

U.S. Dairy Forage Research Center

USDA, Agricultural Research Service

Redesigning Alfalfa For Dairy Cattle

Leading Producer Conference

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Neal P. Martin, Ron Hatfield and David Mertens

Research Lab, Madison, WI

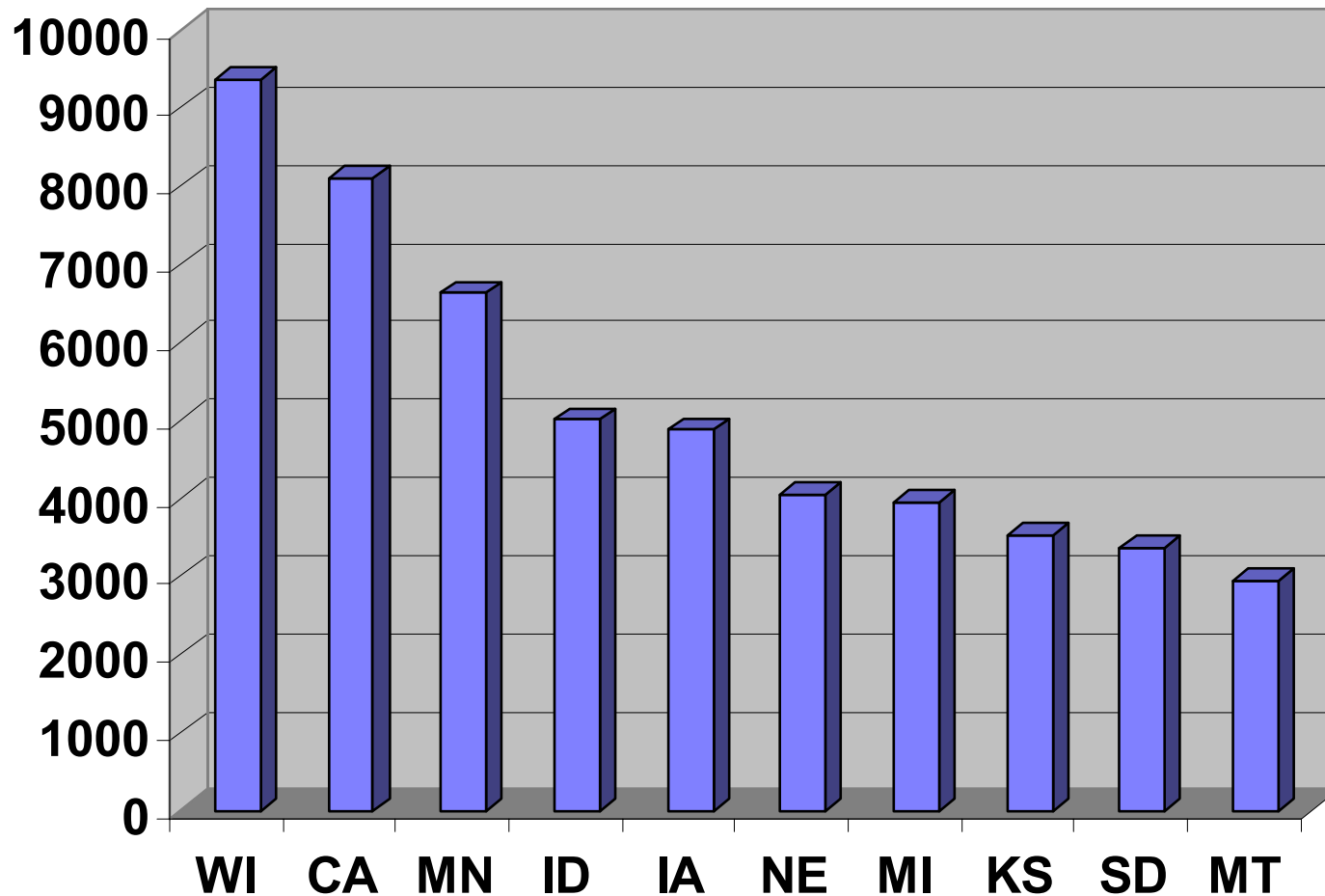
Research Farm, Prairie du Sac, WI



Redesigning Alfalfa For Dairy Cattle

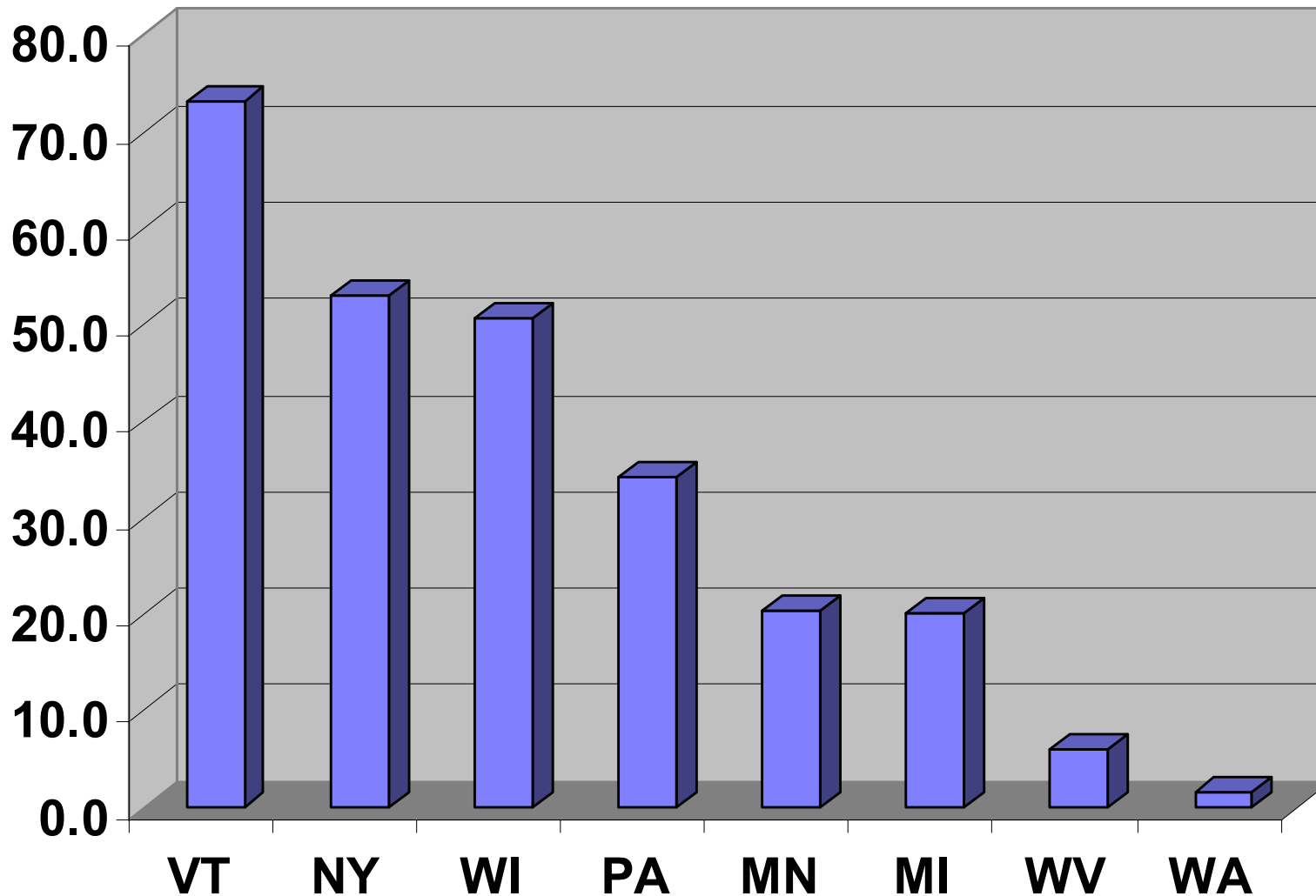
- **Advantages of alfalfa for dairy operations**
 - Outstanding dairy forage
 - Crop rotations
 - Can be a nitrate scavenger
- **The perfect alfalfa plant on dairy farms**
- **Future innovations needed to develop perfect plant**

Leading Alfalfa Forage Production States, 1,000 tons, 2002



- **Top 10 States**
 - 62 % of U. S.
 - 61 % of Acre
 - 4 states NC
 - 6 states West
 - 5 Lead Dairy

Percent of Total 2002 Alfalfa Production - Haylage



Alfalfa – Outstanding Forage for Dairy

✓ High nutrient content

Protein, Minerals

✓ Good fiber digestibility

✓ Rapidly digested

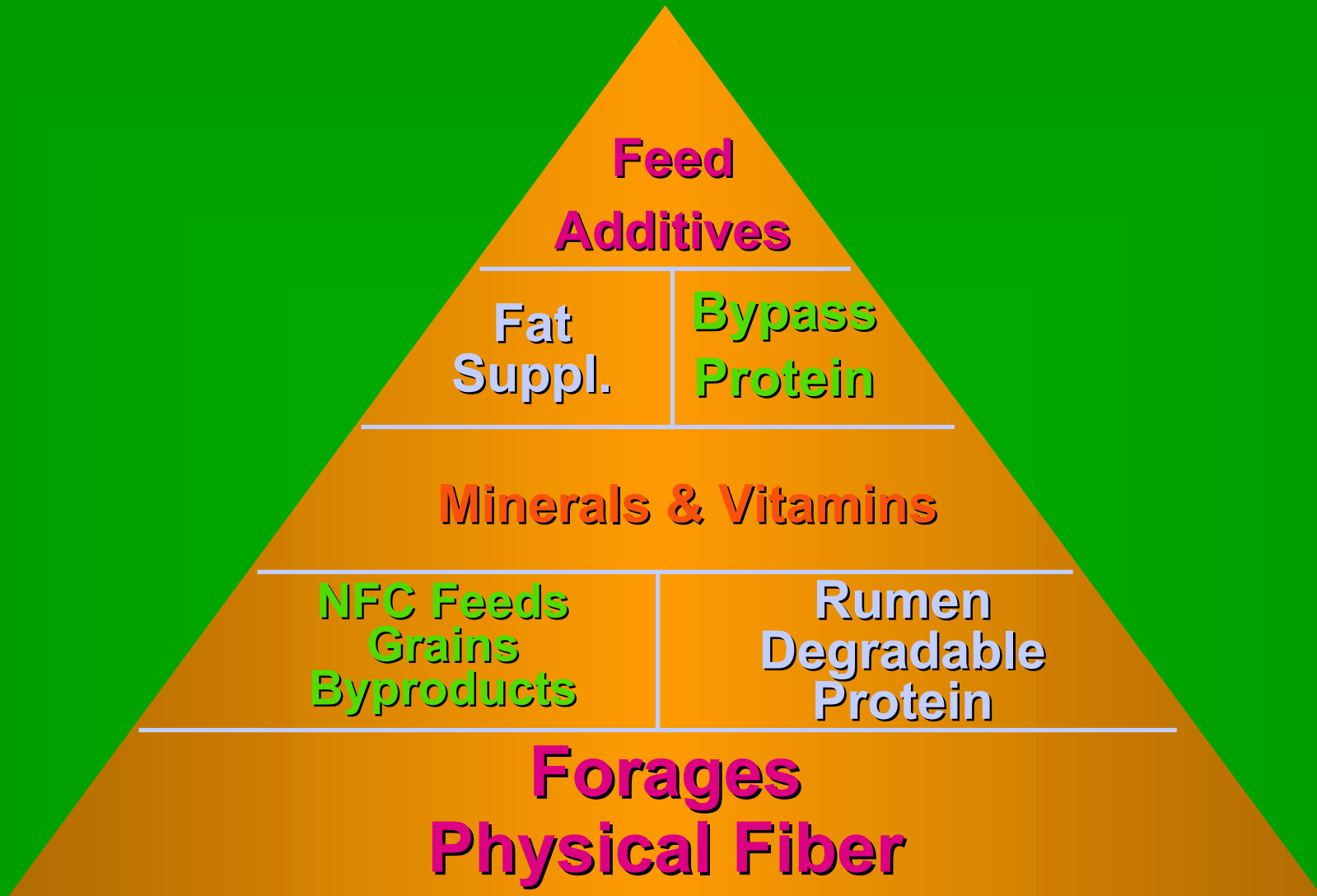
✓ Supports high DM intakes

✓ Supports high milk production

✓ Cows like it



SOURCE: Jim Linn, University of Minnesota



The Feed Pyramid

Rick Lundquist, 1996

SOURCE: Jim Linn, University of Minnesota

Improvements in Alfalfa

■ Improvements in Nutritional Value

- Unique feeding value of alfalfa for dairy cows is its effective fiber and its associated energy value.
- Improved management has resulted in lower NDF levels in alfalfa fed to day cows
- Need to obtain additional energy by increasing digestion rate of fiber

Increasing Digestible Fiber of Alfalfa

Changes in dNDF	CP	NDF	dNDF	TDN
	-----% of dry weight-----			
20 % higher	22	36	68	67.4
10 % higher	22	36	58	64.3
Assumed now	22	36	48	61.3
10 % lower	22	36	38	58.3

Adapted from Robinson, 1998

Alfalfa in Crop Rotations:

- **Adds nitrogen via biological fixation**
- **Improves water infiltration and soil quality**
- **Reduces soil erosion from wind and water**
- **Improves yield of subsequent crop**
- **Reduces N fertilizer demands of subsequent crops**

Alfalfa in Crop Rotations:

- Helps protect surface and ground water
- Acts as waste-water recycler

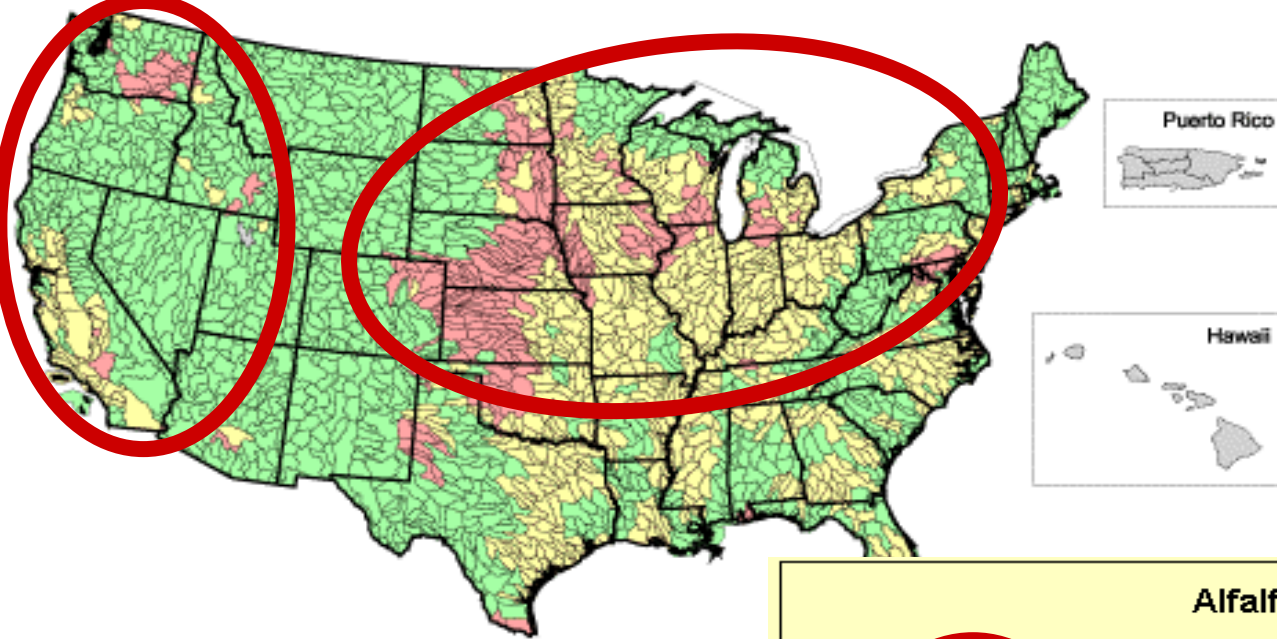


Alfalfa in Crop Rotations:

- **New non-fixing alfalfa developed to increase N uptake from soil**
- **New alfalfa developed for rapid root growth to quickly capture nutrients**



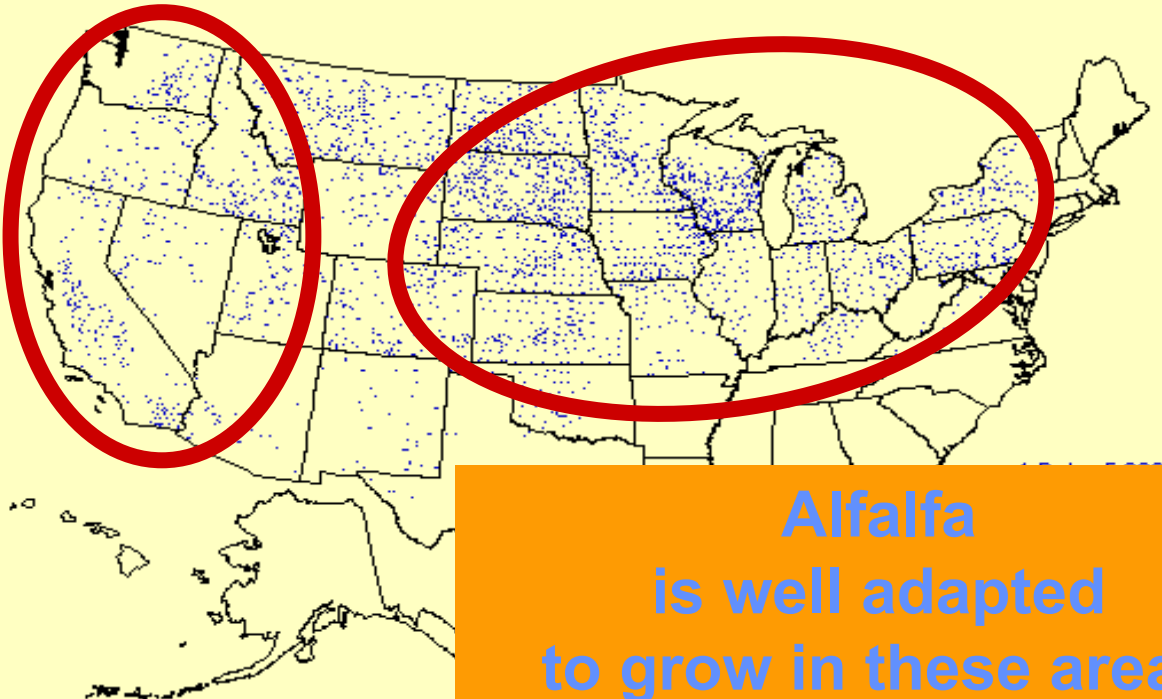
Risk of ground water nitrate contamination



Risk of Groundwater Nitrate Contamination (1970 - 1995)

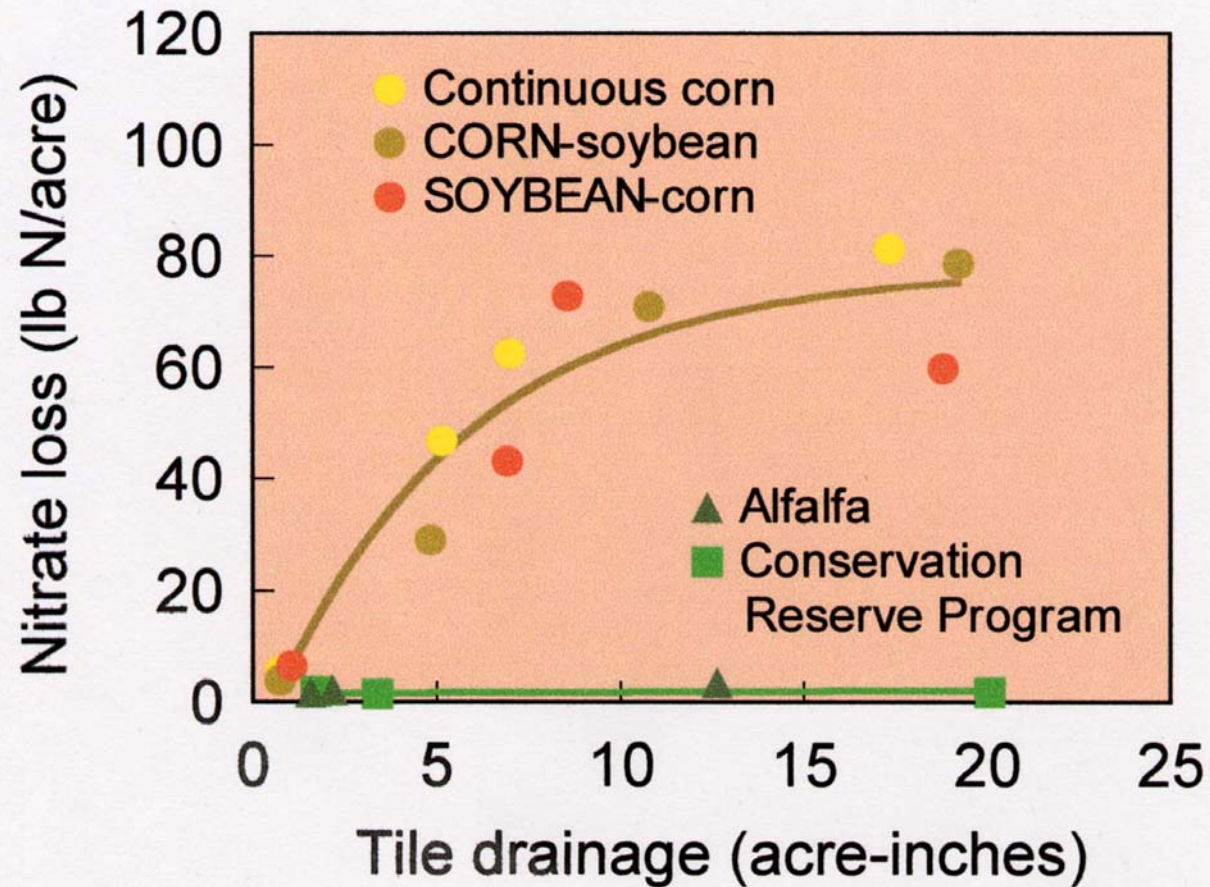
- Low Risk
- Moderate Risk
- High Risk
- Insufficient Data

Alfalfa Hay Harvested: 1997



Alfalfa is well adapted to grow in these areas

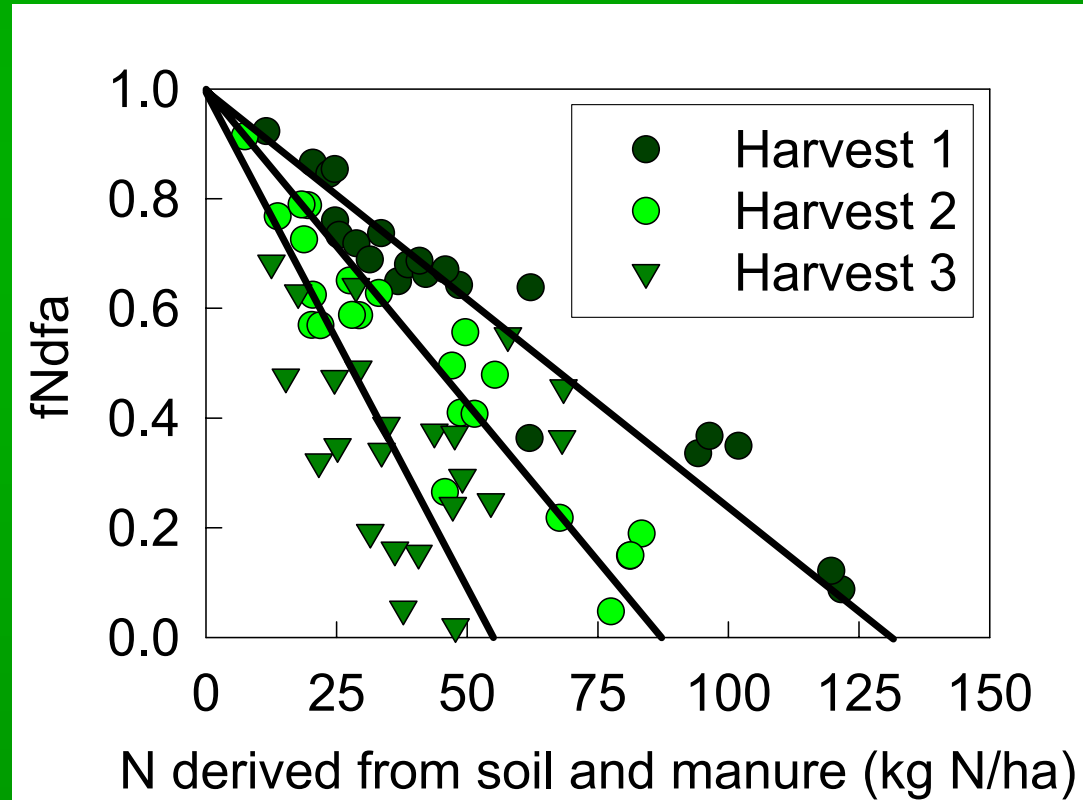
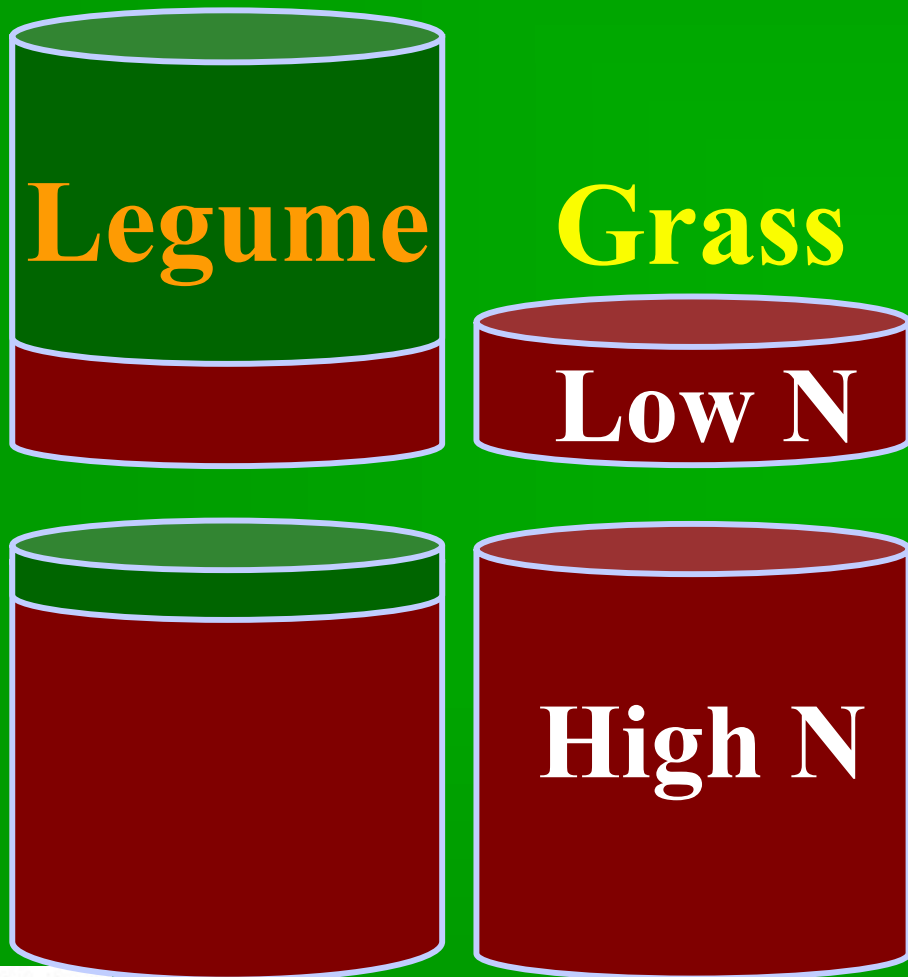
Alfalfa and grass CRP effectively filter tile drain water



>40 million acres are tile drained
in the Upper Midwest

Randall, Huggins, Russelle et al., 1997

Legumes serve as N buffers





Manure alone



Manure + NaCl



Manure + NH₄



Manure + NaCl + NH₄

Limitations of Alfalfa on Dairy Farms

- **Expensive to produce, harvest & store**
 - Low yields
 - Harvest equipment and storage costs
 - Time and labor of multiple cuttings
 - Variation of quality within and between cuttings
- **Excessive Non-protein nitrogen in silage and the rumen**
- **Low fiber digestion**

The Perfect Alfalfa Plant

- Yield of individual cuttings high enough to reduce number of cuts per year (2 or 3)
- Maturation that is not strongly tied to quality
- Minimal leaf loss during growth and harvest
- Total protein available to the animal, 16-18 %, of that 30-35 % ruminal undegradable
- Cell wall digestibility ~ 80 % (20-30 % rapidly fermented pectin)
- Protein loss during ensiling no greater than 10-15 %

Alfalfa Breeding Achievements: St. Paul, MN



- Released germplasm with resistance to *Phytophthora* and other diseases.
- Modified N_2 -fixation and improved N and C assimilation by alfalfa.
- Developed a biomass-type alfalfa to increase stem yield without loss of leaf production.

Cow Performance - High Alfalfa Silage

Item	Control ¹	Protein ²	Fat ³
DM intake, lb	48.4 ^b	55.9 ^a	49.5 ^b
BW gain, lb	50.6	48.4	33.0
3.5 % FCM, lb	63.4 ^c	75.0 ^a	67.5 ^{bc}
Milk protein, lb	1.89 ^b	2.29 ^a	1.94 ^b

¹ 75 % alfalfa silage, 23.2 % HMS Corn – no protein suppl

² Control plus 6 % fish meal, 2.1 % blood meal

³ Control plus 5 % fat (hydrolyzed animal fat)

^{abc} Means in same row with different superscripts differ (p<0.01)

SOURCE: Dhiman and Satter, 1993. J. Dairy Sci 76: 1960-1971.

The “Queen of Forages” has a problem...

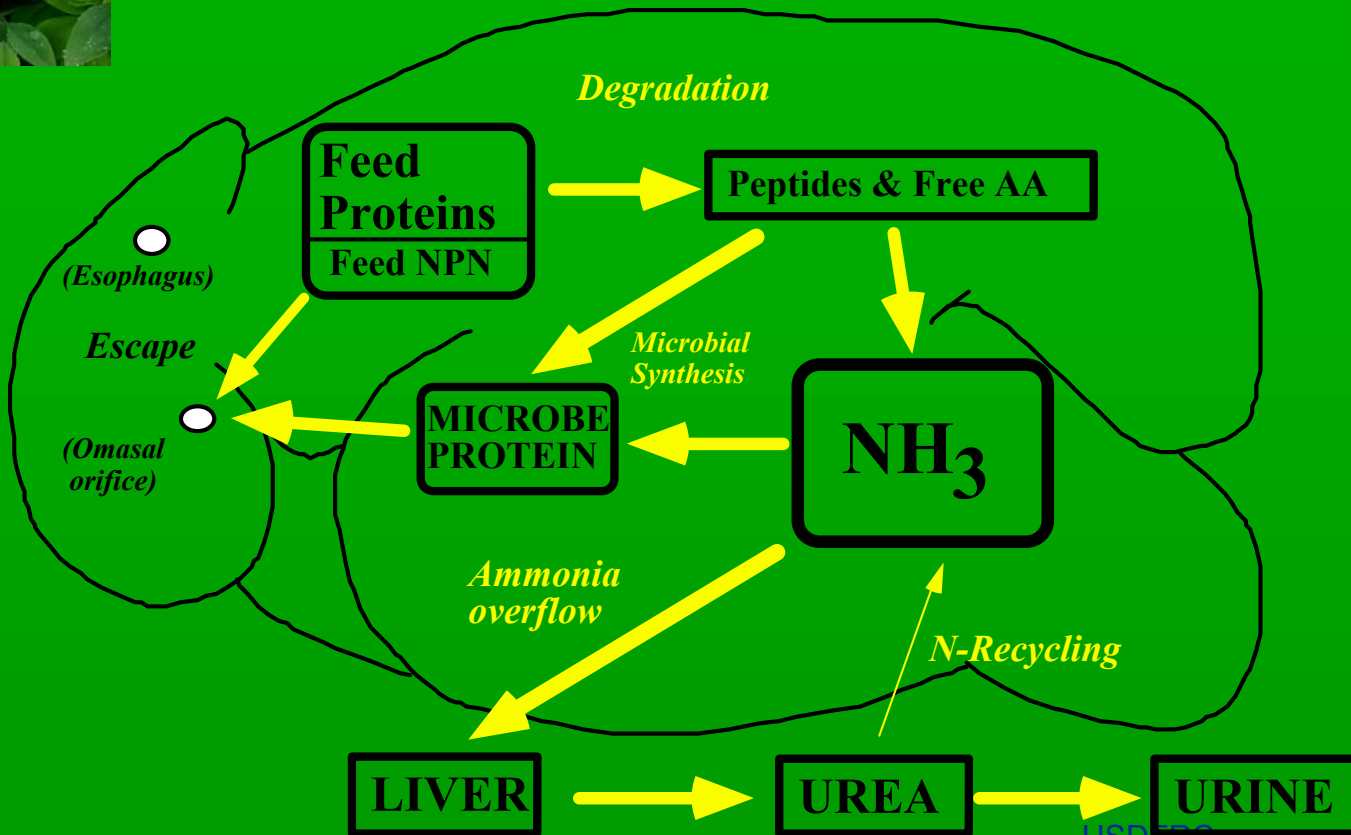
EXCESSIVE protein breakdown in the silo & rumen



- Plant proteases degrade about 50% of the protein in alfalfa silage
- Rumen bacteria degrade about 50% of the remaining plant protein



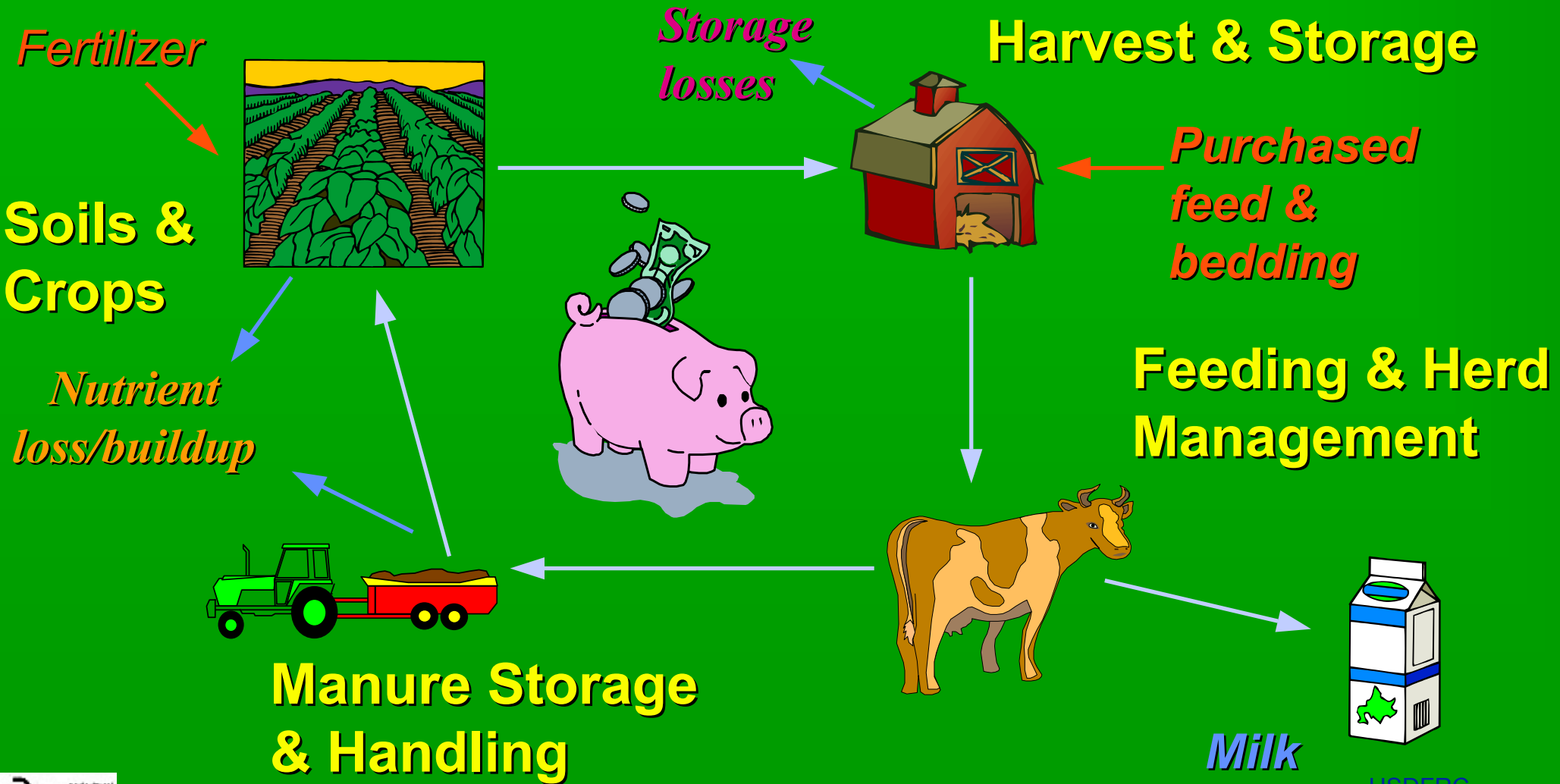
**Alfalfa protein is wasted
20+% protein in the field
5% protein exits the
rumen**



Tannins improve protein utilization

- Condensed tannins are polyphenolic compounds that bind to protein in the pH range 3.5 to 7, potentially protecting protein in the silo, rumen, & soil
- Protein-tannin complexes dissociate at pH <3.5 and >8.5, permitting digestion in the gastrointestinal tract of cattle
- Livestock given tannin-containing feeds need less protein supplementation and excrete less urea
- Tannins slow nitrogen release from crop residues and manure
- Major U.S. feedstuffs, including alfalfa, have inadequate tannin levels to protect protein (< 0.2% DM). Probably about 2% tannin is needed.

Evaluated the potential impact of tannins on dairy farms with DAFOSYM



Farm description

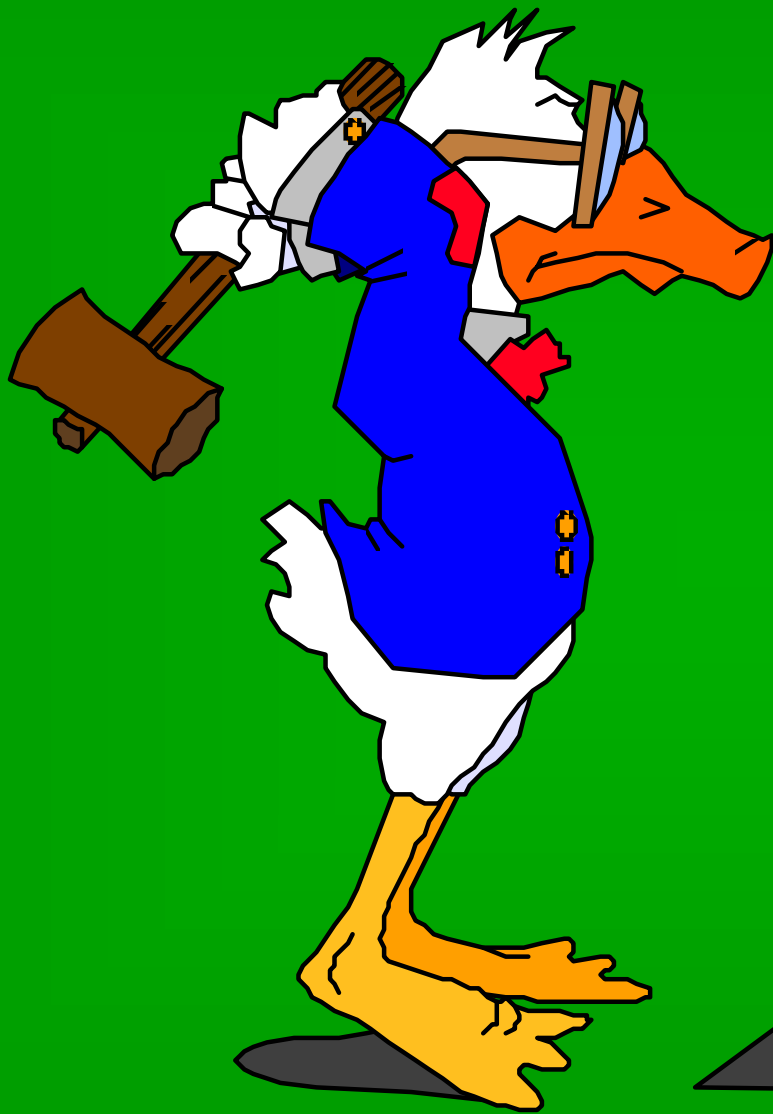
- 100 cows, 85 heifers
- 250 acres of medium silt loam soil in south central Wisconsin
- No-till alfalfa grown for silage or hay
- No-till corn grown for silage and grain
- Forages stored in bunker silos
- Manure shallow injected spring and fall with low ammonia loss (20%)



Herd feeding & management

- Forage comprised 45 to 60% of the diet for lactating cows
- Forage portion was 30 to 70% alfalfa silage or hay with corn silage fed in a TMR with corn grain, roasted soybeans, soybean meal, and fat
- Cows injected with BST and milked 2x daily
- Manure & bedding scraped daily and pumped into base of lagoon with 6-month storage





Milk production (lb per cow)

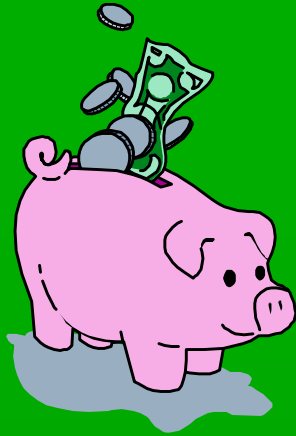


Alfalfa silage

70% 50% 30%

■ Normal alfalfa	27,160	27,460	27,800
■ Tannin alfalfa	27,620	27,830	28,000
■ Tannin impact	+ 460	+ 370	+ 200

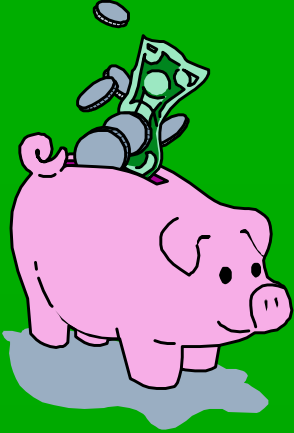
Net return to management (\$ per cow)



Alfalfa silage

	70%	50%	30%
■ Normal alfalfa	1,145	1,185	1,193
■ Tannin alfalfa	1,270	1,283	1,247
■ Tannin impact	+ 125	+ 98	+ 54

Added value of forage with tannin (per ton dry matter)



- Alfalfa silage \$ 23
- Alfalfa hay \$ 11

Gaseous nitrogen losses from farm (t)

Alfalfa silage

70% 50% 30%

■ Normal alfalfa	14.7	10.9	10.0
■ Tannin alfalfa	11.2	8.3	9.5
■ Tannin impact	- 3.5	- 2.6	- 0.5

Nitrogen losses from farm by leaching (t)

Alfalfa silage

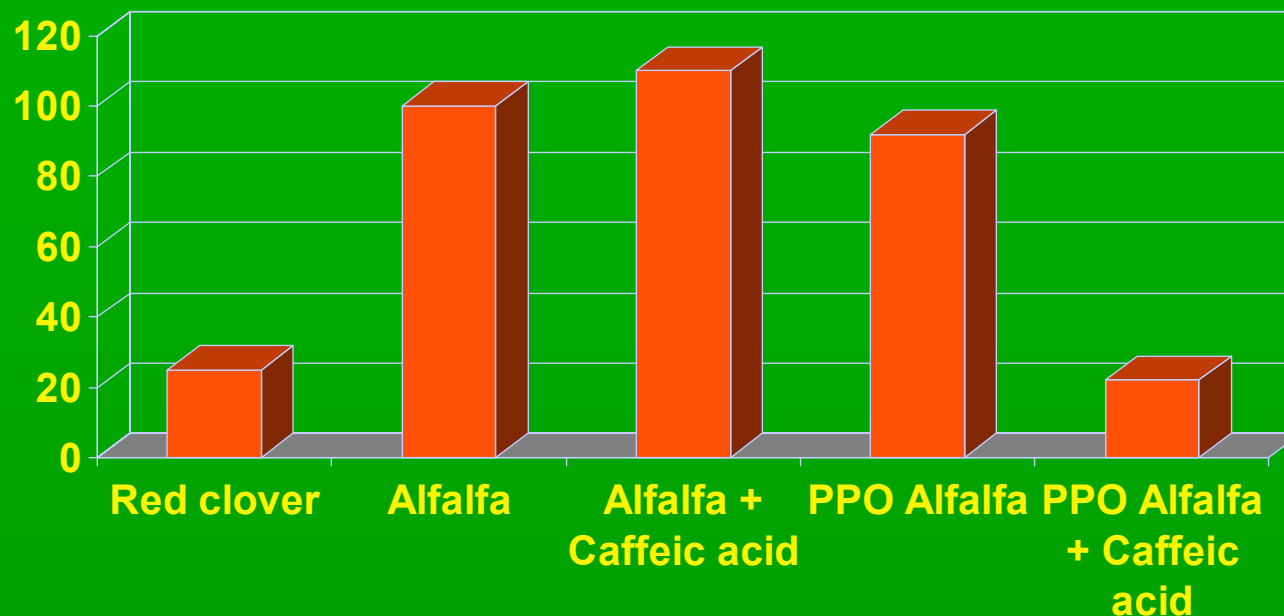
70% 50% 30%

• Normal alfalfa	2.5	1.4	1.4
• Tannin alfalfa	1.8	1.0	1.3
• Tannin impact	-0.7	-0.4	-0.1

N concentration in leachate 6 to 14 ppm, limit is 10 ppm

Red Clover vs. Alfalfa Silage

Protein breakdown (% of alfalfa)



Alfalfa can be used as a model to study the inhibition of protein breakdown in silages.

PPO = Polyphenol Oxidase gene from red clover

Strategies for decreasing post-harvest proteolysis in alfalfa silage

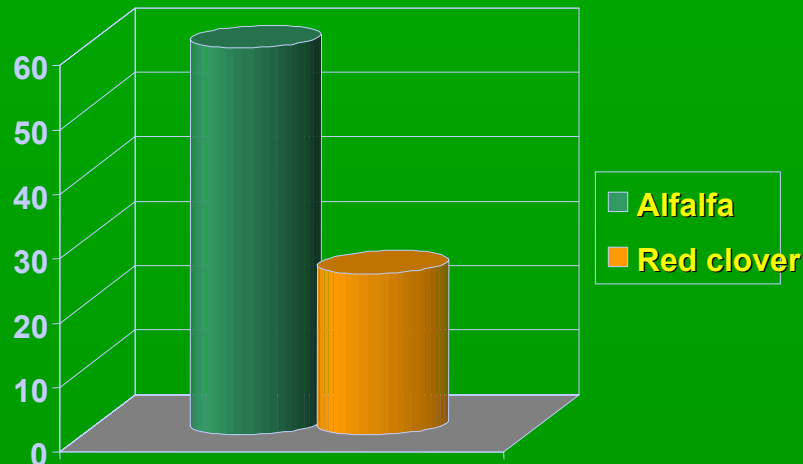
- **Some compounds bind with alfalfa protein to decrease rate of post-harvest proteolysis. Transgenic alfalfa will be produced that contain these compounds.**
 - Tannins – altered expression of genes for alfalfa tannin biosynthesis
 - Polyphenol oxidase (PPO) – gene isolated from red clover (USDA)
- **Potential “knockout” of key plant enzymes important in post harvest proteolysis.**
 - Protease

Post Harvest Proteolysis in Alfalfa

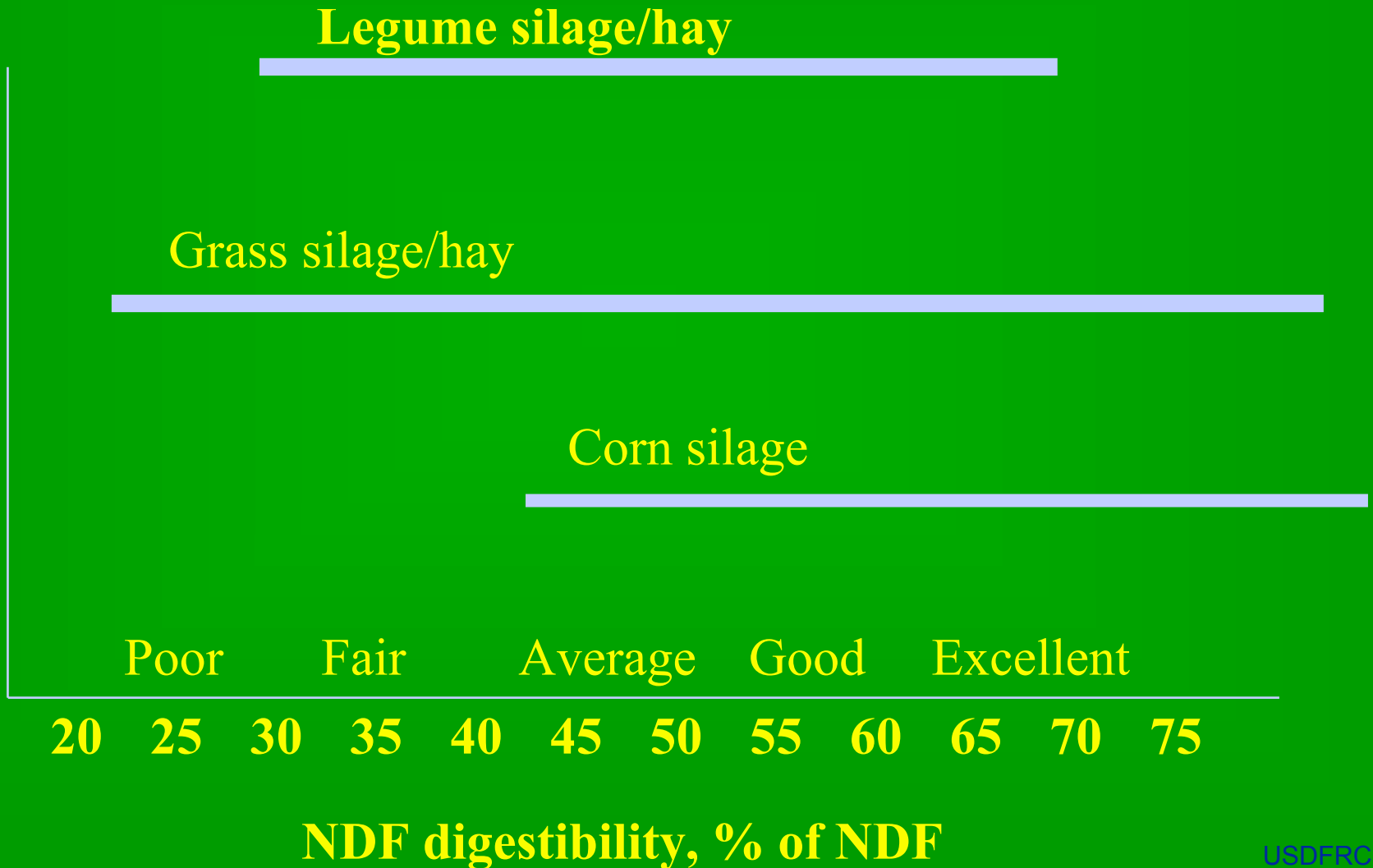
Impact on dairy production

- **Increased NPN decreases the efficiency of protein utilization in ruminants**
 - Inefficient utilization of alfalfa protein requires the feeding of supplemental protein with high RUP to maximize milk production.
 - Inefficient utilization of alfalfa protein also results in the excretion of excess rumen NH₃, leading to increased N losses to the environment.

Typical NPN content of silage

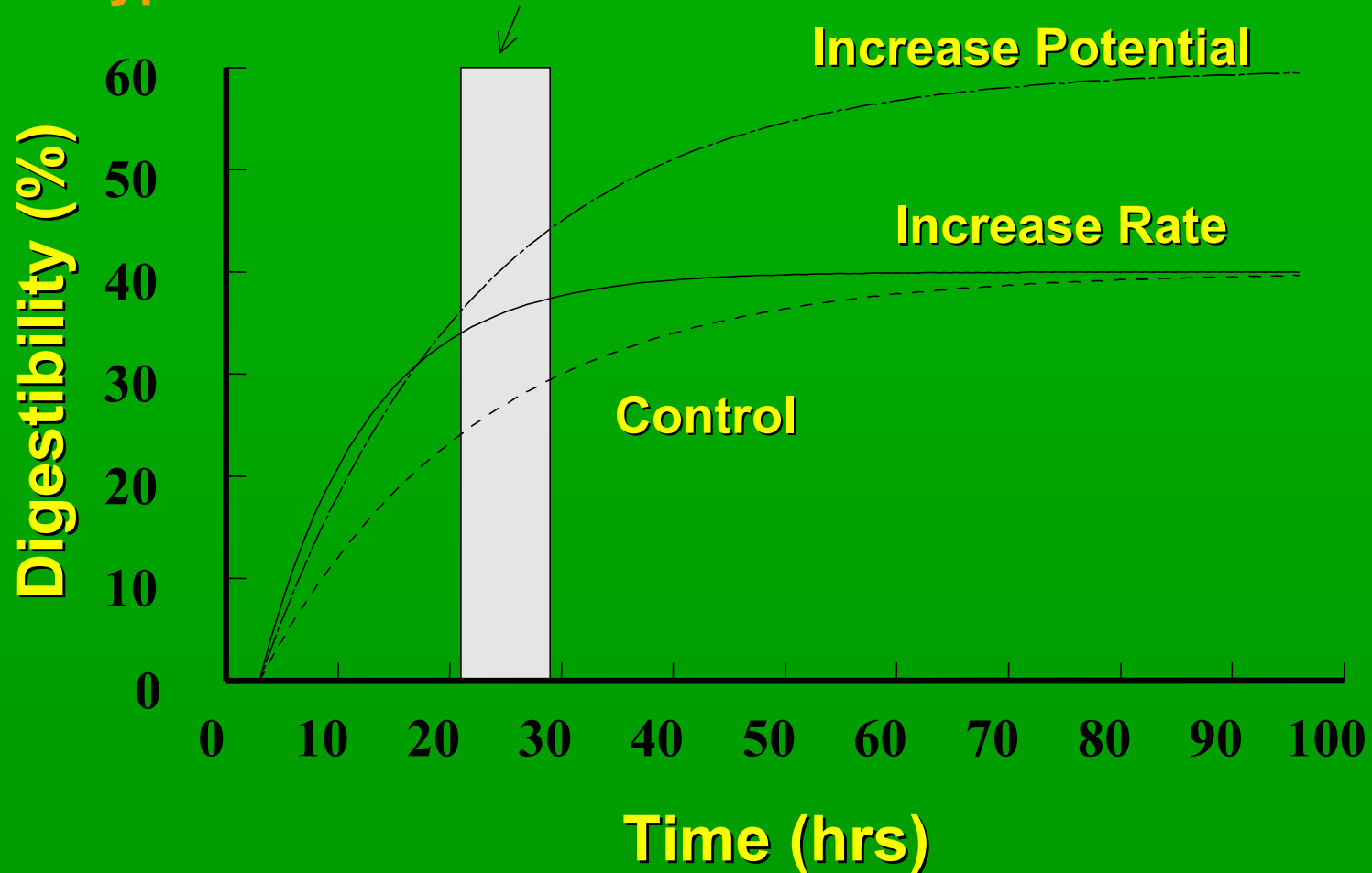


NDF Digestibility of Forages

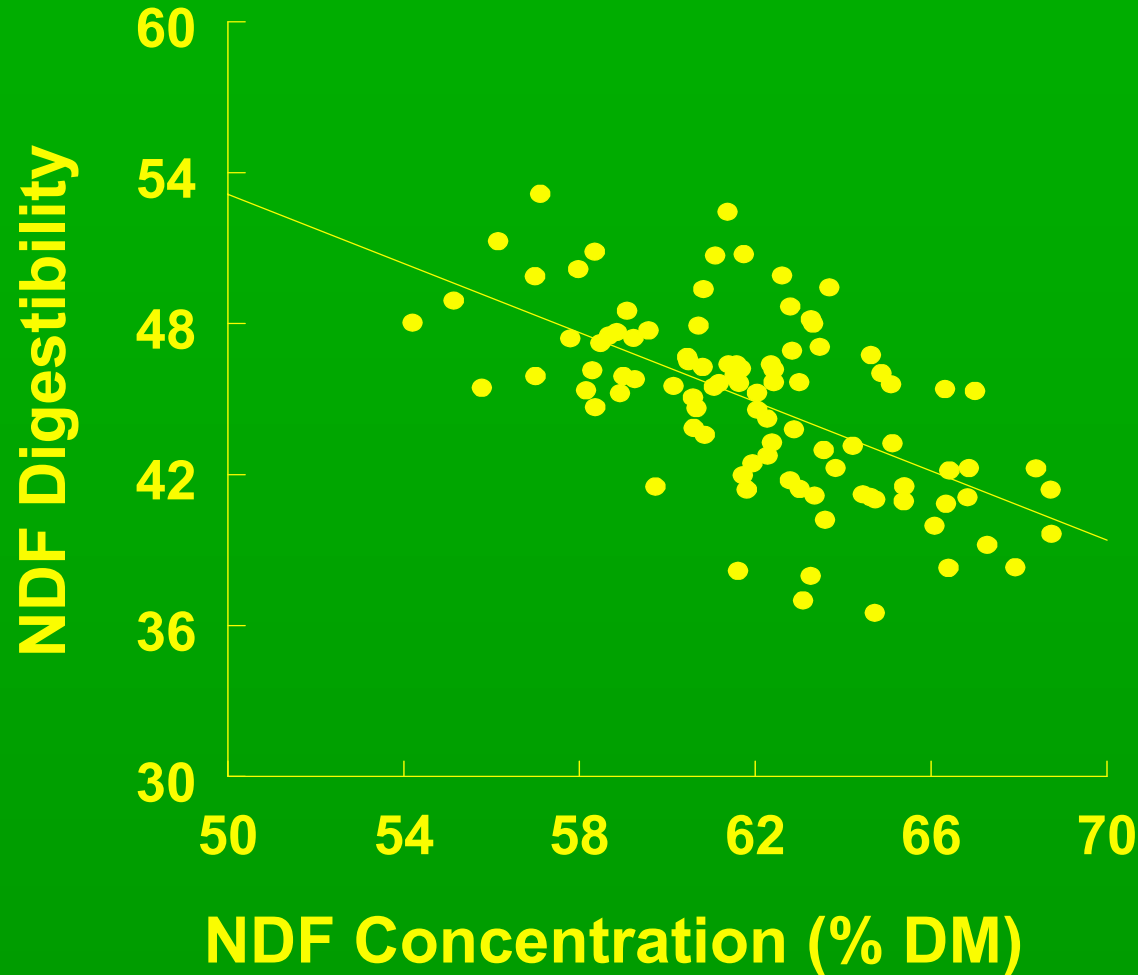


NDF Digestion Profiles

Typical Rumen Retention



NDF Digestibility of Alfalfa Stems

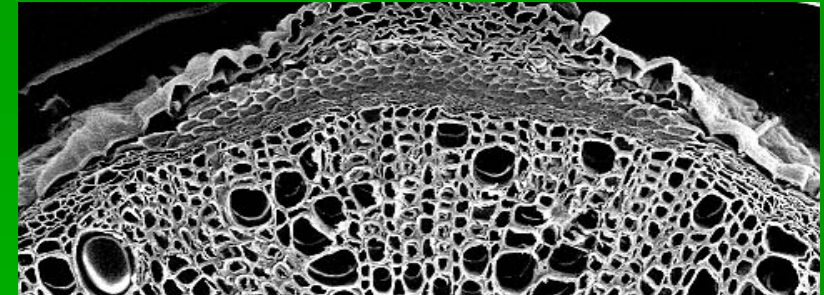
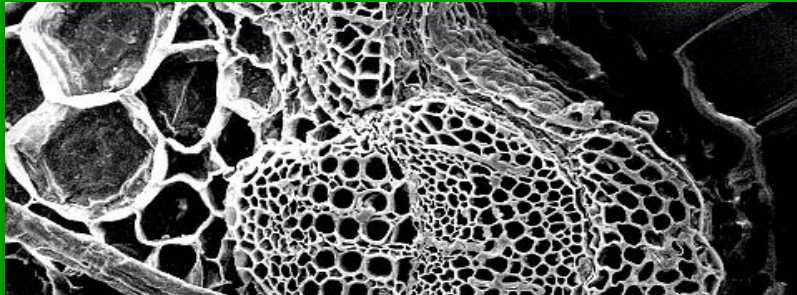


SOURCE: Jung and Lamb, 2002. Unpublished USDA-ARS. St. Paul, MN SDFRC

Rumen Digestion of Alfalfa Stem Tissue

Immature

Mature



Xylem Tissue is #1 Limitation to Alfalfa Stem Digestibility



After 48 h of Digestion

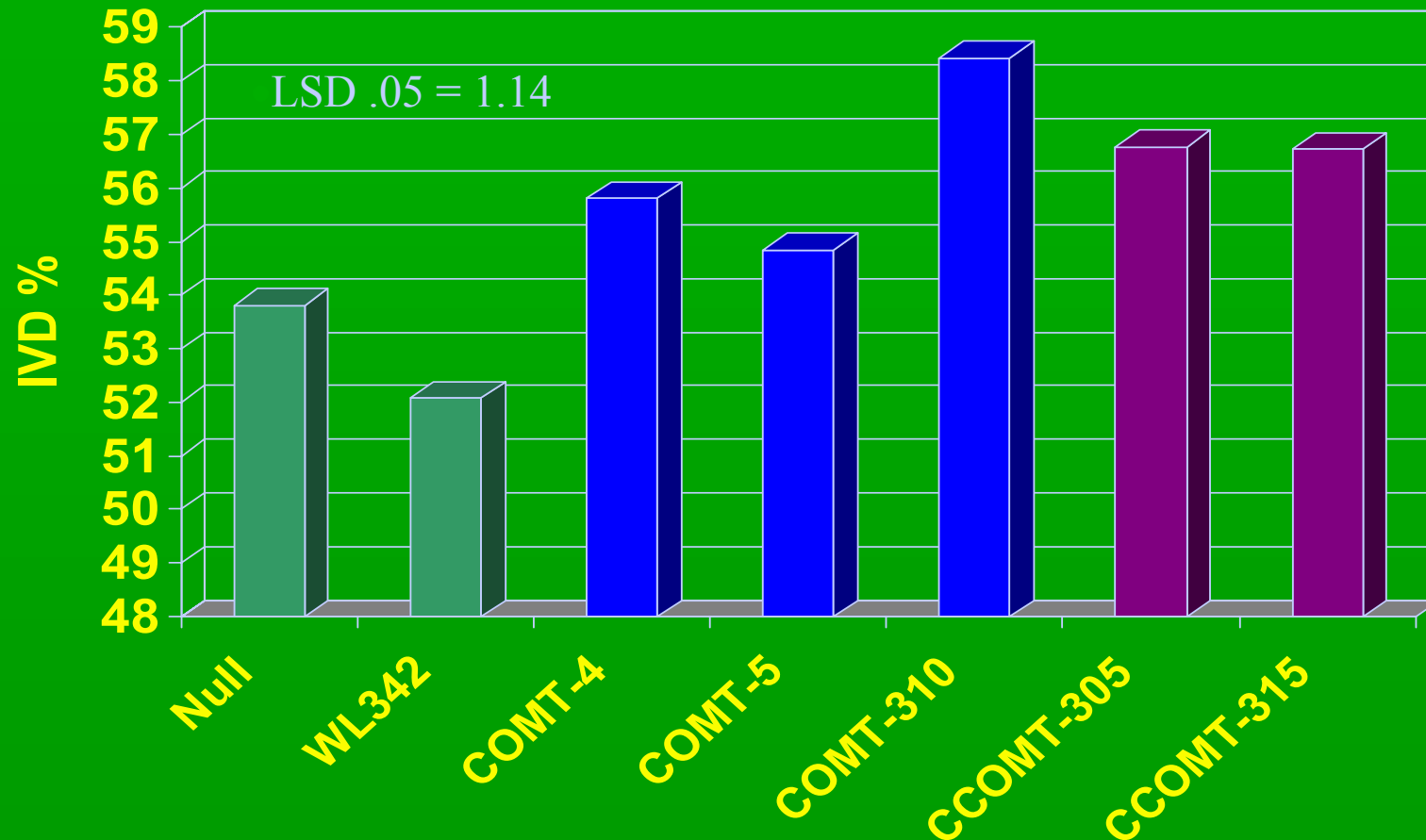
Genetic engineering for improved forage quality in alfalfa

- **Altered lignin content/composition in alfalfa**
 - **Low lignin transgenic alfalfa produced based on “knockouts” of enzymes involved in lignin biosynthesis.**

	COMT pkat/mg	CCOMT pkat/mg	Klason Lignin %	S/G ratio
Control	6.55	23.77	17.91	.47
COMT-	1.24	22.26	12.46	.04
CCOMT-	14.39	0.78	14.58	1.05
Dual-	0.78	5.59	14.72	.23

Dixon et. al., 2000

Lower Stem IVD – 2001 summary

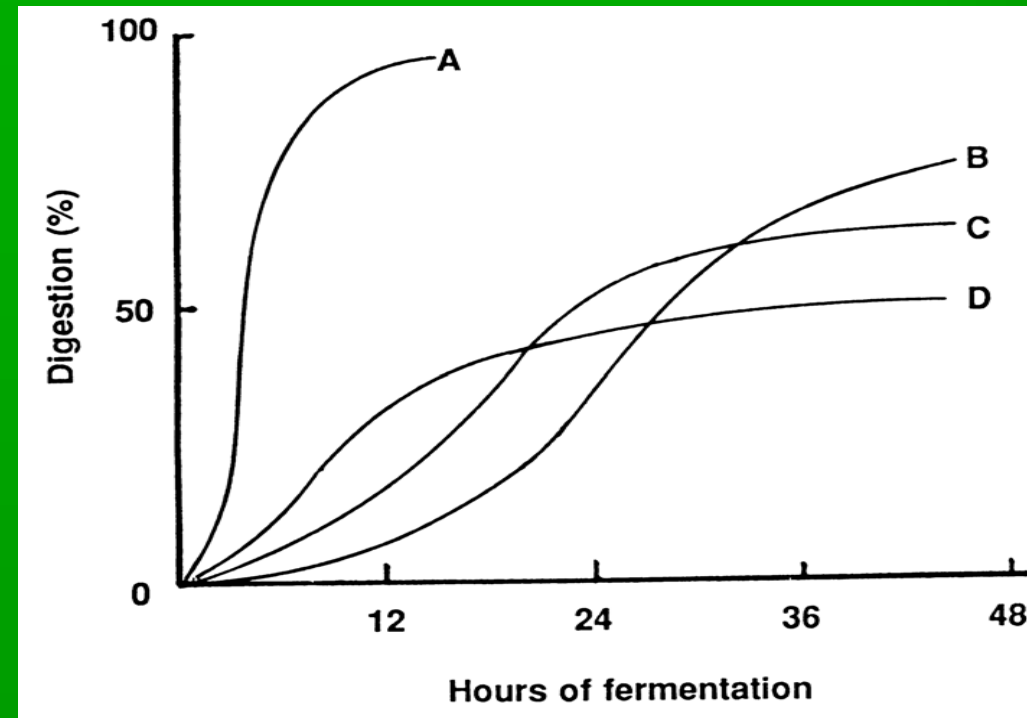


Lignin and Ferulate Cross-links

- **Down-regulation of enzymes in lignin pathway**
 - Transgenic technology (GMO)
 - Alfalfa
 - Noble Foundation, Forage Genetics
- **Phenotypic selection (natural variation)**
 - Laboratory analysis (ARS, St. Paul, MN)
 - Bromegrass, Orchardgrass, Reed canarygrass

Extent of Digestion with Time

- A - pectin (30%/hr)
- B – crystalline delignified cellulose (3-5 %/hr) w/ 12 hr lag
- C - timothy NDF (8 %/hr)
- D - alfalfa NDF (12 %/hr)



SOURCE: Van Soest, Peter J. 1995 NA Symposium. 1-15.

Genetic engineering for improved forage quality in alfalfa

- Genetic engineering for improved forage quality in alfalfa should offer added value for alfalfa growers and dairy producers.
 - Increased cell wall digestibility = more energy from alfalfa = increased milk production.
 - Increased alfalfa protein stability in the rumen and silo will increase efficiency of N utilization
 - Decreased cost of protein supplementation
 - Current cost ~\$.70/cow/day
 - Increasing yield of alfalfa while reducing impact of maturation of quality will improve cost:benefit ratio

Redesigning Alfalfa For Dairy Cattle

- **USDFRC has dedicated resources to designing or redesigning forage for dairy cattle**
- **Collaborators and partners are:**
 - **USDA-ARS, Plant Science Unit, St. Paul, MN**
 - **Noble Foundation, Ardmore, OK**
 - **Forage Genetics, West Salem, WI**