Manure Application Methods to Minimize Ammonia Losses and Maximize Crop N Use

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crop cow soil manure IEIDM

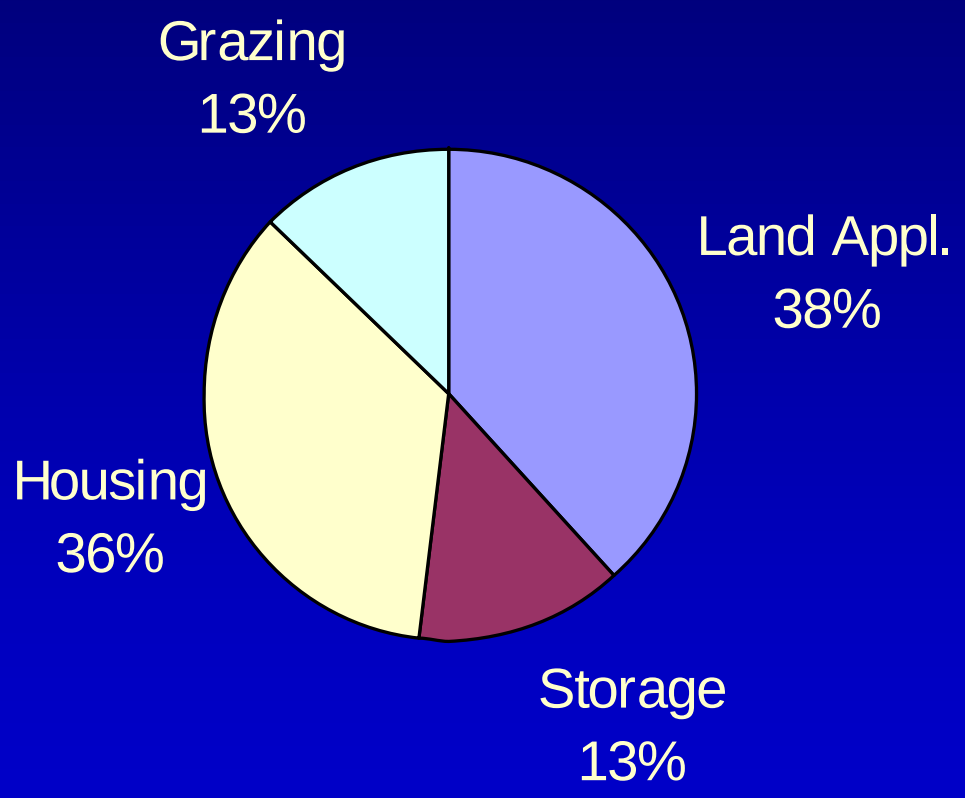
Overview: Ammonia Loss from Manure

- Issues and Concerns
- Factors in Ammonia Volatilization
- Management Practices to Control Ammonia Emissions
  - Annual Crops
  - Grassland, Perennial Forages
- Economics: N- and P-based application.

Why the concern about ammonia losses?

- Loss of N for crops ($)
- Reduces N:P ratio in manure
  - N-based appl: more P build-up in soil
  - P-based appl: buy more fertilizer N
- Eutrophication of surface waters (esp. marine, estuary) via atmospheric deposition
- Air quality – form fine particulates

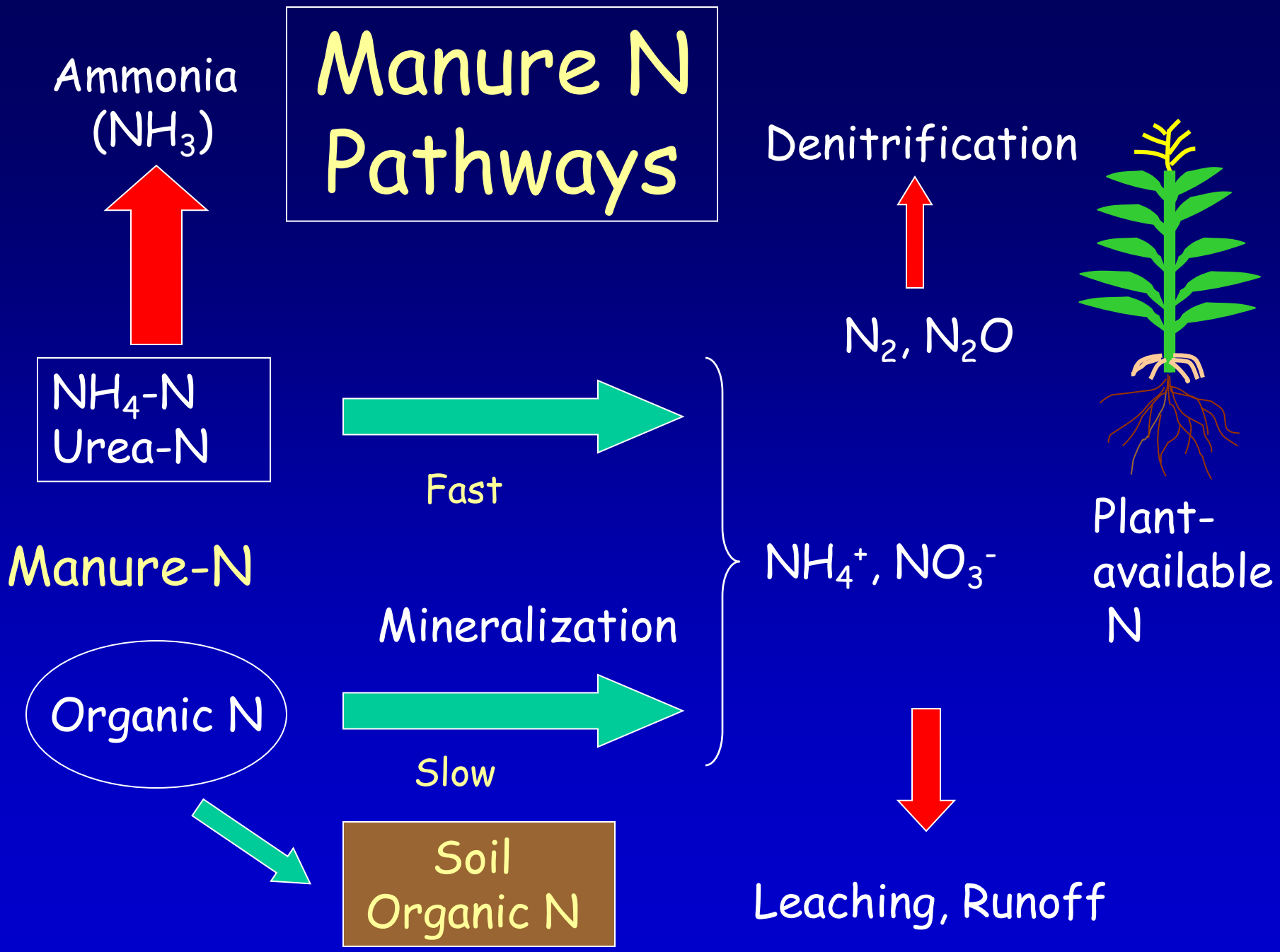
NH_3 Emissions from Cattle Operations in the UK



Misselbrook et al., 2000

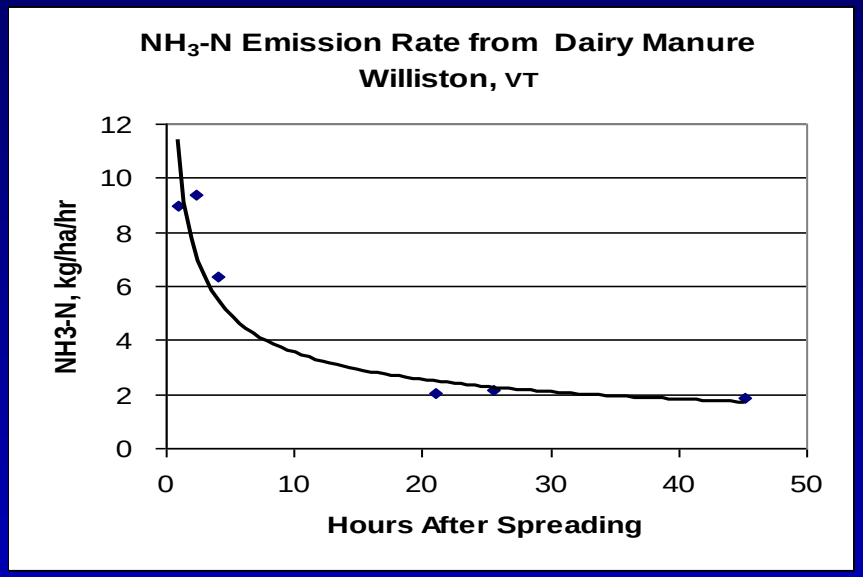
Goal: Minimize Manure Nutrient Losses, Maximize Crop Utilization

Manure N Pathways

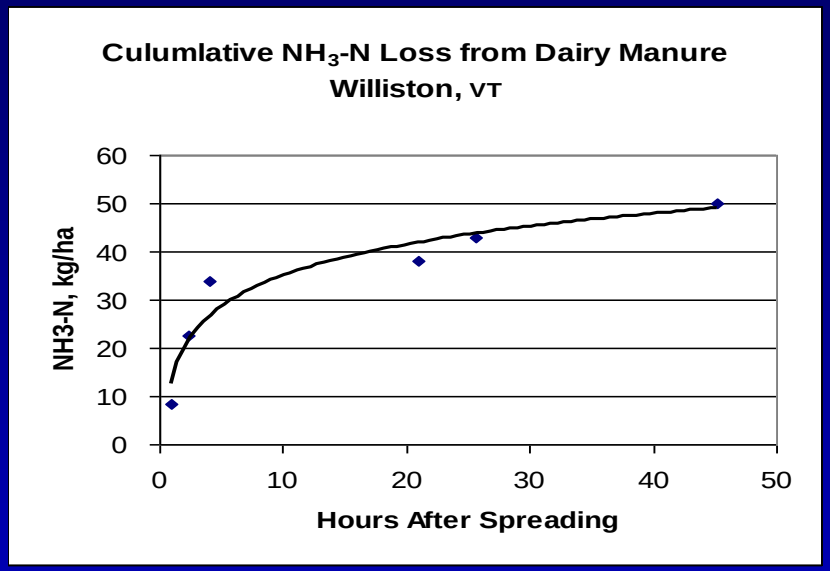


Pattern of NH_3 Loss vs Time

Dairy Slurry on Corn Stubble



NH_3-N Loss Rate



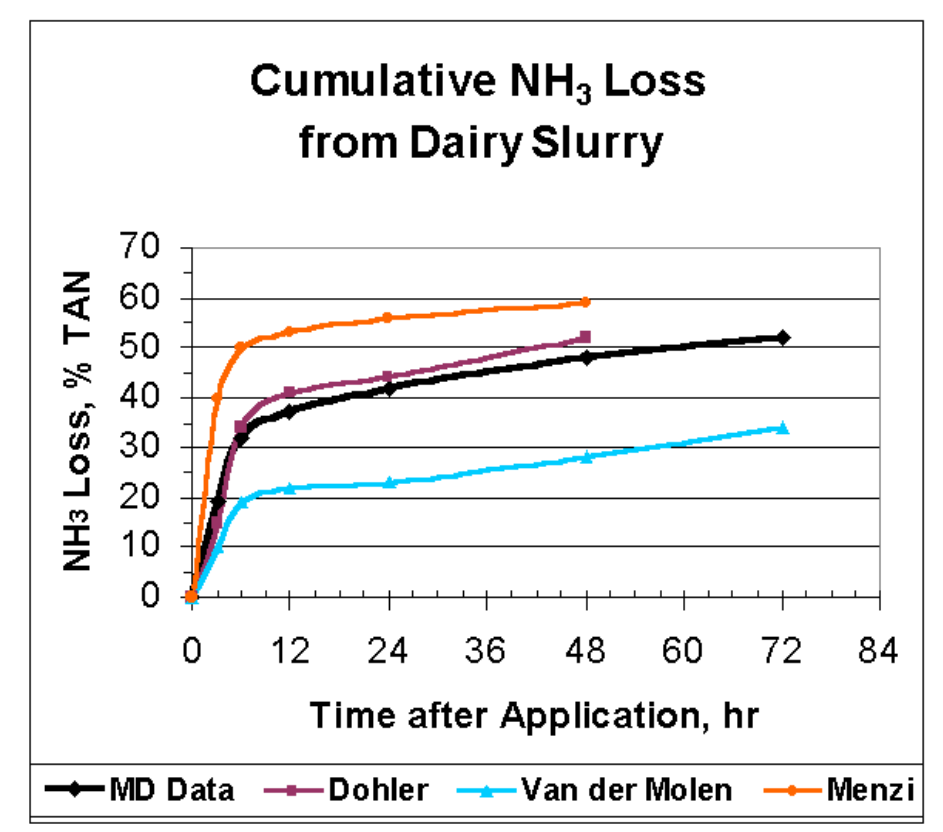
Cumulative NH_3-N Loss

- Dairy and Swine Manure
  - Rapid NH_3 loss initially
  - Low losses after 24-48 hours
- Poultry Litter
  - More gradual loss
  - Most lost in first week

Jokela and Meisinger, Unpubl. 2004

More Research Examples: NH_3 Emission from Dairy Slurry

- Rapid NH_3 loss initially
- Most lost in first 6-8 hours
- Very little lost after 24-48 hours
- Shows importance of early action to control NH_3 loss (incorporation, etc.)



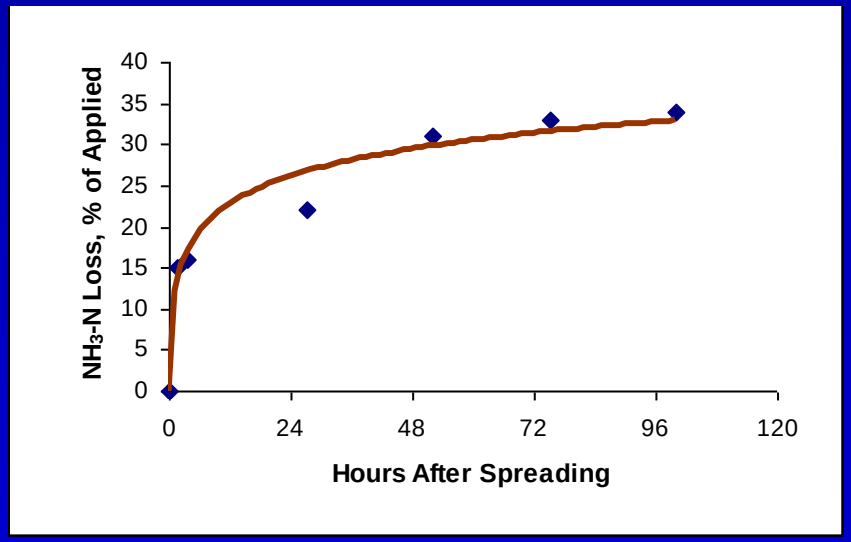
Meisinger, 2004

Factors in NH_3 Losses from Land Application of Manure

- Manure characteristics: NH_4-N, %DM
- Weather: Wind, temperature, rainfall
- Soil properties: pH, CEC
- Surface residue or vegetation
- Application Methods/Incorporation
  - Time until incorporation by tillage or rain
  - Tillage method
  - Injection, direct incorporation, etc.

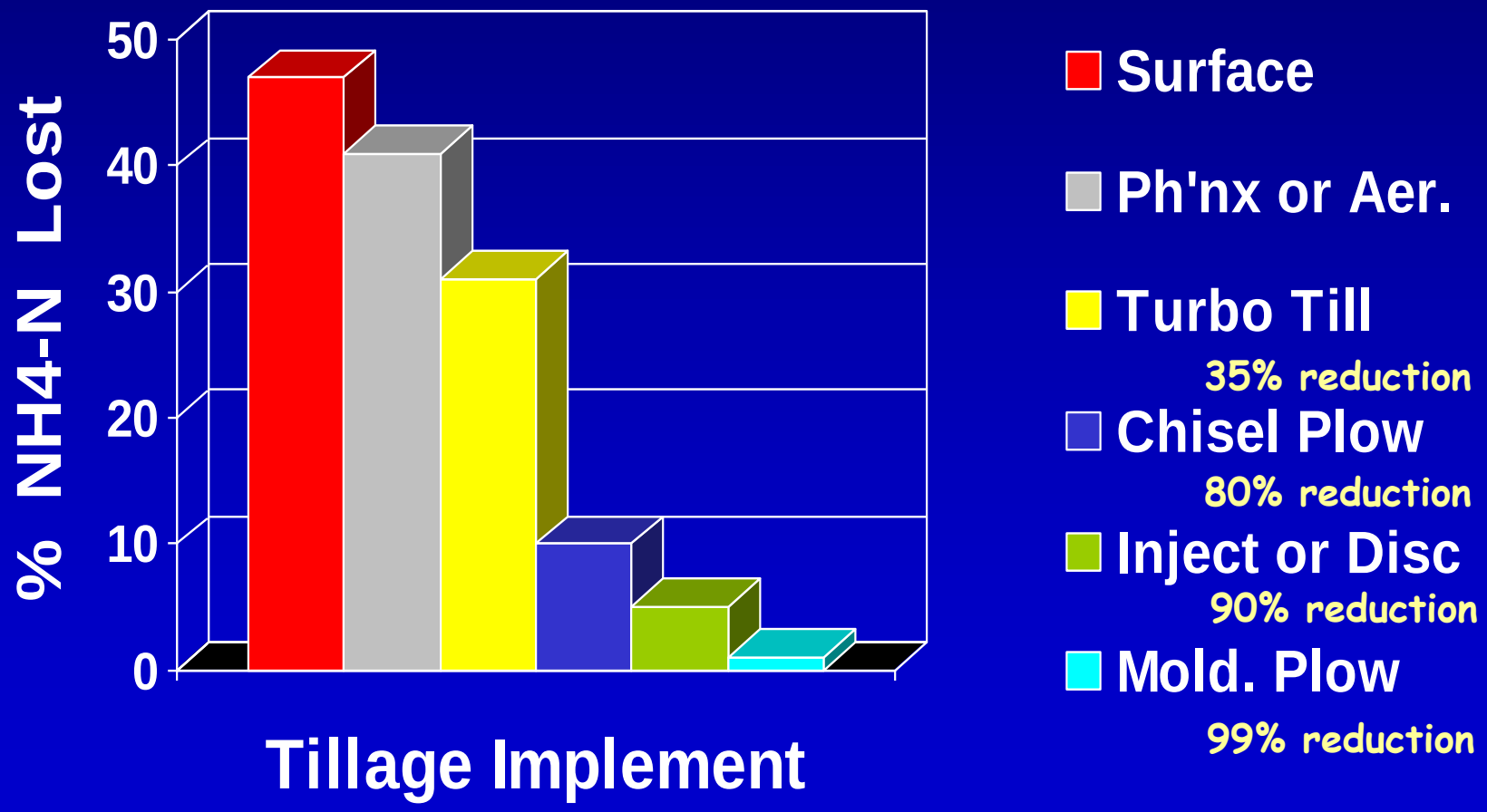
Tillage to Control Ammonia Loss

Timing is critical!



Tillage Effects on NH_3 Loss from Dairy Slurry, 7days

(Thompson & Meisinger, 2002, Meisinger unpub. 2009)



Manure N and Silage Corn Yields

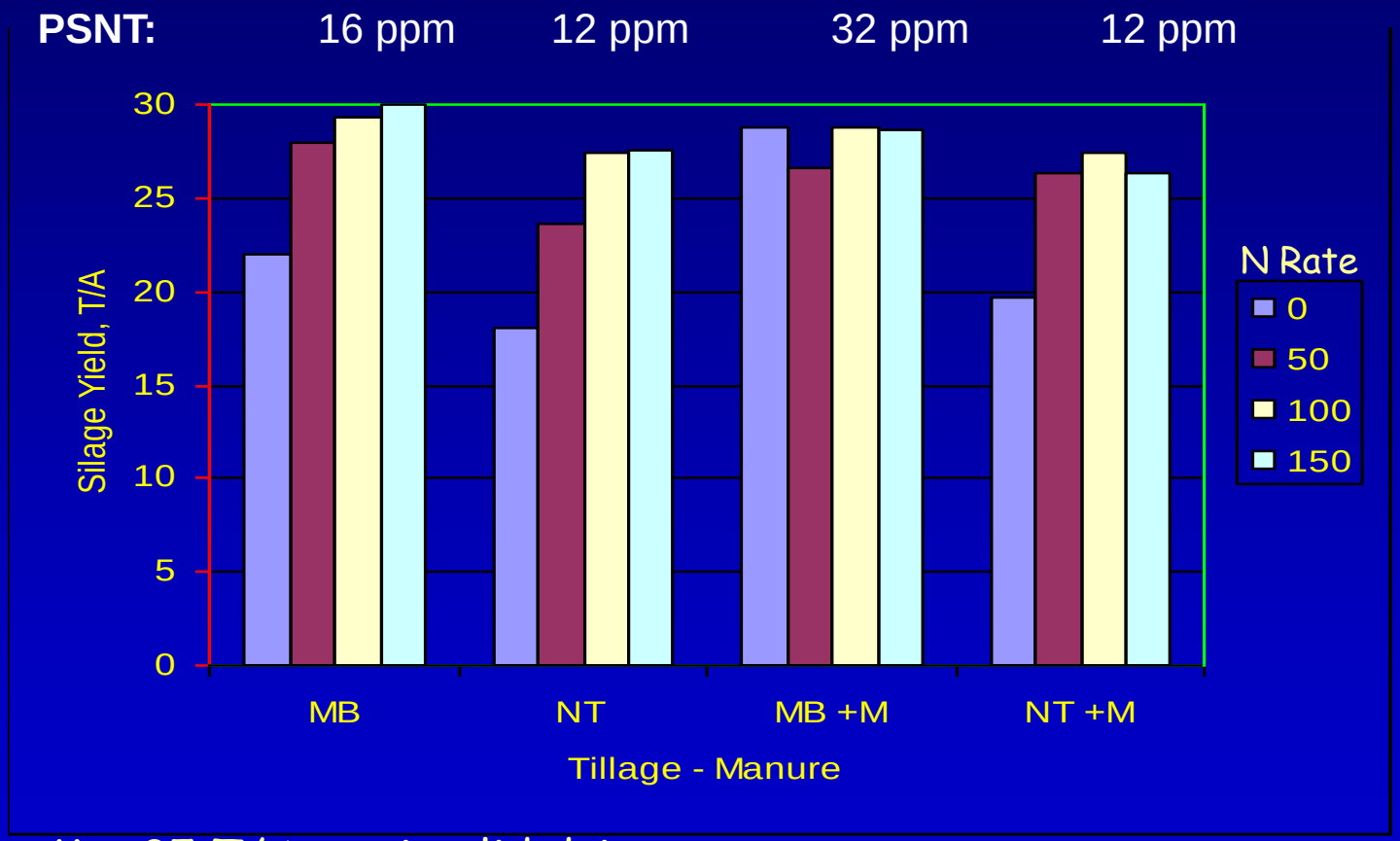
Tillage x Manure x N Fertilizer, VT

- Tillage Methods
  - Moldboard Plow
  - Chisel Plow
  - No-till
- +/- Dairy manure
  - 25 T/A semi-solid
- Fertilizer N
  - 0, 50, 100, 150 lb/A

Jokela, 2004

Manure, Tillage, and Fertilizer N Effects on Corn Silage Yield

No-till vs. Moldboard Plow Incorporation



+ M = 25 T/A semi-solid dairy manure
MB Moldboard Plow; NT No-till
Spring manure and tillage

VT, Jokela et al

Direct Incorporation Methods

Sweep Injection

Benefits

- Assure immediate incorporation to conserve NH_3
- One operation for manure and tillage
- Options for conservation tillage

Limitations

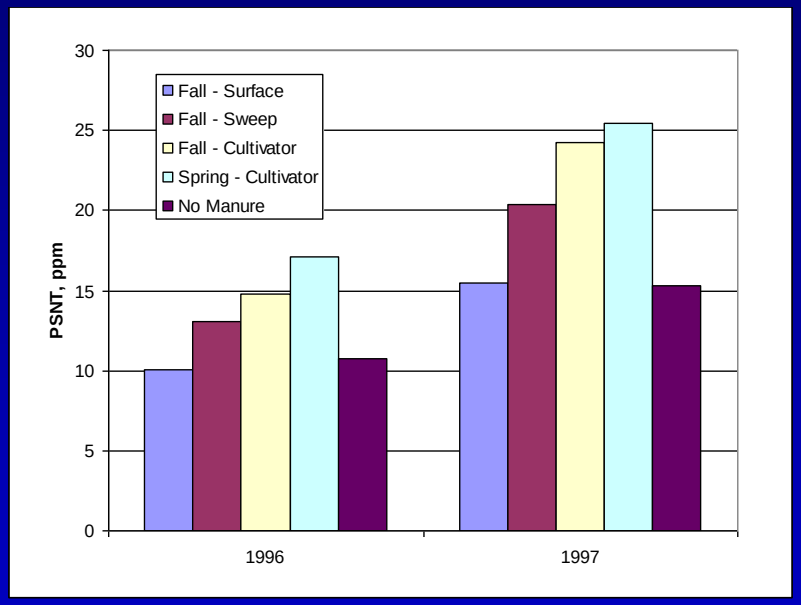
- Slower application
- Higher power requirement

Many Options

Manure Application Method and Timing and N Availability (PSNT)

- Liquid Dairy Manure (8000 gal/A)
- Corn for silage
- Application Methods
  - Surface bdcst (fall)
  - Sweep injection (fall)
  - Shallow s-tine cultivation (fall and spring)

PSNT Results



Corn silage yields followed similar trends

Jokela et al., 1999

Corn yield as affected by method of liquid manure application.

Application Method	Grain Yield 5-site avg.*
	bu/A
Control (no manure)	89
Broadcast (7 day incorp.)	107
Vertical knife injection	115
Horizontal sweep injection	123

* Sites = Dairy = 2, Hog = 3. Minnesota, 1992-93

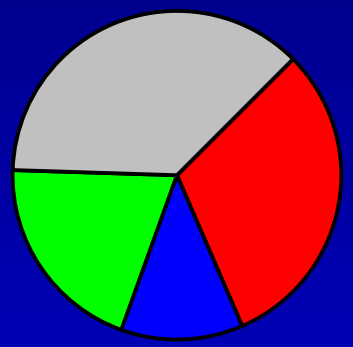
Schmitt et al 1995

Credit: G. Randall

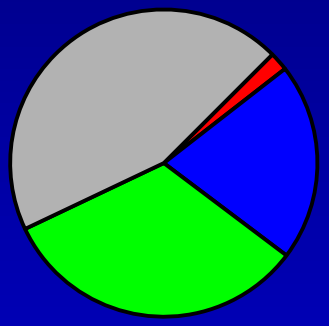
N Budget for Slurry Placement

(Thompson et al, 1987; UK)

Surf. Broadcast



Injected



- NH3
- Denitrification
- Crop N
- Soil Org. N

Application Method and Incorporation Effects on NH_3 and Denitrification Losses

Liquid Dairy Manure on Corn, Marshfield, WI.

Manure Application (6500 gal/a)

- Broadcast vs injection
- Time of incorporation
- Pre-plant and sidedress

Jokela and Laboski, Unpubl. 2010

Prelim. 2010 results Pre-Plant Manure

NH_3 Emission Rates

- Surface >> Disk > Inject

N_2O Flux

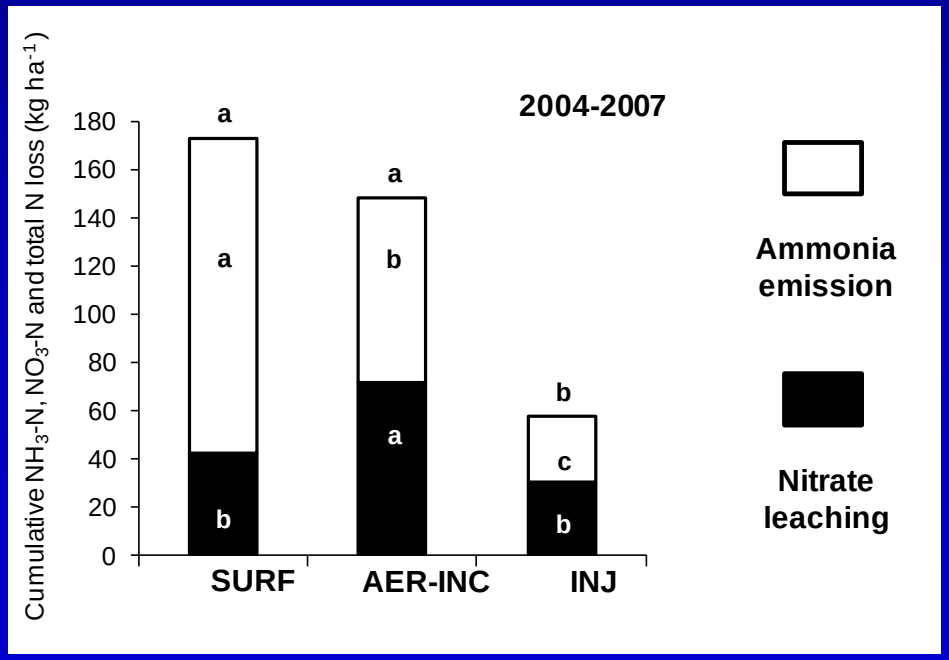
- Inject > Disk > Surface
- N_2O-N << NH_3-N but environmentally important

Application Method Effects on NH_3 and Nitrate Leaching Losses

Liquid Dairy Manure, No-till Silage Corn, Prairie du Sac, WI.

Application Methods

- Injection
- Partial incorporation (aerator)
- Surface application



(Powell, Jokela, and Misselbrook, 2011)

NH_3 and Other N Losses from Liquid Dairy Manure

- Greatest NH_3 emission rate first 6 to 24 h after application
- Injection or incorporation reduced NH_3 loss, but…
  - Possible trade-off with N_2O emission (Marshfield)
  - Possible trade-off with NO_3^- leaching (PduSac)
- Need to adjust manure rate to account for reduced NH_3-N losses
- Consider alternative injection/incorporation methods

Another Alternative: Sidedress Manure?

Injected liquid swine manure in Ontario

Potential Benefits

- Another window to apply manure
- May be drier conditions
- Good N availability and yields
- Can use PSNT to determine rate

Ontario: Ball-Coelho et al. 2005

Is manure incorporation compatible with conservation tillage?



Tillage: manure and residue incorporation




Low-disturbance options

Another option: "Zone-jection"

- Combines zone- or strip-tillage and manure injection

Ball-Coelho 2005, 2006 Ontario

What about manure on grass/perennial forages?

Surface Broadcast Application

- Fast and relatively inexpensive, but…
- Large ammonia-N losses
  - Economic loss for crop
  - Inconsistent crop response
- Can damage sward and contaminate forage
- Poor uniformity
- Runoff losses of nutrients and pathogens

Injection on Grassland

Sweden

MN

Alternatives to Surface Broadcast

Drop-hose/Surface-band

Sweden

Sliding Shoe/Trailing Foot/
Drag-shoe/Sleigh-foot

Quebec

BC

Application Methods Effects on NH_3 Losses on Grassland in Europe

Application Method	NH_3 Loss Reduction*
Surface Band	20-60%
Sliding-shoe/ trailing-foot	40-75%
Shallow Injection	60-95%

* Compared to surface broadcast application, typically 40-75% of applied NH_4-N

Stevens and Laughlin 1997; Huijsmans et al 2001; Sommer and Hutchins 2001

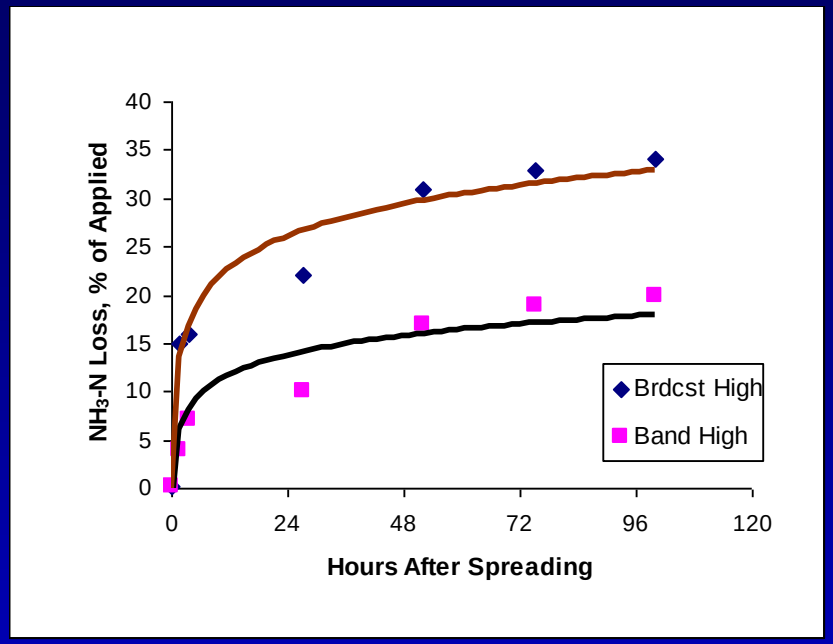
Ammonia Losses

- High variability across experiments

Yields (vs surface broadcast)

- Typically higher with surface band or sliding-shoe (vs surface bdcst)
- Decrease or increase with injection

Trailing-Foot/Band Application



Pfluke, Jokela, and Bosworth, 2011;
Carter, Jokela, and Bosworth, 2010

- Trailing-foot/Band vs Bdcst
  - Reduced NH_3 emission average of 46% (high rate) and 27% (low rate). (6-trial average)
  - Increased grass yields in 2 of 4 site-years (6-14%)

Tine-Aeration with Banded Manure
Assisted Infiltration, or
Sub-surface deposition (SSD)

S. Bittman, BC

Tine-Aeration with Banded Manure

- Ammonia Loss: 50% reduction vs broadcast
- Runoff: 50-90% lower runoff N and P
- Odor: reduced by 1/3,
- N_2O Emission: Tine-Aeration > Bdcst > Control
- Yields: Tine-Aeration > Surface Band > Broadcast

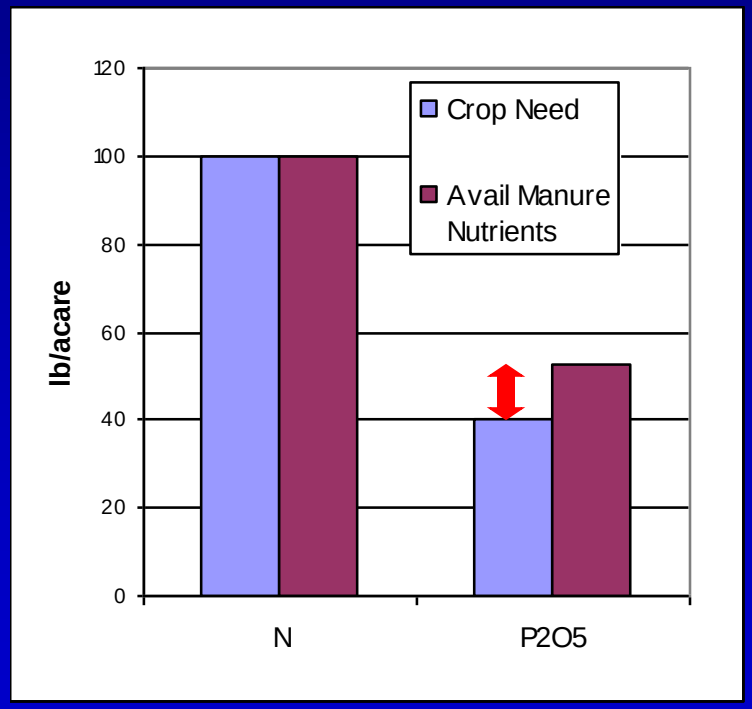
Bittman et al 2005
Van Vliet 2006

Nutrient Balance

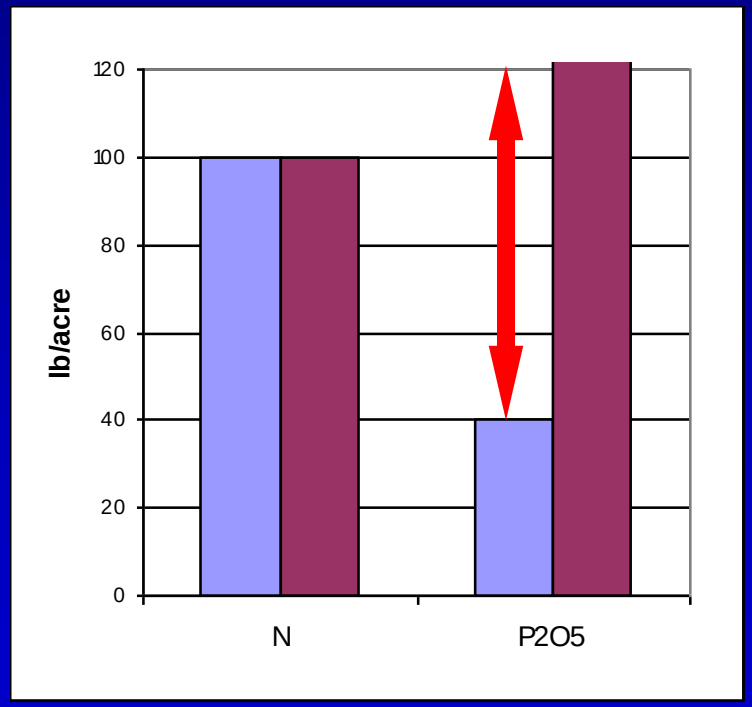
Corn/Dairy Manure

Nitrogen Basis

Quick (< 12 hrs)
Manure Incorporation



> 4-Day
Manure Incorporation

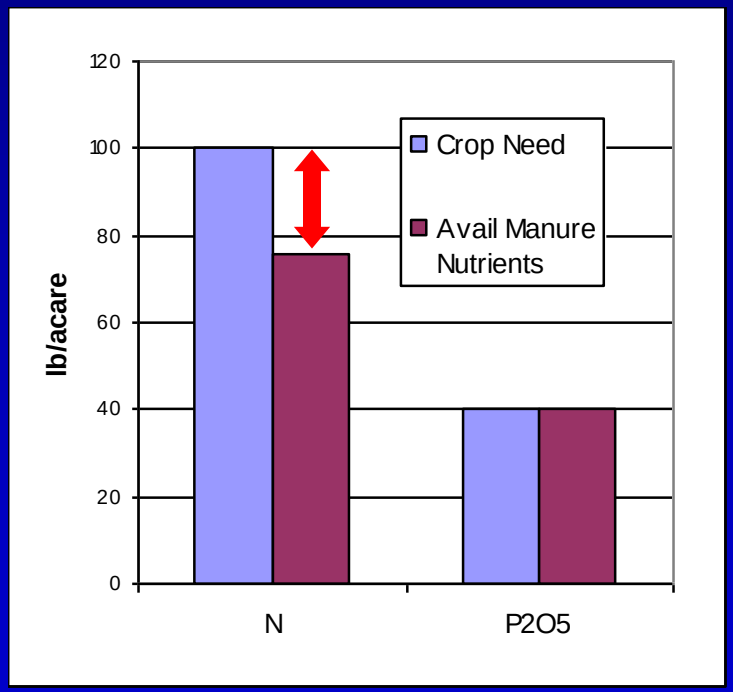


Nutrient Balance

Corn/Dairy Manure

Phosphorus Basis

Quick (< 12 hrs)
Manure Incorporation



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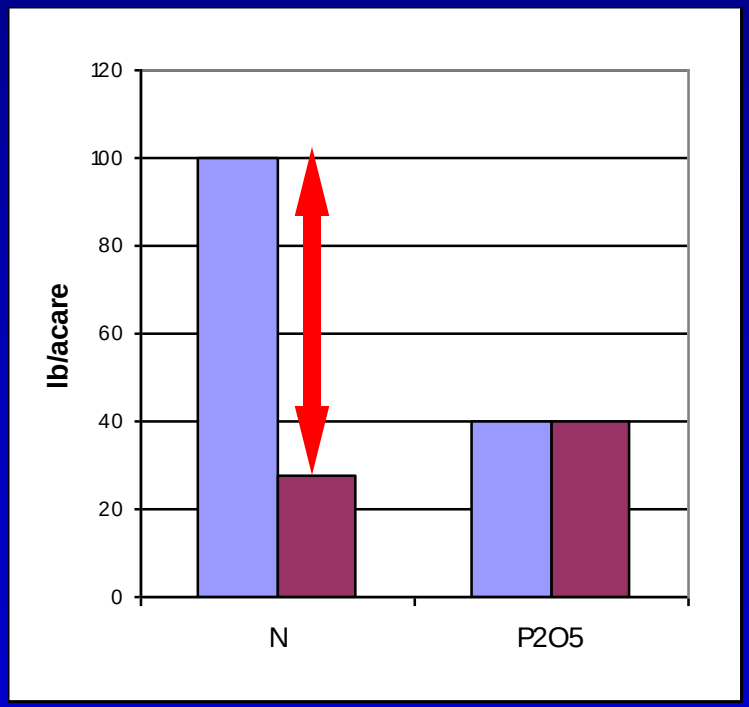

Summary: Manure Management to Control N Loss and Improve Crop Nutrient Utilization

- Poor manure management = NH_3 and other N loss, environmental problems, odor, economic loss.
- Improved management
  - Quick manure incorporation
  - Optimum rate
  - Good timing
- Several application options available for annual crops, conservation tillage, and grassland
- Improved management:
  - Better match with crop need
  - More efficient use of manure nutrients
  - Less impact on environment