

Proceedings of the 2nd Annual Nitrogen: Minnesota's' Grand Challenge & Compelling Opportunity Conference



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Anhydrous Ammonia, Soil, & CEC: Myths and Management





Nitrogen: Minnesota's Grand Challenge & Compelling Opportunity Conference

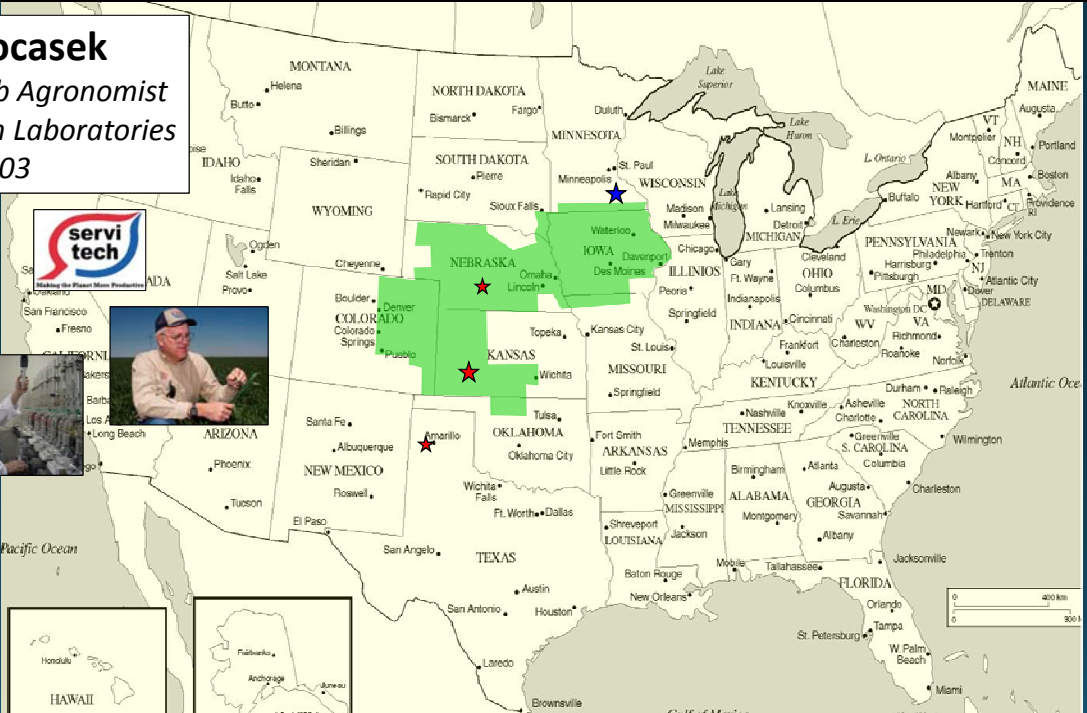
February 23, 2016
International Events Center, Rochester, MN



Fred Vocasek

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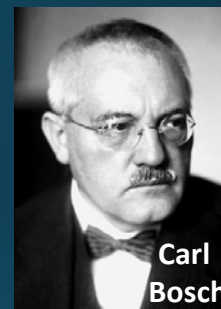
Anhydrous ammonia, 82-0-0

- at 60° = 5.15 lb/gal = 4.2 lb N
- at 65° = 100 psi
- -28°F, boiling point
- 1 ft³ of liquid @ 60°...
expands to 850 ft³ of vapor
- “hygroscopic”
- 1 ft³ of liquid water ...
dissolves 1300 ft³ of ammonia vapor

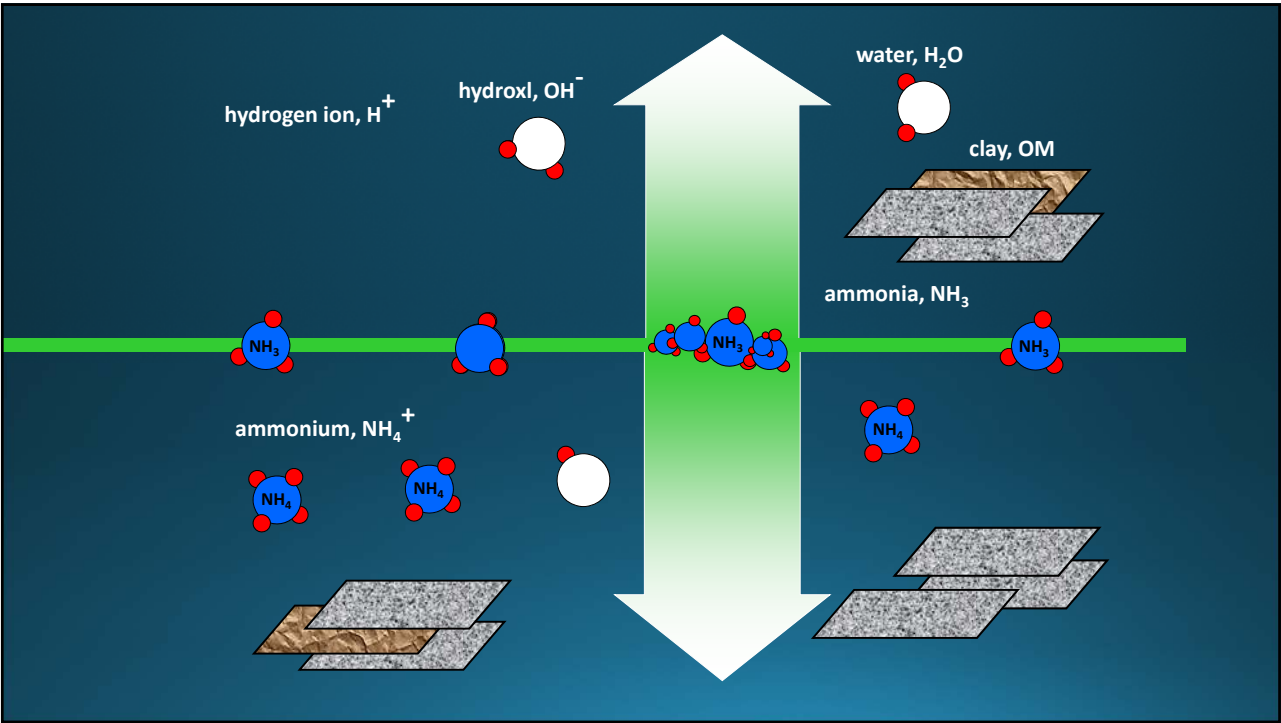
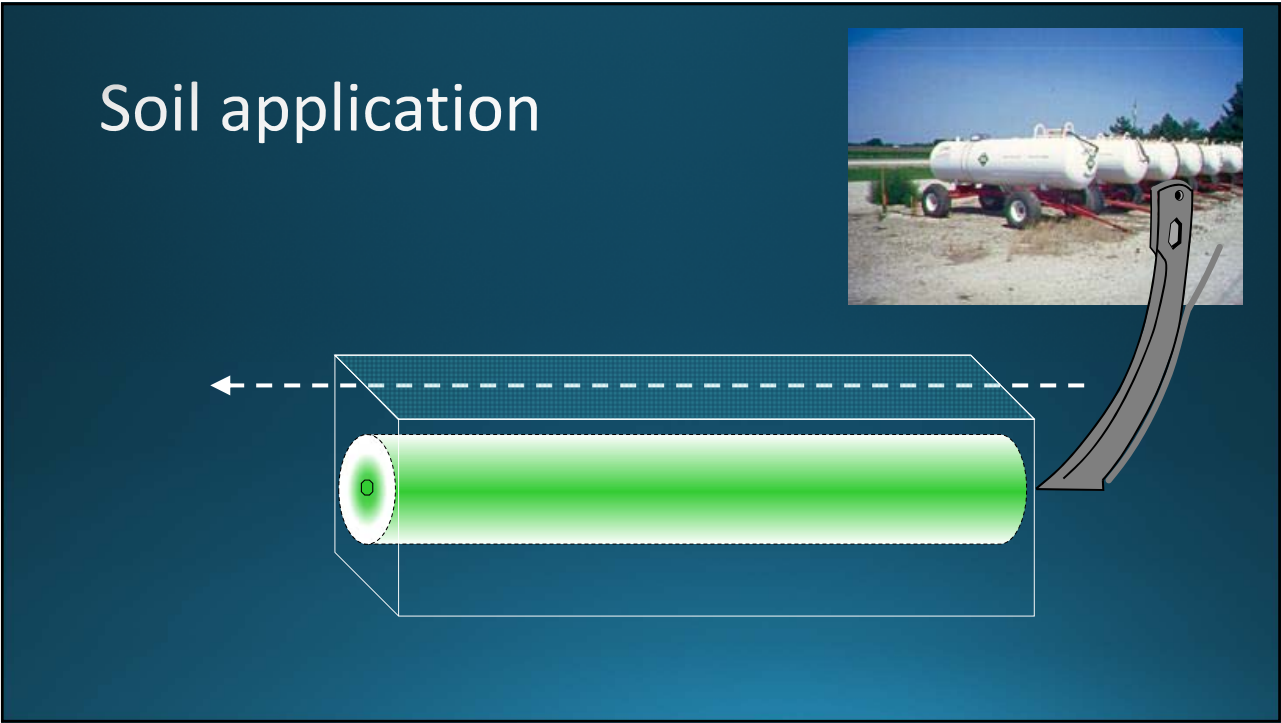


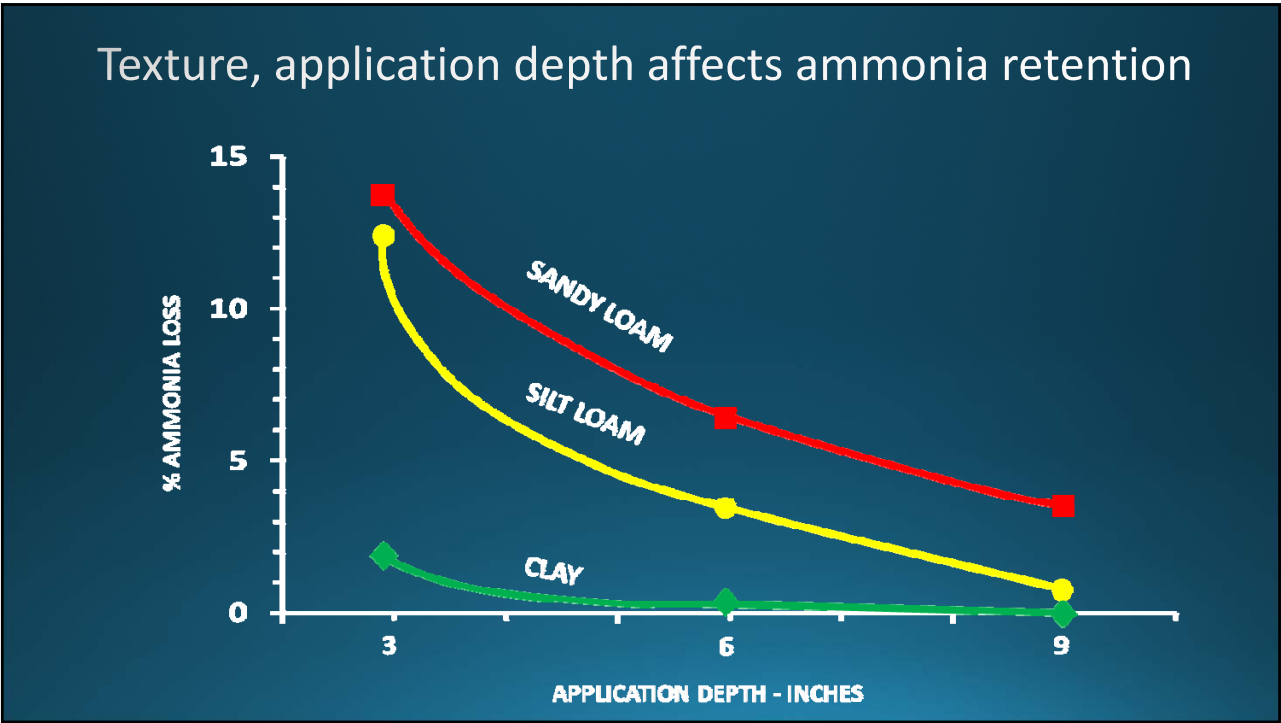
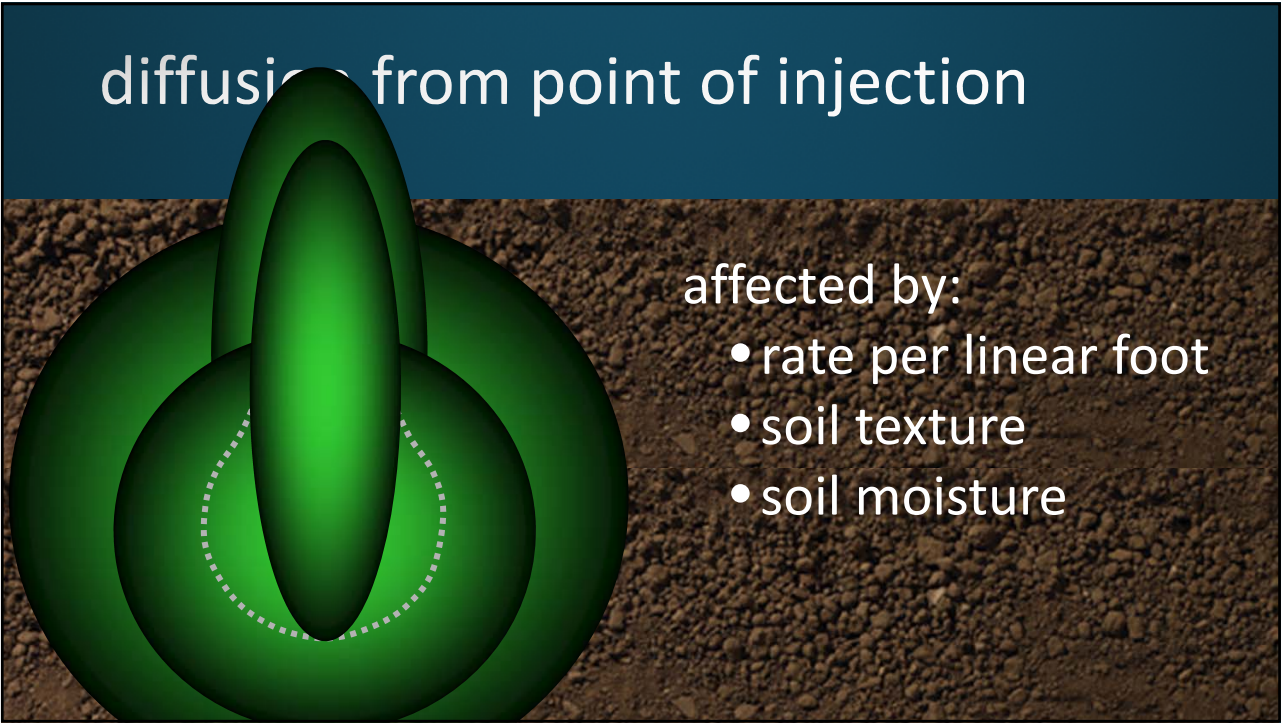
*from “Faces, Places, and Excursions Along the Nitrogen Trail”**


- Haber-Bosch process
 - World War I
 - U.S./England blockade
 - saltpeter (NaNO₃)
- First Haber-Bosch plant in U.S. built in 1920's
- USDA experimented with anhydrous ammonia in 1933
 - considered too expensive to be competitive
 - had other sources of nitrogen
- World War II ... Tennessee Valley Authority
 - munitions → fertilizer → research



*Shepers. 2014. <https://scisoc.confex.com/scisoc/2014am/videogateway.cgi/id/20444?recordingid=20444>






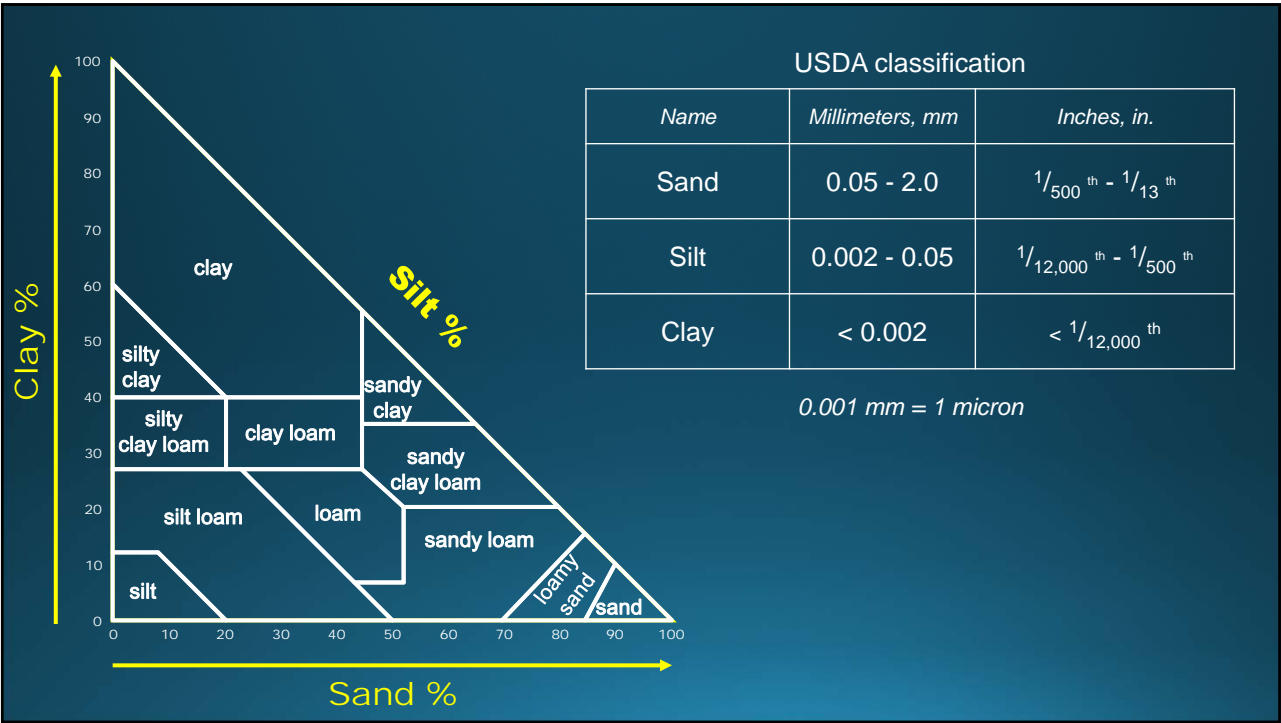


Soil texture

- sand
- silt
- clay

Soil Textural Triangle





Soil clay particles (magnified)



1 micron = 0.001 mm ≈ 1/25,000th inch

Cation Exchange Capacity

- CEC, milliequivalents per 100 grams (meq/100g)
 - centimoles per kilogram (cmol kg⁻¹)
- “true” CEC
 - EPA method #9081, uses sodium acetate
 - \$84.90
- “summation” CEC
 - estimated, calculated from soil test results
 - ammonium acetate (pH 7), Mehlich-3
 - potassium, calcium, magnesium, neutralizable acidity
 - sodium? exchangeable aluminum?

Cation Exchange Capacity					
CEC	%H	%K	%Ca	%Mg	%Na
9	0	9	64	27	0
6	0	10	67	23	0
24	0	5	84	11	0

CEC calculations

• K ppm ÷ 390 = K meq/100g

• Ca ppm ÷ 200 = Ca meq/100g

• Mg ppm ÷ 120 = Mg meq/100g

• Na ppm ÷ 230 = Na meq/100g

} exchangeable bases

• 12 × (7.0 - BpH) = H meq/100g

} exchangeable acidity, estimated

CEC calculations

K, meq/100g +

Ca, meq/100g +

Mg, meq/100g +

Na, meq/100g +

H, meq/100g = CEC, meq/100g

General texture	CEC range, meq/100g
Sands	3 - 5
Loamy sand	4 - 8
Sandy loams	6 - 12
Loams	15 - 20
Silt loams	15 - 25
Clay loams	15 - 25
Sandy clays	15 - 30
Sandy clay loams	15 - 30
Silty clay loams	20 - 35
Clays	25 - 50
Organic soils, mucks (OM > 20%)	50 - 100

CEC calculations

K meq/100g

+

Ca meq/100g

+

Mg meq/100g

+

Na meq/100g

+

H meq/100g

=

}

bases, meq/100g

÷


CEC, meq/100g

×

100

=

% base saturation



“Balance the cations”

• Base Saturation Cation Ratio (BCSR)


• Promoted by certain groups

- “Believers” – “black box”
- Suppliers
 - calcitic vs. dolomitic lime (CaCO₃ vs. MgCO₃)
 - gypsum (CaSO₄)

• 60 to 70 year-old theory

- W.A. Albrecht, **1940**
- F.E. Bear, et. al. **1945**
- others ... **1930’s 1940’s, 1950’s**

• Lots of field research since then



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"A Review of the Use of the Basic Cation Saturation Ratio and the "Ideal" Soil"*

- *“Our examination of data from numerous studies ... would suggest that, within the ranges commonly found in soils, the chemical, physical, and biological fertility of a soil is generally not influenced by the ratios of Ca, Mg, and K.”*
- Cation ratios have no direct impact on yield
 - key = maintain sufficient supply of nutrient cations in crop root zone
 - at “optimum” base cation ratios, may still have nutrient deficiency or pH concern

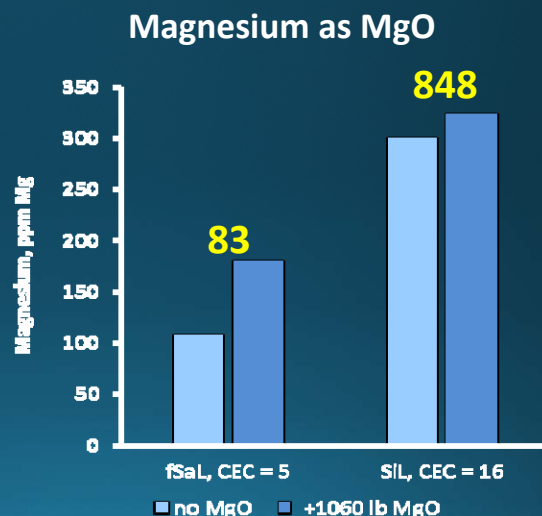
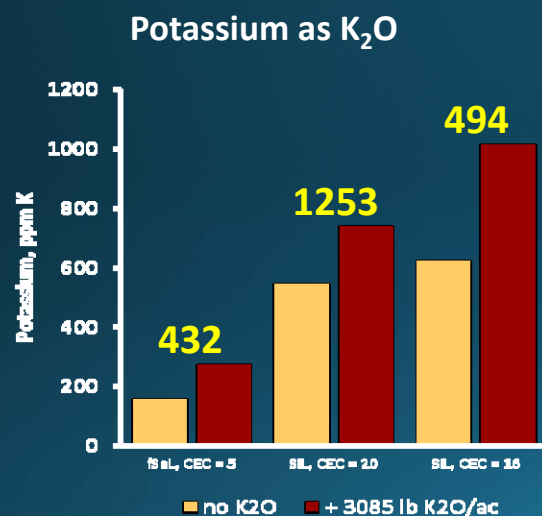
* Kopittke & Menzies, 2007, *Soil Sci. Soc. Am. J.* 71:259–265

in preparing this work. Data in Table 1 is taken from Saaren et al. (2005), in *Journal of Cotton Science* 9:65-71, and is reproduced with permission of Dr. Gene Saaren. Data in Fig. 7 is taken from Table 3 in Rengasamy et al. (1986), in: *Australian Journal of Soil Research* 23(2):229-237, and is reproduced with permission of CSIRO Publishing, Melbourne, Australia.

REFERENCES

- Allen, R.J. and R.J. Soer, 1999. Models of predation risk. *Ecology* 80: 3535-3552. doi:10.1890/1051-0761(1999)080[3535:Models]2.0.CO;2.
- Albrecht, W.A. 1957. Principles of soil microbiology in relation to fertility of soils. *Soil Sci. Soc. Am. Proc.* 21: 375-382.
- Albrecht, W.A. 1973. Some factors in nitrogen fixation in legumes. *Trans. Am. Microsc. Soc.* 92: 1-10.
- Albrecht, W.A. 1975. The legume rhizobia. *Veget. J.* 16: 169-182.
- Albrecht, W.A. 1976. *Soil Microbiology*. The Collins Foundation of the soil as a cultural medium. John Wiley, New York. 258-307.
- Albrecht, W.A., and C.E. Smith. 1941. Biological ecology of soil fertility. *Soil Sci. Soc. Am. Proc.* 5: 1-10.
- Alks, A.K., D.E. Edwards, C.J. Allen, and S. Jankin-Smith. 1987. Effects of soil pH on the growth of rhizobia and nodulation of soybean. *Agronomy J.* 73:902-906.
- Amthor, E.T. 1989. Soil aggregate stability and nitrogen. *J. Soils Agric. Environ.* 14:149-151.
- Amthor, E.T. 1990. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 54:113-115.
- Amthor, E.T., A.L. Fries, S.J. Tied, and E.R. Fries. 1997. Microbes in plant roots: A review of the role of rhizobia in nitrogen fixation. *Soil Sci. Soc. Am. J.* 61:745-754.
- Amthor, E.T., and S.J. Tied. 1994. Factors of carbon in availability of other nutrients. *Soil Sci. Soc. Am. J.* 58:7-14.
- Amthor, E.T. 1999. Carbon, N and P. *Soil Sci. Soc. Am. J.* 63:149-151.
- Amthor, E.T. 2000. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 64:113-115.
- Amthor, E.T. 2001. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 65:113-115.
- Amthor, E.T. 2002. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 66:113-115.
- Amthor, E.T. 2003. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 67:113-115.
- Amthor, E.T. 2004. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 68:113-115.
- Amthor, E.T. 2005. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 69:113-115.
- Amthor, E.T. 2006. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 70:113-115.
- Amthor, E.T. 2007. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 71:113-115.
- Amthor, E.T. 2008. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 72:113-115.
- Amthor, E.T. 2009. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 73:113-115.
- Amthor, E.T. 2010. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 74:113-115.
- Amthor, E.T. 2011. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 75:113-115.
- Amthor, E.T. 2012. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 76:113-115.
- Amthor, E.T. 2013. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 77:113-115.
- Amthor, E.T. 2014. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 78:113-115.
- Amthor, E.T. 2015. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 79:113-115.
- Amthor, E.T. 2016. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 80:113-115.
- Amthor, E.T. 2017. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 81:113-115.
- Amthor, E.T. 2018. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 82:113-115.
- Amthor, E.T. 2019. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 83:113-115.
- Amthor, E.T. 2020. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 84:113-115.
- Amthor, E.T. 2021. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 85:113-115.
- Amthor, E.T. 2022. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 86:113-115.
- Amthor, E.T. 2023. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 87:113-115.
- Amthor, E.T. 2024. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 88:113-115.
- Amthor, E.T. 2025. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 89:113-115.
- Amthor, E.T. 2026. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 90:113-115.
- Amthor, E.T. 2027. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 91:113-115.
- Amthor, E.T. 2028. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 92:113-115.
- Amthor, E.T. 2029. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 93:113-115.
- Amthor, E.T. 2030. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 94:113-115.
- Amthor, E.T. 2031. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 95:113-115.
- Amthor, E.T. 2032. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 96:113-115.
- Amthor, E.T. 2033. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 97:113-115.
- Amthor, E.T. 2034. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 98:113-115.
- Amthor, E.T. 2035. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 99:113-115.
- Amthor, E.T. 2036. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 100:113-115.
- Amthor, E.T. 2037. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 101:113-115.
- Amthor, E.T. 2038. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 102:113-115.
- Amthor, E.T. 2039. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 103:113-115.
- Amthor, E.T. 2040. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 104:113-115.
- Amthor, E.T. 2041. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 105:113-115.
- Amthor, E.T. 2042. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 106:113-115.
- Amthor, E.T. 2043. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 107:113-115.
- Amthor, E.T. 2044. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 108:113-115.
- Amthor, E.T. 2045. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 109:113-115.
- Amthor, E.T. 2046. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 110:113-115.
- Amthor, E.T. 2047. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 111:113-115.
- Amthor, E.T. 2048. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 112:113-115.
- Amthor, E.T. 2049. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 113:113-115.
- Amthor, E.T. 2050. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 114:113-115.
- Amthor, E.T. 2051. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 115:113-115.
- Amthor, E.T. 2052. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 116:113-115.
- Amthor, E.T. 2053. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 117:113-115.
- Amthor, E.T. 2054. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 118:113-115.
- Amthor, E.T. 2055. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 119:113-115.
- Amthor, E.T. 2056. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 120:113-115.
- Amthor, E.T. 2057. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 121:113-115.
- Amthor, E.T. 2058. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 122:113-115.
- Amthor, E.T. 2059. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 123:113-115.
- Amthor, E.T. 2060. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 124:113-115.
- Amthor, E.T. 2061. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 125:113-115.
- Amthor, E.T. 2062. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 126:113-115.
- Amthor, E.T. 2063. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 127:113-115.
- Amthor, E.T. 2064. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 128:113-115.
- Amthor, E.T. 2065. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 129:113-115.
- Amthor, E.T. 2066. Soil aggregate stability and nitrogen. *Soil Sci. Soc. Am. J.* 130:113-115.
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Fertilizer needed to increase saturation by 1% differs



<http://ianrpubs.unl.edu/live/ec155/build/ec155.pdf>

Myth: “Soils can only hold 10 lb. of nitrogen per unit of CEC.”



Anhydrous ammonia application

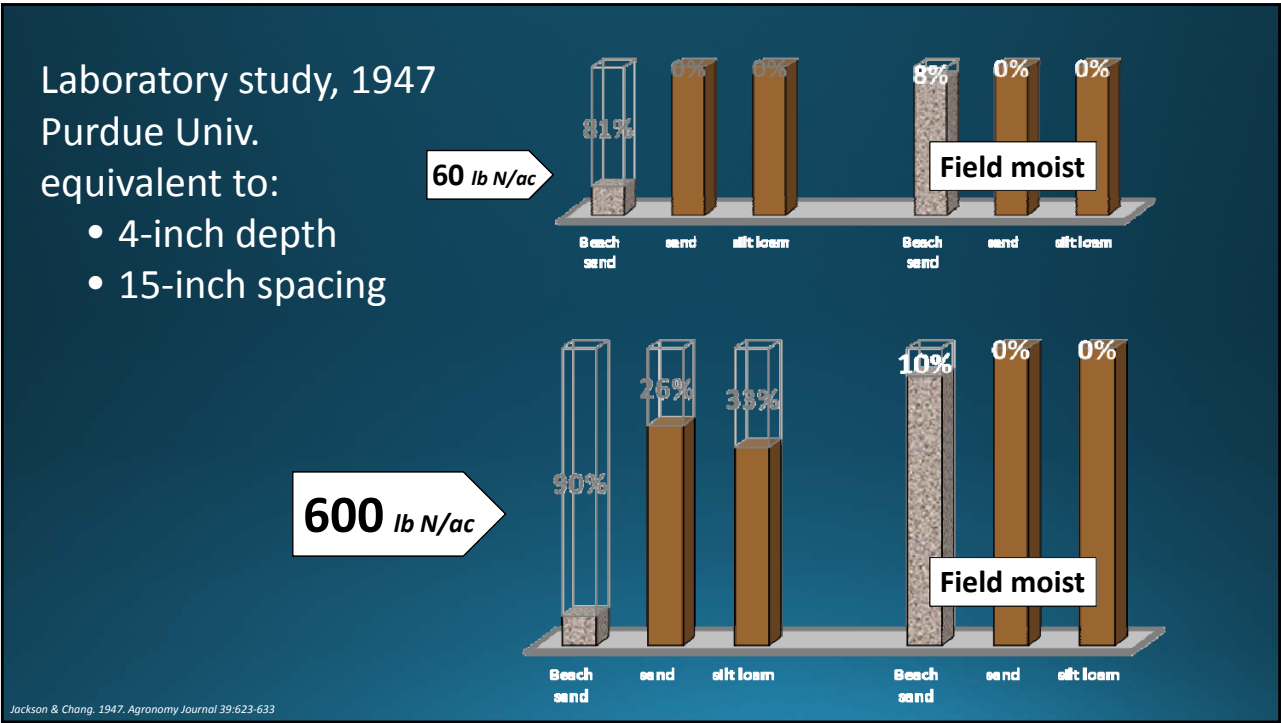
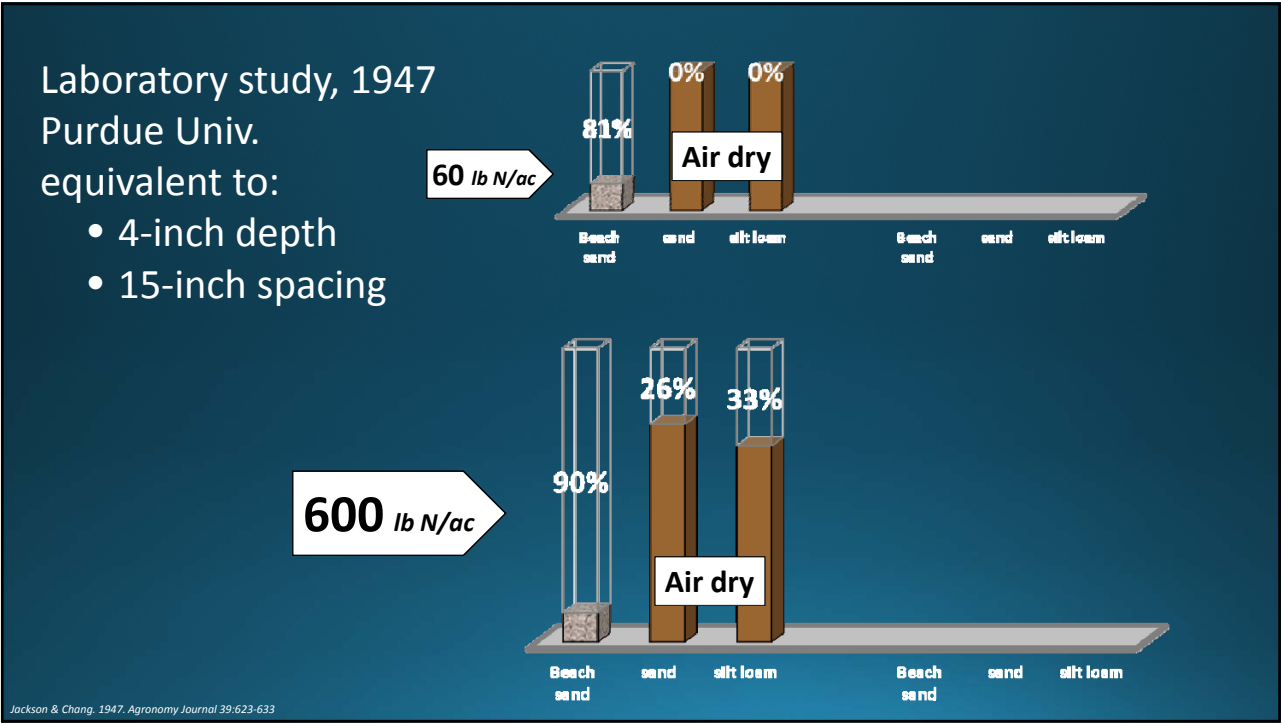
- injected into a flowing irrigation water ditch or lateral

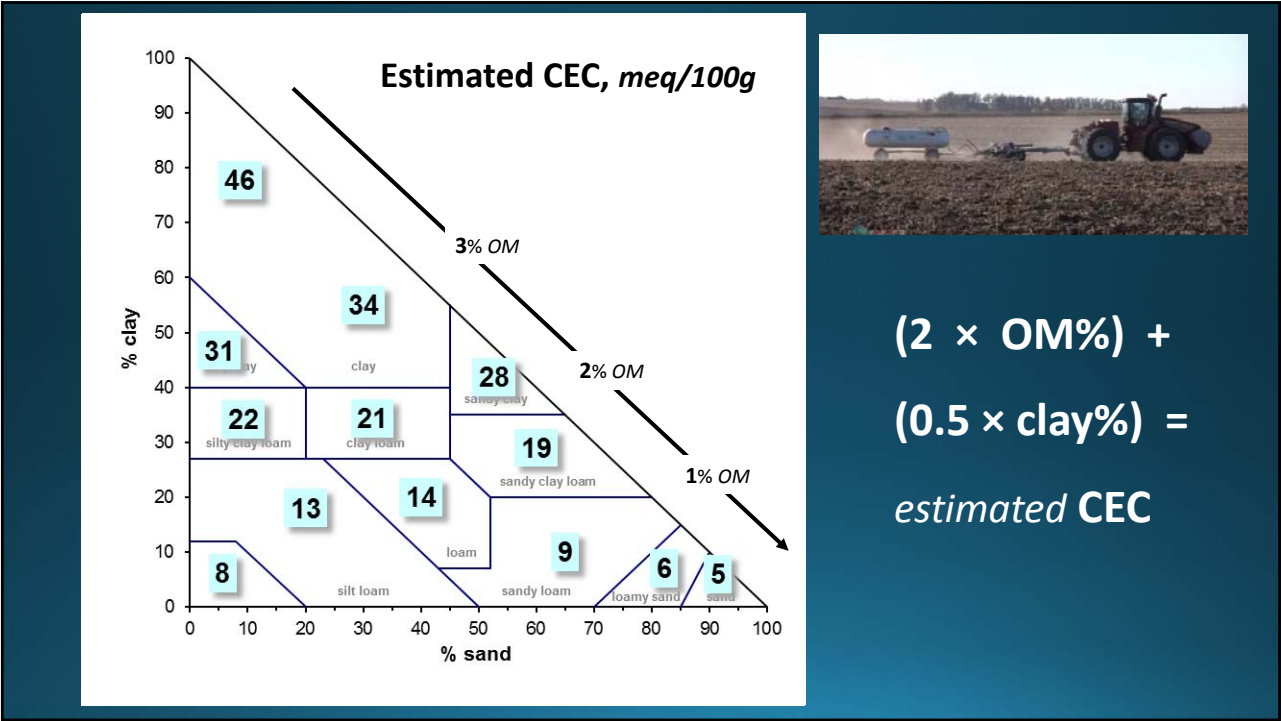
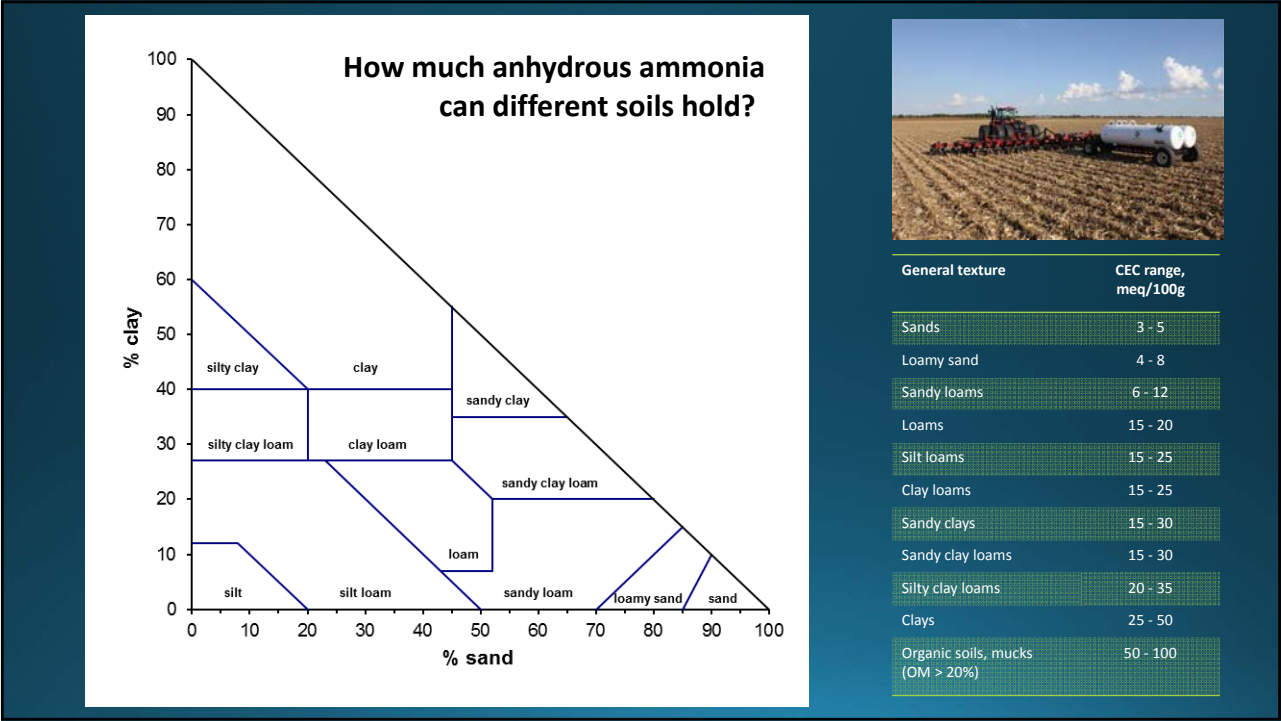


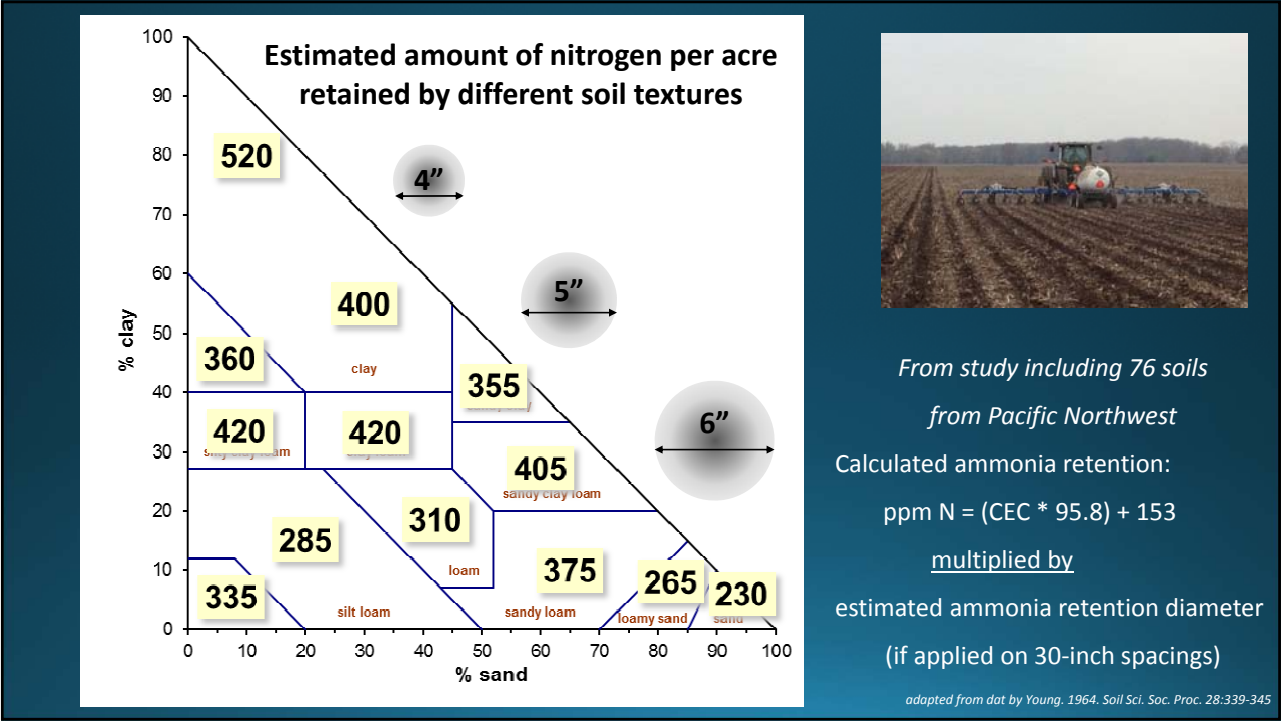
Ammonia New Nitrogen Fertilizer Source

by Cecil Hagen, The Washington Farmer







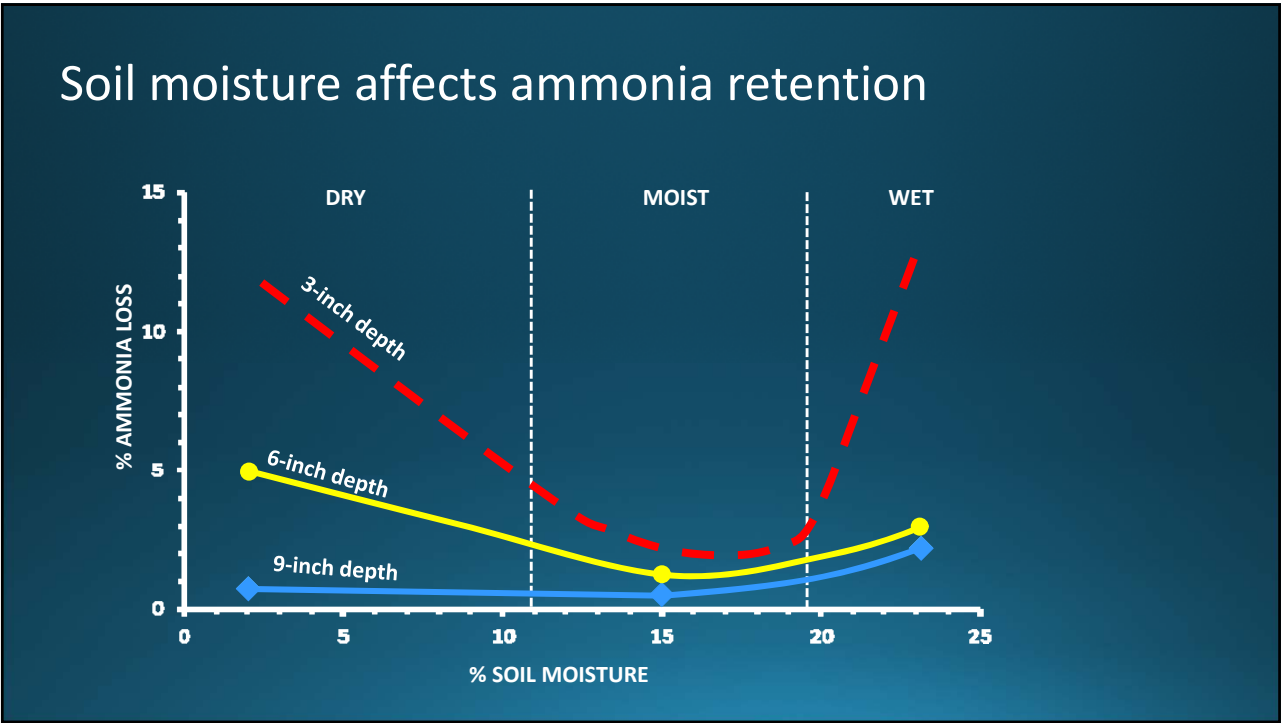
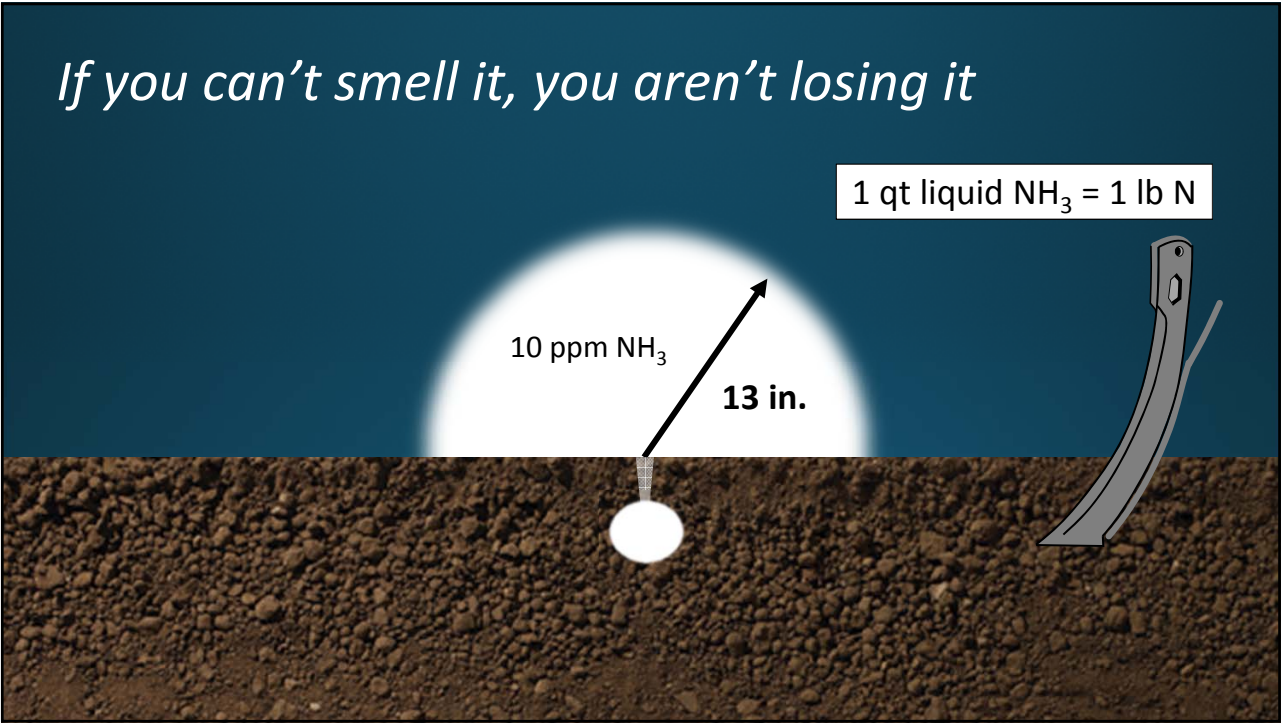


Ammonia loss after application

- ammonia vapor is invisible
- white puffs
 - condensing water vapor
- OSHA odor threshold
 - 5 – 50 ppm
- 100 – 300 ppm = irritation of eye and nose
- typical odor threshold is 10 - 20 ppm
 - noticeable by most

Rule of Thumb:

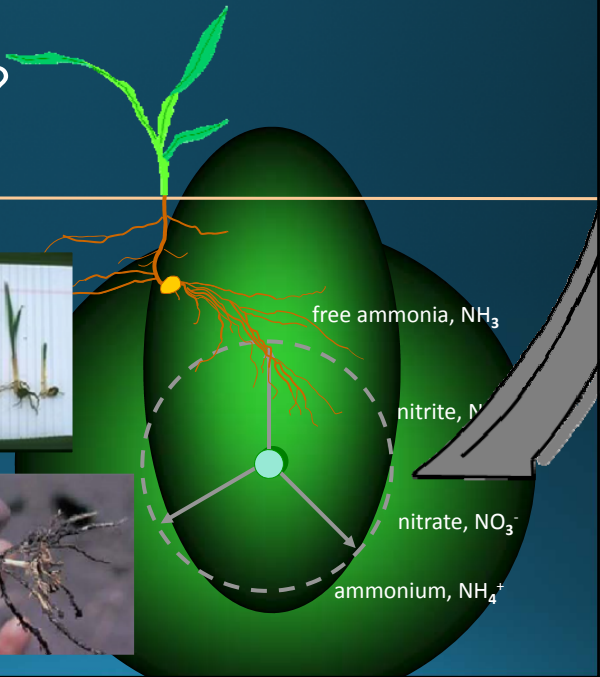
"If you can't smell it, you aren't losing it."



Apply anhydrous ammonia. Safe separation distance?

Ammonia diffusion zone?

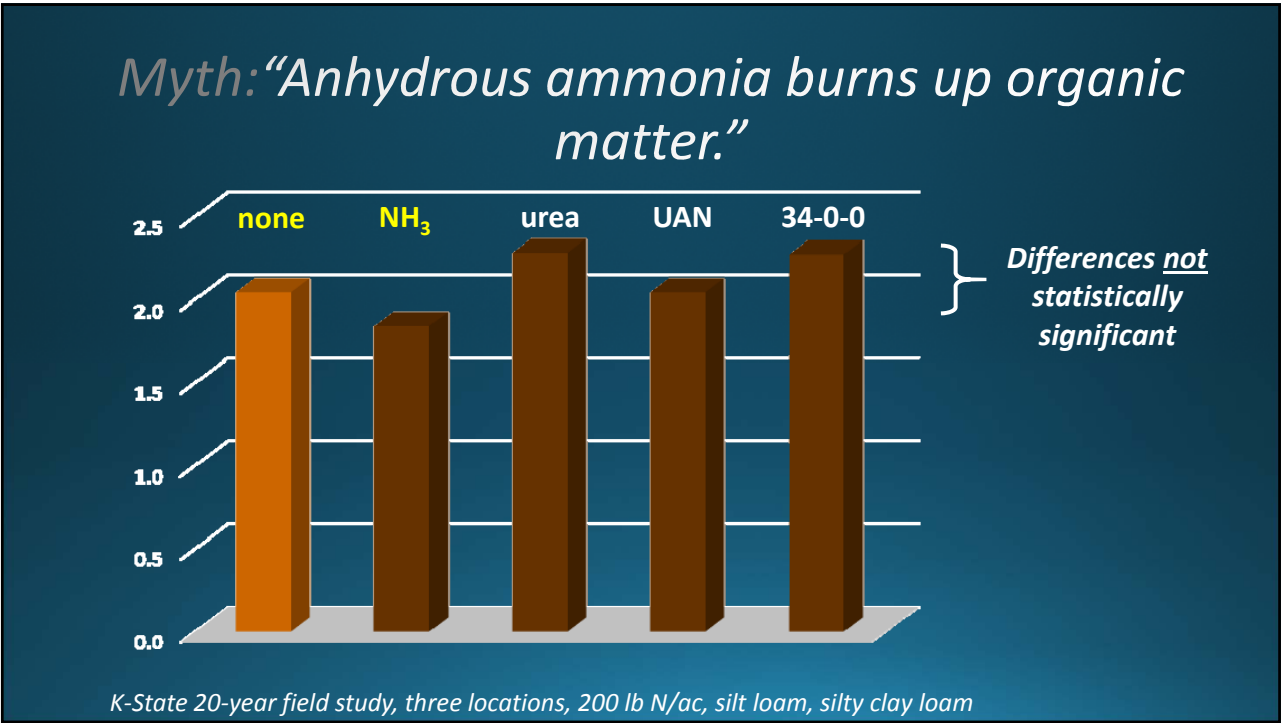
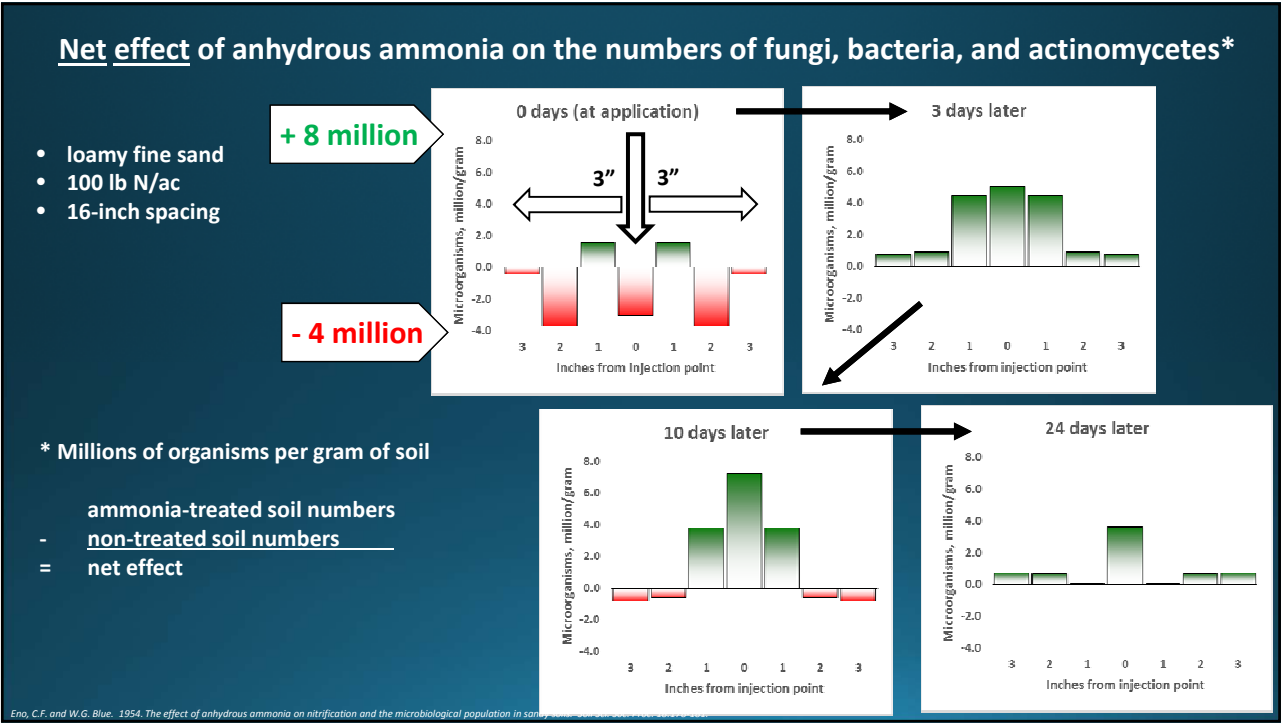
- field moist soil
- 30-inch spacing
- corn nitrogen rates
- fine-textured soils
 - 2½ – 3½ inches
- sandy soils
 - 4 – 6 inches
- dry soil
 - double the distance

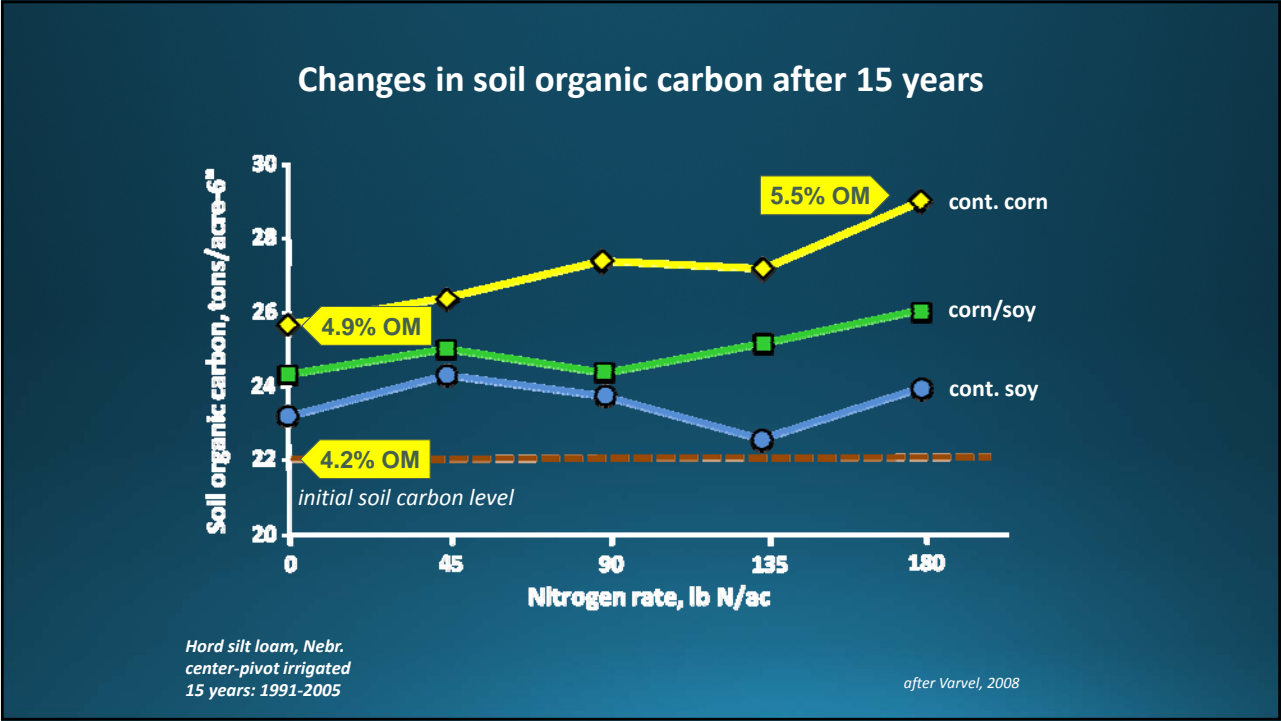


*Myth: “Anhydrous ammonia kills earthworms,
... kills bacteria.”*

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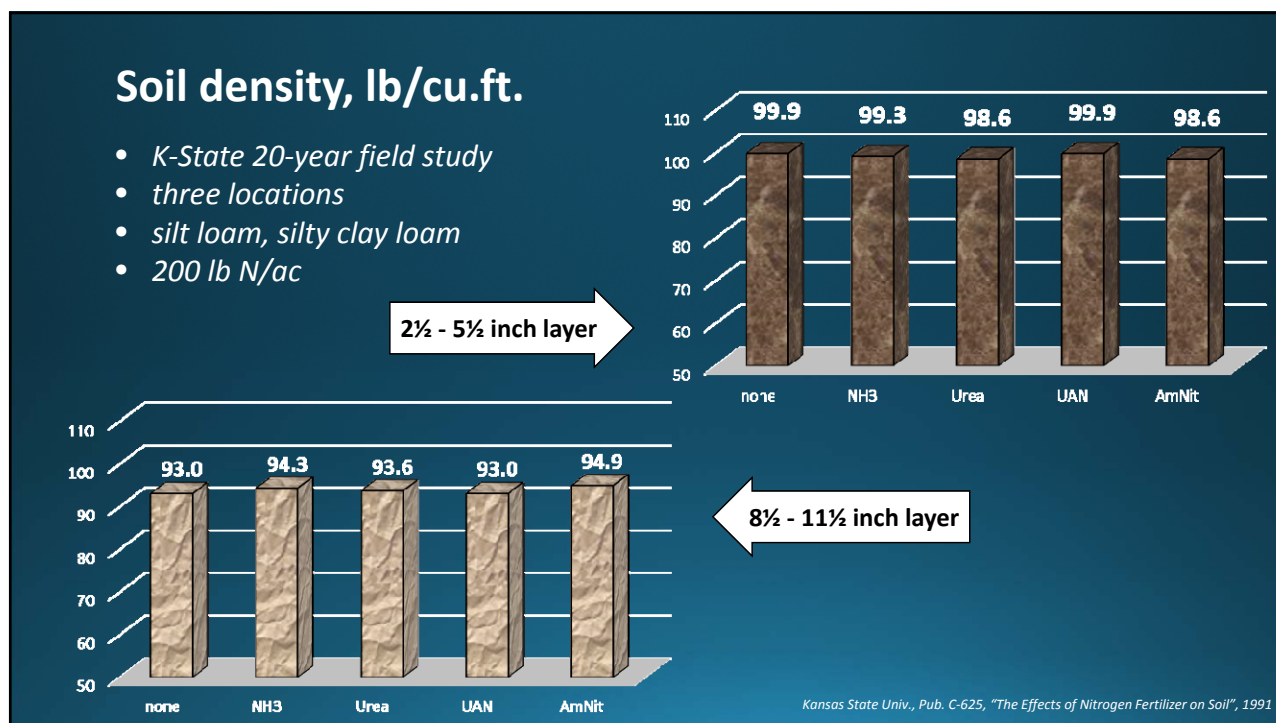


Myth: “Anhydrous ammonia makes the ground hard.”

.....

“The military used it to build runways in ...”





Anhydrous ammonia, myths & management

- Soil diffusion, retention after application affected by:
 - soil texture (clay content)
 - rate per linear foot (per acre rate, spacing)
 - soil moisture (dry ... moist ... wet)
- CEC has role, but field conditions are important
- "If you can't smell it, you aren't losing it."
- Beware of fertilizer myths
 - agronomically, a pound of N is a pound of N

