University of California

Nitrogen Management Training

for Certified Crop Advisers

MODULE 3

Nitrogen Fertilizer Management

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Making Efficient Fertilizer Choices

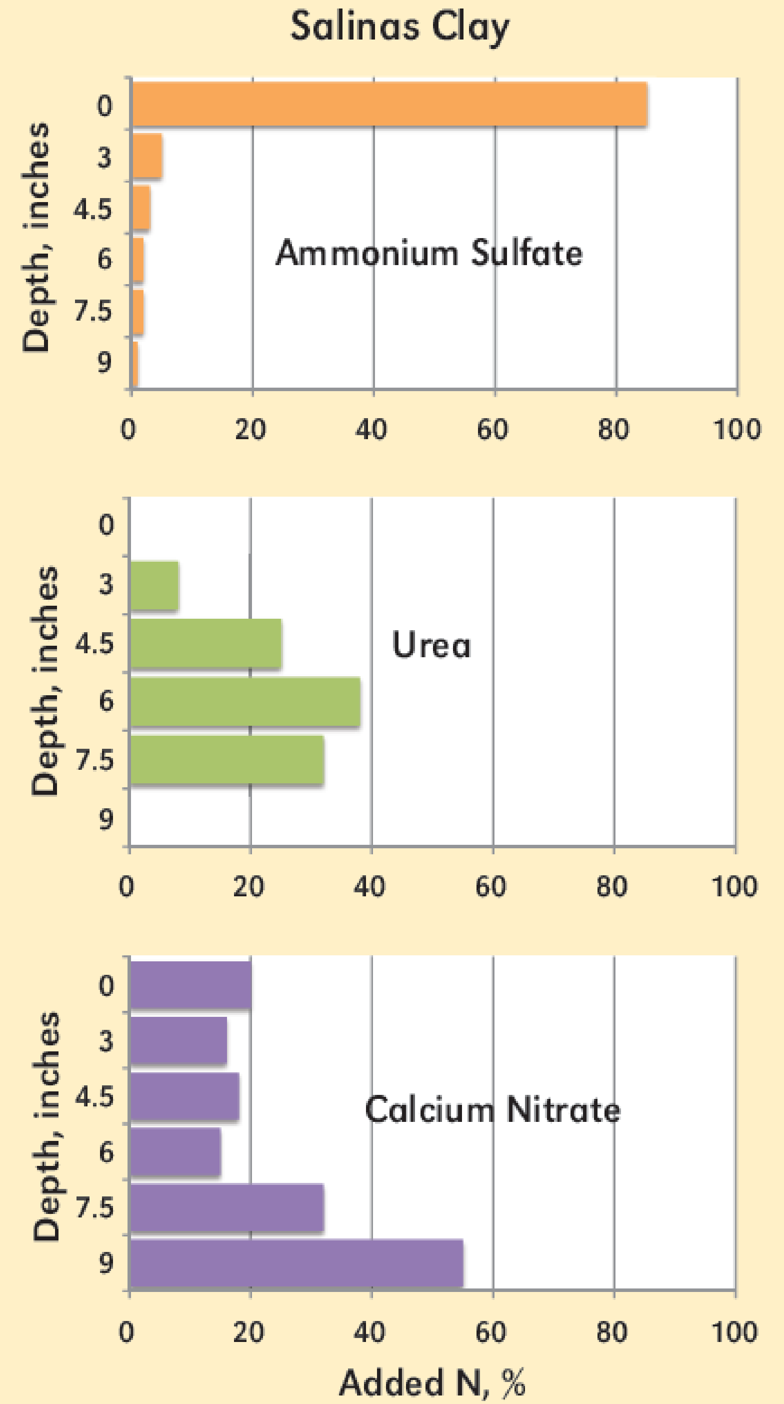
Why do we care about N forms?

- Different agronomic values and costs
- Impact on the environmental efficiency of use, and determine the appropriate management practices

How readily do N forms leach?

- NH_4^+-N movement is restricted
- Urea and NO_3^--N move freely with water

(Broadbent et al., Proc. SSSA 22:303-307, 1958)



Nitrogen Fertilizers

1. Ammonium-forming fertilizers:

- Anhydrous ammonia
- Urea

2. Ammonium fertilizers :

- Ammonium sulfate
- Ammonium/phosphorus combinations (MAP, DAP, 10-34-0)

3. Nitrate fertilizers :

- Potassium nitrate
- Calcium nitrate (CN-9)

4. Combination fertilizers:

- Ammonium nitrate
- Urea-ammonium nitrate (UAN) solutions
- Calcium ammonium nitrate (CAN-17)

5. Organic materials:

- Manure and other animal byproducts
- Compost

Nitrogen Fertilizer Forms

Ammonium-forming Fertilizers

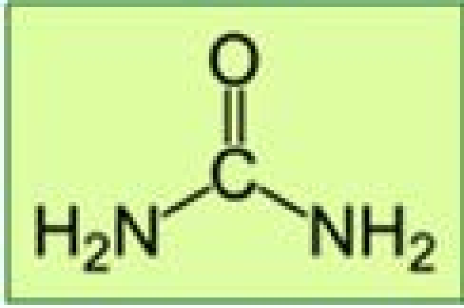
- **Anhydrous ammonia**

Anhydrous ammonia application to soil *or water*:

$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

raises pH

Ammonium-forming Fertilizers



- **Urea**

- Highly soluble, uncharged, moves freely with water

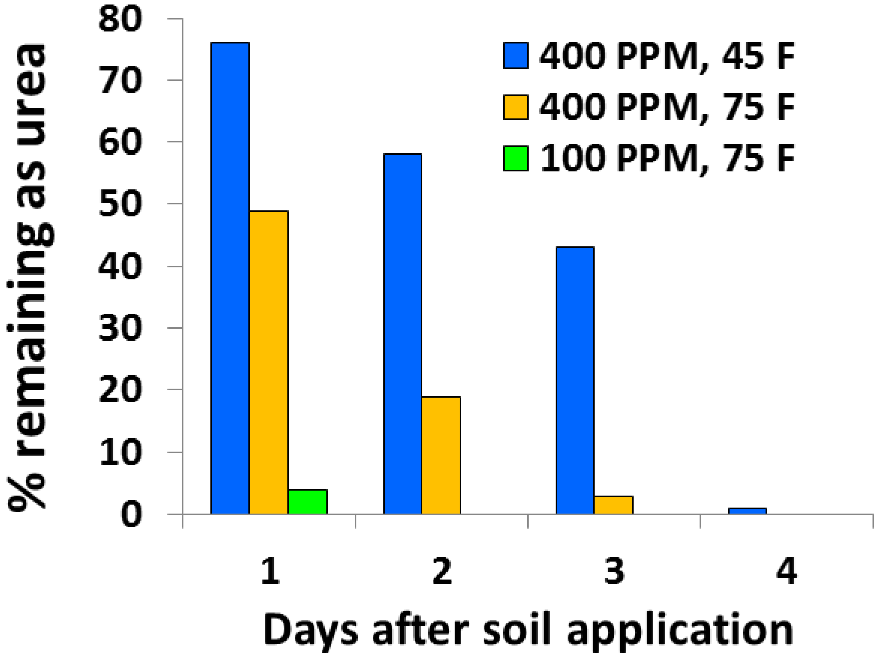
- Enzymatic hydrolysis produces NH_4^+ and alkalinity

$$\underset{\text{urea}}{CO(NH_2)_2} + 2\,H_2O + \underset{\text{acid}}{H^+} \xrightarrow{\text{urease}} \underset{\text{ammonium}}{2\,NH_4^+} + \underset{\text{bicarbonate}}{HCO_3^-}$$

raises pH (bicarbonate)

Ammonium-forming Fertilizers:

Urea hydrolysis occurs rapidly:



Rate of hydrolysis …

- Increases as temperature increases
- Decreases as concentration increases

(Broadbent et al., Proc. SSSA 22:303-307, 1958)

Ammonium Fertilizers

- **Ammonium sulfate [$(NH_4)_2SO_4$]**

- Ammonium/phosphorus combinations
  - Monoammonium phosphate (MAP)
  - Diammonium phosphate (DAP)
  - Ammonium polyphosphate (10-34-0)

- Ammonium fertilizers have:
  - No immediate effects on soil or water
pH - Are temporarily resistant to leaching

Combination Fertilizers

- **Ammonium nitrate (NH_4NO_3)**

- Calcium ammonium nitrate (CAN-17)
  - 32% of N as NH_4^+, 68% as NO_3^-

- Urea ammonium nitrate (UAN) solutions
  - 50% of N as urea, 25% NH_4, 25% NO_3
  - different concentrations (UAN-28, UAN-32, etc.)

Organic Materials

- **Manure and other animal byproducts**
- **Compost and green waste**

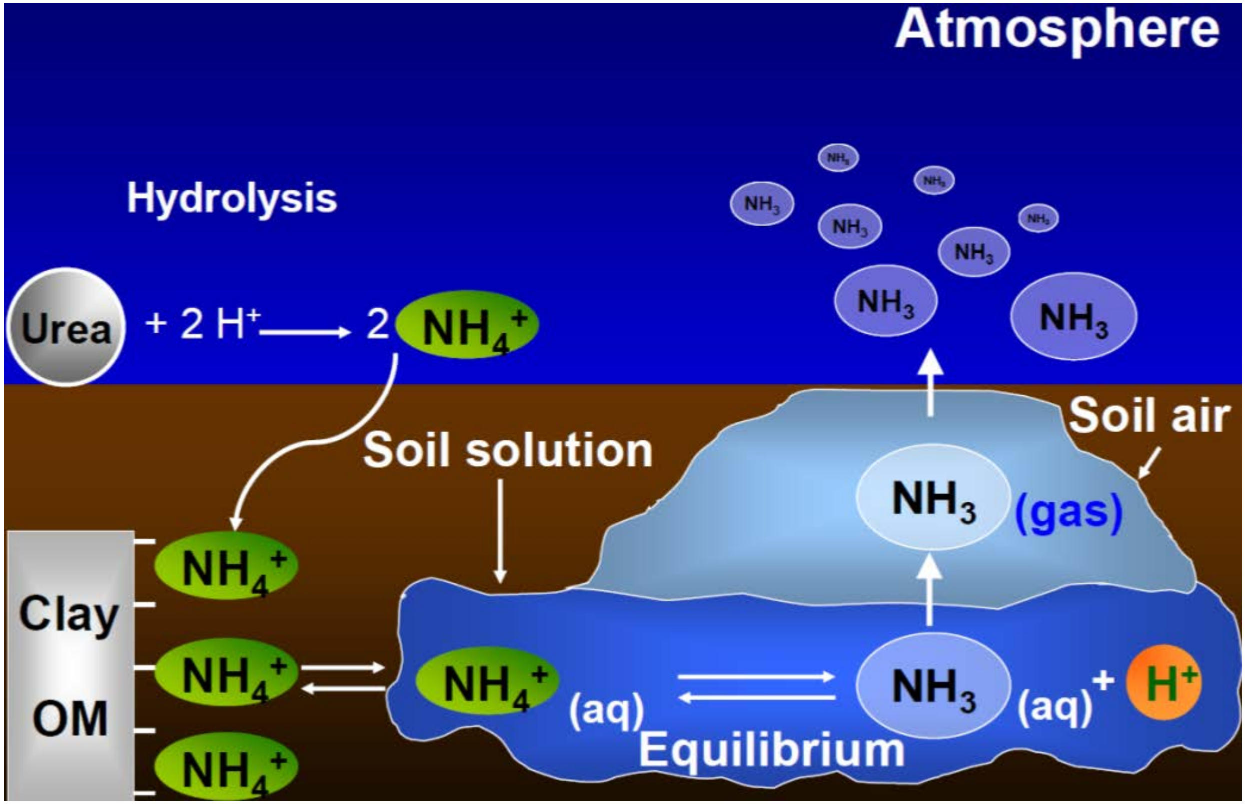
- Contain both mineral N (immediately available) and organic N (slowly available after microbial conversion)



Nitrogen Transformations: Volatilization, Denitrification, and Nitrification

Volatilization

- **The loss of gaseous NH_3 to the atmosphere**

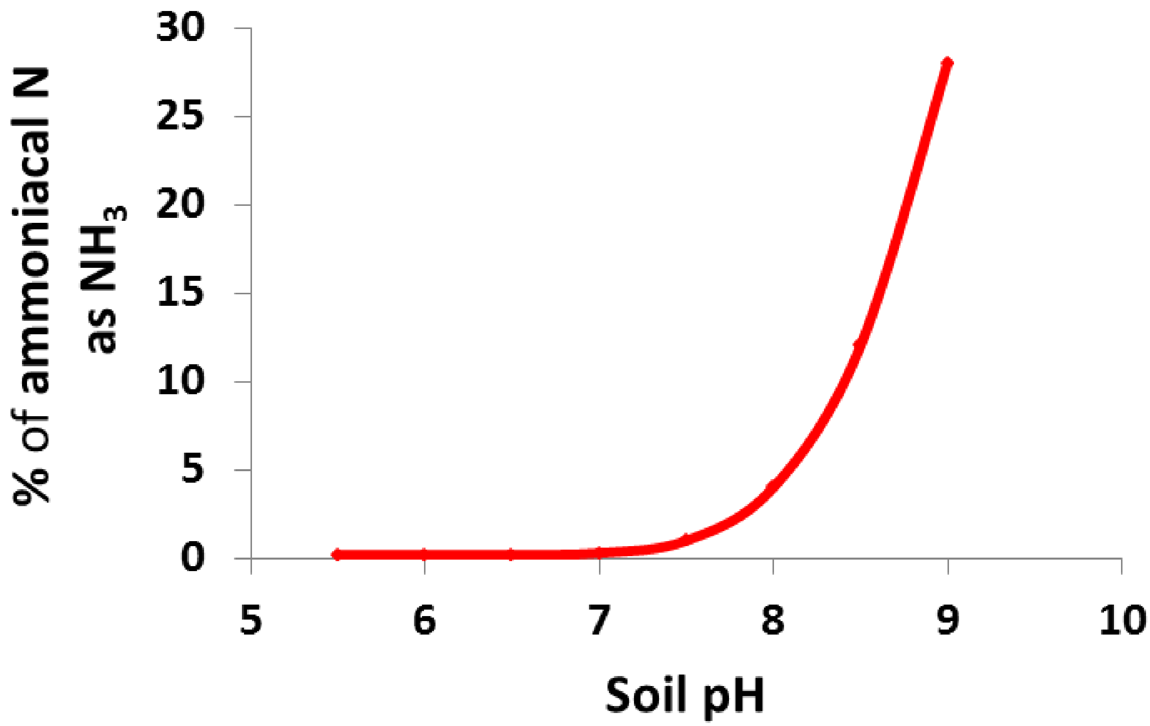


When is volatilization most significant?

- Soil injection of anhydrous ammonia, poorly sealed
- Anhydrous ammonia injection into irrigation water
- Loss from urea after hydrolysis, before nitrification

Volatilization: Effect of pH

Significant volatilization occurs only at high pH:



… but both anhydrous ammonia and urea raise soil pH near the site of application

Volatilization: Corn/Ammonia Example

Anhydrous ammonia application impacts solution pH

Site	pH irrig water	pH irrig water + AA
1	7.3	9.9
4	7.8	10.0
5	7.4	10.0
6	7.1	9.0
9	7.3	10.1
12	7.3	9.2
13	7.8	10.2

(Anhydrous ammonia injection into irrigation water
Tulare Co. 2008 – C. Frate and J. Deng)

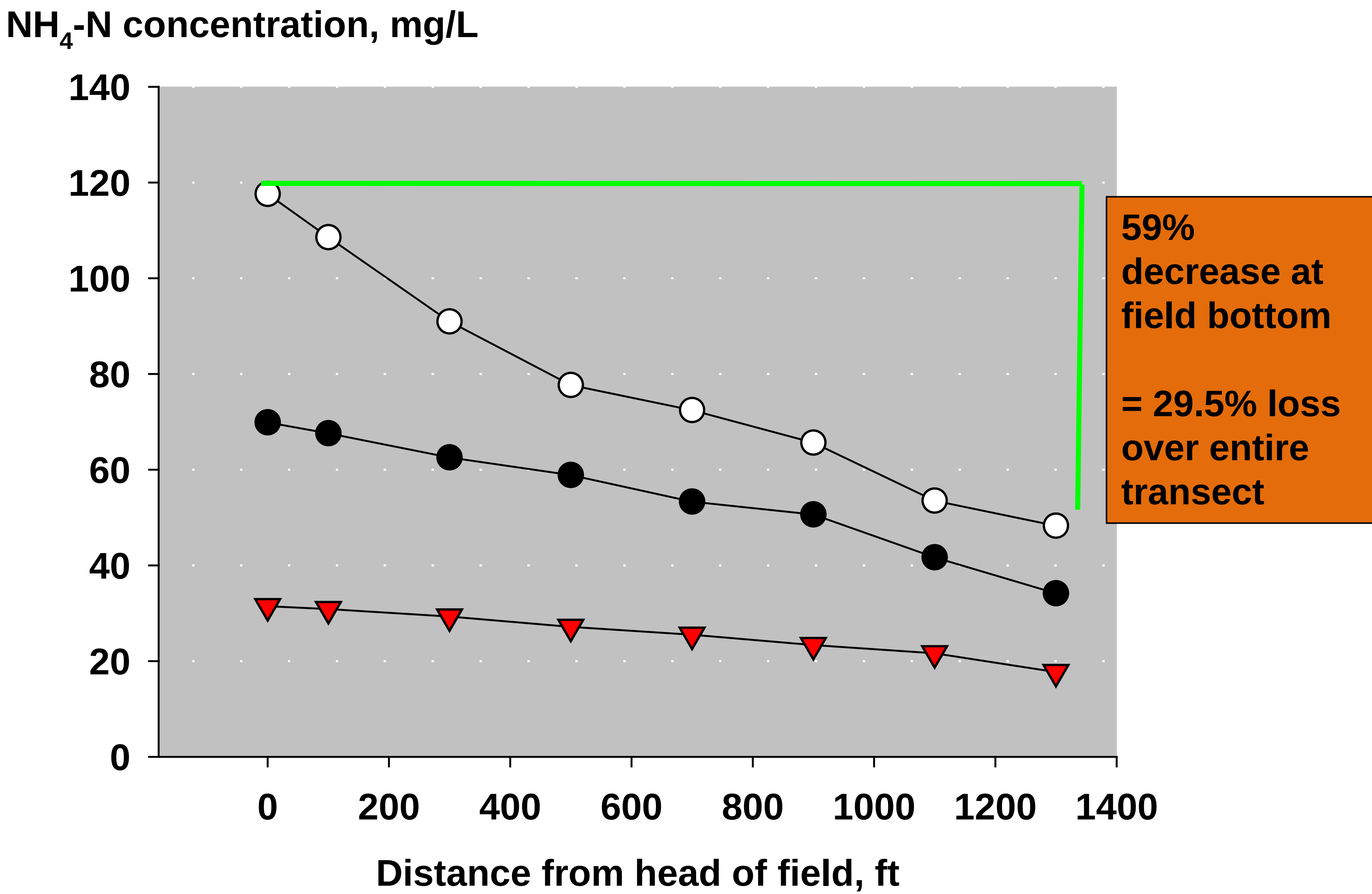
Volatilization: Ammonia Example

How large can ammonia volatilization losses be?

(Pettygrove et al., 2005)

Volatilization: Ammonia Example cont'd.

Fertigating anhydrous ammonia is highly inefficient :



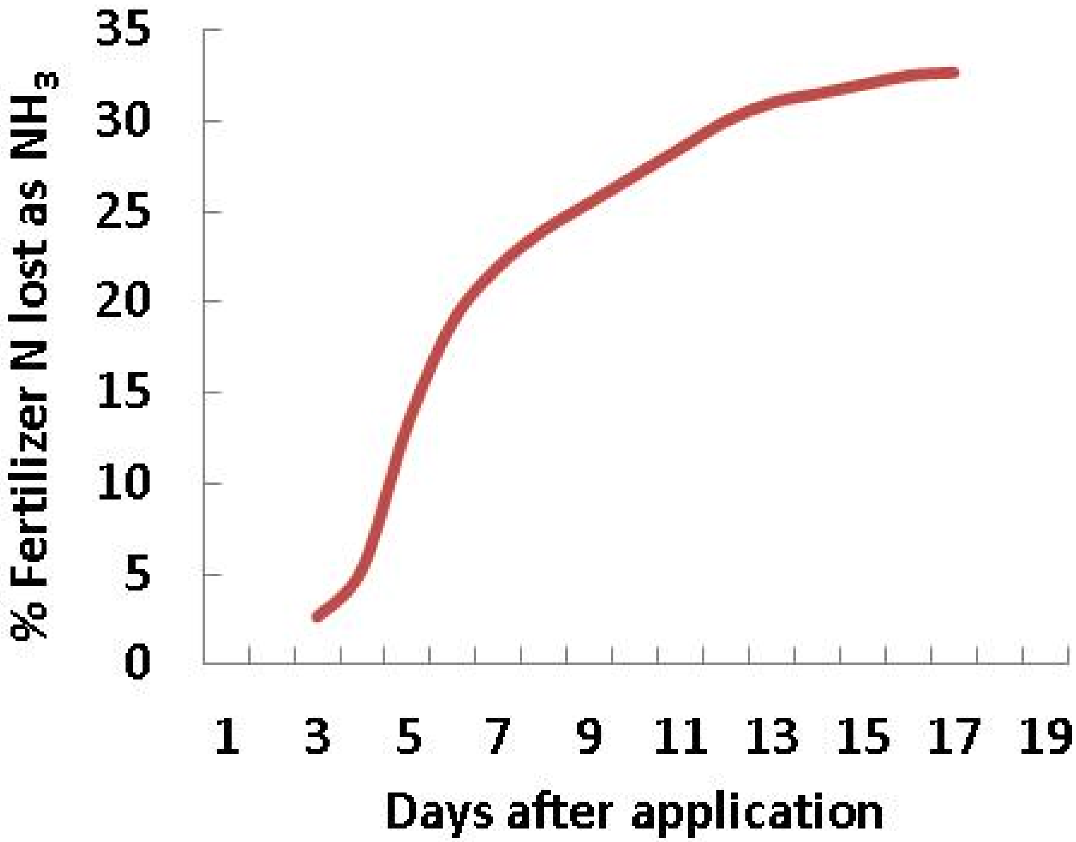
Volatilization: Urea

Factors that increase volatilization :

- Surface application without incorporation or irrigation
- High temperature
- High wind speed
- Low soil buffering capacity

Volatilization: Urea Example

How large can urea volatilization losses be?



(Topdressed dryland wheat in Oregon, no rain until day 13. Data from D. Horneck, OSU)

Nitrification

- Conversion to NO_3^-

$$NH_4^+ + 2\,O_2 \xrightarrow[\text{(Nitrobacter)}]{\text{(Nitrosomonas)}} NO_3^- + H_2O + 2\,H^+$$

Lowers soil pH

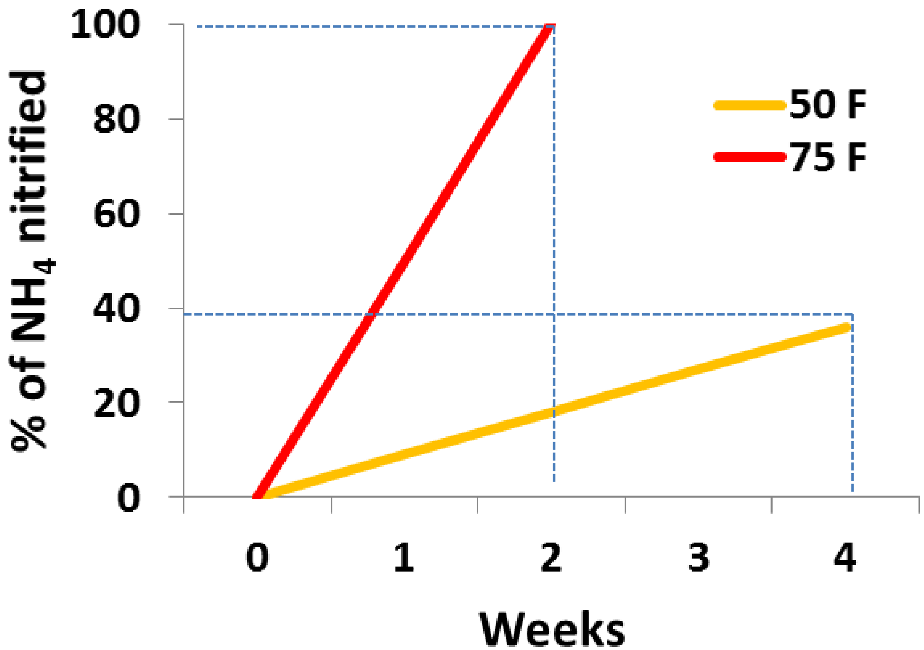
Nitrification: Soil Acidification from N Fertilizers

N Fertilizer	Abbreviation	Analysis	Lime to neutralize acidity
		N-P2O5-K2O-S	lb CaCO3/lb N
Calcium ammonium nitrate	CAN-17	17-0-0	< 2
Anhydrous ammonia	AA	82-0-0	3.6
Urea		46-0-0	3.6
Ammonium nitrate	AN	34-0-0	3.6
Urea ammonium nitrate	UAN	32-0-0	3.6
Ammonium polyphosphate	APP	10-34-0	7.2
Ammonium sulfate	AS	21-0-0-24S	7.2
Mono-ammonium phosphate	MAP	11-52-0	7.2
Ammonium thiosulfate	ATS	12-0-0-26S	10.8
Manure or compost		Variable	Variable

(OSU Eastern OR Liming Guide 2013)

Nitrification: How Quickly Does it Occur?

- **Nitrification rate governed mostly by temperature**

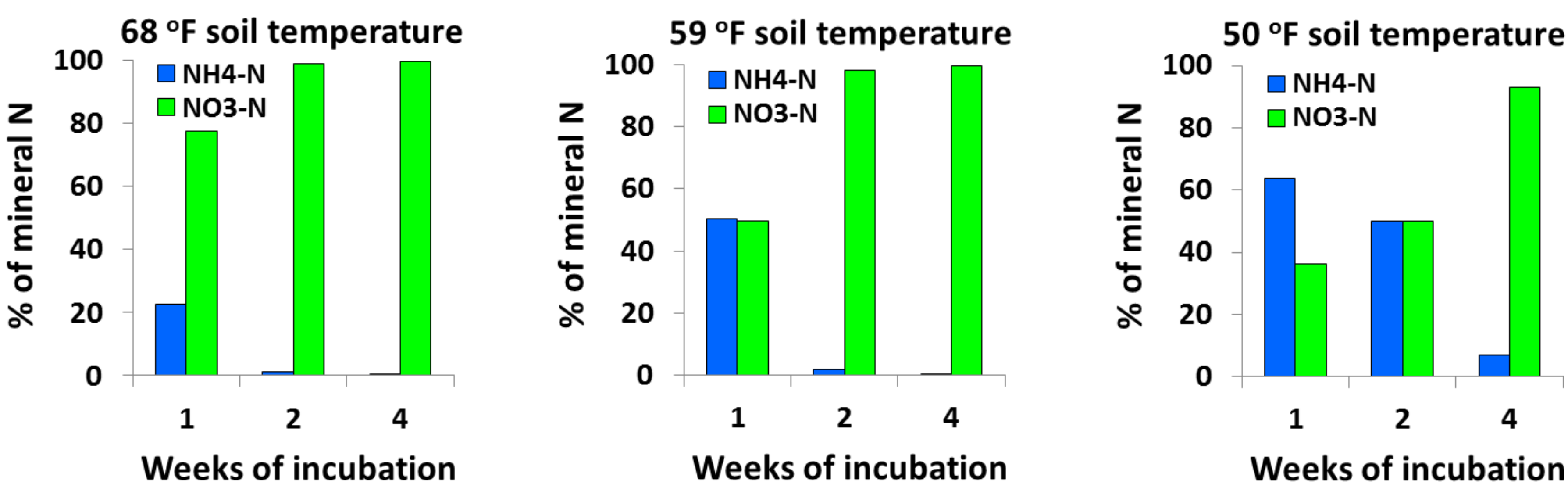


Practical experience suggests that nitrification is often more rapid.

(Western Fertilizer Handbook)

Nitrification: How Quickly Does it Occur?

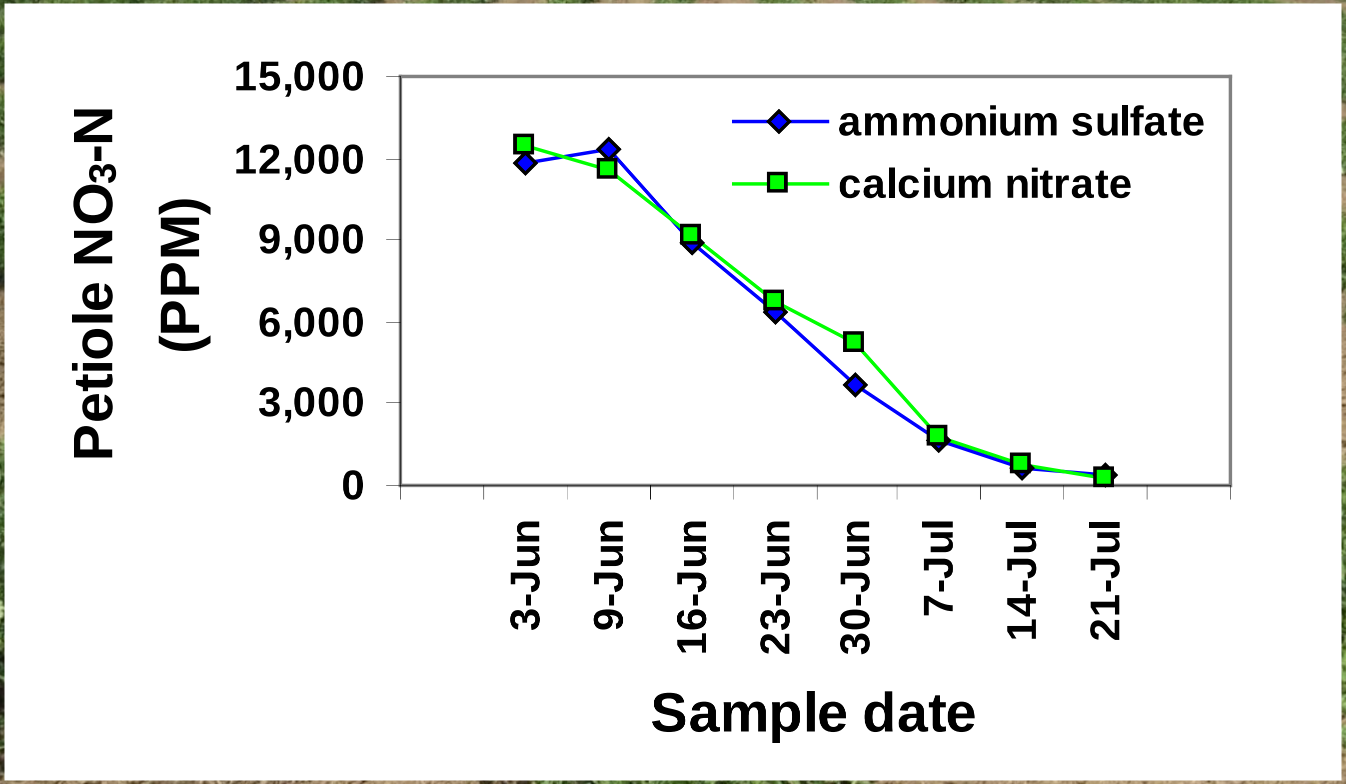
- Feather meal incubated in typical agricultural soils at different temperatures
- Mineralized N was initially in NH_4^+ form, but nitrification was relatively rapid



(Hartz and Johnstone, HortTechnology 16:39-42, 2006)

Nitrification: How Quickly Does it Occur?

Ammonium sulfate vs. calcium nitrate fertigation in tomato

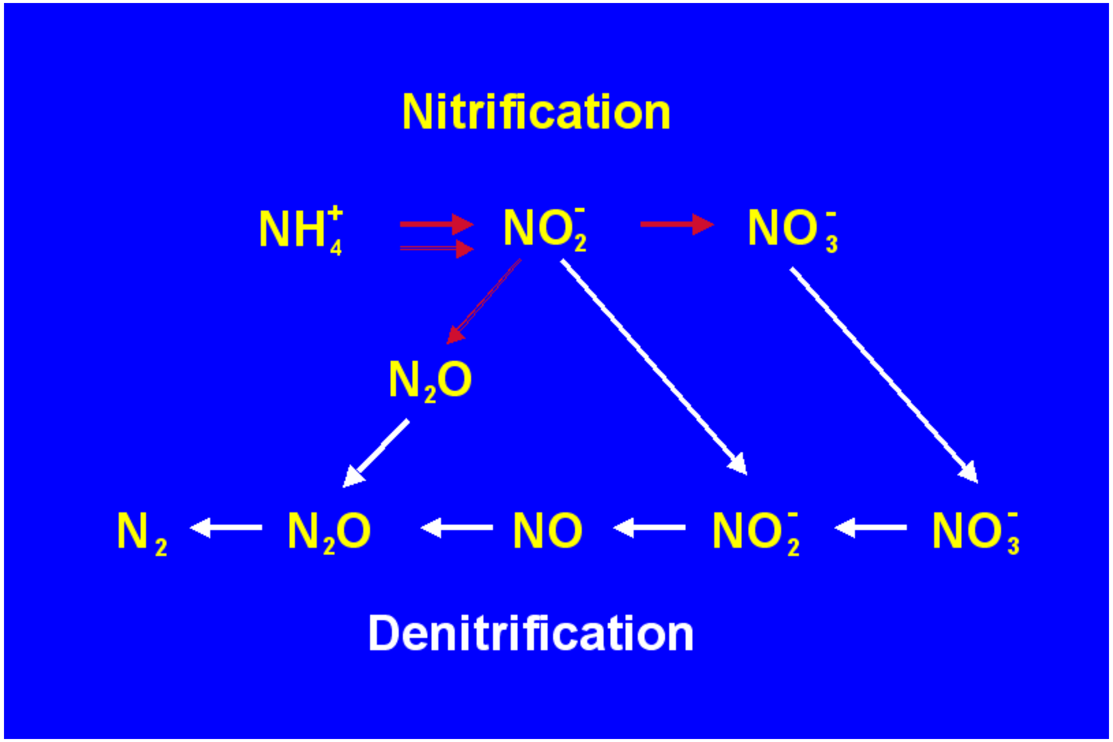


Conclusion:

- In all but the coldest soil, conversion of NH_4-N to NO_3-N occurs relatively rapidly

Denitrification

- Conversion of NO_2^- or NO_3^- to gaseous N forms (N_2, N_2O)

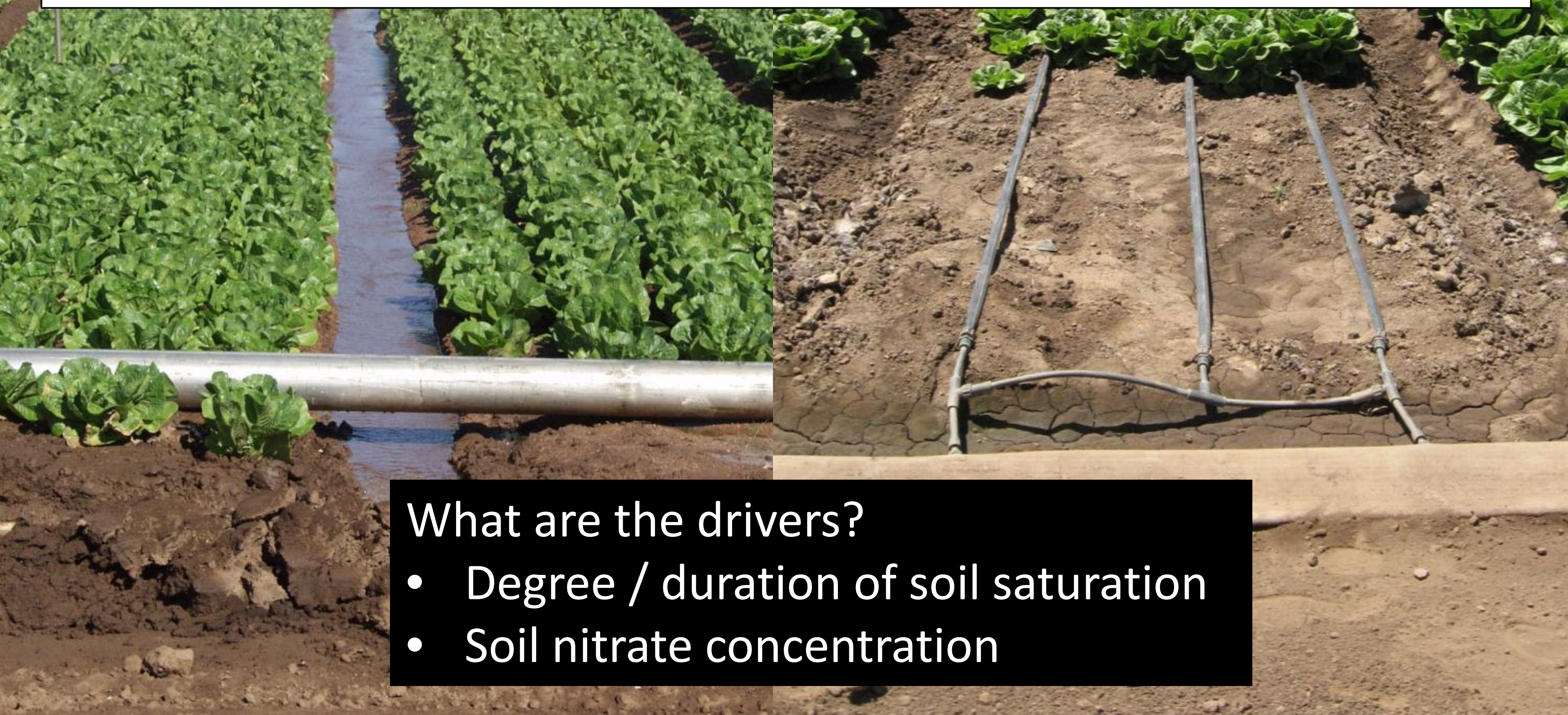


Denitrification requires anaerobic conditions (saturated soils)

Denitrification: Magnitude of Losses

How large are losses under normal field conditions?

- They range from minimal to agronomically significant, depending on field conditions



What are the drivers?

- Degree / duration of soil saturation
- Soil nitrate concentration

Denitrification: Magnitude of Losses

On the high end:

Sprinkler-irrigated vegetables with high N fertilizer rates

- up to 2-4 lb N/acre per irrigation cycle or rainfall event (Ryden and Lund, SSSAJ 44:505-511, 1980)

On the low end:

Furrow-irrigated tomatoes

- < 1 lb N/acre per irrigation event

(Burger et al., Biol. Fert. Soils 42:109-118, 2005)

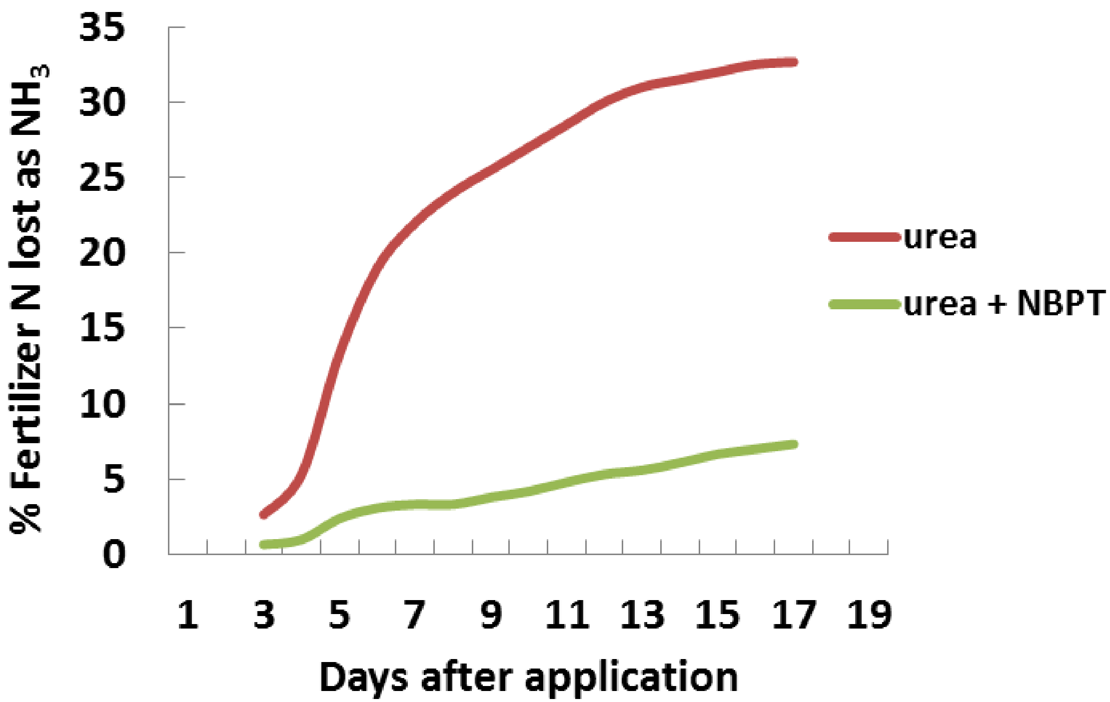
Denitrification: Controlling Losses

- **Good irrigation management** (limit anaerobic conditions, switch to low-volume irrigation systems)
- **Avoid high soil NO_3-N concentration** (limit feedstock)

Manipulating N Transformations for Improved N Efficiency

Urease Inhibition

- **Slowing the conversion of urea to NH_4^+**
- **NBPT** (N-(n-butyl) thiophosphoric triamide)
  - Longer lasting effect in alkaline soils, and in cooler soils
  - Most useful when urea is topdressed



(Topdressed dryland wheat in Oregon, no rain until day 13. Data from D. Horneck, OSU)

Nitrification Inhibition

Suppress the bacteria that drive nitrification

Inhibitors:

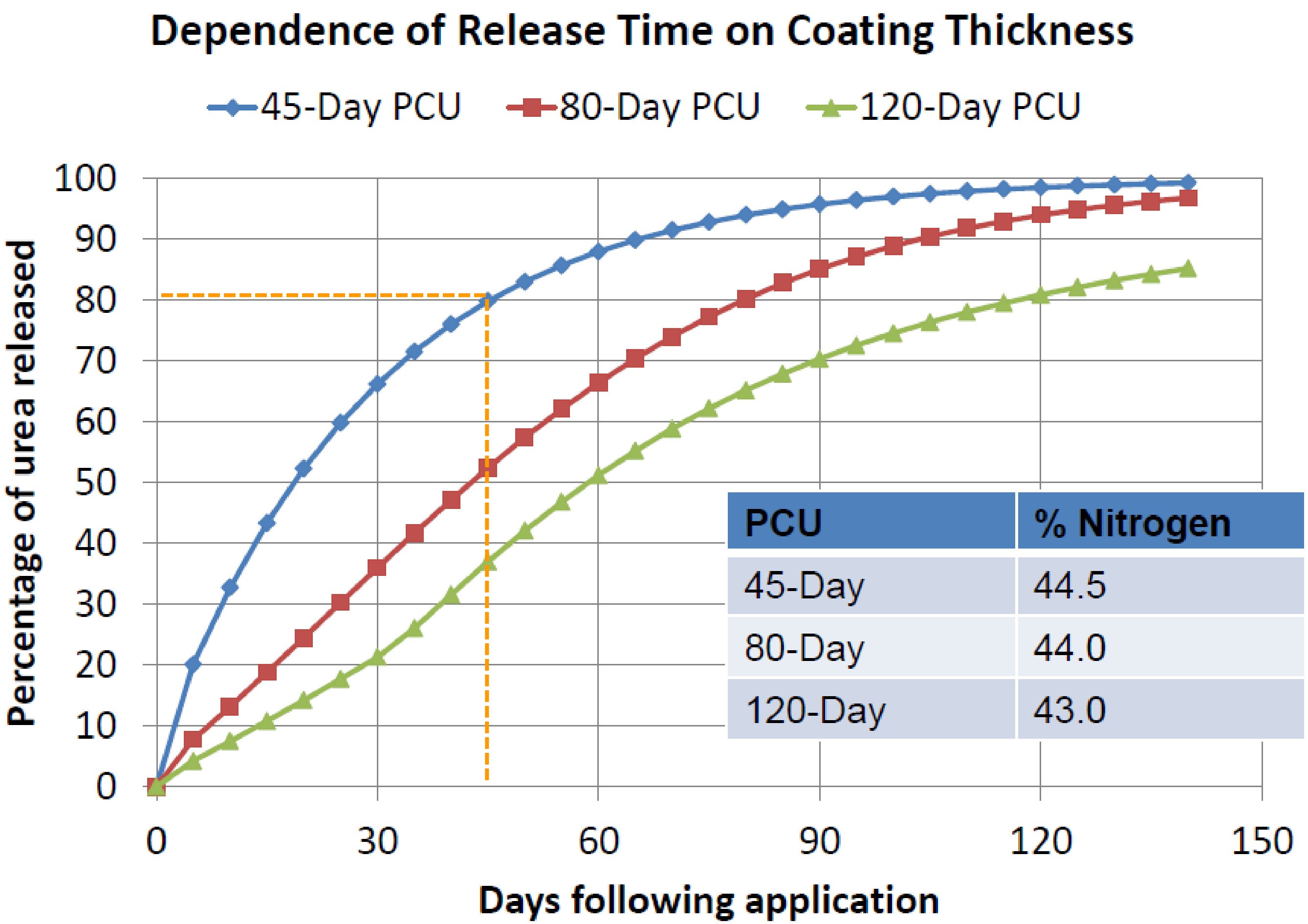
- Nitrapyrin (‘N-Serve’ or ‘Instinct’)
  - Proven track record of efficacy
  - California registration currently being sought
- Dicyandiamide (DCD)
  - Currently available as a constituent of ‘SuperU’ (NBPT + DCD)
  - DCD is soluble, so it can be leached away from NH_4^+ fertilizer, limiting effectiveness
- DMPP (Novatec)
  - Currently available only as treated fertilizer (Solub 21-0-0, Solub 16-10-17)

Controlled Release Fertilizers

Fertilizer Type	Nutrient Release Mechanism	Properties
Polymerized/ reacted urea	Microbial Action	• ureaform, IBDU, and triazone • solid or liquid forms + combinations common • common products include Coron, N-fusion, Nitamin and N-sure
Sulfur-coated urea	Physical / microbial action	
Polymer-coated fertilizer	Diffusion	• can contain any soluble fertilizer form • common products include Agriform, Duration, ESN, and Polygon

Controlled Release Fertilizers

Release rating is based on time to release 80% of N at a standard temperature:



PCU	% Nitrogen
45-Day	44.5
80-Day	44.0
120-Day	43.0

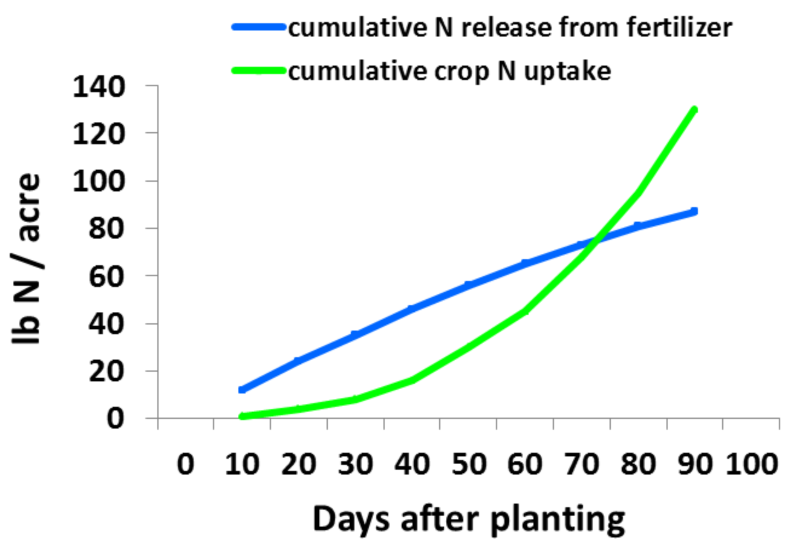
Controlled Release Fertilizers:

Benefits:

- May reduce leaching potential compared to preplant or single sidedress systems
  - weather, soil, and crop factors determine whether this benefit is realized

Drawbacks:

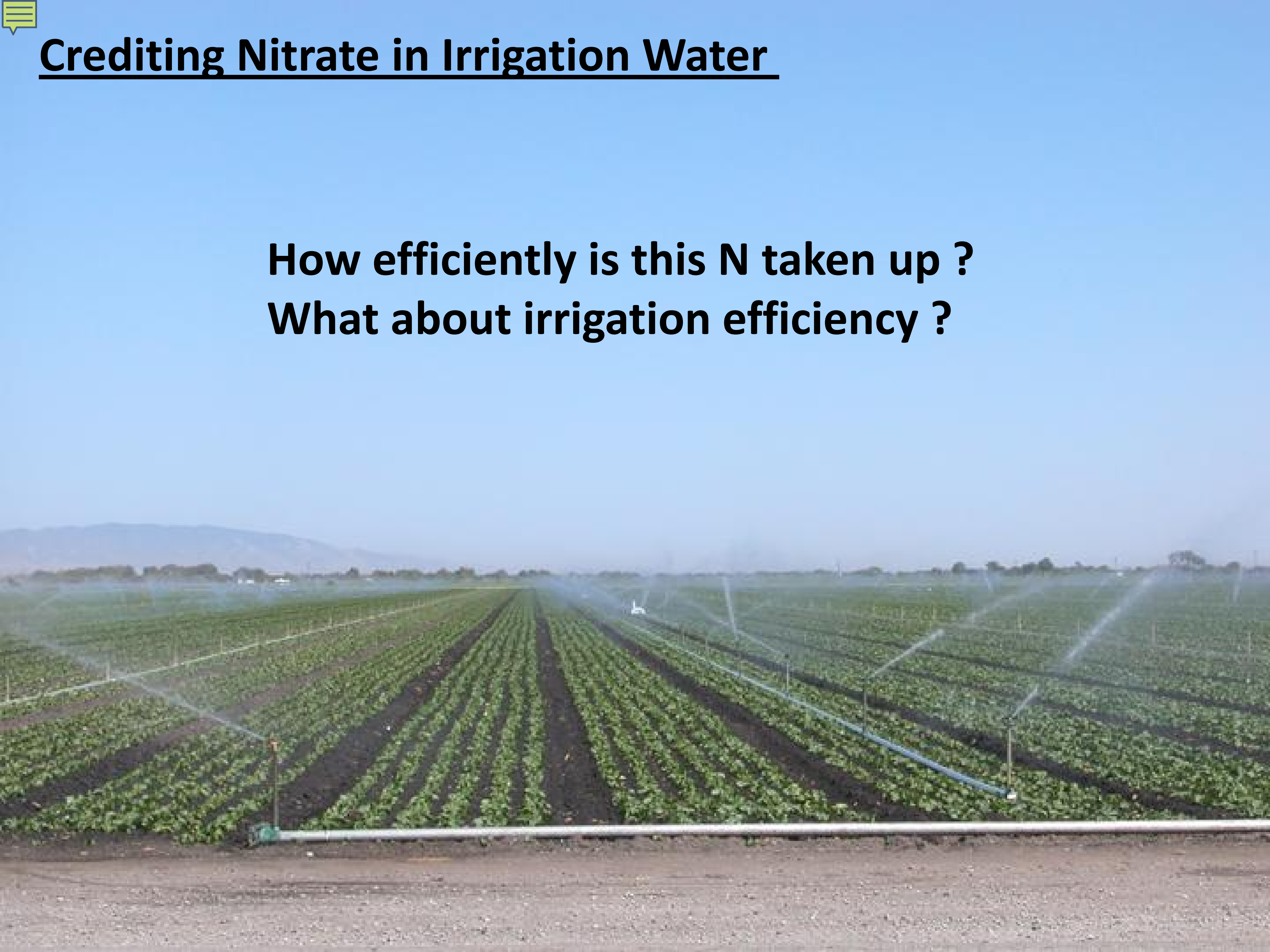
- Higher cost per unit of N
- Match between N release and crop N uptake is often imperfect
  - more appropriate in some cropping scenarios than in others



Crediting N from Other Sources

Crediting Nitrate in Irrigation Water

How efficiently is this N taken up ?
What about irrigation efficiency ?



Crediting Nitrate in Irrigation Water: Tomato Example

- **Count only the NO_3^--N contained in water transpired by the crop**

Processing tomato transpires about 25 inches of water
If irrigation water NO_3^--N is 6 PPM, the ‘fertilizer credit’ would be:

6 PPM NO_3^--N x 0.23 = 1.4 lb NO_3^--N per acre-inch

1.4 lb NO_3^--N per acre-inch x 25 inches = 35 lb NO_3^--N per acre

Crediting N in Organic Sources

Organic fertilizers and amendments:

- Animal waste products (dry or liquid)
- Compost

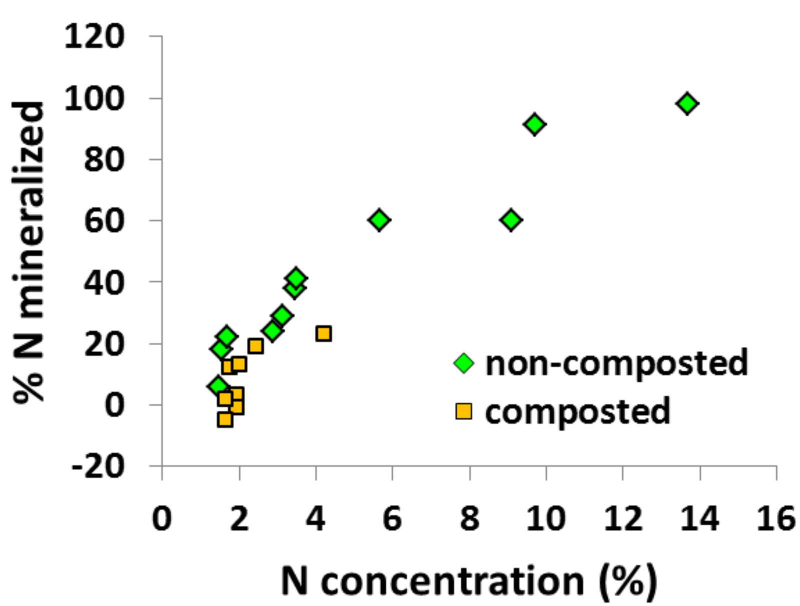
- Initial mineral N content is typically low, predominately in NH_4^+-N form
- Organic N initially mineralizes to the NH_4^+-N form and is then nitrified

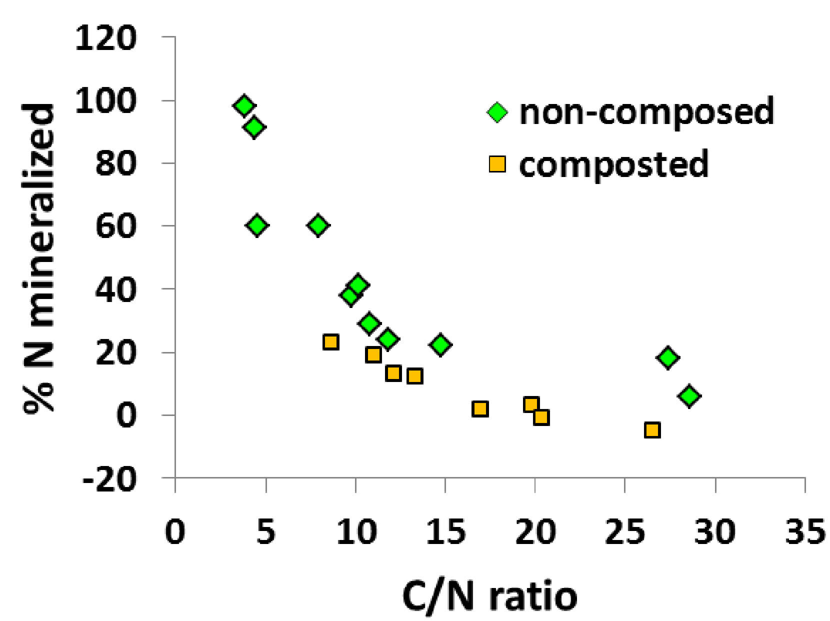
Crediting N in Organic Sources

Nitrogen 'credit' from organic amendments depend on:

- 'Fresh' or composted
- Percent N
- C:N ratio

% N mineralized in full field season, Oregon:





(Gale et al., JEQ 35:2321-2332, 2006)

Crediting N in Organic sources

- Cover crops
- Crop residues

Residue N content and C:N ratio predict N mineralization behavior and potential to provide N

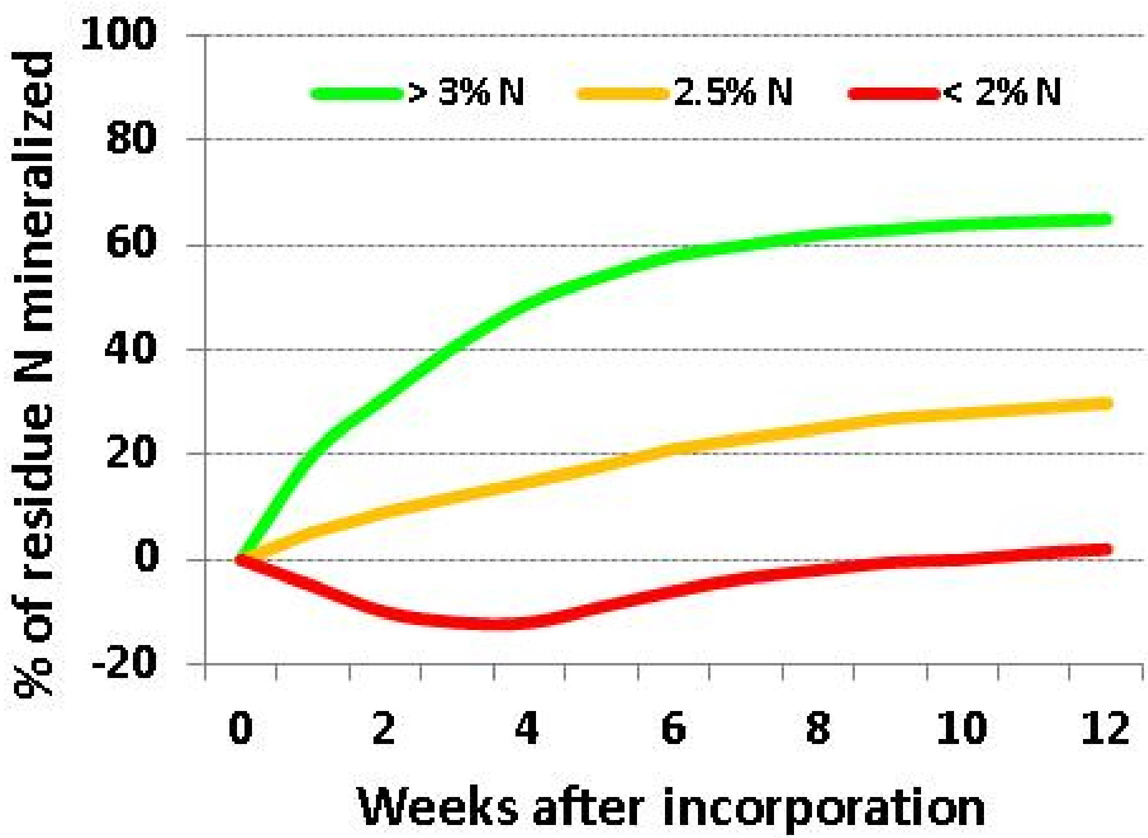
Crediting N in Organic Sources:
Cover Crops and Crop Residue Examples

Residue N content predicts N mineralization behavior:

	wheat	tomato	broccoli
Typical residue N content (kg/ha)	60	80	200
Residue %N	1.5	2.5	3.5

Crediting N in Organic Sources:

Cover Crops and Crop Residue Examples cont'd.



- Greatest activity occurs in the initial 6-8 weeks after incorporation
- Soil temperature / moisture effects can be significant

Summary:

- Regardless of N fertilizer form applied, rapid conversion to NO_3^--N is likely, and plant uptake is predominately NO_3^--N in most crop systems
- Some combinations of N fertilizer form and application technique are more prone to environmental N loss
- N transformations can be manipulated to minimize environmental loss, but success is variable
- N from sources other than mineral fertilizers can significantly affect crop nutrition, and must be accounted for on a field-specific basis

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ciwr.ucanr.edu/NitrogenManagement

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