2012 Fertilizer Outlook and Technology Conference

Philadelphia Marriott Downtown
Philadelphia, PA
Thursday, 15 November 2012

Enhanced Efficiency Fertilizer Technology

John A Hassell
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Koch Agronomic Services, LLC
Austin, Texas

Source: “The Blue Marble” NASA Goddard Space Flight Center
The Visible Earth (http://visibleearth.nasa.gov/)

Citation: Image Science and Analysis Laboratory, NASA-Johnson Space Center. "The Gateway to Astronaut Photography of Earth. http://eol.jsc.nasa.gov/scripts/sseop/QuickView.pl?directory=ISD&ID=AS11-44-6552>01/02/2012 16:42:08.


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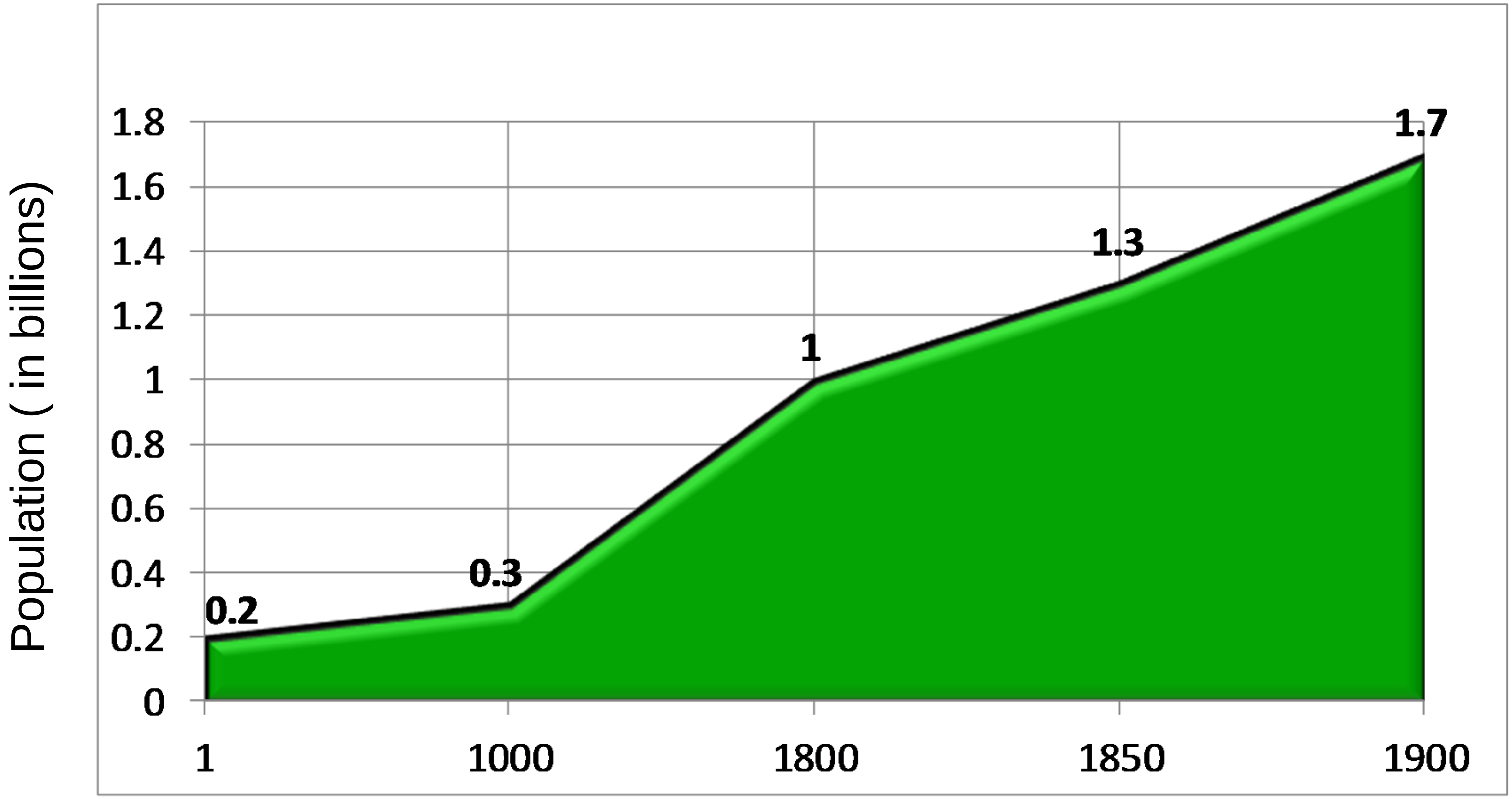
Today's topics

- The population explosion – it's not slowing down
- The advent of nitrogen technology
- The challenge for today
- Nitrogen inefficiency
- EEF's can help
  - Advantages
  - disadvantages
- Closing

Population Growth



Source: http://geography.about.com/od/obtainpopulationdata/a/worldpopulation.htm

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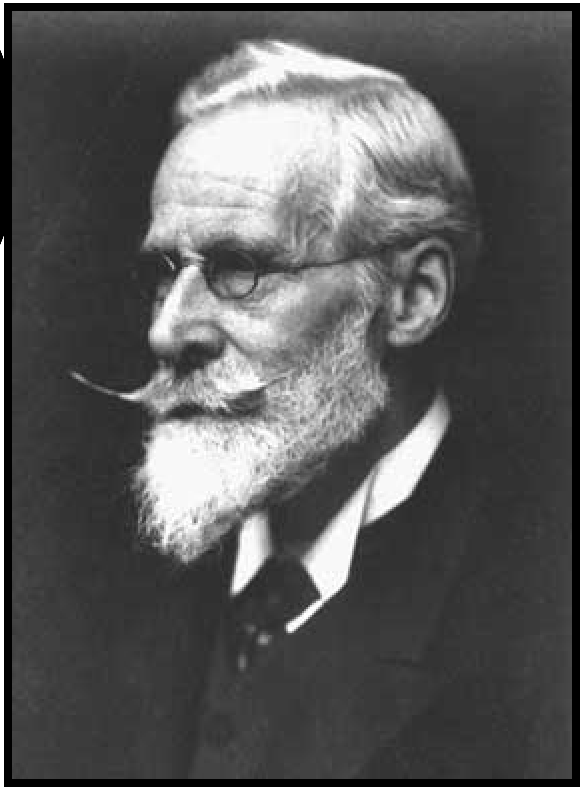
Early Agriculture

- Early civilizations farmed in flood plains
- Outside of flood plains, farming mined the land of nutrients
- Over time people learned about soil fertility
  - Chinese found that Potassium Nitrate (saltpeter) used in fireworks also helped plants grow
  - Early Romans used manure, urine and blood as fertilizer
  - Early travelers to South America discovered islands covered with bird dung rich with soil nutrients which could be used as fertilizer)
  - Later, large areas of Potassium Nitrate were discovered in Peru and later in Chile (still mined today)
- Late 1800's, not enough manure or potassium nitrate for increased food production



Sir William Crookes
1832 -1919

1898 – Incoming president of the British Academy of Sciences

In his Inaugural speech he stated:

“England and all civilized nations stand in deadly peril. As mouths multiply…food sources dwindle.” **The reason**, there was not enough natural fertilizer.

The answer, Crookes said was, “the creation of vast amounts of fertilizer, new fertilizer by the thousands of tons. This is the greatest challenge of our time. It is through the laboratory that starvation may ultimately be turned into plenty.”

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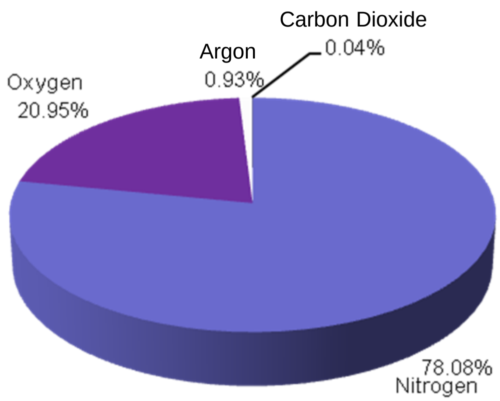


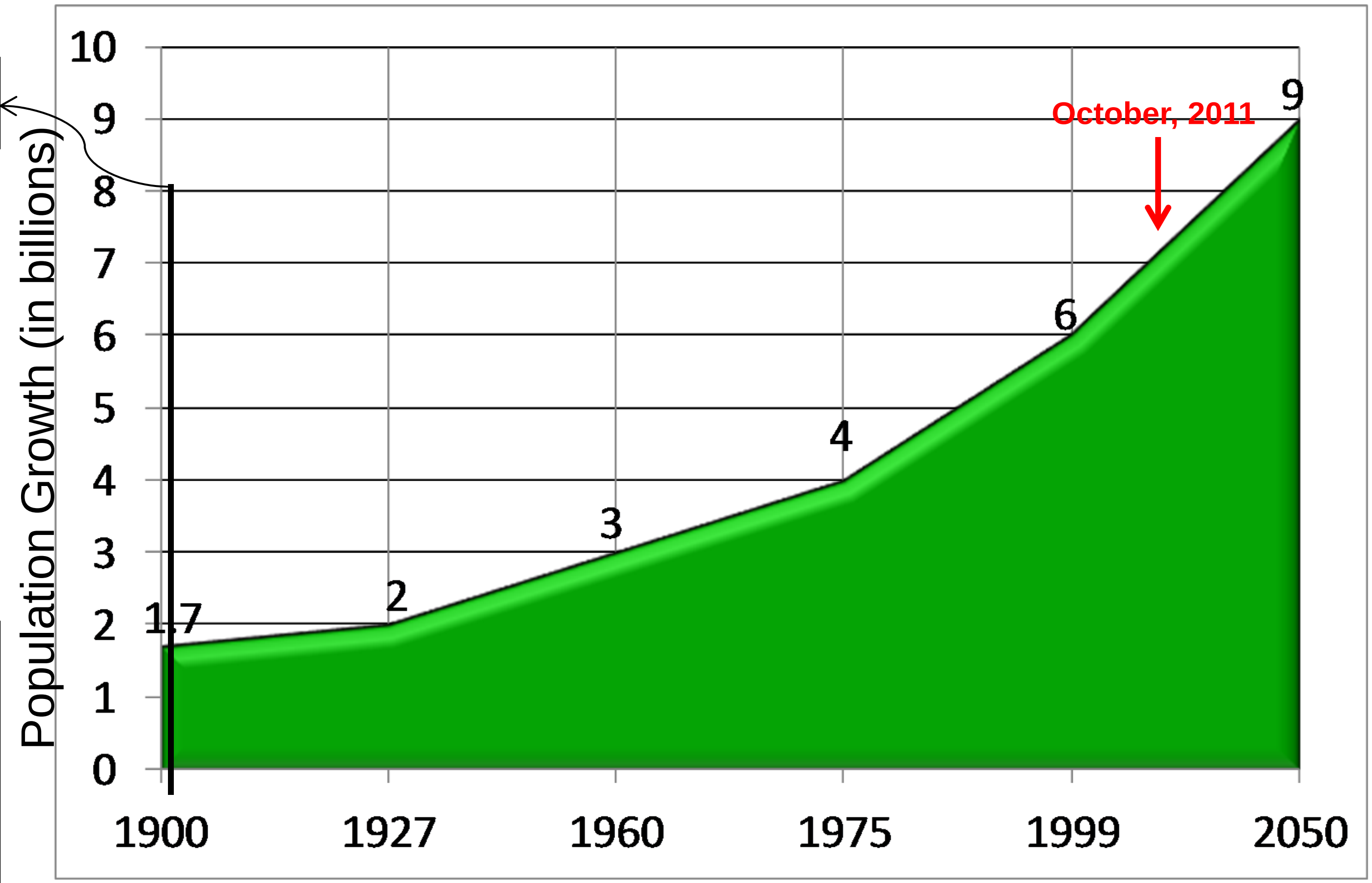
- Atmosphere was made of 78% N, but unavailable
- Some plants could fix N from the atmosphere
- The question was how to harness this abundance of N

Fritz Haber, 1918

- Enter Fritz Haber
  - Brilliant German Scientist
  - Worked to create process to take N from atmosphere
  - Demonstrated the process in 1909
  - First to synthesize NH_3 on an industrial scale in 1913
    - Known as the Haber-Bosch Process
    - Still used today
  - 1918 won Nobel Prize for Chemistry

Population Growth (1900 – 2050)

1909 – Advent of
Haber Process



- Current Population – 7 billion
- 3 people/sec, 260,000/day
- 94 million people born each year
- 9 billion estimated by 2050
- Population growth, affluence and protein requirements are outpacing food production

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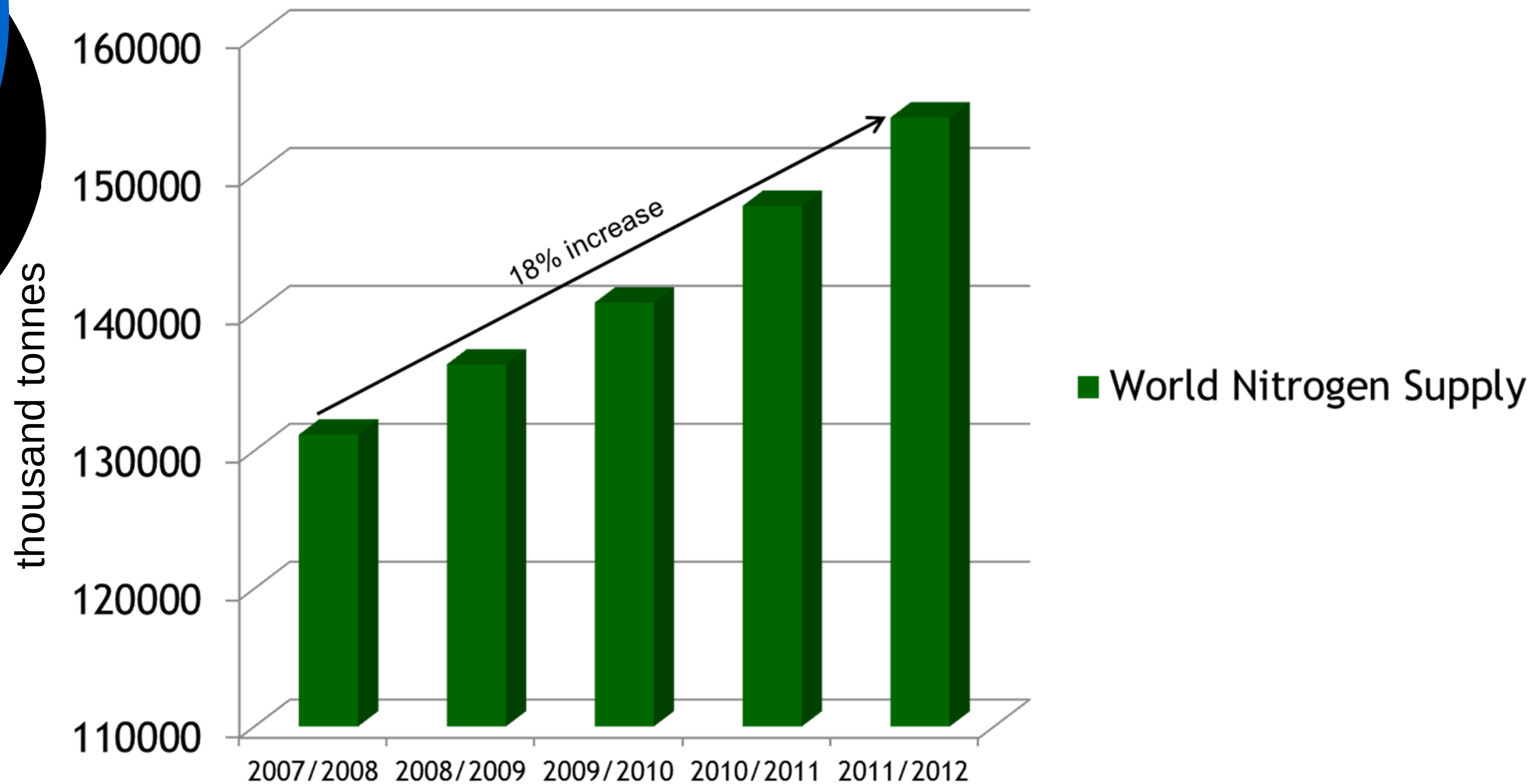
Population Growth Contributing Factors

- Improvements in and use of soap in the early 1800's
- Improved sanitation in the late 1800's
- Discovery of antibiotic therapy in early 1900's
- Discovery of Penicillin in the late 1920's
  - Other antibiotics followed
- Improvements in medicine
- Improvements in water treatment
- Improvements in land management, nutrient management, genetics and chemical technology
- Haber-Bosch Process 1909 (**one of the most significant discoveries in all of history**)

World Nitrogen Outlook 2007 - 2012



Source: Current world fertilizer trends and outlook to 2011/2012, Food and Agriculture Organization of the United Nations, Rome, 2008.

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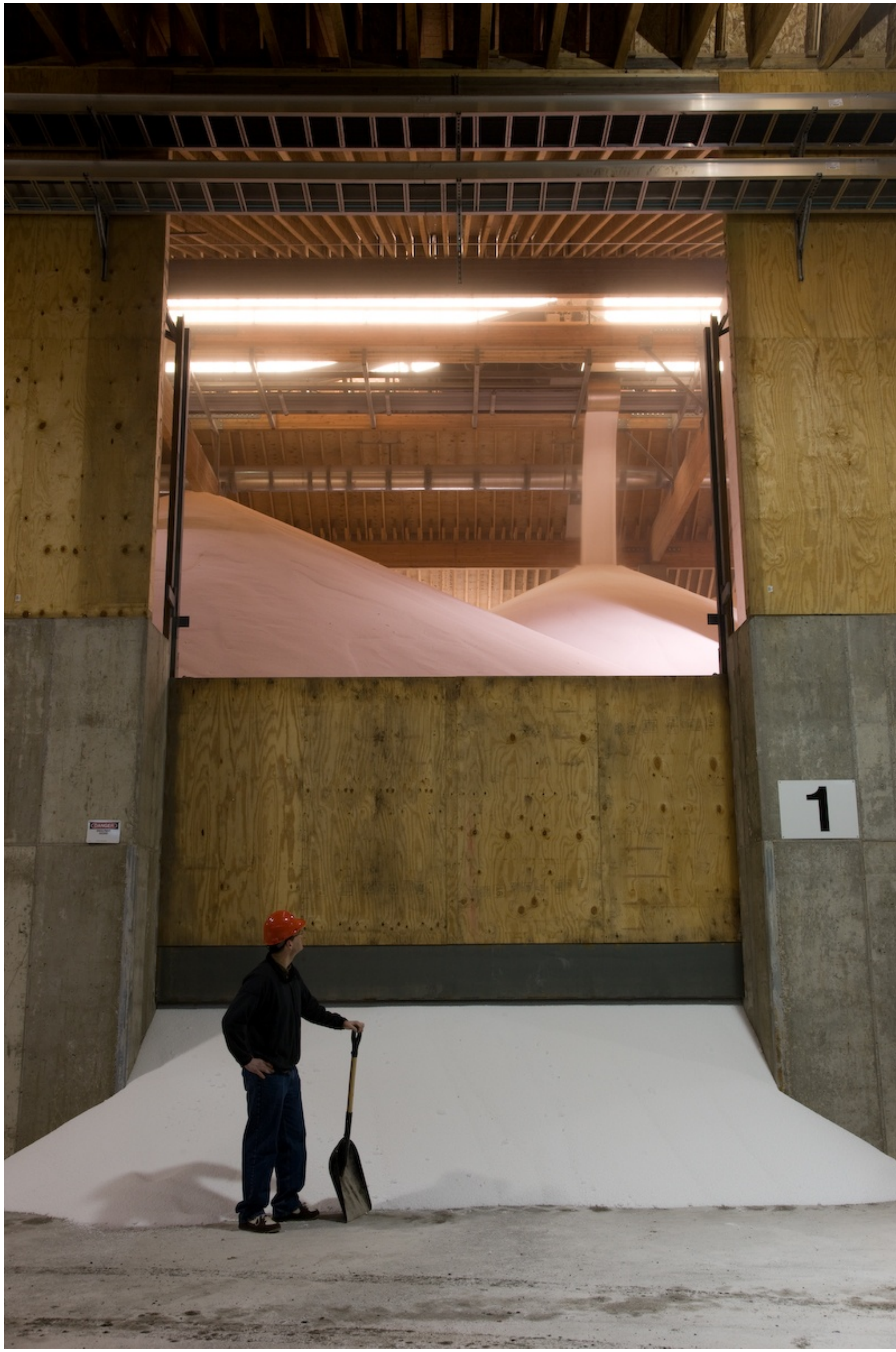
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면제
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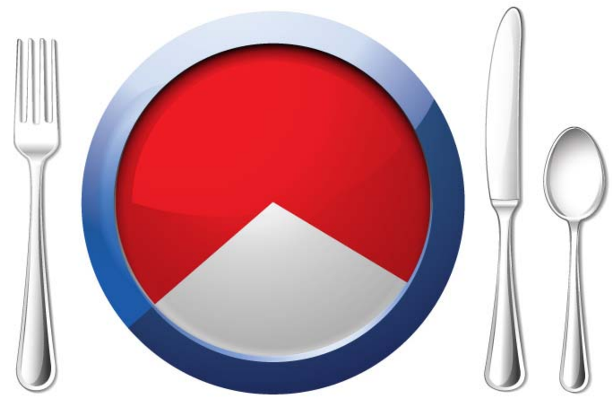
Importance of Enhanced Efficiency Fertilizers



In **50** years, the world population will require

100% more food,[1] and

70% of this food must come from efficiency-improving technology[2]

- It took 10,000 years of agriculture to produce the amount of food we produce today, and
- We're going to have to double food production in the next 50 years.

Source: [1]Green,R. et al. January 2005. "Farming and the Fate of Wild Nature." Science 307.5709:550-555; And Tilman, D. et al. August 2002. "Agricultural sustainability and intensive production practices." Nature 418.6898:671-677.

[2]"Number of hungry people rises to 963 million." United Nations Food and Agriculture Organization, Rome. Accessed 12/1909. <http://www.fao.org/news/story/en/item/8836/icode/>

Let's start exploring ways of growing 100% more food

- Things we have to consider
  - Population growth rate
  - Conserving our soil resources
  - Slow agricultural expansion
    - Tropical areas
  - Closing the yield gap
  - Becoming more efficient
  - Change diets (close the gap)
  - Reduce food waste

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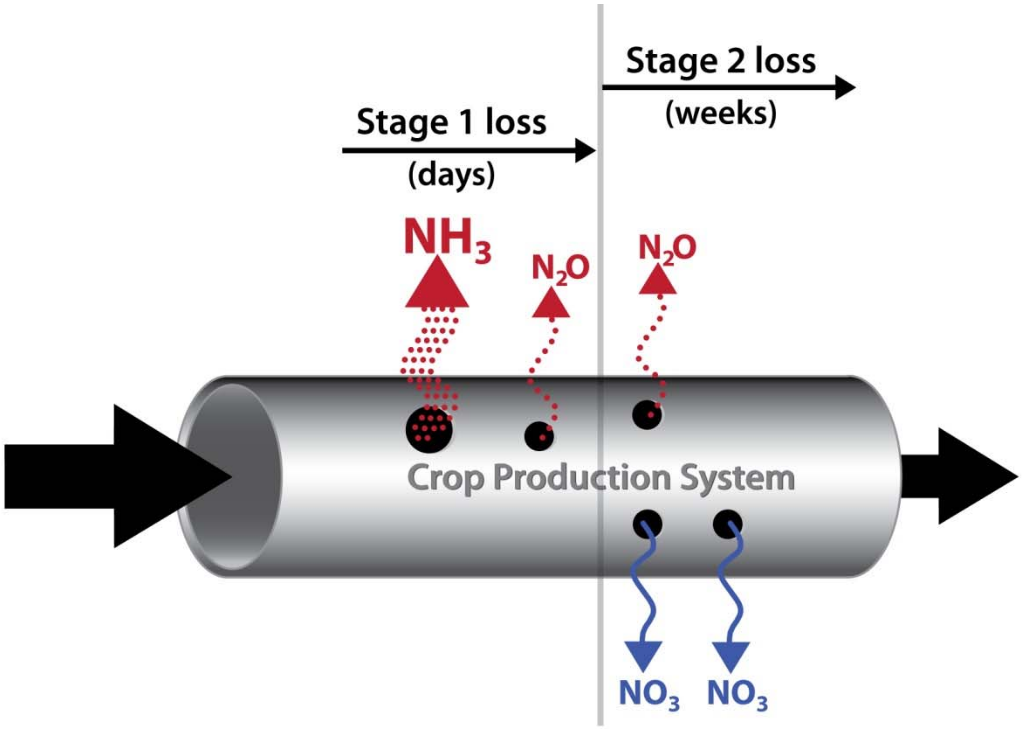
Making Nitrogen More Efficient

- Nitrogen management looks simple, but it's really complex
- Operating in a "leaky" system
  - multiple loss mechanisms

Holes in “crop production pipe” decreases nitrogen availability

Nitrogen In



Nitrogen out

Strategy: use technology to fix the holes

- control nitrogen losses
- increase soil nitrogen level in soil
- achieve higher yield and quality

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Nitrogen Loss

After application --- Nitrogen can be lost to the environment in three ways:

Volatilization

N loss through urea breaking down to ammonia gas(NH3) then evaporating

Most commonly occurs with urea that is broadcast **applied to the surface** and **does not receive rainfall** within a few days to dissolve the urea granule into the soil. **High temperature and humidity**, **wind, and high soil pH** can also contribute to volatilization.

Denitrification

Nitrogen loss to the air as applied N is converted to nitrogen gas(N_2) & nitrous oxide (N_2O) in the soil

Warm, wet soils favor denitrification. Soil organisms get their oxygen from nitrates (NO_3-), allowing nitrogen and nitrous oxide gases to form. Denitrification **becomes significant when the soil is waterlogged for 36 hours** or more.

Leaching

Loss of N as applied N is converted to nitrates in the soil, which work down into the soil and are lost in groundwater runoff

Leaching occurs **when soils are saturated and warm** and **water moves below the root zone**. Leaching is **more likely in sandy soils vs. heavy clay** soils.

Technology Provides a Portion of the Answer

- For improved
  - pest control
  - animal health and nutrition
  - food safety
  - food production using fewer resources
- Improvements in agronomics
  - Planting density
  - Fertilizer use efficiency
    - Using enhanced efficiency fertilizers
  - Water efficiency
- Improvements in biotechnology
  - Drought tolerance
  - Herbicide tolerance

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Enhanced Efficiency

Defined by the Association of American Plant Food Control Officials

Describes fertilizer products with characteristics that allow increased plant uptake and reduce potential of nutrient losses to the environment (e.g., gaseous losses, leaching or runoff) when compared to an appropriate reference product.

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a substance that inhibitors the biological oxidation of ammoniacal-N to nitrate-N

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Types of Enhanced Efficiency Fertilizers

Slow and Controlled Released

- Slow Release
  - Methylene Urea
    - Liquid
    - Granular
  - isobutyledene-diurea – IBDU

- Controlled release
  - Sulfur Coated Urea (SCU)
  - Polymer Coated Urea (PCU)

Stabilized Nitrogen

- Urease inhibitors
  - N-(n-Butyl) thiophosphoric triamide – nbpt
  - phenylphosphorodiamidate (PPD/PPDA)
  - N-(2-nitrophenyl) phosphoric acid triamide (2-NPT)
  - Hydroquinone

- Nitrification inhibitors
  - 2-chloro-6-(trichloromethyl-pyridine) Nitrapyrin
  - Dicyandiamide (DCD)
  - 3,4-dimethylpyrazole phosphate (DMPP)
  - Ammoniumthiosulphate (ATS)

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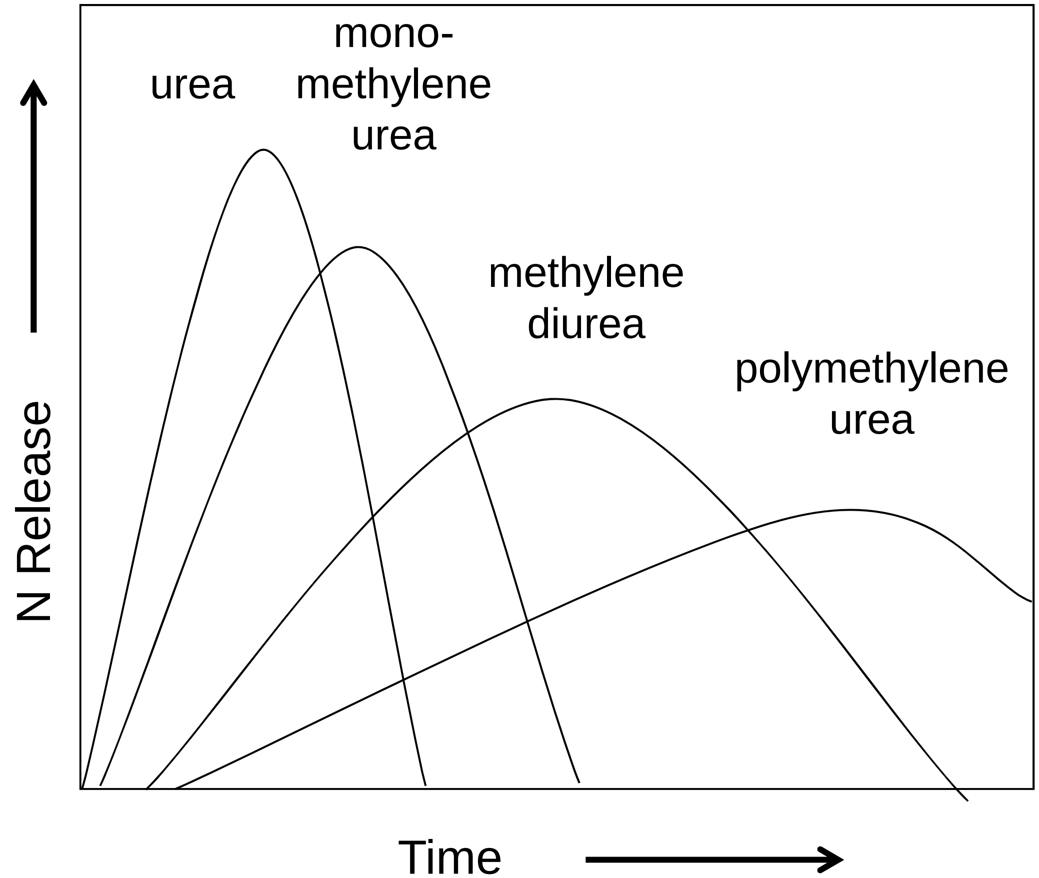
Release Curves for Various Slow Release Products

Slow Release Nitrogen

- Delay N availability
- N available through chemical/biological breakdown
- Protection: weeks to months
- Release rate determined by:
  - Chemical structure
  - Molecular weight
  - Environmental conditions



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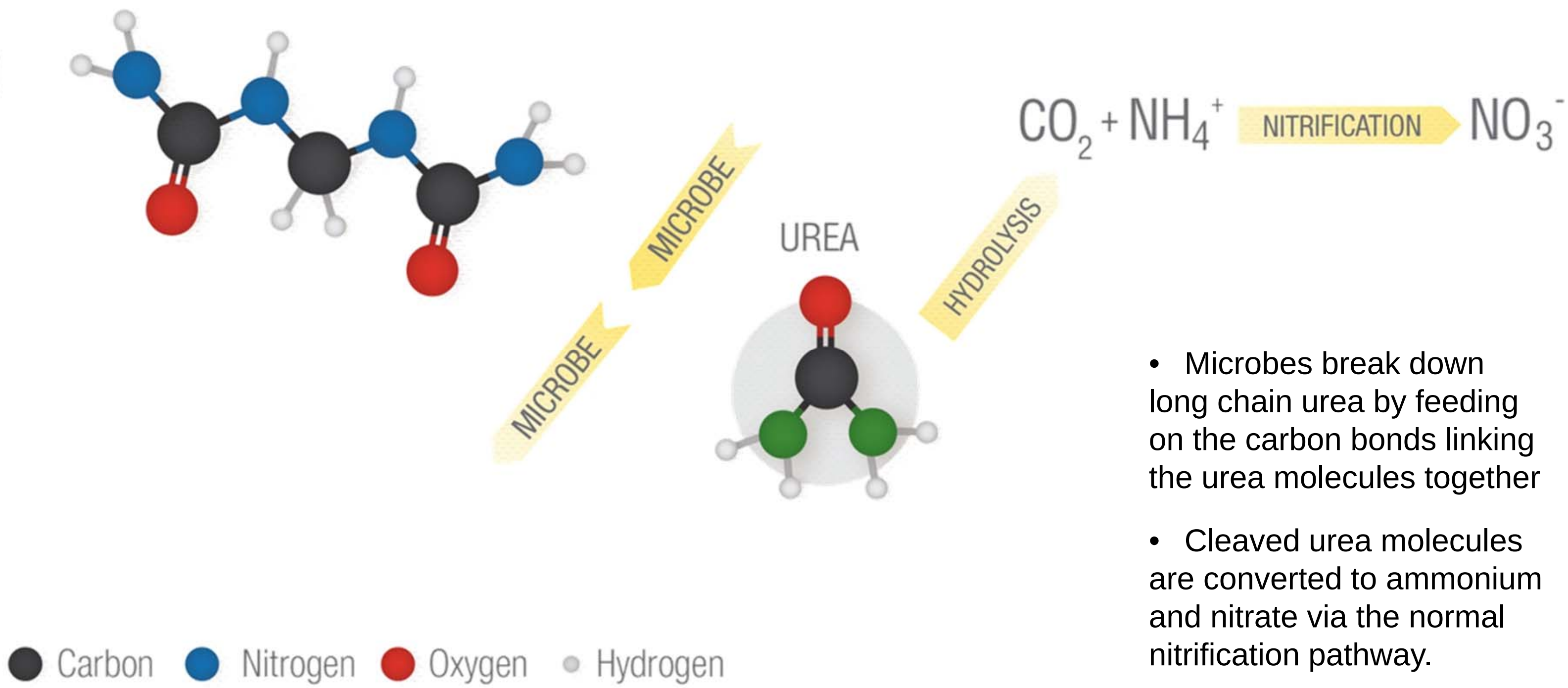
Conversion of long chain urea to plant available forms of nitrogen



- Microbes break down long chain urea by feeding on the carbon bonds linking the urea molecules together
- Cleaved urea molecules are converted to ammonium and nitrate via the normal nitrification pathway.

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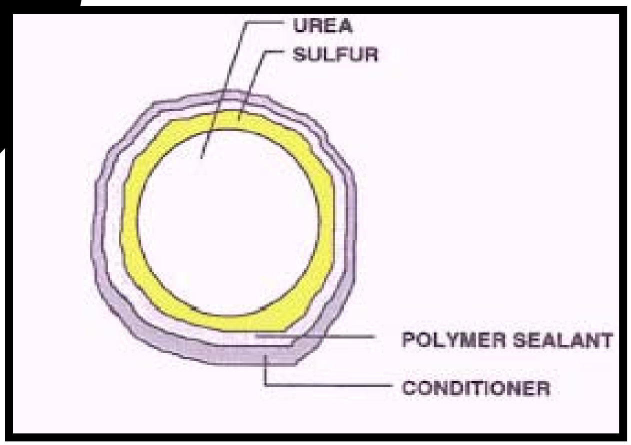
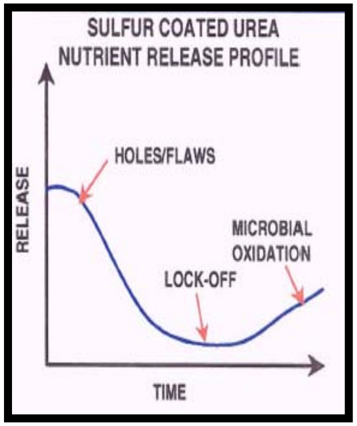
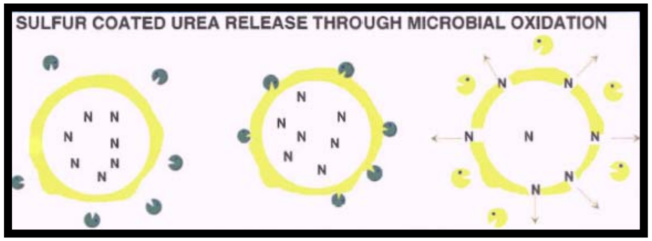
Sulfur Coated Urea

- Sulfur Coated Urea
  - Delay N availability
  - Dependent on destruction of sulfur coating and diffusion
  - Protection: weeks to months
  - Release rate determined by:
    - Thickness of coating
    - Environmental conditions







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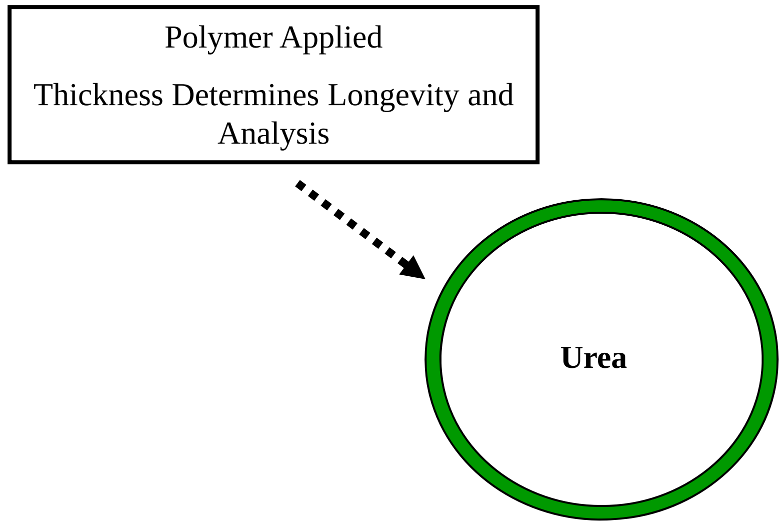
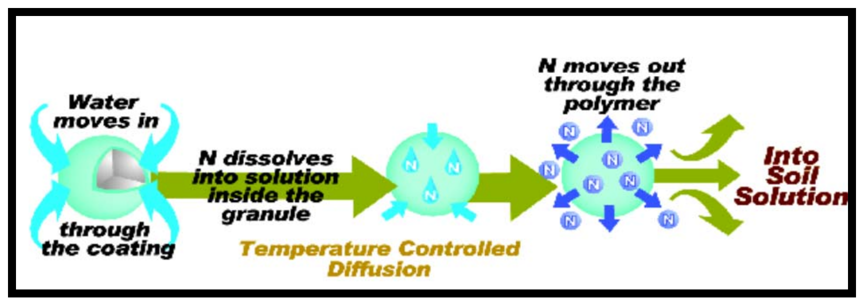
Polymer Coated Urea

- Polymer Coated Urea
  - Polymer coatings applied to soluble fertilizer
    - Release: diffusion though coating
  - Protection: weeks to months
  - Release rate determined by
    - Polymer chemistry
    - Thickness
    - Coating process
    - Temperature





Source: Alan Blaylock, Agrium, InFoAg 2007 Conference, July 10, 2007

PCU in Corn Stubble

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Stabilized Nitrogen

- Not a slow or controlled release fertilizer
- Nitrogen product that contains:
  - Urease inhibitor and/or a
  - Nitrification inhibitor
- Protection from days to months

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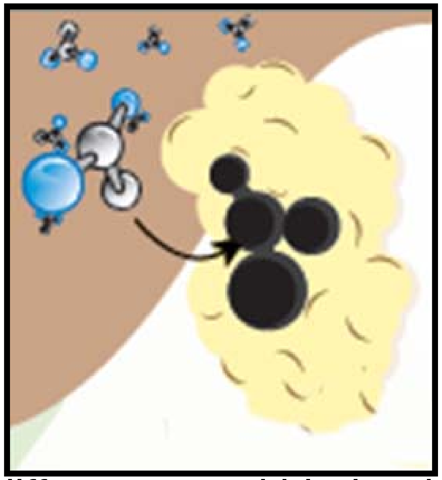
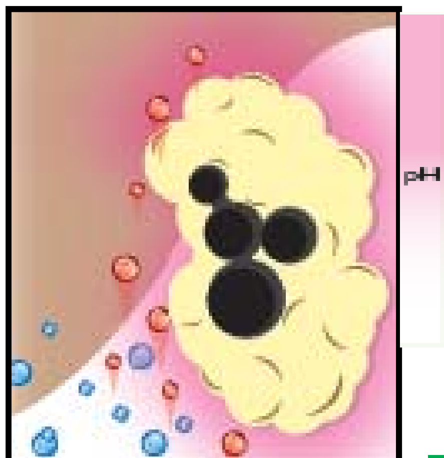
Urea Hydrolysis – What does it look like



Urea diffuses to and binds with the urease enzyme in the soil.

The enzyme rapidly separates 2 ammonium ions from the urea molecule

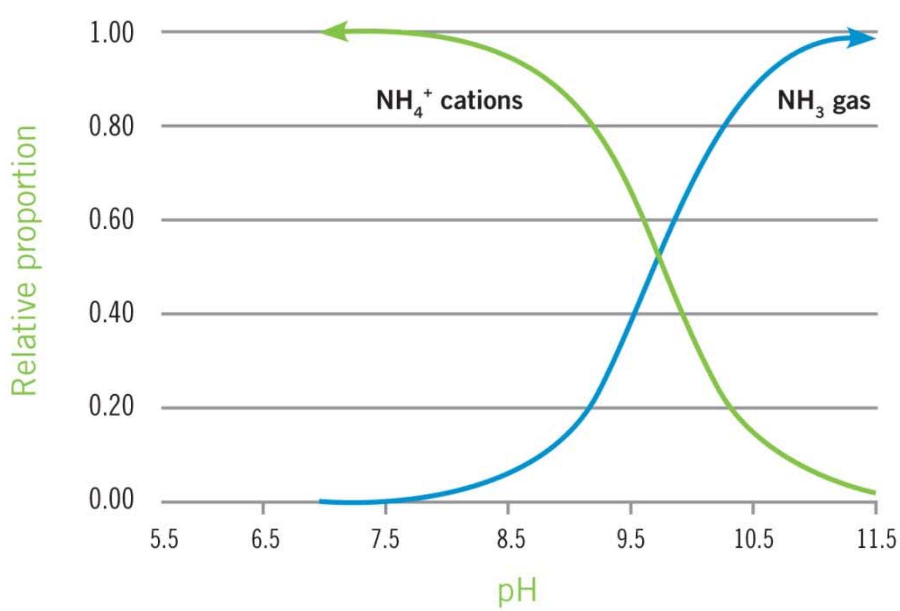


Urease action also raises the local pH converting NH_4^+ into NH_3 gas which rises up and out of the soil

Urease enzyme

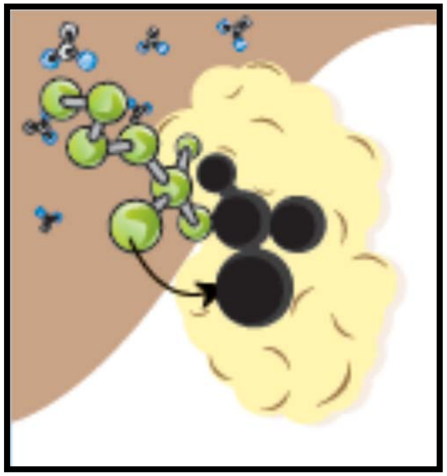
Urea

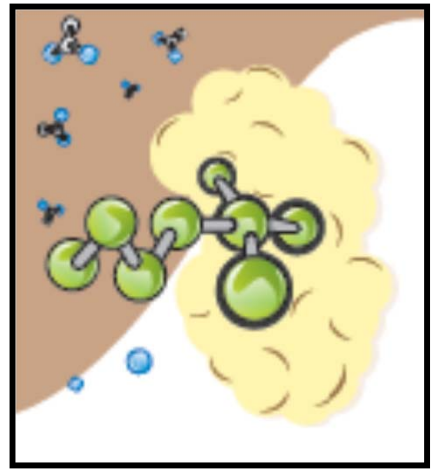
Distribution of Ammonia Species



pH	(NH_3)	(NH_4)
7.3	1	99
8.3	9	91
9.3	50	50
10.3	91	9
11.3	99	1

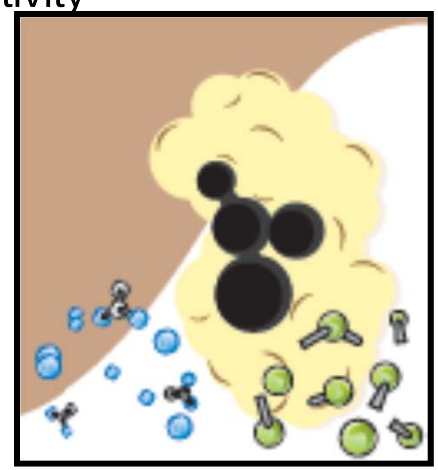
How a urease inhibitor works - competitive inhibition



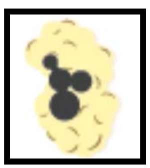


Blocked urease allows urea diffusion into the soil and limits pH increases.

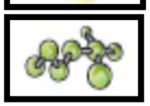
The urease inhibitor binds to urease to temporarily block urease activity



After the risk is past, the urease inhibitor decomposes and the urease enzyme regains full function



Urease Enzyme



Urease Inhibitor

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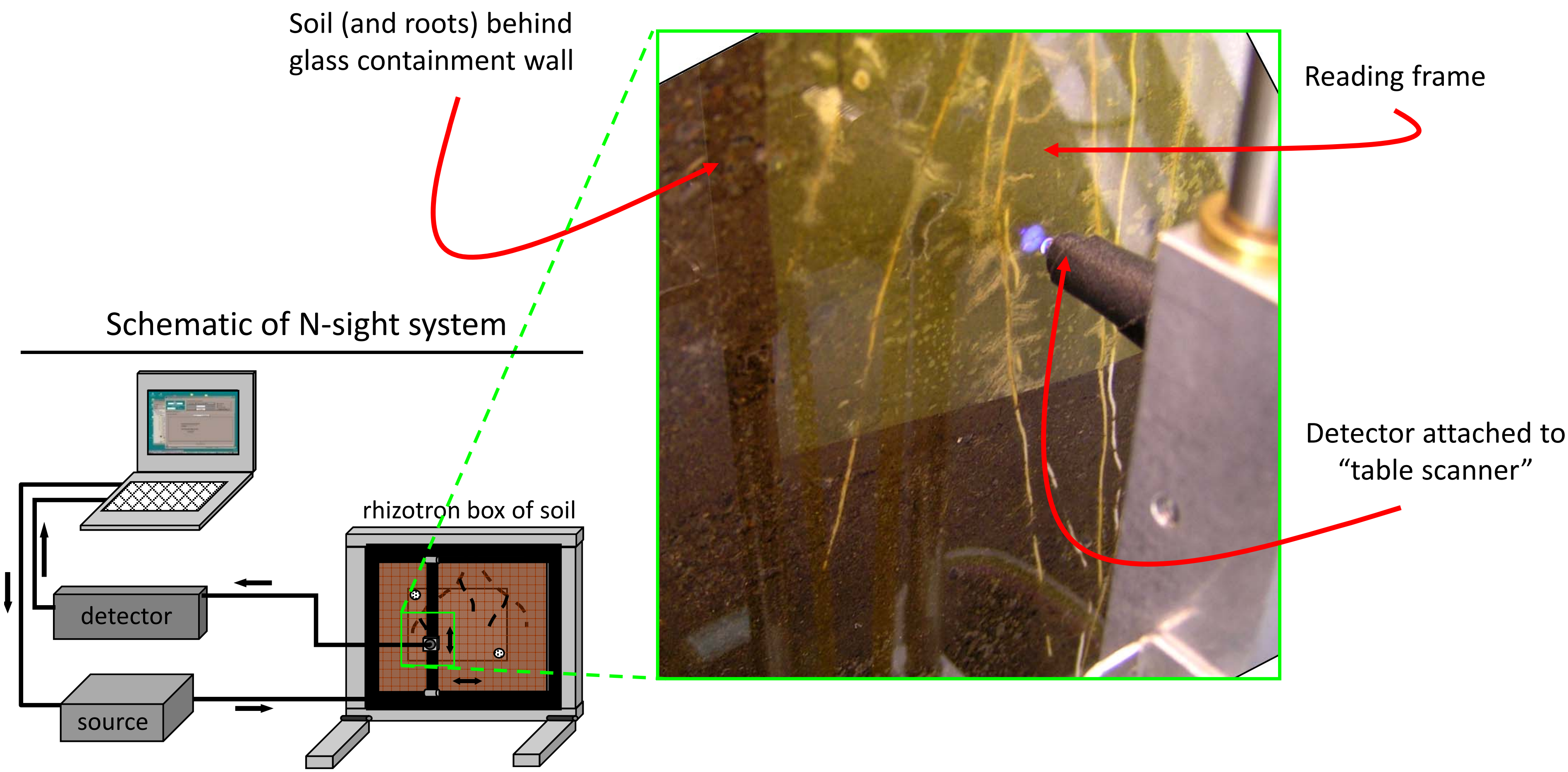
Research: Understanding Nitrogen Transformation

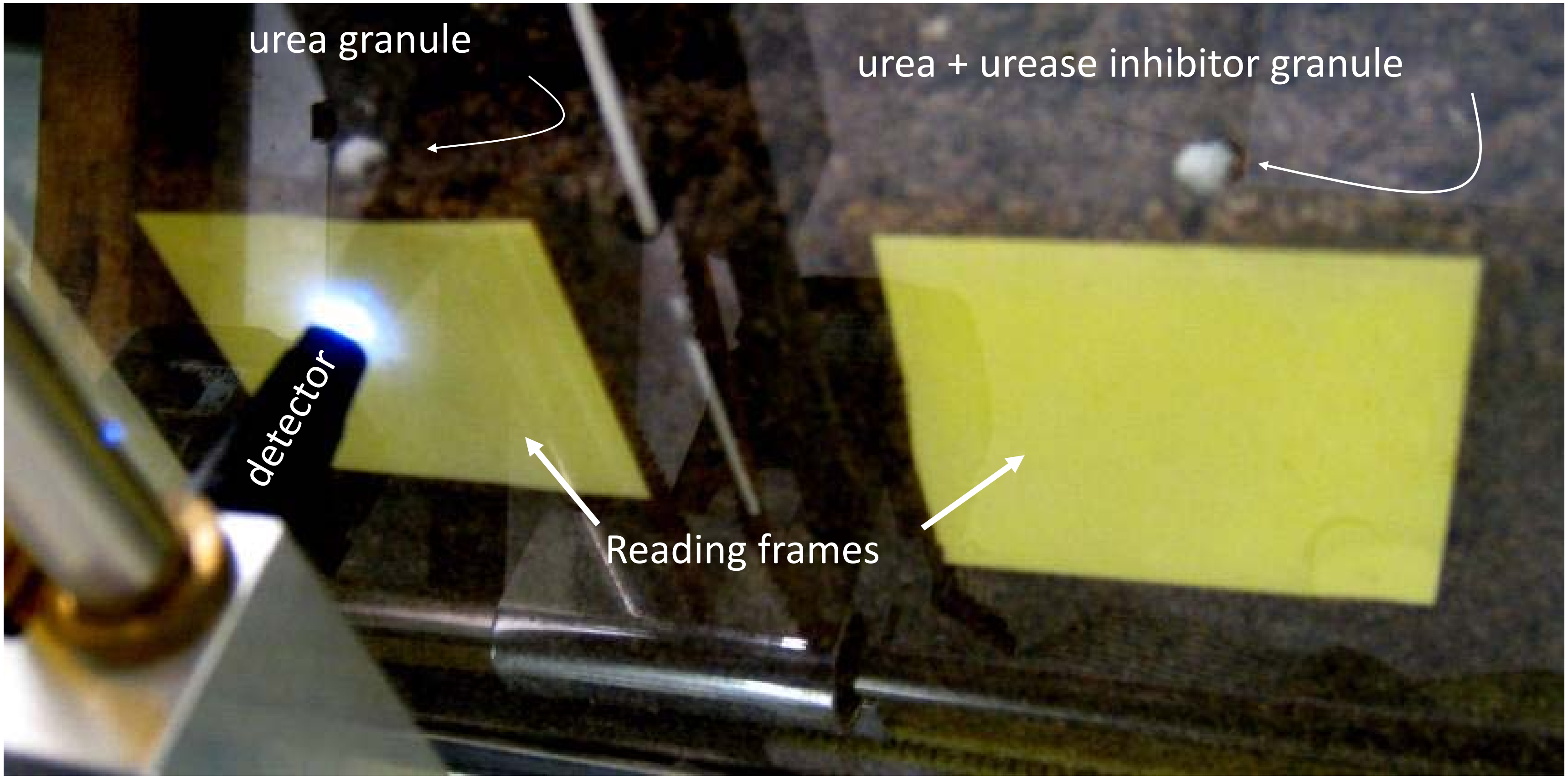
Non-invasive detector scans soil conditions, signals analyzed by computer.

System is called “N-sight”. To be introduced in 2009.



Research: Understanding Nitrogen Transformation

N-sight system analysis of normal urea versus urea treated with urease inhibitor



Research: Understanding Nitrogen Transformation

trial initiated 08 Aug 2008

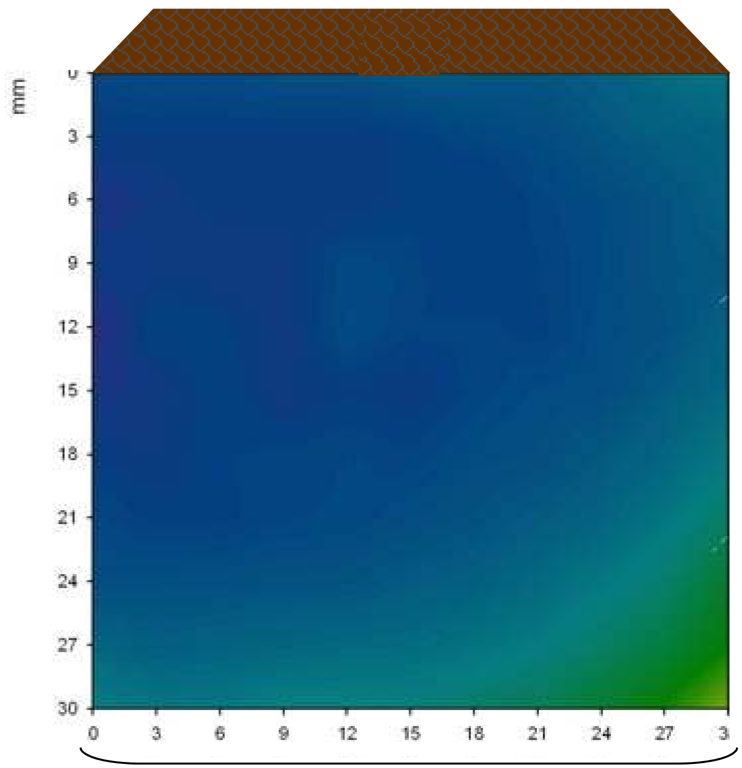
Sandy soil, 1 urea granule added to surface, 1.3in^2 reading frame, 5.5 day run time

Click here once to start animation

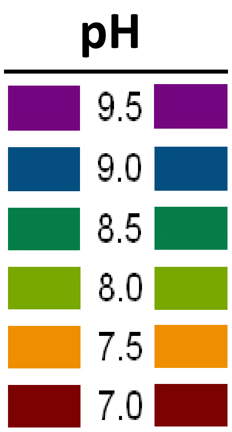
Hours:	0	3	8	12	24	36	48	60	72	84	96	108	120	132
					1 day		2 days		3 days		4 days		5 days	

Press up arrow to replay

Normal urea



N-sight 'reading frame' 30mm^2



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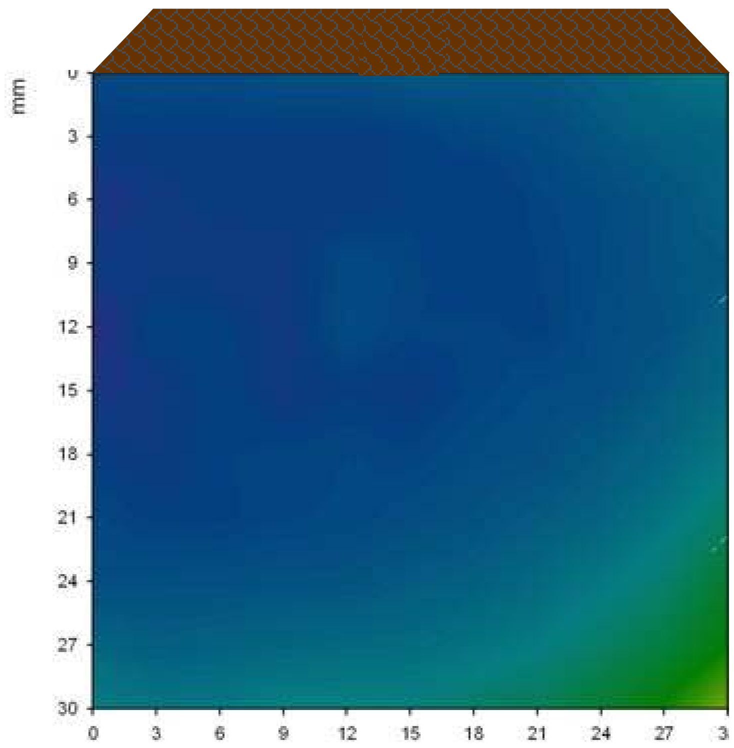
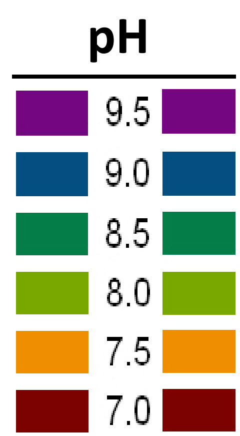
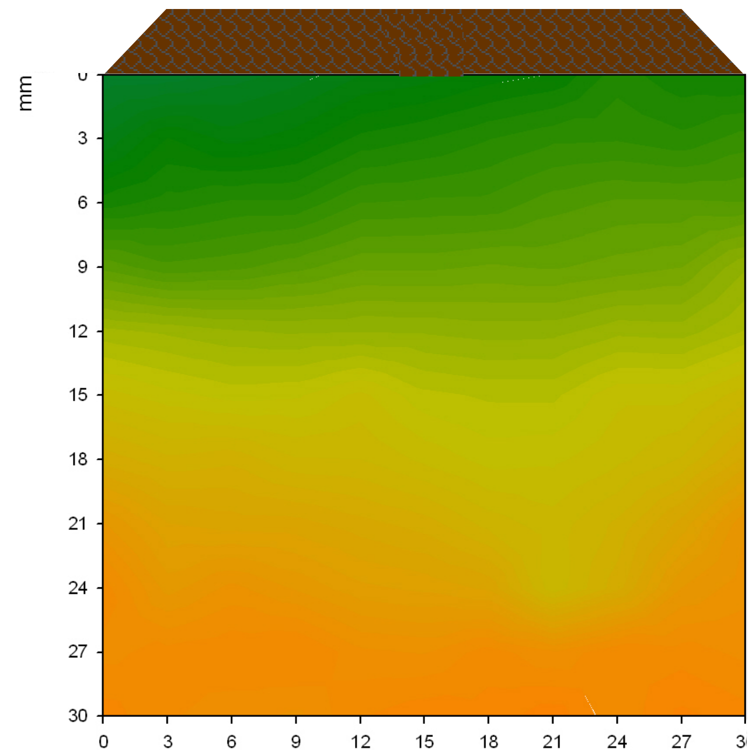




Urea + urease inhibitor



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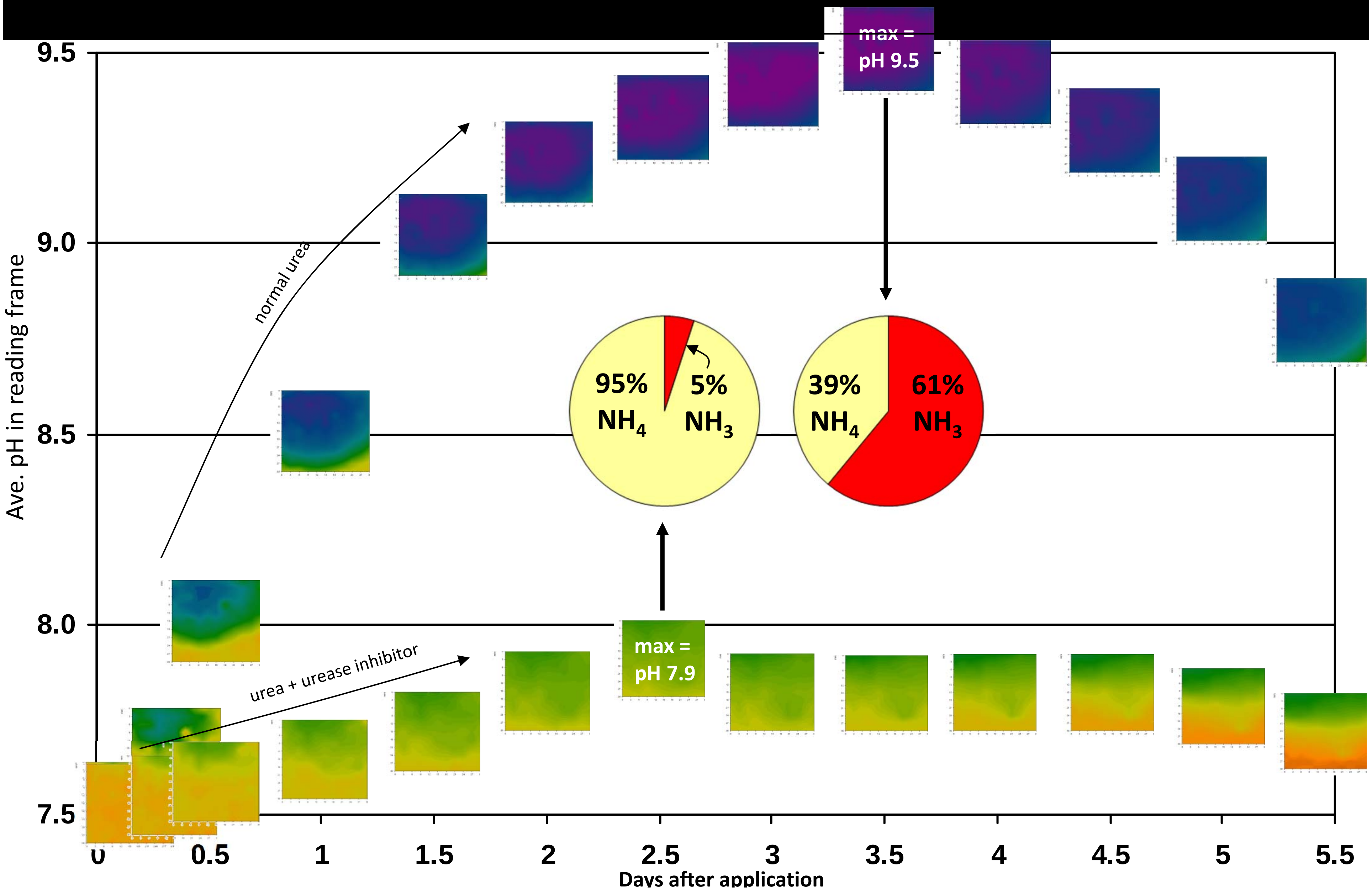

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AGROTAIN nitamin nitamin NFUSION

Function of nitrification inhibitors

Nitrification inhibitors **delay the bacterial oxidation** of the **ammonium ion (NH_4^+)** by depressing (four to ten weeks) the activity of *Nitrosomonas* bacteria in the soil.

The objective of using nitrification inhibitors is to control the loss of nitrate (leaching) or nitrous oxide (N_2O) production by **keeping N in the ammonium form longer** and increasing N-use efficiency.

- Two types of nitrification inhibitors
  - Enzymatic (competitive inhibition)
  - Microbicide

Nitrification Inhibitor "Mode of Action" (simplified characterization)

"Nitrification"

$$NH_4^+ \xrightarrow[\text{AMO}]{\text{Nitrosomonas}} NO_2^- \xrightarrow{\text{Nitrobacter}} NO_3^-$$

(ammonium) (nitrite) (nitrate)

Nitrification inhibitors slow the nitrification process
by blocking the ammonia monooxygenase enzyme (AMO)

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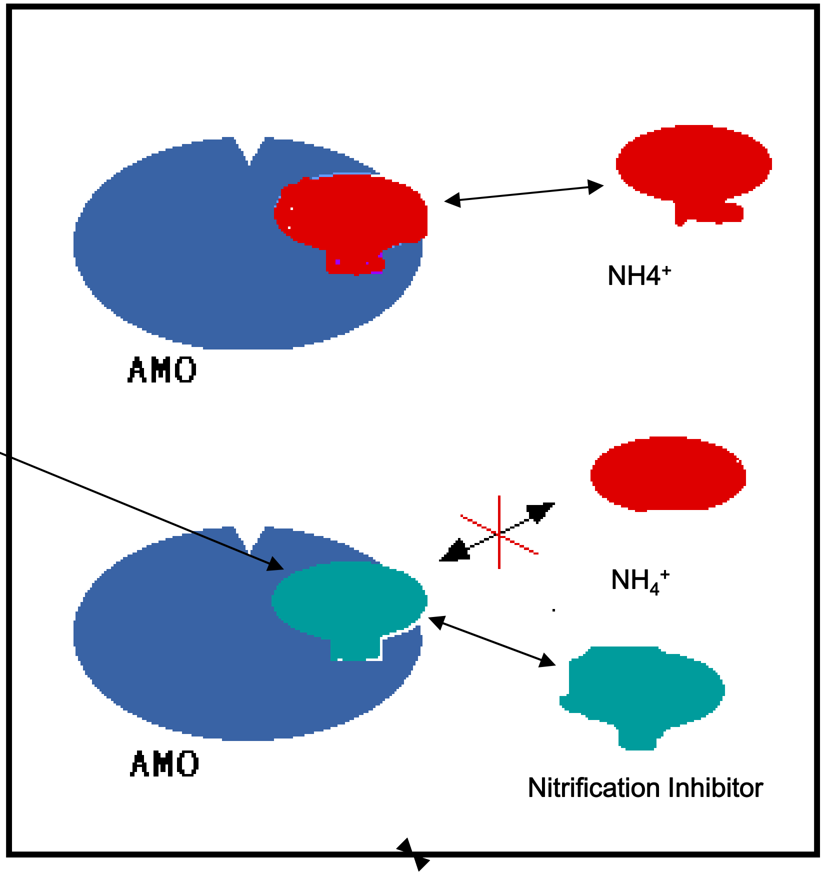
Competitive Inhibition

Nitrification inhibitor attaches to the AMO active site and inhibits the oxidation of NH_4^+



Microbicide

Microbicide works here

$$\underset{\text{(Ammonium)}}{NH_4^+} \xrightarrow{\cancel{\text{Nitrosomonas Bacteria}}} \underset{\text{(Nitrite)}}{NO_2^-} \xrightarrow{\text{Nitrobacter Bacteria}} \underset{\text{(Nitrate)}}{NO_3^-}$$

Slow – Controlled Release

Advantages

- Decreases nutrient losses
- Enhances nutrient use efficiency
- CRU may reduce toxicity to seedlings
- SCU may favor uptake of P and Fe
- CRU may improve uptake of nutrients through synchronized nutrient release
- CRU may reduce N loss from leaching, volatilization losses of NH_3 and N_2O omissions

Disadvantages

- N release may be extremely slow
- SCU may increase acidity of soil
- PCU may leave residue of synthetic material on soil
- PCU if surface applied may float during heavy rains
- PCU cost

Urease Inhibitors

Advantages

- Provides more N to crop by reducing NH_3 loss resulting in increased yields
- Reduction in NH_3 loss can reduce eutrophication and acidification
- Slows ammonia soil pH increases which could damage seedlings, crop emergence and inhibit germination
- Reduction in severe leaf-tip burn

Disadvantages

- Small yield when urease inhibitors are used in soils rich in N

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Nitrification Inhibitors

Advantages

- Improves N-use efficiency
- Possible to reduce the amount of N applied without loss of yield
- Number of applications could be reduced
  - Saves labor
  - Flexibility of application timing
- Provides NH_4^+ nutrition to plant
  - Less energy necessary for conversion to amino acids and protein
- May reduce losses of NO_3^- by leaching
- May reduce losses of N_2O

Disadvantages

- If surface applied - can favor increase NH_3 volatilization
- Soil bacteria may be killed (Microbicide)
- Yield responses occur only if N is prone to losses by leaching or denitrification (DCD)

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Which Product to Pick

- Depends on the management goals of the producer
- Depends on if loss is an issue
  - Volatilization
  - Leaching
  - Denitrification
- Cost

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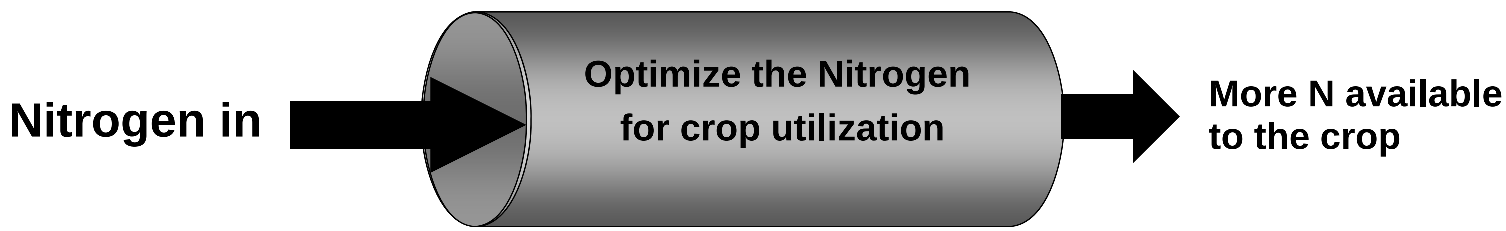
Enhanced Efficiency Fertilizers



Strategy: use technology to fix the holes

- control nitrogen losses
- increase soil nitrogen level in soil
- achieve higher yield and quality

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In Summary

- Able to take N from “out of the air”
- N sources can be inefficient
- Advent of new products increase N availability
    - More N available to the crop
    - Reduces volatility
    - Reduces leaching
    - Reduces denitrification
- Advantages and disadvantages of inhibitors

This is home:

- Population will continue to grow
- Ability to feed this population will require change
- This is possibly the biggest challenge we face this century
- Enhanced Efficiency Fertilizers are <u>one</u> tool to help

Conservation is more than just a word, it's a way of life – and it's forever.

John Hassell

Source: "The Blue Marble" NASA Goddard Space Flight Center
The Visible Earth (http://visibleearth.nasa.gov/)

Thank You

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A global company offering products that provide

to a growing, consumptive, demanding population

Source: “The Blue Marble” NASA Goddard Space Flight Center
The Visible Earth (http://visibleearth.nasa.gov/)