Critical Steps for Optimum Soil Fertility

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Today's Outline

- Figuring out what nutrients we need.
- Phosphorus
- Potassium
- Nitrogen
  - ✓The main nutrient of concern in conservation tillage systems.

Plant Growth and Plant Nutrition are Complex!

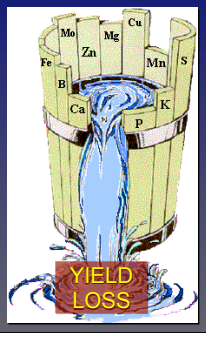
"Providing adequate plant nutrients to growing crops is not rocket science, it is a lot more complex!"
– Dr. Jerry Hatfield, National Soil Tilth Lab, USDA-Ames Iowa.

EXTERNAL FACTORS CONTROL PLANT GROWTH

Influencing a crop's potential

- Air
- Temperature
- Light
- Mechanical support
- Nutrients
- Water

What nutrients should I apply?



- Liebig's Law of the Minimum
- Fertilize if needed
  - ✓Yield loss
- Focus $ on correct nutrient
- Do not over-apply
  - ✓Agronomic
  - ✓Environmental

(ETT, 2008)

Crop Uptake and Removal

		P_2O_5		K_2O	
Crop	Yield	Uptake	Removal	Uptake	Removal
		----------Pounds per acre----------			
Wheat	80 bu	54	40	184	28
Corn	180 bu	102	79	240	52
Soybeans	40 bu	38	32	144	56
Sweet Potatoes	400 bu	68	52	295	224
Tomatoes	40 tons	87	68	463	288

(IPNI, 2009)

Supplying Nutrients to Plants

- Nutrient "holding" capacity is an inherent property of soil texture.
  - ✓Sand
  - ✓Silt
  - ✓Clay

Change the Soil

- What can we do to the soil to change chemical and physical properties the most?
  - ✓Increase productivity
  - ✓Increase water holding capacity
  - ✓Increase nutrient holding capacity
  - ✓Increases ability of soil to cycle or "bank" nutrients naturally

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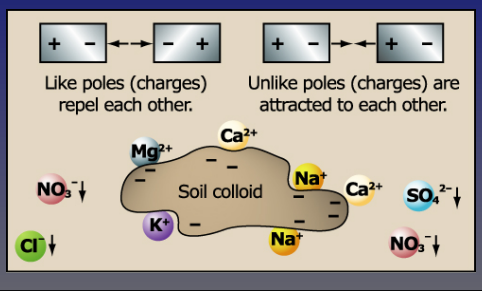
- What can we do for soil to change chemical and physical properties the most?
  - ✓Increase productivity
  - ✓Increase water holding capacity
  - ✓Increase nutrient holding capacity
  - ✓Increases ability of soil to cycle or "bank" nutrients naturally
- ADD ORGANIC MATTER

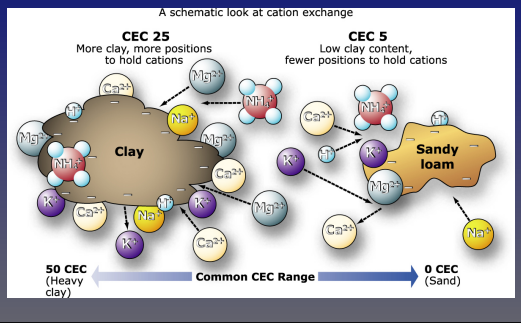
ORGANIC MATTER BENEFITS SOIL IN MANY WAYS:

- Improves physical condition
- Increases water infiltration
- Decreases erosion losses
- Supplies plant nutrients
- Increases cation exchange capacity (CEC)

CEC - NEGATIVELY CHARGED COLLOIDS ATTRACT CATIONS



CATION EXCHANGE CAPACITY



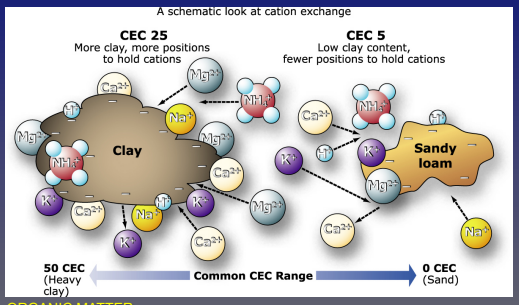
CLAY AND ORGANIC MATTER HAVE GREATEST INFLUENCE ON CEC

Clay	Organic matter
10-150 cmol(+)/ kg	200-400 cmol(+)/kg

Organic matter has a higher CEC

Note: cmol(+)/kg = meq/100g

CATION EXCHANGE CAPACITY



ORGANIC MATTER

The Right Amount of Nutrients

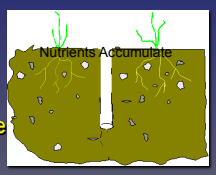
- Soil Testing
  - ✓Our methodology in the lab doesn't change
    - ❖Conventional
    - ❖No-Tillage
  - ✓Still excellent way to test phosphorus and potassium
- Nitrogen cannot accurately be tested using conventional soil testing methods.

Apply What is Needed

- Soil sample
  - ✓Determines plant extractable nutrients
  - ✓Mehlich-1 extractant
  - ✓Free for commercial growers
  - ✓Sample for accuracy
    - ❖Be careful in conservation tillage systems

Accuracy is Key!

- Test is only as good as your sample.
  - ✓Only about 3 oz. (10 g) of soil represents 20 acres or more
- Depth
  - ✓6 inches (or plow depth)
  - ✓4 inches in no-till
- UNIFORM sample = probe
  - ✓Nutrient stratification
- Avoid leaf litter, roots, etc.
  - ✓But don't scrape away the top layer of soil.



Soil Tests Results

County	Phosphorus		Potassium	
	Need Fertilizer (L and M)	No Fertilizer (H and VH)	Need Fertilizer (L and M)	No Fertilizer (H and VH)
	% of samples taken			
Dinwiddie	30	70	77	23
Prince George	43	57	84	16
Sussex	30	70	84	16

(Virginia Tech, 2010)

Applying Nutrients
VA Cooperative Extension Recommendations

Crop: Soybeans **VALUES Crop Code**: 10, 410

Target pH = 6.2 See Notes: 1, 2, 4

Possible Trace Element Need: Mn (see page 9) and Mo (when soil pH < 5.8)

Soil Test Level	Fertilizer Recommendations (lb/A)		
	N	P_2O_5	K_2O
L	0	80 - 120	80 - 120
M		40 - 80	40 - 80
H		20 - 40	20 - 40
VH		0	0

Fertilizer Amounts

- There is no "Magic" product.
- Plant metabolism and cell structures dictate that so much of each nutrient is needed.

Fertilizer Amounts

- For example:
- 144 K_2O/acre uptake need to produce 40 bushel soybeans per acre
- A foliar spray = 2 lbs. equivalent K_2O/acre
- Where MUST the other 142 lbs. K_2O/acre come from?

Fertilizer Amounts

- For example:
- 144 K_2O/acre uptake need to produce 40 bushel soybeans per acre
- A foliar spray = 2 lbs. equivalent K_2O/acre
- Where MUST the other 142 lbs. K_2O/acre come from?
  - ✓The Soil
  - ✓Fertilizer

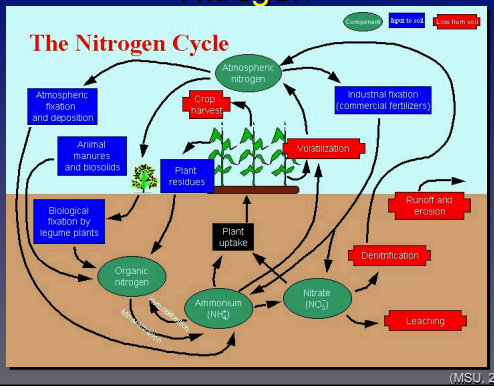
Fertilizer Amounts

- But, a foliar feed is more efficient?
  - ✓ True – Foliar products are more efficient
    - ❖Unit taken up versus unit applied
    - ❖2 lbs. K_2O/acre x 90% efficient = 1.8 lbs./acre uptake
      - ❑0.2 lbs./acre "banked" in the soil for next crop
      - ❑142.8 lbs. K_2O/acre removed from soil
- Soil fertilizers
  - ✓ Maybe less "efficient" for that particular crop, but are much cheaper and are "banked" in the soil for future years.
    - ❖80 lbs. K_2O/acre x 70% efficient = 56 lbs K_2O/acre uptake
      - ❑24 lbs. K_2O/acre "banked" in the soil for next crop
      - ❑88 lbs. K_2O/acre removed from soil

Overall…

- Phosphorus and potassium are pretty easy to manage.
  - ✓Follow your soil test recommendations.
  - ✓Put the right amount in the right place.
- Sulfur and nitrogen are a different story
  - ✓Mobile in the soil system

Nitrogen



(MSU, 2007)

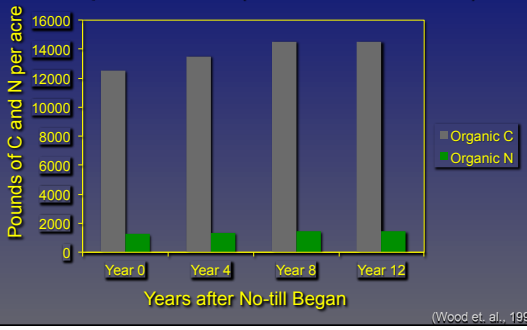
Nitrogen Fertilizer Considerations

- The most difficult nutrient to manage, especially in conservation tillage systems.
- 4-R's of fertilizer management.
  - ✓Right Rate.
  - ✓Right Application Method.
  - ✓Right Source.
  - ✓Right Timing.

Right Rate

- Make sure you have enough nitrogen available…
  - ✓But not too much!
- Initially, more nitrogen will be needed in conservation tillage systems when converting from conventional tillage.
- Eventually, less nitrogen is needed.
  - ✓Organic matter cycling.

Carbon and Nitrogen Equilibrium (10:1; C:N ratio)



(Wood et. al., 1991)

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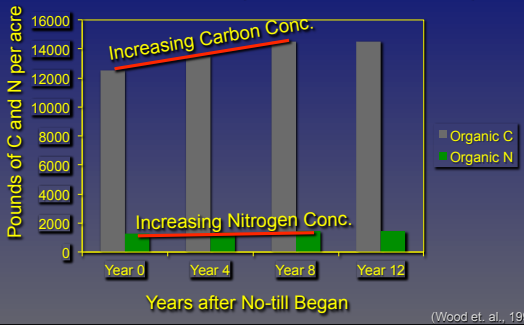

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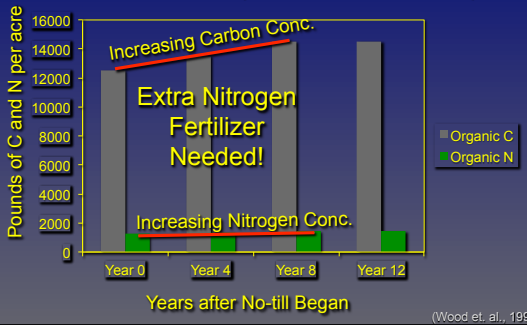

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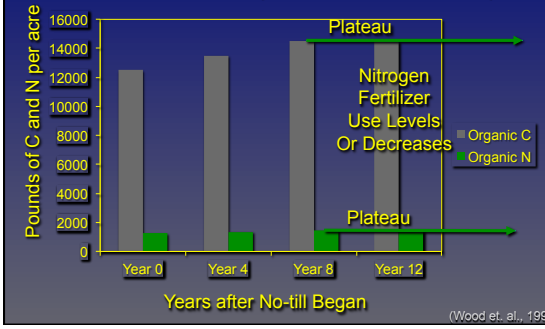


(Wood et. al., 1991)

ORGANIC MATTER DECOMPOSITION

- Will eventually increase soil supplies of most nutrients
- Will temporarily tie up soil N when a high C residue is incorporated
  - ✓ Adjust N rates as necessary based on the age of your system.
  - ✓ Based on amounts of biomass added.
- Soil Organic matter will eventually release nitrogen.

Killing Rye Cover Crop

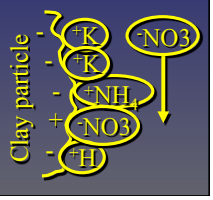
Nitrogen Timing

- Nitrogen rate is important but…

APPLICATION TIMING IS MOST IMPORTANT FOR EFFICIENCY!

Nitrate Nitrogen

- Nitrates are an issue = Lower fertilizer use efficiency.
- Nitrate is common component of fertilizers
  - ✓ Highly soluble
  - ✓ Mobile
    - ❖ Anion leaches easily



Nitrogen Transformation

NH_4^+ —(Oxygen plus bacteria)→ NO_3^-

Nitrification

(IPNI, 2009)

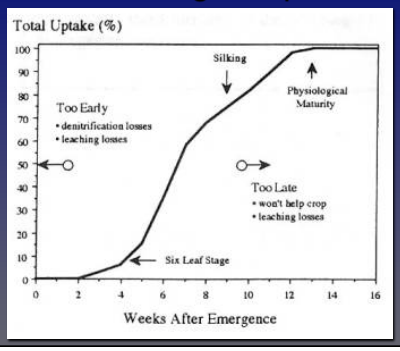
Nitrogen Fixation

- Soil microbes utilize nitrogen to break down organic matters in soil.
- They are "competition" for plant fertilizer uptake.
- The more time you give them, the more nitrogen microbes will consume and "tie up" in organic matter.

Nitrogen Timing

- The Key: Apply nitrogen as close as you can for plant uptake
  - ✓Higher fertilizer use efficiency
  - ✓Higher yields
  - ✓Larger profits
  - ✓Less nitrogen lost to the environment
- But not too much or too late…
  - ✓Lower yields
  - ✓Lower fertilizer use efficiency

Corn Nitrogen Uptake



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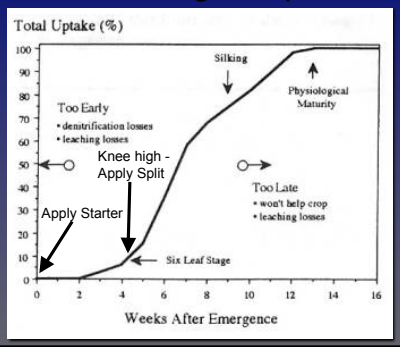

Nitrogen Source

- Conventional Tillage:
  - ✓Nitrogen source really does not matter.
  - ✓IF APPLIED PROPERLY (Timing).
    - ❖"Traditional fertilizers"
      - ❑Ammonium nitrate
      - ❑Calcium nitrate
      - ❑Urea-ammonium nitrate
      - ❑Urea, etc.
- Conservation tillage
  - ✓Urea containing sources may see reduced efficiency if not managed properly.

Problems with Nitrogen

- Volatilization
  - ✓Important with urea containing fertilizers
    - ❖Liquid urea-ammonium nitrate (30% N)
    - ❖Enzymes on crop residue break down urea
    - ❖Problem in no-tillage systems

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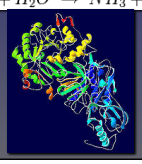
$$(NH_2)_2CO + H_2O \xrightarrow{urease} NH_3 + H_2NCOONH \rightarrow 2NH_{3(gas)} + CO_{2(gas)}$$



Problems with Nitrogen

- Volatilization
  - ✓Important with urea containing f zers
    - ❖Liquid urea-ammonium nitrate (UA 0% N)
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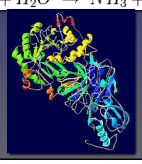
GAS

$$(NH_2)_2CO + H_2O \xrightarrow{urease} NH_3 + H_2NCOONH \rightarrow 2NH_{3(gas)} + CO_{2(gas)}$$

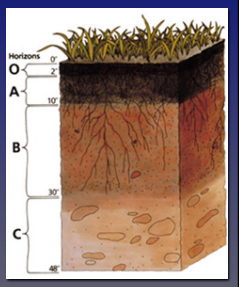


Nitrogen Source

- Additives.
  - ✓Urease inhibitors (NBPT).
  - ✓Nitrification inhibitors (DCD).
- Slow release fertilizers.
  - ✓Aid in fertilizer application timing.
  - ✓Match plant uptake pattern.
  - ✓Fewer trips across the field.
  - ✓Increased fertilizer use efficiency.
  - ✓Costs?

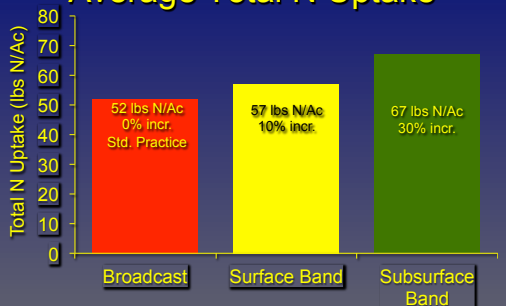
Right Application Method

- Reduce nitrogen contact with residue because of urease
- Place the nitrogen under the crop residue
  - ✓Reduce losses from:
    - ❖Microbes
    - ❖Volatilization



(USDA-NRCS, 2009)

Wheat Study
Average Total N Uptake



(Kelley and Sweeney, 2007)

Take Home Message…

- Soil test for phosphorus and potassium.
- Nitrogen is the hardest nutrient to manage.
- Make sure you use the proper nitrogen rate based on your system's age.
- Place N properly to avoid urease issues.
- Use sources/additives to decrease urease losses.
- Time N to match crop uptake pattern.

Contact:

- Mark Reiter
- Virginia Tech Eastern Shore AREC, Painter, Virginia
- 757-414-0724 ext. 16
- mreiter@vt.edu

Soil Tests Results

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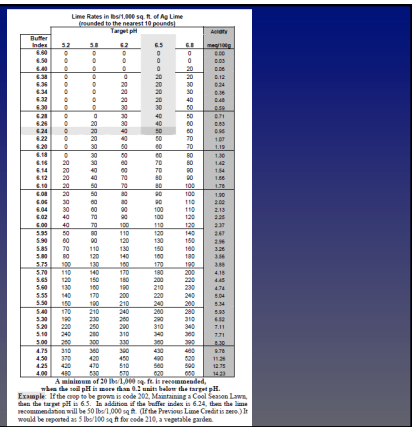
	Need Fertilizer (L and M)	No Fertilizer (H and VH)	Need Fertilizer (L and M)	No Fertilizer (H and VH)
	----------% of samples taken----------			
Chesapeake	39	61	73	27
Isle of Wight	25	75	77	23
Southampton	21	79	91	9
Suffolk	22	78	75	25
Virginia Beach	18	82	57	43

(Virginia Tech, 2009)

Soil Tests Results

County	Lime		
	Need Lime pH below 6.0	Optimal pH Range 6.0 to 7.0	High pH Problems pH above 7.0
	----------% of samples taken----------		
Chesapeake	53	41	6
Isle of Wight	26	70	4
Southampton	26	71	3
Suffolk	29	66	5
Virginia Beach	54	45	1

(Virginia Tech, 2009)



Lime Rates in lbs/1,000 sq. ft. of Ag Lime
(rounded to the nearest 10 pounds)

Buffer Index	Target pH 5.2	5.8	6.2	6.5	6.8	Acidity meq/100g
6.50	0	0	0	0	0	0.00
6.50	0	0	0	0	0	0.03
6.40	0	0	0	0	20	0.06
6.38	0	0	0	20	20	0.12
6.36	0	0	20	20	30	0.24
6.34	0	0	20	20	30	0.36
6.32	0	0	20	20	40	0.48
6.30	0	0	30	30	50	0.59
6.28	0	0	30	40	50	0.71
6.26	0	20	30	40	60	0.83
6.24	0	20	40	50	60	0.95
6.22	0	20	40	50	70	1.07
6.20	0	30	50	60	70	1.19
6.18	0	30	50	60	80	1.30
6.16	20	30	60	70	80	1.42
6.14	20	40	60	70	90	1.54
6.12	20	40	70	80	90	1.66
6.10	20	50	70	80	100	1.78
6.08	30	50	80	90	100	1.90
6.06	30	60	80	90	110	2.02
6.04	30	60	90	100	110	2.13
6.02	40	70	90	100	120	2.25
6.00	40	70	100	110	120	2.37
5.95	50	80	110	120	140	2.67
5.90	60	90	120	130	150	2.96
5.85	70	110	130	150	160	3.26
5.80	80	120	140	160	180	3.56
5.75	100	130	150	170	190	3.85
5.70	110	140	170	180	200	4.15
5.65	120	150	180	200	220	4.45
5.60	130	160	190	210	230	4.74
5.55	140	170	200	220	240	5.04
5.50	150	190	210	240	260	5.34
5.40	170	210	240	260	280	5.93
5.30	190	230	260	290	310	6.52
5.20	220	250	290	310	340	7.11
5.10	240	280	310	340	360	7.71
5.00	260	300	330	360	390	8.30
4.75	310	360	390	430	460	9.78
4.50	370	420	450	490	520	11.26
4.25	420	470	510	550	590	12.75
4.00	480	530	570	620	650	14.23

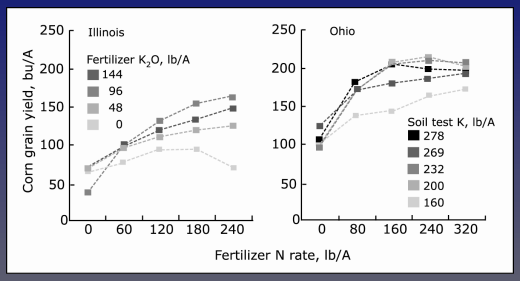
A minimum of 20 lbs/1,000 sq. ft. is recommended, when the soil pH is more than 0.2 units below the target pH.

Example: If the crop to be grown is code 202, Maintaining a Cool Season Lawn, then the target pH is 6.5. In addition if the buffer index is 6.24, then the lime recommendation will be 50 lbs/1,000 sq ft. (If the Previous Lime Credit is zero.) It would be reported as 5 lbs/100 sq ft for code 210, a vegetable garden.

Phosphorus Deficiency Corn (Sweet Corn)

- Problem in cool soils = slow growth
- Conservation tillage/ High residue = cooler soils
- Band placements a better alternative?
- Low soil test phosphorus

POTASSIUM IMPROVES YIELD RESPONSE TO N FERTILIZER AND NUE



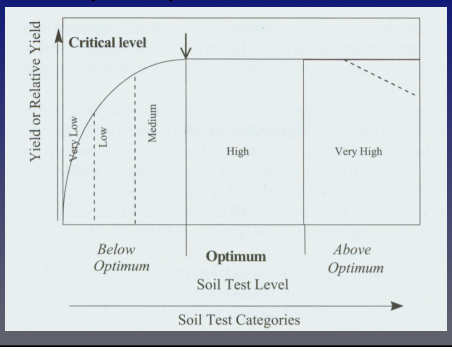
(IPNI, 2008)

Potassium Deficiency Soybean (Edamame)

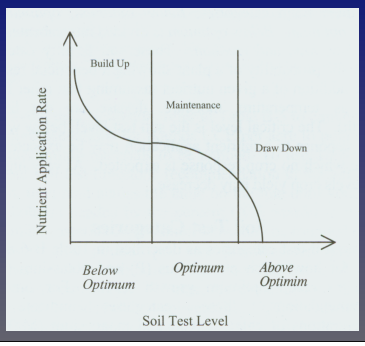
Problems with Nitrogen

- Immobilization increased in no-tillage
  - ✓Microbes assimilate nitrogen fertilizer
  - ✓Their bodies C:N = 8:1
    - ❖8 parts carbon to 1 part nitrogen
  - ✓Corn stover C:N ~ 65:1
  - ✓Microbes need the fertilizer nitrogen to equilibrate the C:N ratio.
  - ✓Residue on the soil surface
    - ❖Great for soil erosion
    - ❖Building soil quality

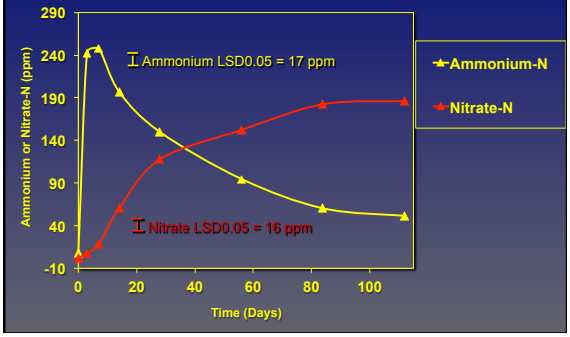
Crop response to fertilizer



Fertilizer recommendations



Urea Nitrification Rate



Fertilizer Speeds Maturity

	Rate N-P_2O_5-K_2O, lb/A	
	300-150-0	300-150-200
Silked, July 21, %	4	42
Yield, bu/A	151	188

	Rate N-P_2O_5-K_2O, lb/A	
	0-50-50	100-50-50
First pick, %	66	81
Lint yield, lb/A	1,896	2,089

Effect of Balanced Fertility and Corn Yields on Water Use Efficiency

Fertility level	Yield, bu/A	Water use efficiency, bu/in[1]
Low	76	3.1
Medium	149	6.0
High	240	9.6

[1]25 inches of water

Florida