Plant Nutrient Uptake Timing and Enhanced Efficiency Fertilizers

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Objectives

• Illustrate crop nutrient uptake patterns
• Present fertilizer management options to better match nutrient uptake and INCREASE GRAIN PROTEIN
• Explain pros and cons of enhanced efficiency fertilizers (EEFs)
• Show research results for EEFs
Cumulative N uptake by wheat

Nutrient Uptake Timing by Crops: to assist with fertilizing decisions
http://landresources.montana.edu/soilfertility/publications.html
N uptake by oil seed crops

Adapted from Malhi et al. 2006

Saskatchewan

Cumulative N uptake (% maximum)

Days after emergence

Seedling

Bud formation

Flowering

Ripening

canola
mustard
flax

Saskatchewan
Adapted from Malhi et al. 2006
Single application of conventional fertilizer

Options?

Modified from HortTechnology. 9(4): 603.
How can you better match N release to reduce potential losses and increase yield?

• Use split application (pre-plant and topdress or just topdress)
• Use an “enhanced efficiency fertilizer”
Reduction of potential N loss through split applications

Modified from HortTechnology. 9(4): 603.
Example on per acre basis:

- 200 lb N total need, 40 lb N in soil, 60 lb preplant N
- soil and preplant supply 100 lb N = 50% total N required
- \((200 - 100) = 100\ \text{lb N top-dress}\)
Top-dress amount and timing based on plant growth stage

50% required N used up by mid-tillering must topdress 100 lb N by early- to mid-tillering
N application timing effects on yield and protein

Nitrogen early
Number of tillers and kernels/head

Grain protein from remobilized N
Nutrient availability from ideal fertilizer

Theoretical Nutrient Release

Plant Uptake for Optimal Yield
Enhanced Efficiency Fertilizers
EEFs

- Any fertilizer designed to:
  - Increase fertilizer availability
  - Decrease fertilizer losses

- 3 major methods of action
  - Stabilized - alter soil microbial or enzymatic reactions
  - Slow release - have additives which require chemical or biological decomposition to release nutrients
  - Controlled release - a semipermeable coating, usually a polymer, regulates release
Stabilized Urease Inhibitors

Volatilization

N\textsubscript{2} and N\textsubscript{2}O

Plant Uptake

Denitrification

Leaching

NH\textsubscript{3}

slow urea hydrolysis here, most common is NBPT

Urea

UAN

NO\textsubscript{2}^{-}

Nitrification

NO\textsubscript{3}^{-}

Plant Uptake

NH\textsubscript{4}^{+}

Leaching
Stabilized Nitrification Inhibitors

\[
\begin{align*}
\text{NH}_4^+ & \rightarrow \text{NH}_3 \\
\text{NO}_2^- & \rightarrow \text{NO}_3^- \\
\text{N}_2 \text{ and N}_2\text{O} \\
\text{Volatilization} \\
\text{Plant Uptake} \\
\text{Nitrification} \\
\text{Leaching} \\
\text{Denitrification}
\end{align*}
\]
Slow and Controlled Release

NH$_4^+$ → NO$_3^-$

Volatilization

NH$_3$ → N$_2$ and N$_2$O

Nitrification

NO$_2^-$

Plant Uptake

Urea → slow release here

UAN → control release here

Leaching

Denitrification
Questions?
Under what growing conditions would you expect EEFs to work better?

- High potential volatilization loss
  - coarse soils
  - moist surface
  - warm temps
  - long time between application and incorporation

- High potential leaching
  - coarse soils
  - high moisture content/irrigation/rainfall
Effect of irrigation and NBPT on volatilization

0.8 inch irrigation on days 2 and 8

Rawluk 2000
Manitoba
NBPT uses

- Can minimize urea volatilization for several weeks
- ‘Buys’ time for rainfall, irrigation or mechanical incorporation to protect urea
- Warm weather top-dressing
- Cool weather broadcast
N release by polymer-coated fertilizers

- Water moves in through coating.
- Urea dissolves in prill.
- N moves out through coating into soil solution.
- Collapsed prill biodegrades.

Schematic adaptation and photo courtesy of Agrium, U.S. All rights reserved.
Effects of over-winter moisture conditions on effectiveness of PCU

Grant & Downbenko 2008

Yield change with spring-banded PCU over conventional urea (%)

- Barley
- Canola
- Wheat

WHY?

Grant & Downbenko 2008
spring banded PCU
Saskatchewan
What type of crops would you expect slow release to work better?

- Irrigated
- Warm season

What about dryland cool season crops?
Timing of N uptake by wheat
Timing of N uptake by wheat and ESN® N release

Options for wheat?

Approx % N released by typical ESN seed placed in mid May
How does PCU work for small grains?

- Fall/winter pre-plant works well. PCU is in soil long enough to dissolve in time for plant need.
- Late winter/spring broadcast PCU does not - may dry out, release is too slow.
- Incorporation is important, especially late winter/spring.
- Blending is recommended with late winter/spring surface applied PCU.
Effect of EEF source and application method on winter wheat yield

Location: Beiseker, Alberta
Soil: silt loam, 4.5% organic matter
Precipitation: 13.5 in. seeding to harvest

5 N sources:
- AN – ammonium nitrate
- Urea
- Agrotain® treated urea – urease inhibitor
- Super Urea® – urease and nitrification inhibitor
- ESN® – polymer coated urea

Rate: 80 lb N/ac

Subsurface side-banded (1.2” below and 1” side of seed) at seeding or broadcast in spring
Yield with N fall subsurface side-banded

Fall subsurface banded at 80 lb N/acre

Winter Wheat Yield (bu/acre)

AN  Urea  Agrotain  Super Urea  ESN (side)  ESN (seed-row)

Why did urea outcompete AN?

Nitrogen Source

Jensen 2010
Stabilized Urease Inhibitors

\[ \text{NH}_4^+ + \text{NO}_3^- \rightarrow \text{N}_2 \text{ and N}_2\text{O} \]

Volatilization

Plant Uptake

Nitrification

Leaching

Urea

AN

\( (\text{NH}_4^+ + \text{NO}_3^-) \)
Yield with N spring broadcast

Spring broadcast 80 lb N/acre

Jensen 2010

Nitrogen Source

AN
Urea
Agrotain
Super Urea
ESN

Why equal AN, Urea and Agrotain yields?
Each form of N is suitable – if used properly

- Urea and Agrotain®-urea best used in spring
- Super Urea® best fall banded
- ESN® best side- or seed-row banded in fall – advantage likely less in MT. Why?
- Blend urea with ESN® to ensure early N availability (50/50?)
Winter wheat with Nutrisphere-N® (NSN) side-banded at seeding

Location: North of Conrad (WTARC)

2 N sources:
• Urea
• Nutrisphere-N® – urease and nitrification inhibitor

Rate: 40 and 80 lb N/ac

Subsurface side-banded (1” above and to side of seed) at seeding
Yield with NSN treated urea side banded

- check
- 40 lb N urea
- 40 lb N urea+NSN
- 80 lb N urea
- 80 lb N urea+NSN

Jackson 2008 unpubl.

Nitrogen Rate and Source

banded 1" to side and above seed
Seed placing EEFs

- Can apply ~ 2 – 4x as much slow release product as urea directly with small grain seeds
- Saves on field passes – fuel, labor, soil disturbance
Effect of N source applied with the seed on dryland spring wheat yield

**Urea**

**Urease inhibitor**

**Polymer-coated**

Saskatchewan Malhi et al. 2003
How to manage PCUs

- Apply several weeks before peak crop demand
- Incorporate into the soil or seed place
- Blend with conventional fertilizer
- Adjust rates, blends and application timing for handling abrasion
Questions on N?
Cumulative P and K uptake by small grains

Nutrient Uptake Timing by Crops: to assist with fertilizing decisions
http://landresources.montana.edu/soilfertility

Saskatchewan adapted from Malhi et al. 1998
P and K fertilization considerations

- P and K are not readily lost from the system, so they can be:
  - Placed with seed or banded early in season to ensure availability
  - Built up over time in the soil
- P and K bind strongly to soil surface so less effective topdressed than N
- Avail® is an EEF designed to extend P availability
Phosphorus EEF

• Types
  Polymer coated
  Avail® which reduces the rate of P mineral formation

• Limited regional research
  Soil P levels often above critical
Wheat response to P and Avail®

Karamanos et al. 2009
Alberta

WHY no consistent difference?

Breton Olsen P 5ppm

Ellerslie Olsen P 11 ppm
Potential limitations of Avail®

- Mechanism may have difficulty in highly calcareous soils
- Existing soil properties may outweigh product ability

Ex: 100 lb MAP with Avail® contains < 0.25 lb of organic acids – the active ingredient

Organic acids occur naturally in soil, and are elevated in the root zone
Conclusions

- Crops’ highest rates of N, P and K uptake are during tillering and branching.
- N, P and K must be available early in growing season for optimal production.
- If all the needed N is applied at seeding there is higher potential for N loss.
- Options are to split applications or use EEFs
Conclusions

- Improved EEFs and blending with conventional fertilizer may provide a good match between crop uptake and fertilizer availability.
- More EEF can be placed with the seed than conventional fertilizer, possibly saving a fertilizer pass and fuel costs.
- EEFs can reduce N losses.

Additional info in:

* Nutrient Uptake Timing by Crops (EB0191)*
* Enhanced Efficiency Fertilizers (EB0188)*

http://landresources.montana.edu/soilfertility

Go to Fertilizer Information