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Evaluating nitrogen stabilizers, my experience

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- Nitrogen stabilizers 101
- Nitrogen stabilizers are fertilizer additives that slow
  - Urea hydrolysis
  - Nitrification

- Urea hydrolysis
- Urea manufacture

  $2\ NH_3 + CO_2$ -------> Urea + H_2O

  Manufacture takes place under high pressure and temperature
- Urea hydrolysis in soil

  Urea + H_2O -------> $2NH_3 + CO_2$

  Reaction catalyzed by an enzyme…*urease*

- Urease enzyme
  - Widely distributed in nature
  - Soil, microbes, and especially crop residues
- Kinetics of urea hydrolysis
  - Think…days
- When is urea hydrolysis of concern?
  - When urea-containing fertilizers are left on the soil surface
  - Part of the N can escape to the atmosphere
  - Ammonia volatilization

- What does a urease inhibitor do?
  - Slows urea hydrolysis by soil/crop residues
  - Gives the soil a better opportunity to absorb the NH_3 generated as NH_4^+
  - Increases the opportunity for rainfall to incorporate the fertilizer

- So, the possible benefits of using a urease inhibitor are observed in a short time (< 2 weeks)

- Nitrification
- Most of the N applied by farmers is reduced in nature (anhydrous ammonia, urea, proteins in manure or compost)
- Reduced forms of nitrogen eventually get oxidized by microbes in an aerated soil
  - End result….nitrate (NO_3^-)
  - This is the process of nitrification

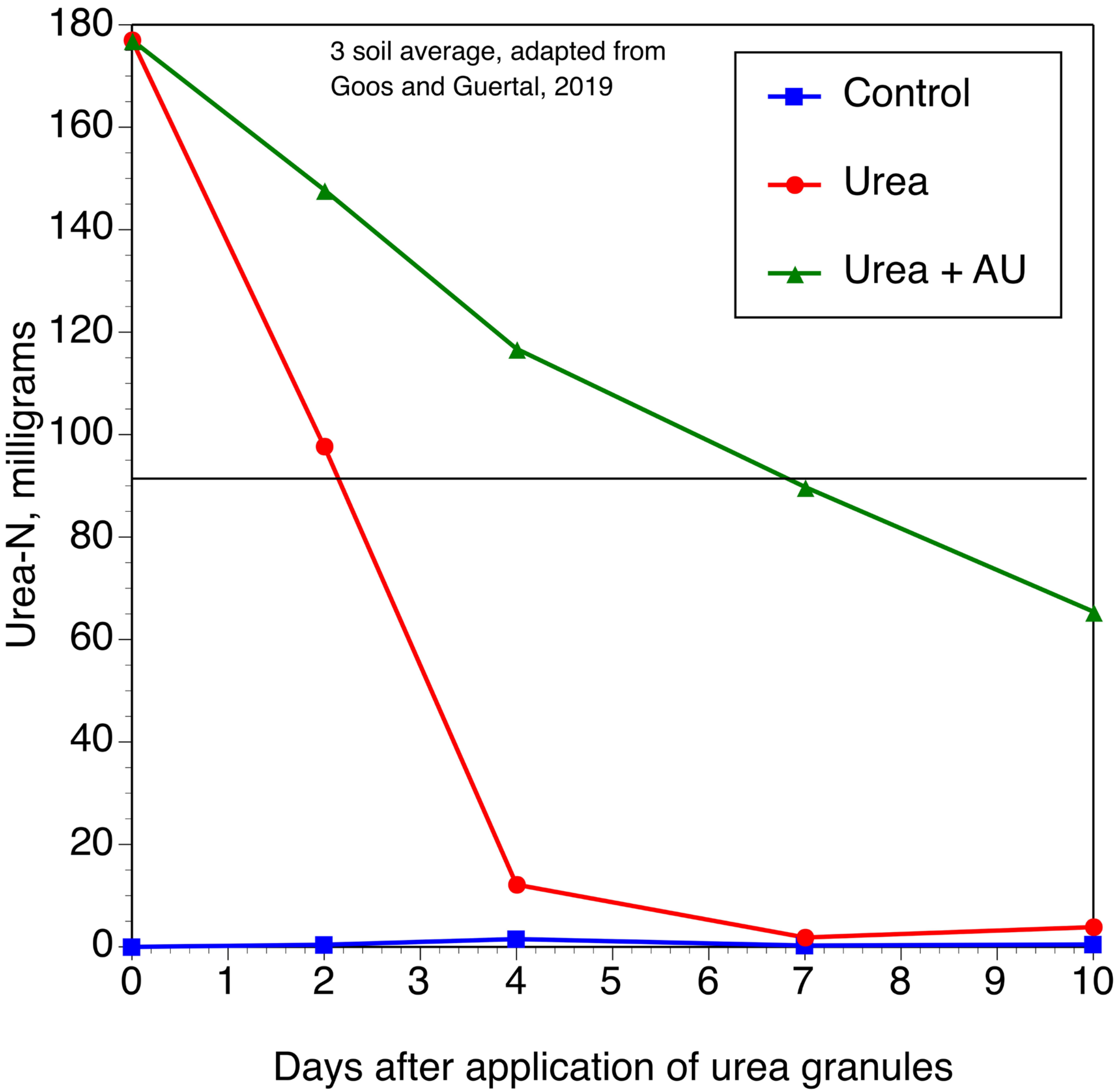
- For example, a farmer spreads urea in the spring, and tills it in....what happens?
- Urea hydrolysis turns urea into NH_3 and CO_2
- The soil simultaneously turns NH_3 into NH_4^+
- The kinetics of this....*days*

- Then, microbes convert the NH_4^+ into NO_3^-
- The kinetics of this....*about a month*

- Plants love nitrate…..what's the problem?
  - Nitrate can leach into groundwater or into tile drains
  - Nitrate can be lost as N_2 and N_2O if the soil becomes waterlogged (denitrification)
- What does a nitrification inhibitor do?
  - Slows the conversion of NH_4^+ to NO_3^-, hopefully reducing loss from leaching or denitrification

- One problem with explaining urease and nitrification inhibitors to farmers
- Control vs. Inhibition
- Farmers understand *control*
  - Example: a soil-applied herbicide controls target weeds for 6 weeks, before weeds begin to reappear
  - The farmer got….6 weeks of *control*
  - Farmers want to know how long with this or that stabilizer will control urease or nitrification
  - It doesn’t work like that

- Control implies: *stopping something*
- Inhibition implies: *slowing something down*
- <u>Nitrogen stabilizers provide inhibition, not control</u>



Half-life without, ~2.4 days; with, ~ 7 days… ~65% inhibition

- The industry-standard urease inhibitor, NBPT
  - “Rusty key” analogy
- Originally available as Agrotain, but other brands available today
- READ THE LABEL, HOWEVER….some brands don’t give the % NBPT

AGROTAIN®
ULTRA

CONTAINS: Active ingredient (26.7%): N-(n-butyl)-thiophosphoric triamide (NBPT) (CAS RN 94317-64-3)
Inactive ingredients (73.3%): N-methyl-2-pyrrolidone (CAS RN 872-50-4), 1,2-propanediol (CAS RN 57-55-6), dyes

CONTIENT: Ingr
thiophosphoriq
Ingrédients ina
1,2-propanedio

Drexel®

X®-NBPT
Nitrogen Stabilizer

ACTIVE INGREDIENT:	
NBPT (N-(n-butyl)-thiophosphoric triamide)	26.7%
OTHER INGREDIENTS:	73.3%
TOTAL:	100.0%

IF ON SKIN OR CLOTH
• Take off contaminated
• Rinse skin immediately

Another product…

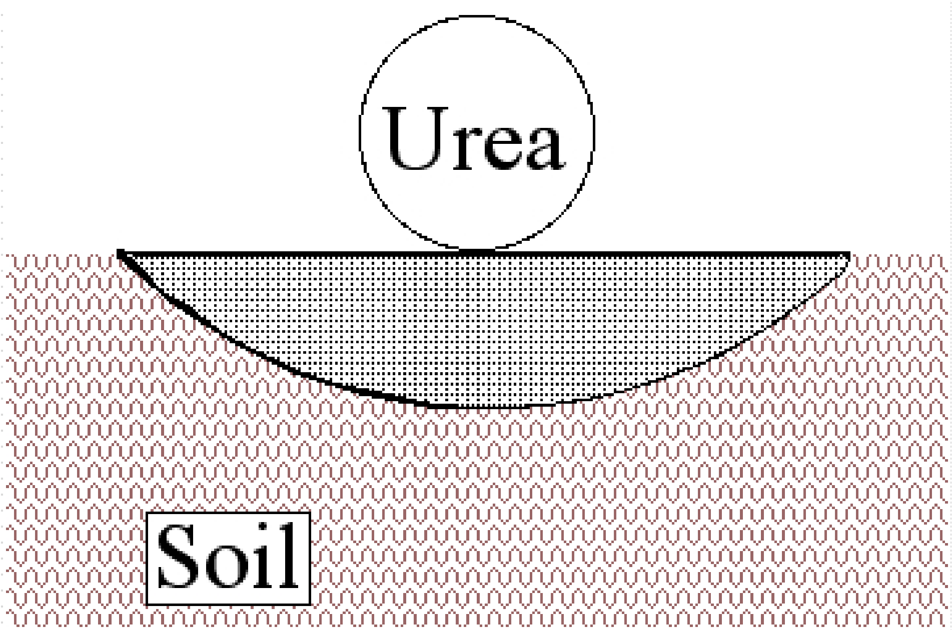
ACTIVE INGREDIENTS:
NBPT, co-polymers, alcohols, and emulsifiers
Total 100.0%

?????

- So, with regard to NBPT-containing products
- NBPT is the industry-standard soil urease inhibitor
- But…make sure the actual % NBPT is on the label

- And…watch out for ineffective products

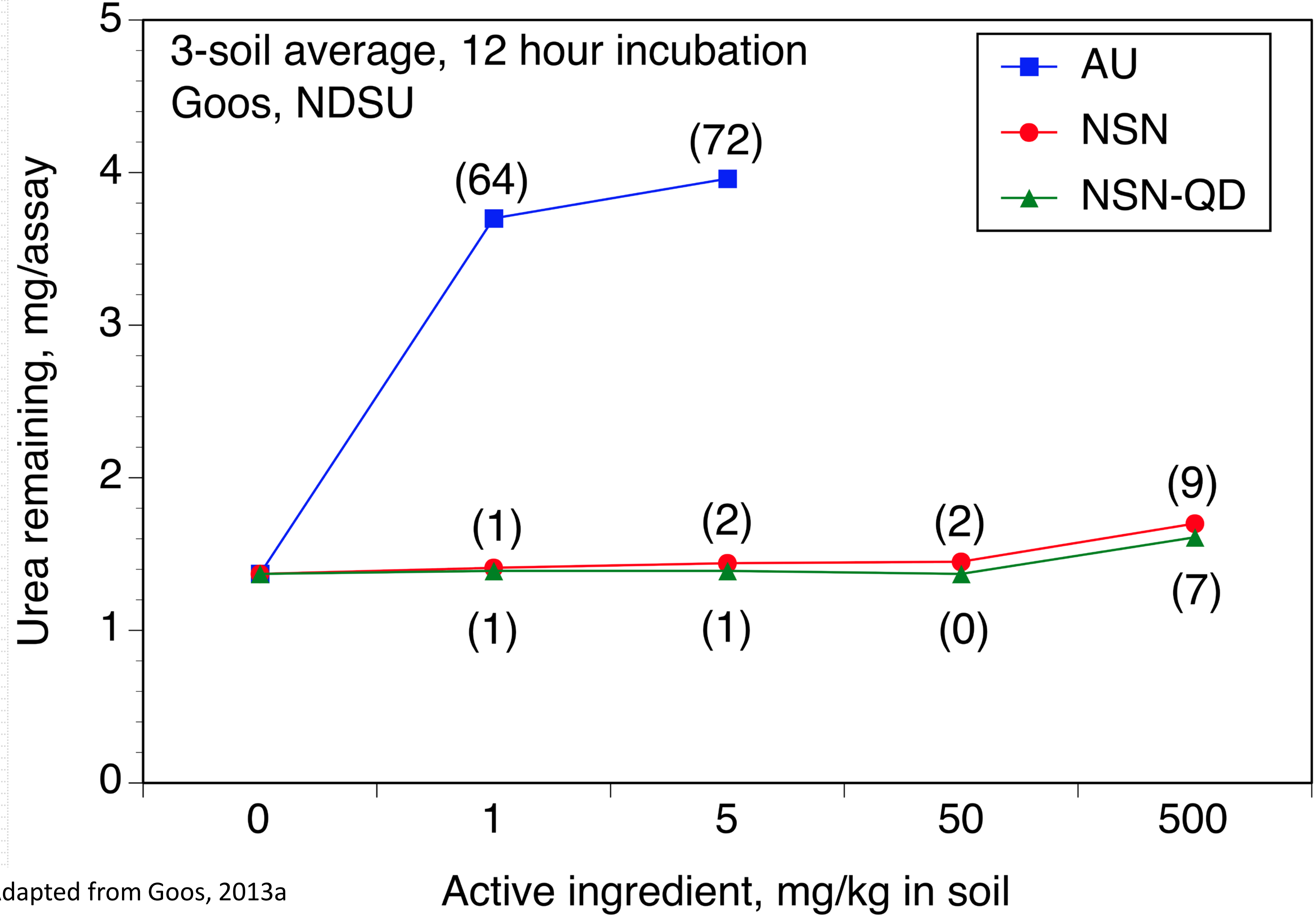
- Urease inhibitors and granular urea
- 10 mg urea granule, labeled rate of Agrotain Ultra (NBPT)
- Concentration of NBPT in the fertilizer reaction zone, single digits of ppm



- So, a standard rate for testing urease inhibitors for application to urea granules, soil concentration of 5 ppm in soil
- Usually a short-term incubation when screening potential urease inhibitors

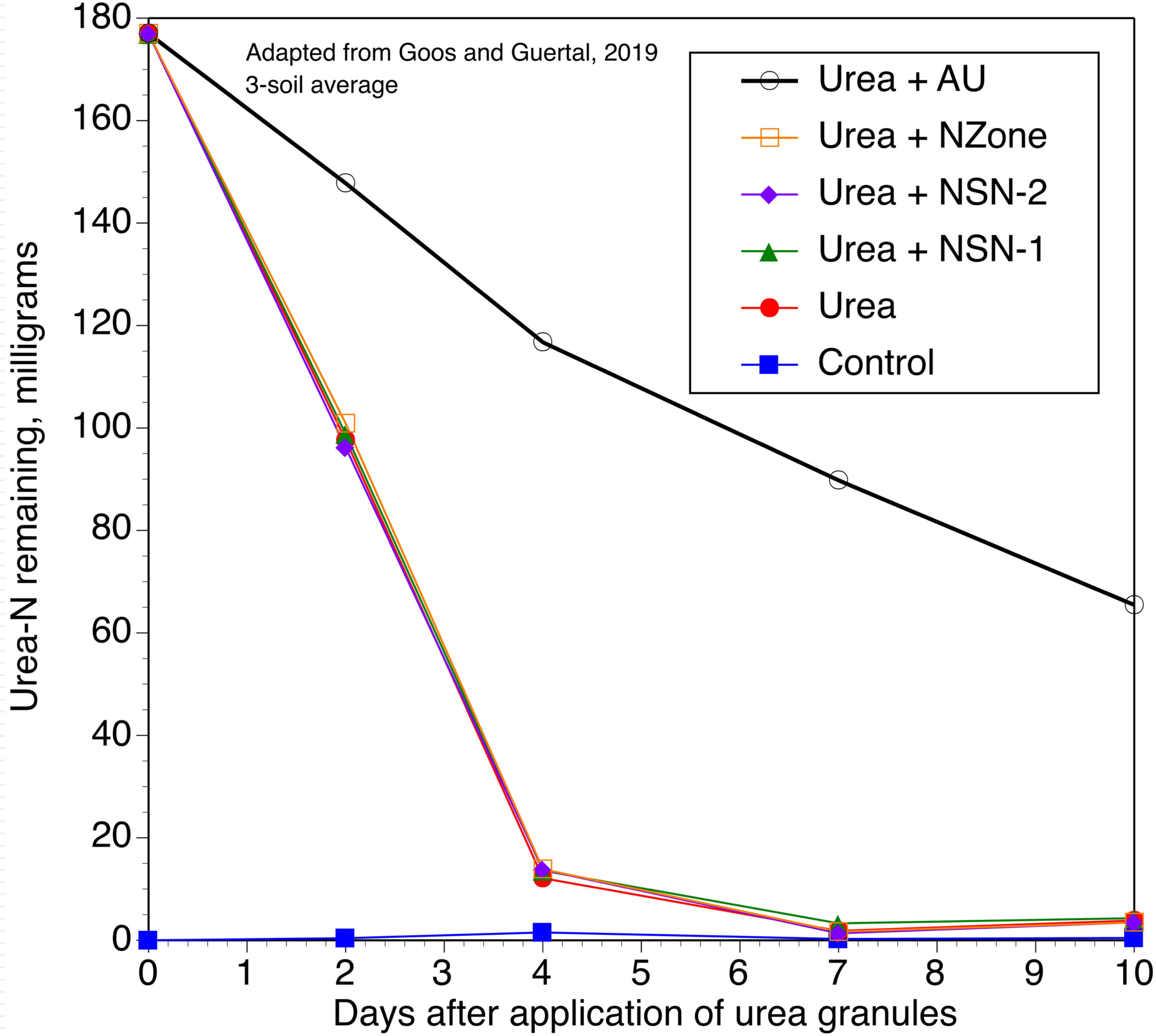

2
3
4
5

(% Inhibition)



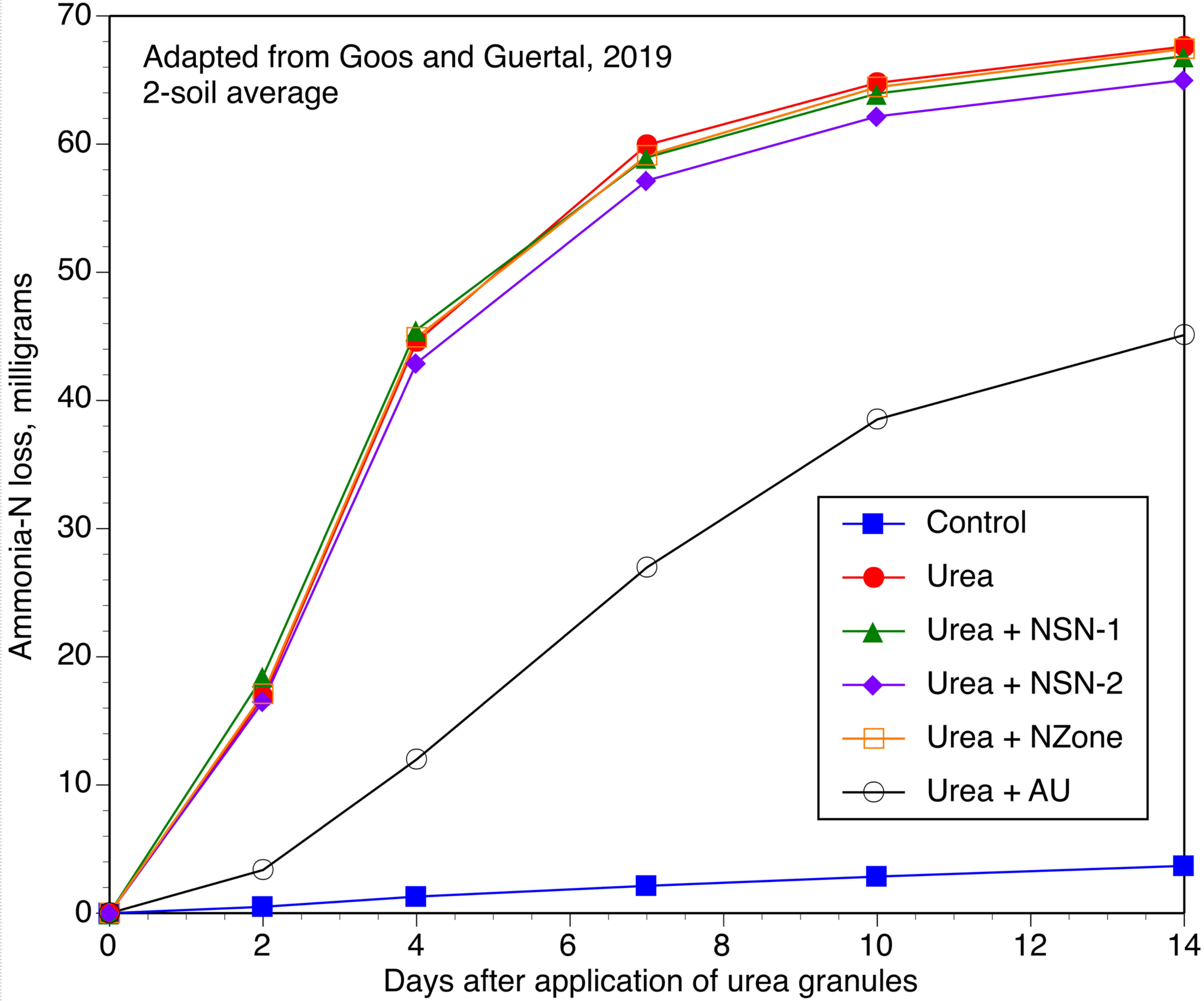
Adapted from Goos, 2013a

- Evaluation of urease inhibitors, intact granules, urea hydolysis



Adapted from Goos and Guertal, 2019
3-soil average
Urea + AU
Urea + NZone
Urea + NSN-2
Urea + NSN-1
Urea
Control
Urea-N remaining, milligrams
Days after application of urea granules
180
160
140
120
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10

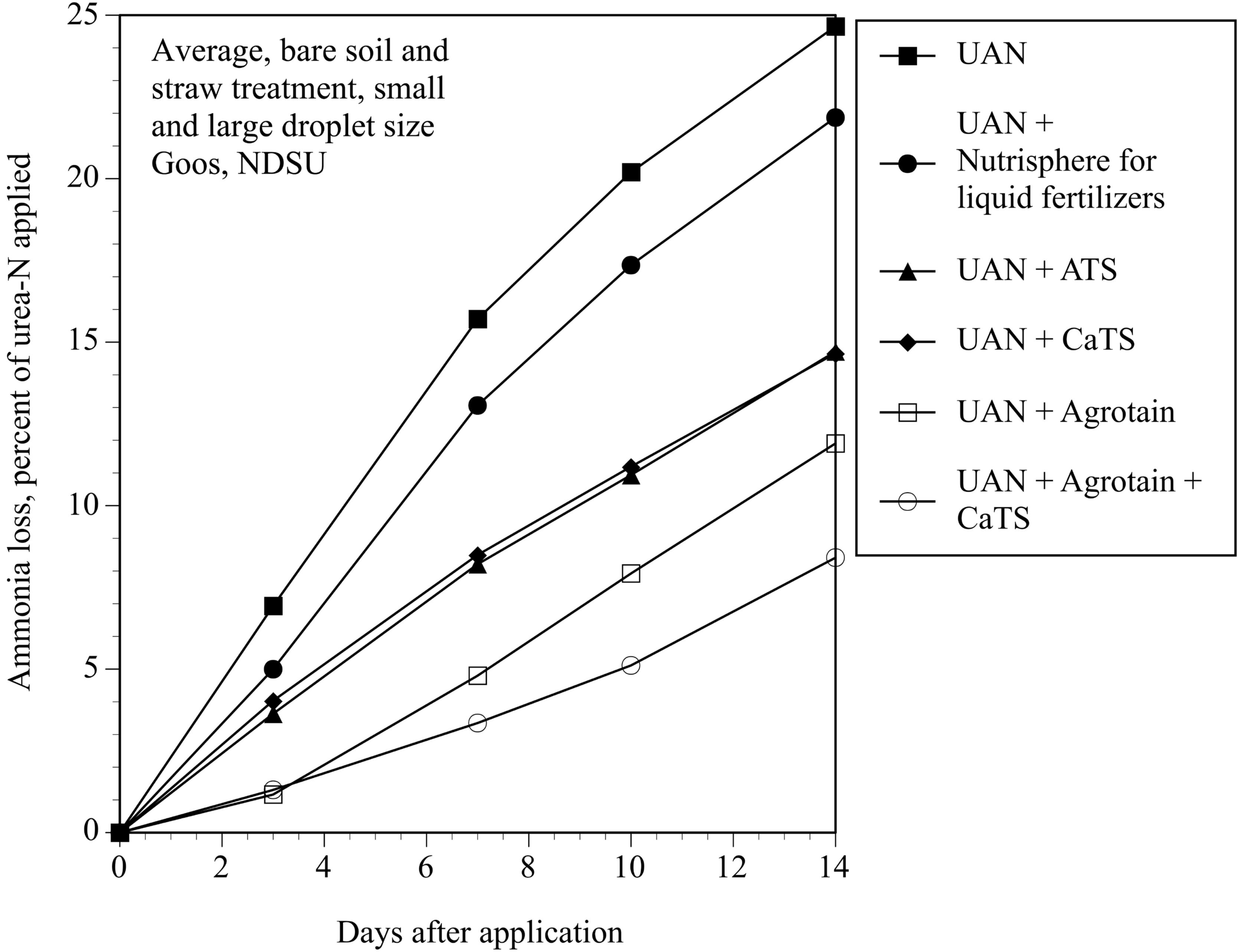
- Evaluation of urease inhibitors, intact granules, ammonia volatilization


Adapted from Goos and Guertal, 2019
2-soil average
Ammonia-N loss, milligrams
Days after application of urea granules
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12
14
Control
Urea
Urea + NSN-1
Urea + NSN-2
Urea + NZone
Urea + AU

- Some general thoughts on urease inhibitors and granular urea
- Surface application of urea on no-till, use an *effective* urease inhibitor
- You don’t need a urease inhibitor if:
  - Urea is tilled in within a couple days
  - Significant rain is expected
- New products…
  - Limus and Anvol, effective

- Liquid fertilizers (UAN)
- Positives:
  - Only half of the N is urea, and subject to volatilization
  - Can be streamed/dribbled, shallowly injected
  - If sulfur is needed, ATS can slow volatilization
- What is definitely out:
  - Spraying on heavy crop residues


65

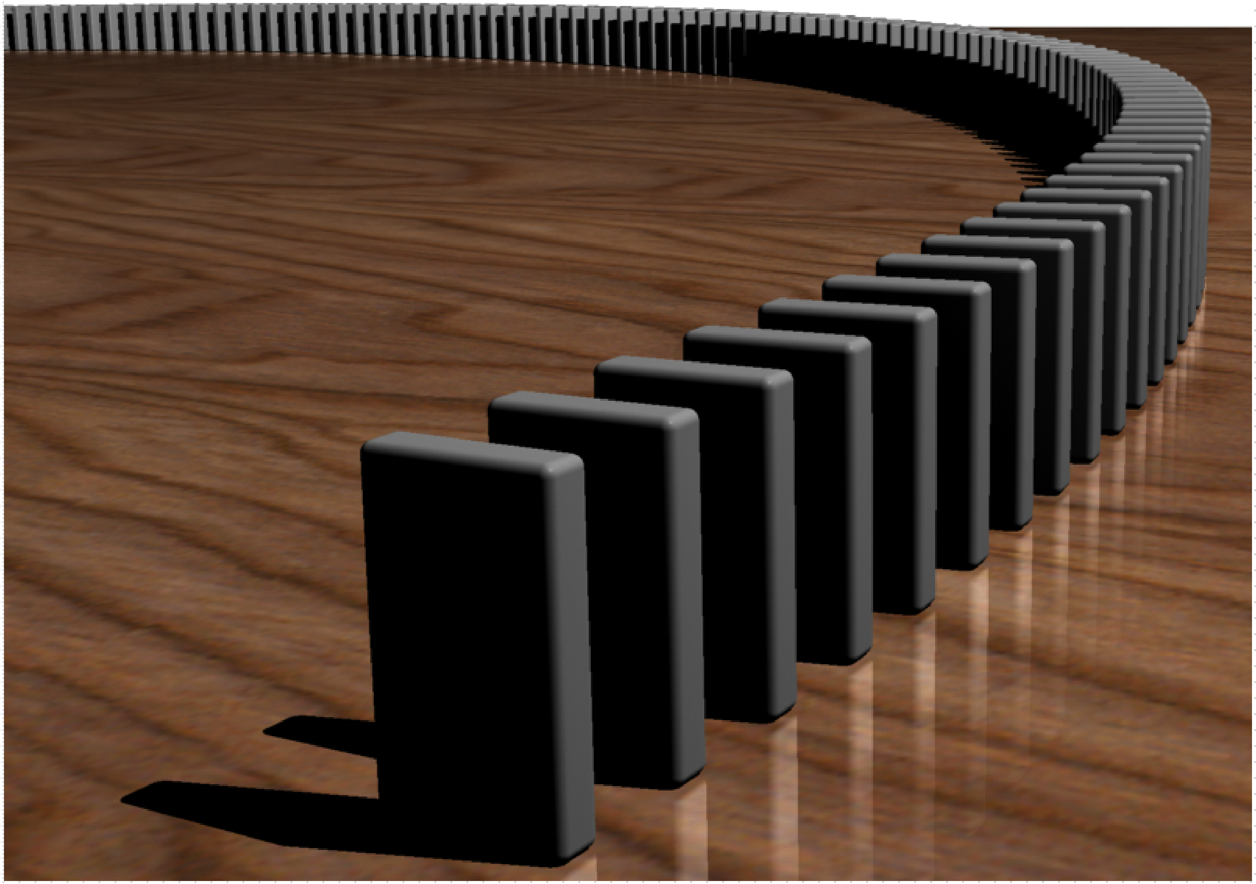

Average, bare soil and straw treatment, small and large droplet size Goos, NDSU
UAN
UAN + Nutrisphere for liquid fertilizers
UAN + ATS
UAN + CaTS
UAN + Agrotain
UAN + Agrotain + CaTS
Ammonia loss, percent of urea-N applied
Days after application
0
5
10
15
20
25
0
2
4
6
8
10
12
14

- Goos, 2013b

- With UAN…
  - Surface banding/dribbling/streaming reduces contact with stubble
  - NBPT is effective
  - If S is needed, ATS can slow volatilization, but not as well as NBPT

- Nitrification inhibitors…
- Slow the conversion of ammonium to nitrate
- Most studies don’t show much of a yield benefit, and here is why…

- When does the use of a nitrification inhibitor benefit the farmer?
- We have to talk about dominoes



- When does the use of a nitrification inhibitor lead to a crop yield increase????
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  - 1. The N rate cannot be excessive

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  - 3. This nitrogen loss <u>has to occur during a "sweet spot" of time</u>

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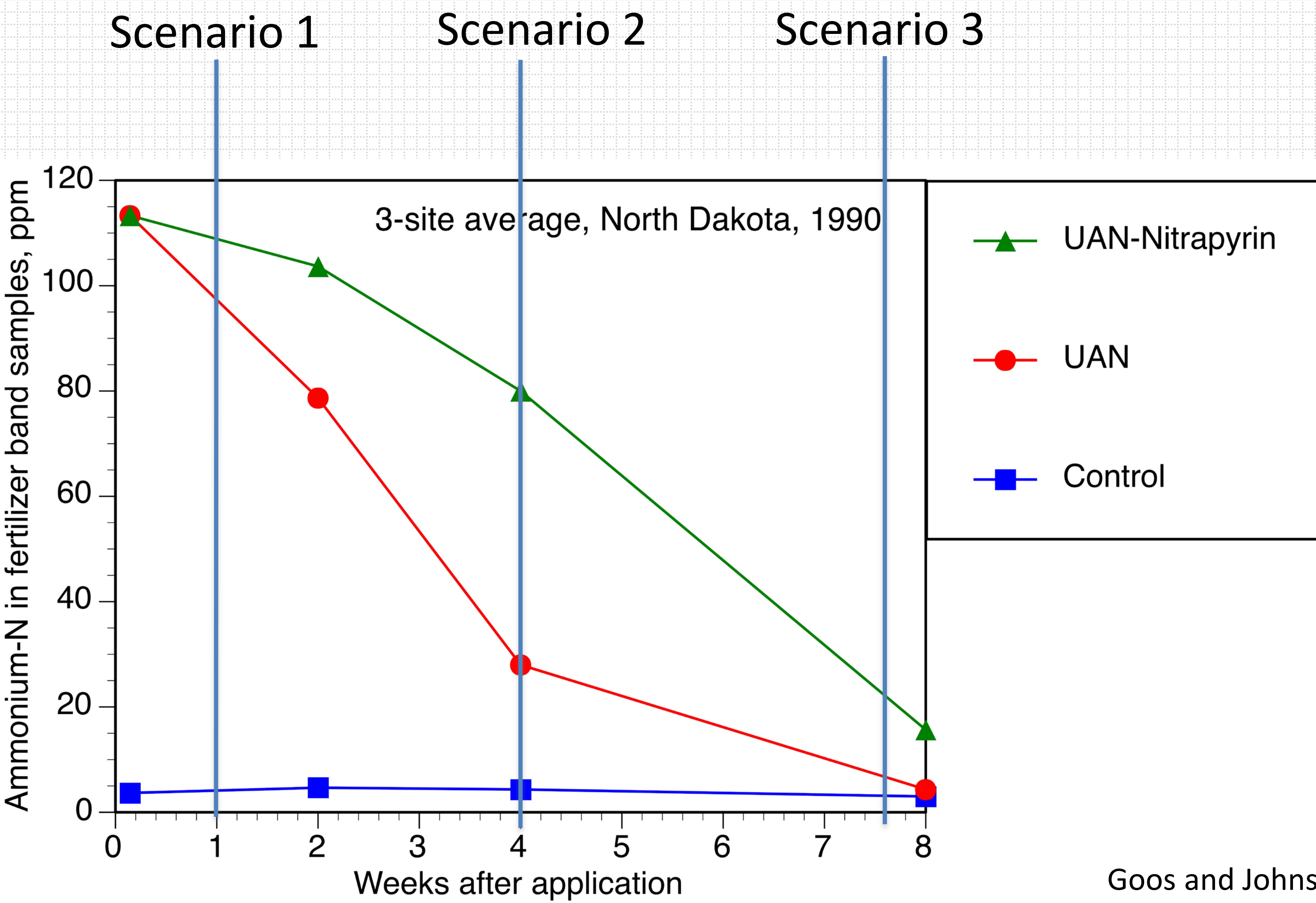
- All the "dominoes" need to line up:
  - 1. The N rate cannot be excessive
  - 2. Nitrogen loss by leaching or denitrification has to occur
  - 3. This nitrogen loss <u>has to occur during a "sweet spot" of time</u>
  - 4. The amount of N saved by the use of an inhibitor has to be large enough to lead to a measurable difference in yield

- The "sweet spot" of time

- Consider three loss scenarios
  - Scenario 1....N loss event happens shortly after N application
  - Scenario 2....N loss event happens during the period of time that the inhibitor is effective
  - Scenario 3....N loss event happens after the N is nitrified, with or without inhibitor

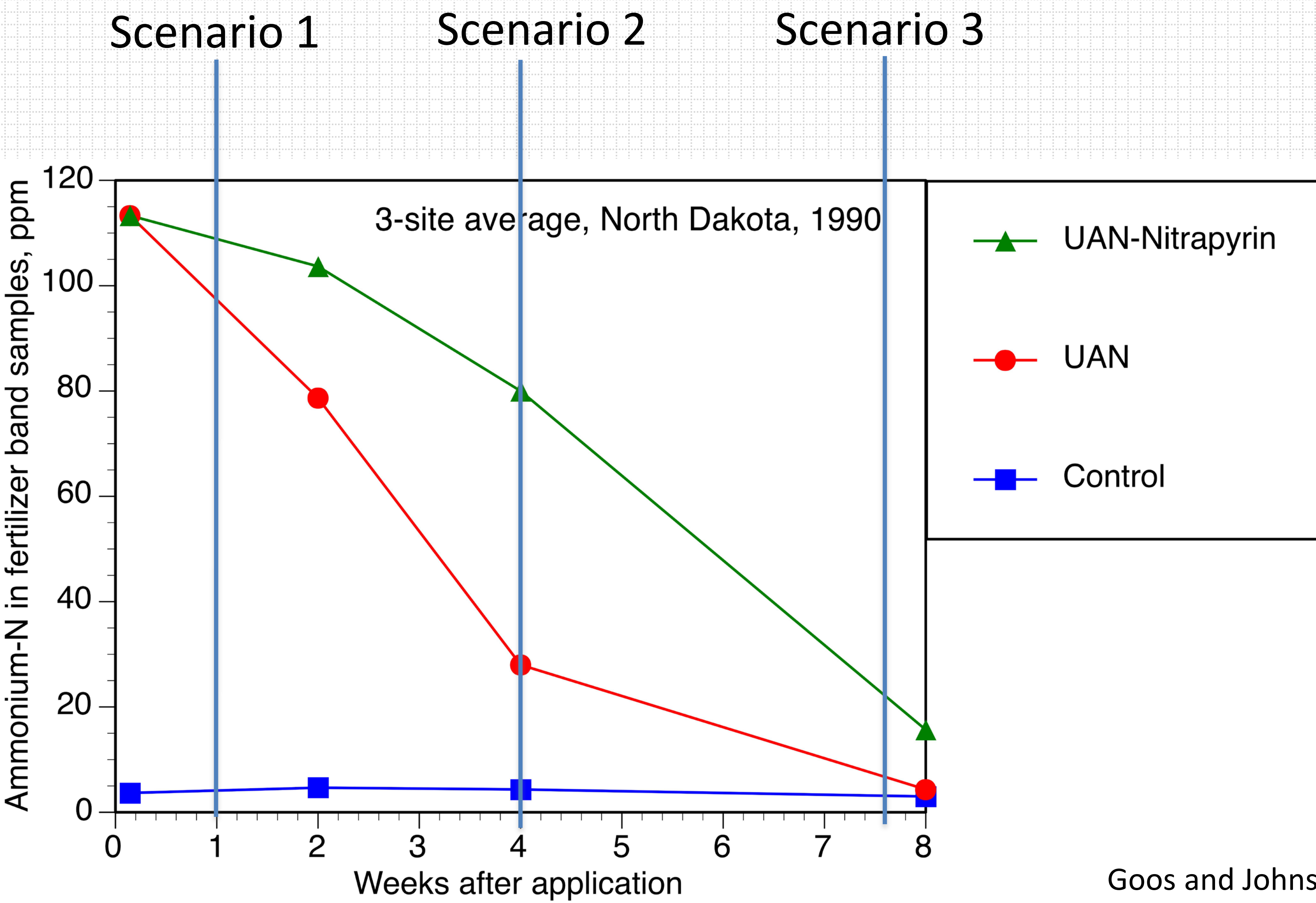
- The "sweet spot" of time....



Goos and Johnson, 1992

- Scenario 1….loss event happened shortly after application
  - No effect of a nitrification inhibitor expected
- Scenario 3….loss event happened after most of the N had nitrified, even with an inhibitor
  - No effect of a nitrification inhibitor expected
- Scenario 2…the “sweet spot” of time

- The "sweet spot" of time....



Goos and Johnson, 1992

- An example of all of the dominoes lining up....
- A fertilizer experiment set out in the fall of 1996

- Ammonia was applied in early October, on 12 inch centers. N rate was 75 lb N/A
- Additives were:
  - N-Serve at the recommended rate (0.5 lb/A)
  - N-Serve at 3 X the recommended rate
  - ATS at 15 lb S/A
- Soils were somewhat poorly drained
- The fall was normal, a bit on the dry side...

- Band samples taken about 3 weeks later, 23-24 October
- Nitrification was proceeding slowly, and would essentially cease in another week or so

- Both N-Serve and ATS were slowing nitrification, and the soil froze for the winter with a difference in the soil ammonium content between the minus and plus inhibitor treatments....the "sweet spot"

Treatment	Site 1	Site 2	Average
Control	0	3	2
Aqua	54	32	43
Aqua + NP	80	63	72
Aqua + 3X NP	88	68	78
Aqua + ATS	76	54	65

Goos and Johnson, 1999

- The fall was normal, but the winter was NOT
- The winter of 1996-1997....nothing like it before, or (thankfully) since.
  - Average snowfall in Fargo is about 3 feet
  - Previous record snowfall in Fargo, about 6 feet
  - Snowfall 1996-1997, officially, ~9 feet.
  - That fall application of N went through a "worst case scenario" for overwinter losses

- Band samples taken in the spring, how much mineral N (ammonium + nitrite + nitrate-N) made it through such an awful winter?????

	Site 1	Site 2	Average
Control	3	4	4
Aqua	7	9	8
Aqua + NP	22	31	27
Aqua + 3X NP	37	41	39
Aqua + ATS	29	36	33

- Site 2 was planted to wheat.

Goos and Johnson, 1999

- Yield and NUE data, one site...

Treatment	Grain yield bu/A	Total N uptake in grain + straw lb/A	Nitrogen fert. use efficiency %
Control	23.4	34.6	--
Aqua	37.0	52.9	24
Aqua + NP	45.0	72.2	50
Aqua + 3X NP	45.9	72.5	50
Aqua + ATS	47.3	77.0	56

Goos and Johnson, 1999

- All of the dominoes lined up...
  - The N rate was not excessive
  - Nitrogen loss occurred
  - The loss event occurred during the "sweet spot" of time, when there was a difference in the ammonium level in the soil
    - Soil was frozen during the "sweet spot" of time
  - The loss was big enough to reduce yield
  - There was a <u>big</u> payoff from using an inhibitor

- So, where do nitrification inhibitors fit?
- A tough call, as there are alternatives
  - Avoiding fall application, instead of using ammonia + N-Serve
  - Split application
- But, there can be small benefits of a nitrification inhibitor, apart from N loss prevention
  - Keeping N shallower in the soil

Fertilizer	NH4-N in soil, ppm	N uptake, lb/A
Control	1	45
Calcium nitrate	2	100
10 mg urea gran.	9	105
10 mg urea-DCD	21	112*
100 mg urea gran.	20	112*
100 mg urea-DCD	68	114*

NH4-N in top six inches, 4 weeks after fertilization

*Significantly greater than calcium nitrate

3 sites, 1993

Goos, et al. 1999

- Some consideration with regards to products
- N-Serve, nitrapyrin, is still the “gold standard”
- Encapsulating nitrapyrin to make Instinct, does reduce its effectiveness somewhat
- DCD, rates needed much greater

Inhibitor	Concentration of a.i.	% Inhibition
N-Serve	1 ppm	72
Instinct	5 ppm	79
DCD	25 ppm	73

Four soil average, 4 week incubation
Goos, 2019

- DCD shennanigans……watch out….
  - DCD needs to be added to molten urea during manufacture. SuperU is almost 1% DCD by weight
  - Surface-applied DCD products, the rate is just too low

- As with urease inhibitors, there are ineffective products out there


REMOVE

Fertilizer source	% of N as ammonium after 4 weeks
Urea	7
Urea + NSN-1	7
Urea + NSN-2	8
Urea + NZone	7
Urea + Instinct	30
SuperU	41

Intact pellets incubated with soil for 4 weeks,
3 soil average

Adapted from Goos and Guertal, 2019

- To summarize
  - Urease inhibitors are probably the easier decision
    - Strict no-till, broadcast urea granules
    - Use an effective product, and rate
  - Nitrification inhibitors, a more difficult decision
    - Particularly if split-application is practical for the farmer
    - Use an effective product, and rate

- Papers quoted:
  - Goos and Johnson, 1992. Comm. Soil Sci. Plant Anal. 23:1105-1117
  - Goos, et al. 1999. Agron. J. 91:287-293
  - Goos and Johnson, 1999. Agron. J. 91:1046-1049
  - Goos, 2013a. Soil Sci. Soc. Am. J. 77:1418-1423
  - Goos, 2013b. Comm. Soil Sci. Plant Anal. 44:1909-1917
  - Goos, 2019, Comm. Soil Sci. Plant. Anal. 50:503-511
  - Goos and Guertal, 2019, Agron. J. 111:1441-1447