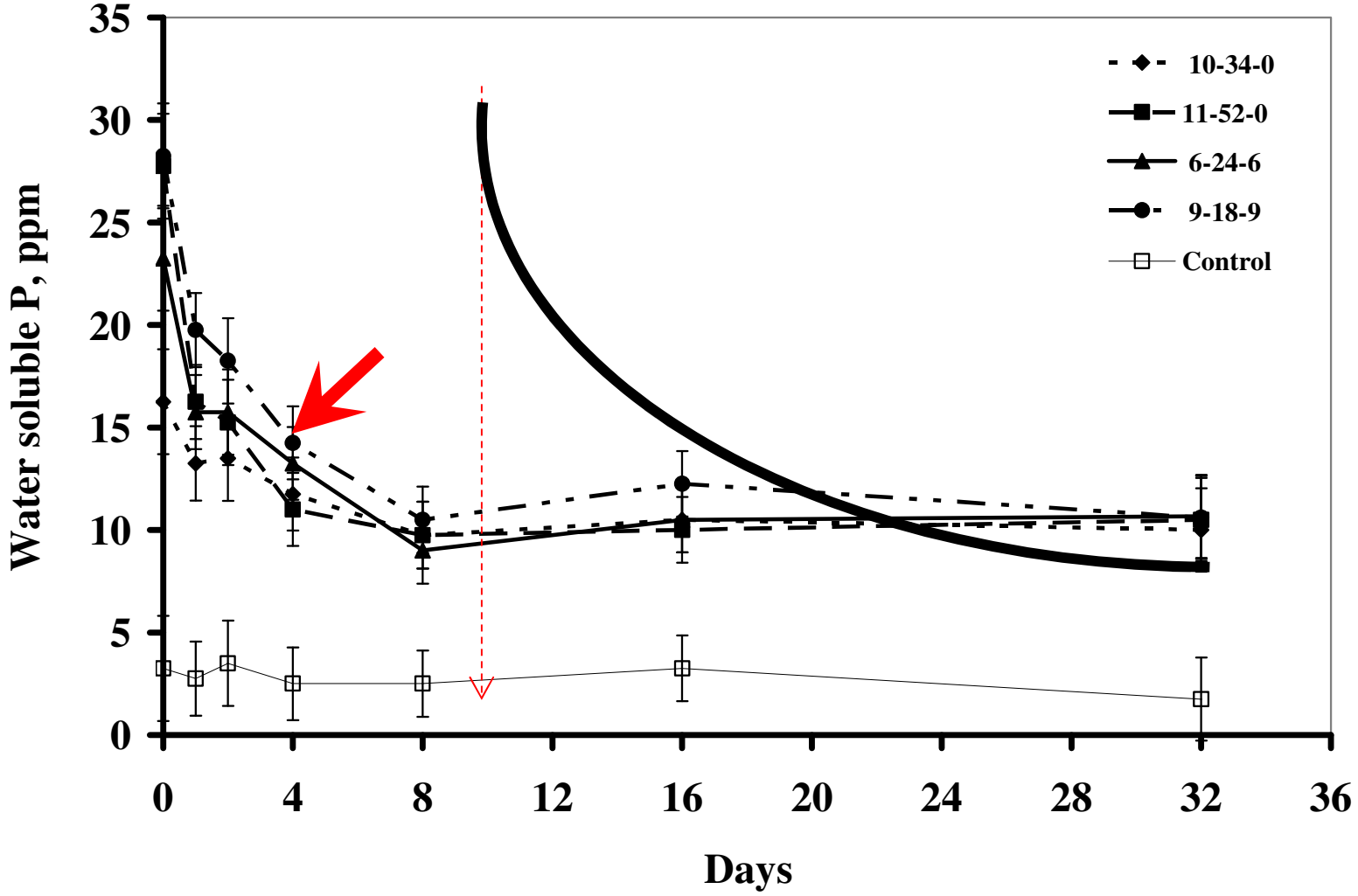
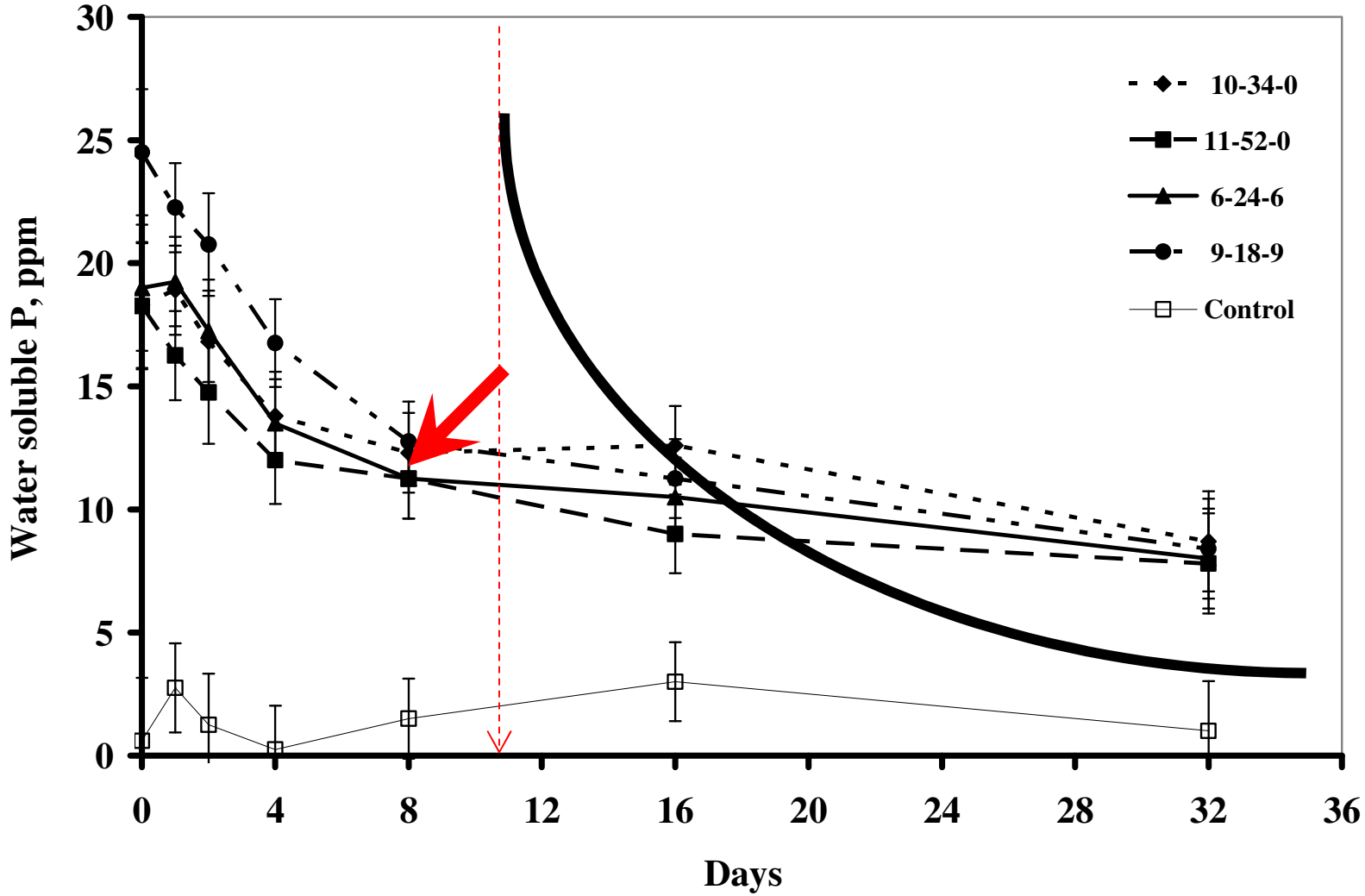


Soil pH = 6.0



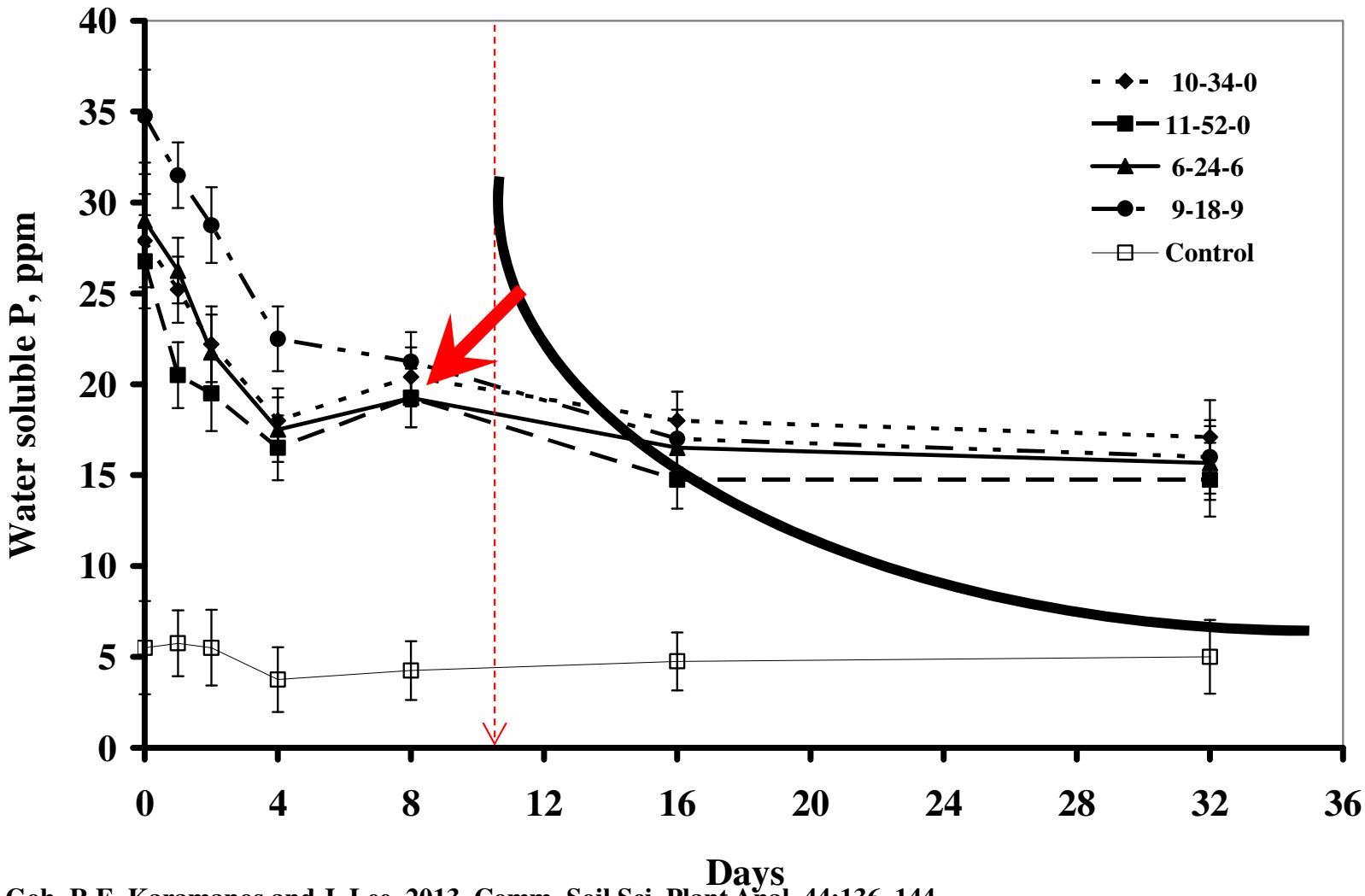
*T.B. Goh, R.E. Karamanos and J. Lee. 2013. Comm. Soil Sci. Plant Anal. 44:136–144

Soil pH = 7.9 (10.8 % carbonates)



*T.B. Goh, R.E. Karamanos and J. Lee. 2013. Comm. Soil Sci. Plant Anal. 44:136–144

Soil pH = 7.8 (no carbonates)



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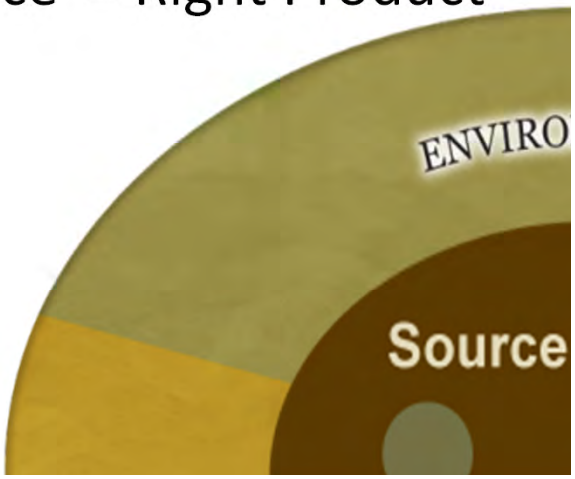
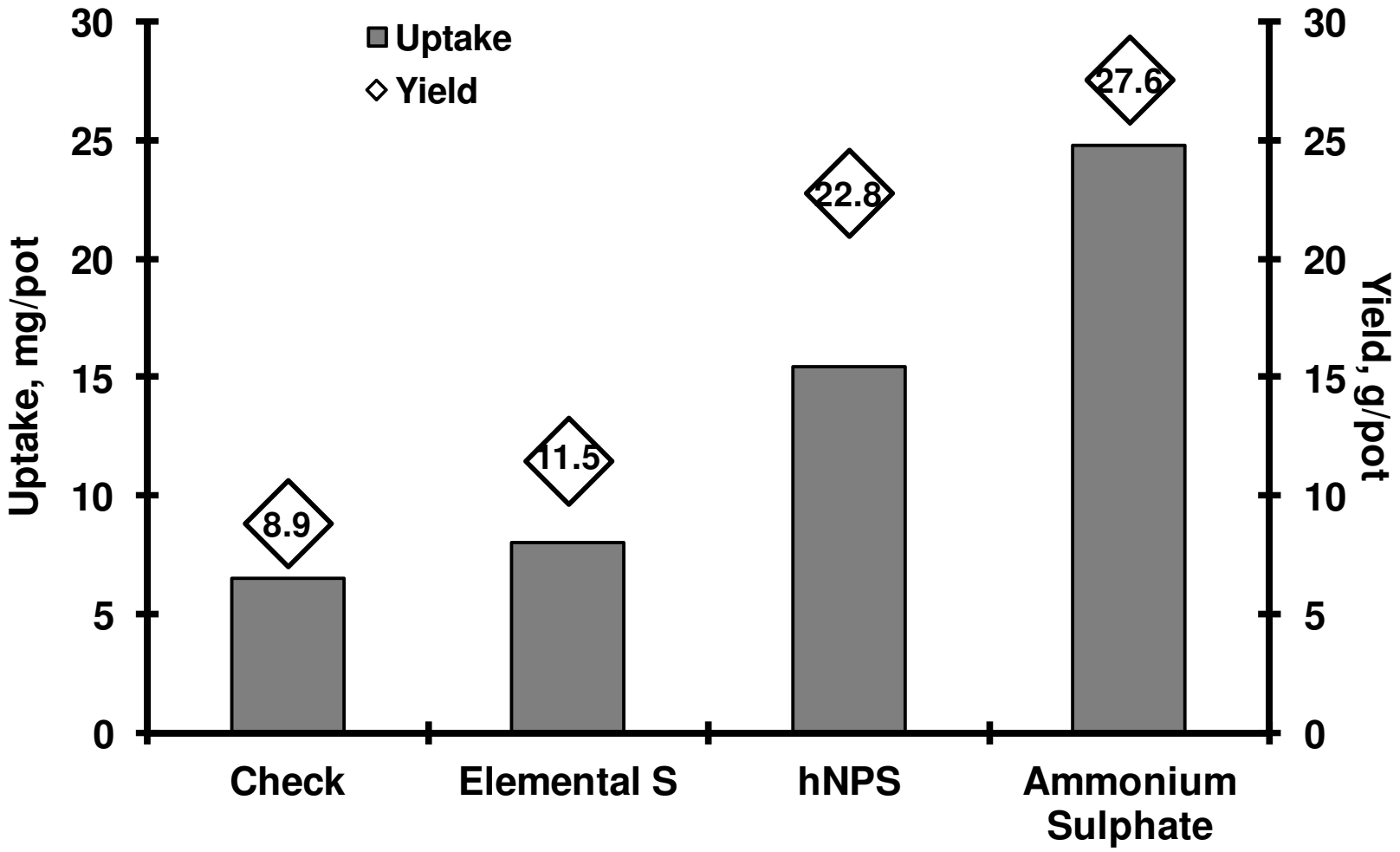


Sulphur

Courtesy IPNI

Manitoba Research



Myron Kroeker, 2005. M.Sc. Thesis, University of Manitoba

So, what is the best S source?

- Ammonium sulphate (21-0-0-24) has been repeatedly proven to be the best form of sulphur for western Canadian soils and crops.
- Ammonium sulphate is effective both in the year of application and often can provide substantial residual benefit to annual crops.
- The value of ammonium sulphate relative to elemental sulphur fertilizers extends to forage crops such as alfalfa. Even in these conditions, elemental sulphur is not as effective, and poses risk to lost yield if sufficient sulphate is not formed for crop uptake during the growing season.
- Overall, soil, climate and crop conditions in western Canada make ammonium sulphate the most effective sulphur fertilizer for maximum yield and best crop management.

Seed fertilizer treatments….

- ~~Seed primers~~
- Wrong terminology
- Search of scientific literature on “seed nutrient treatments”:
- ONLY SINGLE NUTRIENT treatments referred to as SEED SOAKING

Seed nutrient treatment/primer studies

Nutrient	Crop(s)	Location	Worked?
Miscellany	Wheat, barley	Oklahoma	No
Zinc (soaking)	Rice	Alabama	Yes
Molybdenum	Soybeans	Georgia, USA	Yes
Miscellany	Corn	Ottawa	No
Zinc	Beans	Washington State	No
Zinc	Rice	Arkansas	Yes
Iron	Soybean	North Dakota	No
Manganese	Soybeans	Iowa	No
Zinc and Boron	Chickpeas, Lentil, Peas and Wheat	Nepal	No
Micronutrients	Review article	W. Australia	Yes
Phosphorus	Oats	Finland	Yes
Micronutrients	Rice-Wheat	South Asia (Cornell)	NO!

Putting Rates into Perspective – Product A

- **Applied at 300 ml/100 kg seed – 350 g per 100 kg seed**
- **Seed wheat at 120 lb/ac (55 kg/ac) – Product A applied at approx 200 g/ac**

Nutrient Seed Dressing			
Nutrient	Analysis	Grams Applied per Acre	Nutrients (grams) Contained in 120 lb of Wheat Seed
N	6.0%	12	1300
K2O	1.0%	2	350
Zn	5.05%	10	3.0
Cu	0.25%	0.5	0.7
Mn	0.25%	0.5	8.0
Fe	0.25%	0.5	6.5
B	0.03%	0.06	1.0

Putting Rates into Perspective – Product M

- **Applied at 6 ml/ kg canola seed – 6.6 g per kg seed**
- **Seed canola at 5 lb/ac (2.27 kg/ac) – Product M applied at approx 15 g/ac**

Nutrient Seed Dressing			
Nutrient	Analysis	Grams Applied per Acre	Nutrients (grams) Contained in 5 lb of Canola Seed
P_2O_5	27.0%	4.0 ⟷	41.0
K_2O	6.0%	0.9 ⟷	28.0
Zn	3.8%	0.6 ⟷	0.13
Mn	1.5%	0.23 ⟷	0.09

Calculating nutrient cost . . .

Product M: 0-27-6, 3.8% Zn, 1.5% Mn

Total Nutrients: 27 + 6 + 3.8 + 1.5 = 38.3%

1 tonne contains 2204 x 38.3% = 844 lb of nutrients

SRP is $300.^{00}$ per 10 litre jug → approx. 12 kg → 0.012 tonne

$$\frac{\$300.^{00}}{0.012\ \text{t}} \approx \$25{,}000.^{00}\ /\ \text{tonne}$$

$$\frac{\$25{,}000.^{00}}{844\ \text{lb}} = \textbf{\$29.60 per pound of nutrient}$$

Sustainability of Post-Green Revolution Agriculture: The Rice-Wheat Cropping System of South Asia

- Annual Report February 10, 2001 - September 30, 2002, submitted to the Soil Management CRSP Management Entity University of Hawaii by Cornell University
- We have worked mostly with in vivo seed enrichment, achieved through fertilization of mother plants by either foliar or soil application of micronutrients. The impact of enriched seed on crop productivity comes from:
  - increasing resistance to root diseases, and
  - supplying micronutrients when these are deficient
- The concentration of Zn and Mo in grain of rice and wheat can be increased by 2-3-fold and 10-20-fold, respectively. Copper can be increased 2-3 fold in rice grain but not in wheat. Levels of Fe, Mn and B are little altered, if at all. The level of Mo in enriched seed is sufficient to meet the micronutrient need of rice and wheat, whereas the levels of Zn and Cu are not.

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Effect micronutrient seed dressing on crop establishment and yield of crops

	Crop Type			
Treatment	CWRS Wheat	Canola	Lentil	Field Pea
		(plants m^{-2})		
Untreated Check	220.2 a	67.4 a	113.0 a	66.7 a
Seed Dressing Applied	206.1 b	65.5 a	114.8 a	62.4 a
LSD ($P \leq 0.05$)	13.8	10.4	11.3	5.3
		(bu/acre)		
Untreated Check	44.1 a	31.6 a	20.3 a	42.2 a
Seed Dressing Applied	43.8 a	32.1 a	21.6 a	41.4 a
LSD ($P \leq 0.05$)	1.7	2.4	1.8	3.0

Agricultural Demonstration of Practices and Technologies (ADOPT) Program

Table 3. Description of treatments in seed applied fertilizer demonstration.

Trt.	Trade Name	Description / Rate / Nutrient Analyses
1	Untreated check	N/A
2	EZ20 Essential Zn®	ZnSO4 (2-0-0-14 + 20% Zn) applied in-furrow at 12 kg/ha
3	Awaken ST®	Seed-applied at 325 mL 100 kg seed-1; 6-0-1-0 + 5% Zn + 0.8% B, Cu, Fe, Mn & Mo
4	Alpine Seed Nutrition®	Seed applied at 510 ml 100 kg seed-1; 6-22-2-0 + Zn
5	Protinus®	Seed applied at 323 g 100 kg seed-1; 40% Zn, 10% Mn + Fe
6	Undisclosed - Zn	Seed-applied; commercial product containing Zn
7	Undisclosed - Cu	Seed-applied; commercial product containing Cu

Table 10. Treatment effects on days to maturity of spring wheat. Interactions and main effect means followed by the same letter do not significantly differ (Tukey's test; $P \leq 0.05$).

Effect	Days to Maturity		
	Site	Treatment	Site X Treatment
	p-value		
Tests of Fixed Effects	<0.001	0.241	0.241

Treatment		Indian Head	Melfort	Scott	Swift Current	All Sites (main effect)
		kg / ha				
	All Treatments (main effect)	**100.8 a**	**n/a**	**93.4 b**	**89.6 c**	**—**
1	Untreated check	101.0 a	n/a	93.0 bcd	90.0 de	**94.7 a**
2	Granular ZnSO4	100.6 a	n/a	93.0 bcd	89.3 e	**94.3 a**
3	Awaken ST®	101.0 a	n/a	92.0 cde	89.8 de	**94.3 a**
4	Alpine Seed Nutrition®	100.6 a	n/a	94.0 bc	89.3 e	**94.6 a**
5	Protinus®	101.0 a	n/a	95.0 b	89.8 de	**95.3 a**
6	Undisclosed - Zn	100.8 a	n/a	93.8 bc	89.8 de	**94.8 a**
7	Undisclosed - Cu	100.3 a	n/a	93.0 bcd	89.8 de	**94.3 a**

Table 11. Treatment effects on grain yield of spring wheat. Interactions and main effect means followed by the same letter do not significantly differ (Tukey's test; $P \leq 0.05$).

Effect	Yield (bu/acre) Site	Treatment	Site X Treatment
	p-value		
Tests of Fixed Effects	0.010	0.938	0.549

	Treatment	Indian Head	Melfort	Scott	Swift Current	All Sites (main effect)
		kg / ha				
	All Treatments (main effect)	**40.4a**	**48.5a**	**n/a**	**43.4a**	**—**
1	Untreated check	39.8 a	48.8 a	n/a	44.5 a	**44.4 a**
2	Granular ZnSO4	45.3 a	46.4 a	n/a	43.4 a	**45.0 a**
3	Awaken ST®	40.0 a	49.3 a	n/a	43.7 a	**44.3 a**
4	Alpine Seed Nutrition®	38.4 a	48.2 a	n/a	42.8 a	**43.1 a**
5	Protinus®	41.0 a	49.4 a	n/a	41.4 a	**43.9 a**
6	Undisclosed - Zn	39.6 a	49.0 a	n/a	43.6 a	**44.1 a**
7	Undisclosed - Cu	38.8 a	48.6 a	n/a	44.0 a	**43.8 a**