Nitrification Inhibition for Nitrogen Efficiency and Environment Protection

W. W. Frye

Nitrification Process

Autotrophic nitrification (energy from N oxidation)

Nitrosomonas

$\mathbf{NH_4^+}$ $-H^+ \rightarrow NH_3 + O_2 + 2H^+ \rightarrow NH_2OH + H_2O$

$NH_2OH + H_2O \rightarrow\rightarrow \mathbf{NO_2^-} + 5H^+$

Nitrobacter

$H^+ + NO_2^- + H_2O \rightarrow\rightarrow \mathbf{NO_3^-} + 3H^+$

Nitrification Process cont'd

Heterotrophic nitrification—oxidation of organic N and NH_3 to NO_2^- or NO_3^- by chemoheterophic bacteria and fungi in acid soils. Energy from amino acids.

Organic N ($R\text{-}NH_2$) → NO_2^- or NO_3^-

Importance of Nitrification

- Economic consequences
  - —Makes N more vulnerable to losses
    - $NH_4^+ \rightarrow NO_3^-$ leaching and denitrification
- Environmental consequences
  - —NO_3^- pollutant in surface and groundwater
    - Eutrophication, hypoxia, and health risks
  - —Greenhouse gases into the atmosphere
    - Nitrous oxide (N_2O)—global warming
    - Nitric oxide (NO)—destroys stratospheric O_3

Nitrogen Losses

- Conditions favoring NO_3^- leaching
  - Prolonged periods of rainfall
  - Soil with large pores, cracks, root channels, worm and insect holes
    - More prevalent in no-tillage (zero tillage)
    - Rapid movement to great depths
  - Coarse-textured (sandy) soil

Nitrogen Losses

- Conditions favoring denitrification
  - Poorly drained or somewhat poorly drained soil
  - Substantial denitrification can occur in well-drained soil
    - Periods of wet weather
    - Anaerobic conditions inside soil aggregates, especially with no-tillage (zero tillage)
    - Heavy residue cover

Effects of Nitrification Inhibitors (NI)

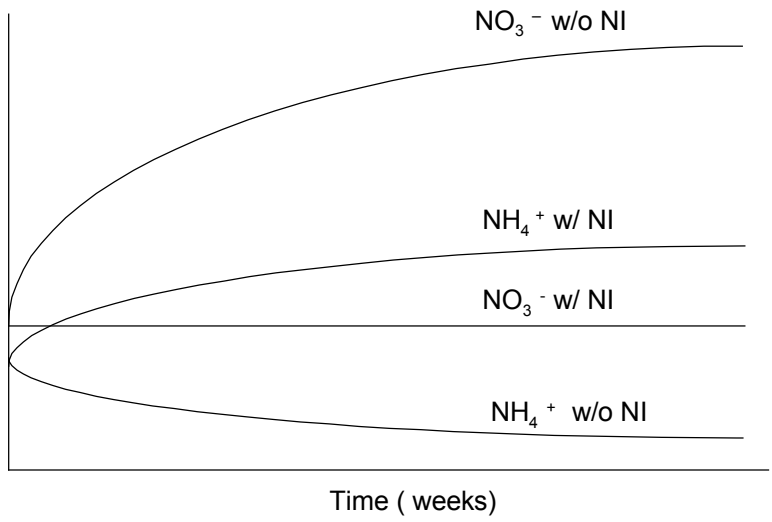

Table 1. Some patented nitrification inhibitors.

Chemical name	Common name	Inhibition by day 14
		%
2-chloro-6-(trichloromethyl)pyridine	**Nitrapyrin**	**82**
4-Amino-1,2,4-6-triazole-HCl	ATC	78
2,4-Diamino-6-trichloromethyltriazine	CL-1580	65
Dicyandiamide	**DCD**	**53**
Thiourea	TU	41
1-Mercapto-1,2,4-triazole	MT	32
2-Amino-4-chloro-6-methylpyrimidine	AM	31

Adapted from Paul and Clark (1989).

Nitrification Inhibitors

- Nitrapyrin
  - Advantages
    - 82% inhibition by day 14
    - Fairly reasonable cost ~ 15^{+} ha^{-1}
    - Proven performance
  - Disadvantages
    - Volatility—2.8 x 10^{-3} mm Hg v.p.@ 23˚C
    - Must be incorporated into soil
    - Petroleum-based—can't impregnate ammonium nitrate

Nitrification Inhibitors

- DMPP (3,4-dimethylpyrazole phosphate)
  - Advantages
    - Highly effective
    - Easily incorporated into granular fertilizers
    - No environmental concerns
  - Disadvantages
    - No major disadvantages?

Yield Response to Inhibitor

- Effective inhibition but no yield effect—
  What does it mean?
  - Optimum N rate, no N loss, no yield response to inhibitor
  - Excessive N rate, N loss, still optimum N, no yield response
  - Optimum N rate, N loss, yield response
  - Excessive N rate, excessive N loss, yield response

Table 2. Grain yield of no-tillage maize (*Zea mays* L.) as affected by nitrapyrin* in Kentucky.

N rate, kg ha^{-1}	0	90	135	180
	----- Yield, Mg ha^{-1} -----			
Without nitrapyrin	3.41	5.96	5.13	7.45
With nitrapyrin	----	7.91	8.29	7.73

*Nitrapyrin sprayed directly onto granular ammonium nitrate at rate of 0.56 kg ha-1 and surface-applied broadcast.

Deterrents to Use of Inhibitors

- Inexpensive N fertilizers–excessive rates
- Inconvenience of using nitrapyrin
- USEPA restrictions on DCD
- Other means of efficiency
  - -Delayed application
  - -Split application
  - -Slow-release N for turf and specialty crops

Clarification Needed!

- Slow-release N—form that delays availability for plant uptake
- Stabilized N—N stabilizer added to fertilizer
- N stabilizer—extends time N is in urea or ammoniacal form in soil
  - – Urease inhibitor
  - – Nitrification inhibitor
- Enhanced Efficiency (EE)—includes slow-release and stabilized N

Conclusions

- Nitrification makes soil N more susceptible to leaching and dinitrification.
- Results are decreased N-use efficiency and environmental pollution.
- Nitrification inhibitors have been shown to slow nitrification.

Conclusions

- Slowing nitrification keeps N in more stable form (NH_4^+) longer:
  - Allows more time for plant uptake
  - More efficient use
  - Less loss to environment
  - Less environmental pollution

Future of Enhanced Efficiency Fertilizers

- Industry has focused on N for specialty uses, e.g., turf, nursery, high-value crops
- Recently turning attention to field crops
  - Good job with specialty products and uses
  - Greatest opportunities—economic and environmental—is in production agriculture, especially field crops