Redesigning Forages for Sustainable Dairy Production

2007 Intermountain Pre-Nutrition Conference

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USDA-ARS, Madison, WI

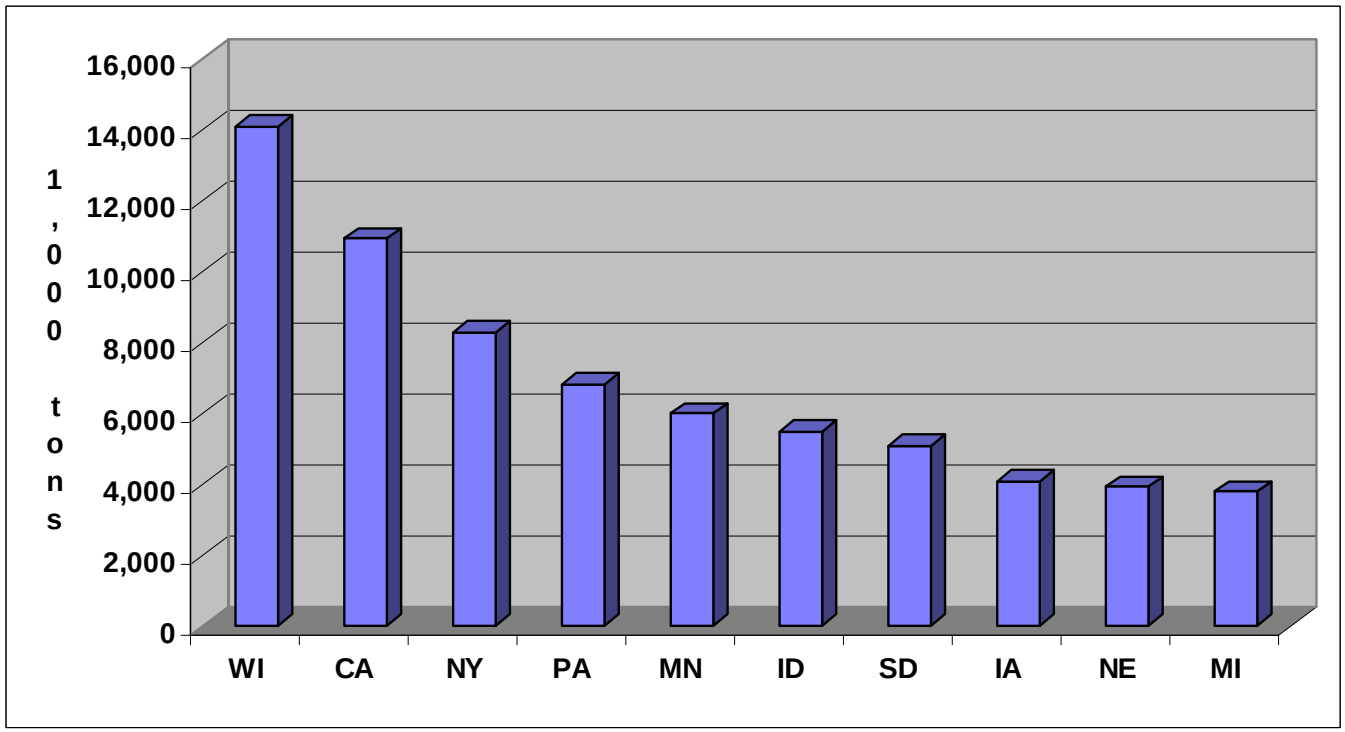
Link to U.S. DFRC Home

This talk will explore . . .

- Trends in corn silage & alfalfa production and use
- Barriers to increasing alfalfa in dairy diets
- Redesigning alfalfa for dairy cows
- Resigning grasses for dairy cows

Trends . . .

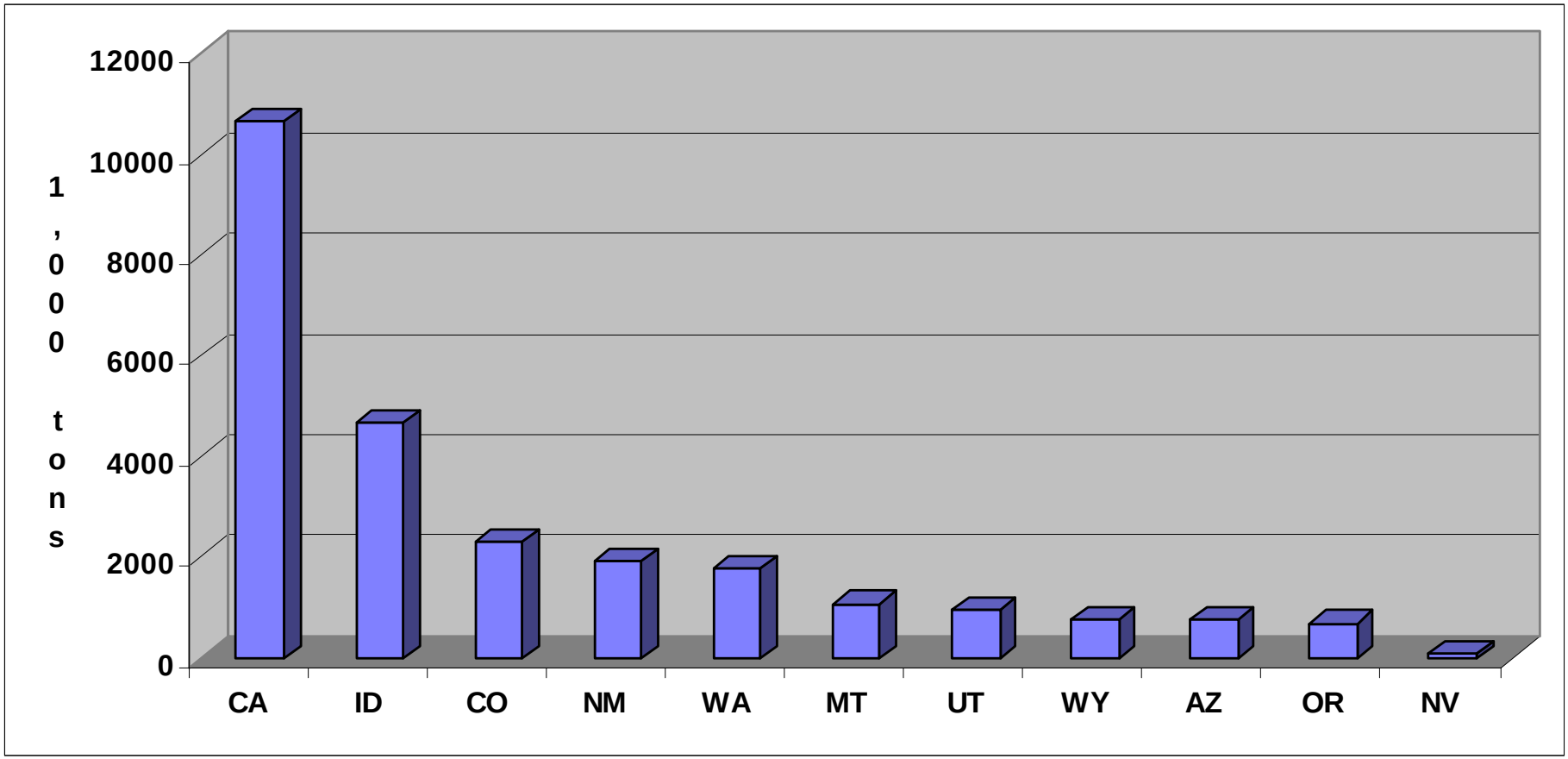
Leading Corn Silage States, 2006



Top 10 States

- 65 % of U. S.
- 66 % of Acres
- 6 states NC
- 2 states NE
- 2 states West
- 7 Lead Dairy

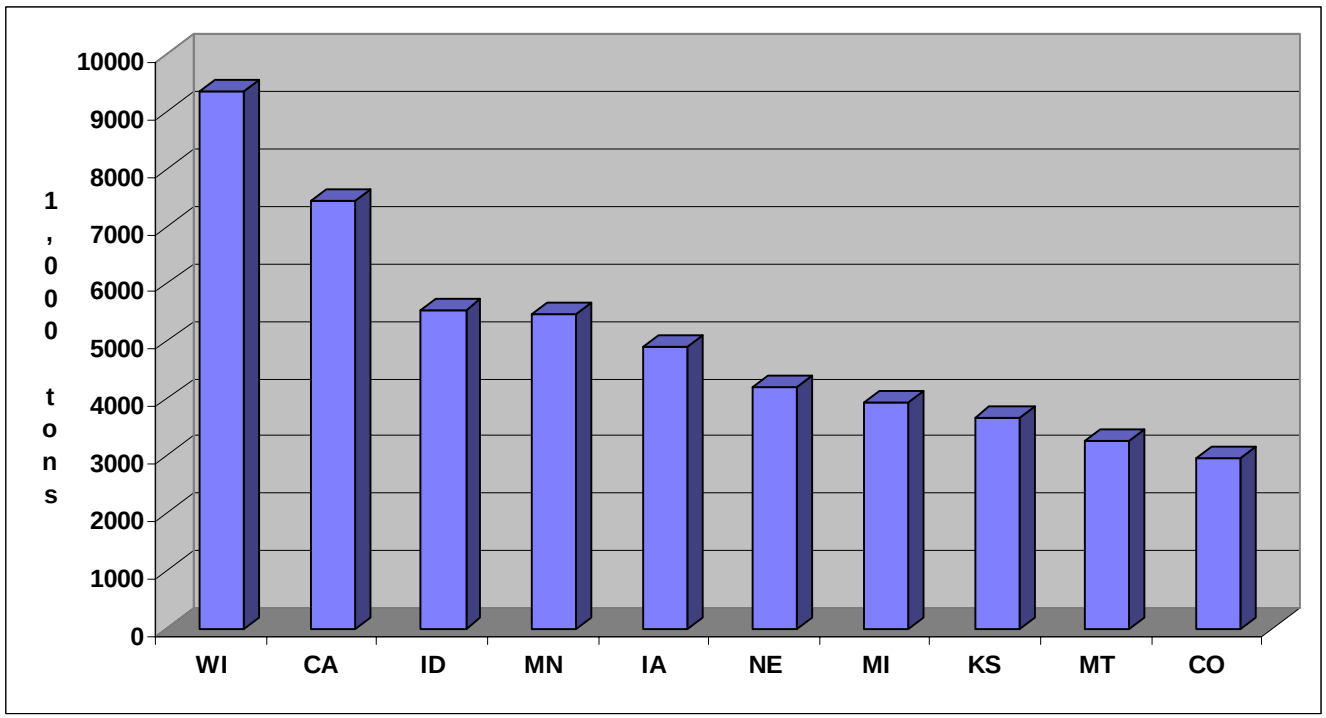
Corn Silage Production - West



2004-06 average

Trends . . .

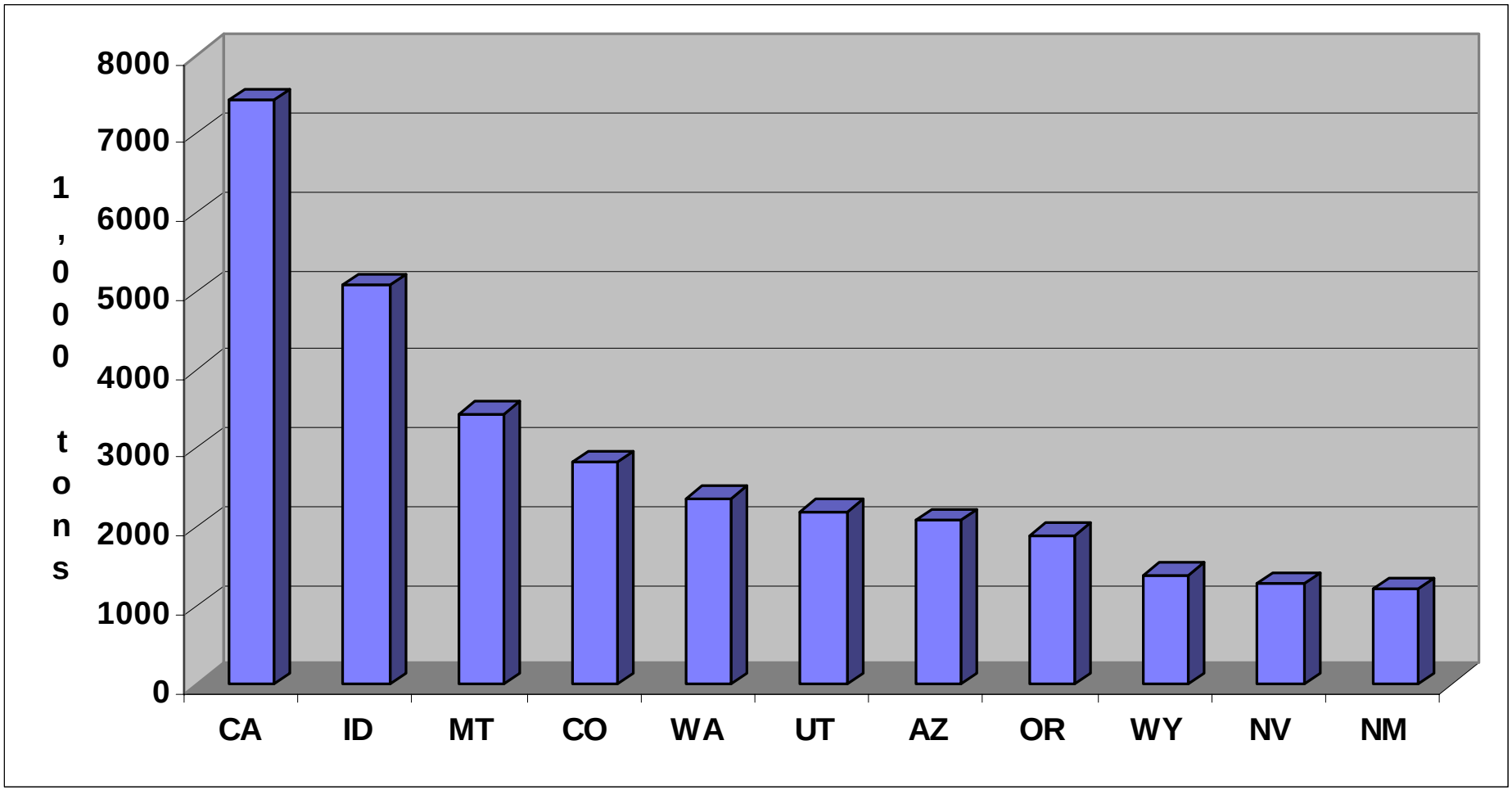
Leading Alfalfa Forage States, 2006



Top 10 States

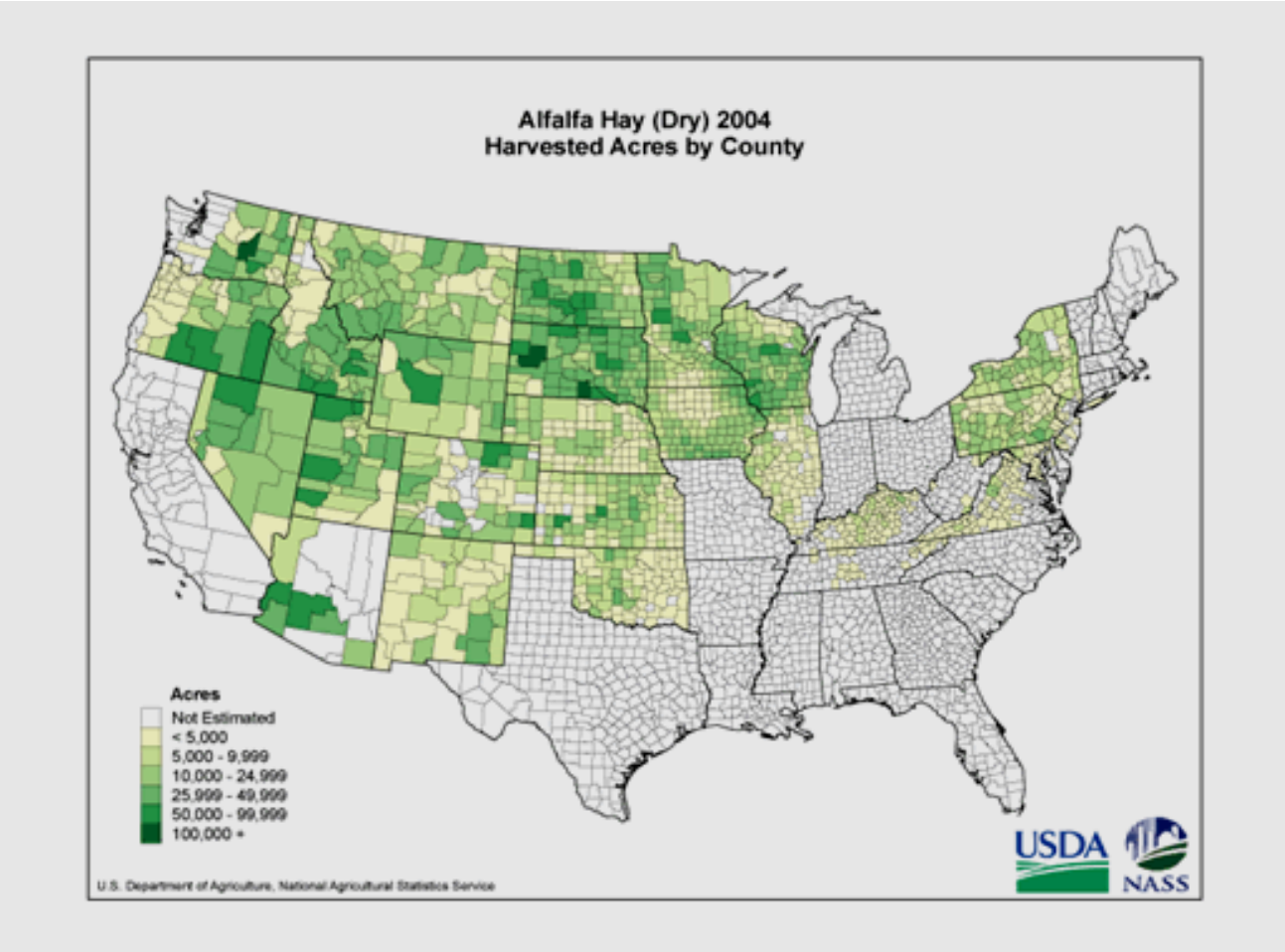
- 61 % of U. S.
- 56 % of Acres
- 6 states NC
- 4 states West
- 5 Lead Dairy

Alfalfa Forage Production - West

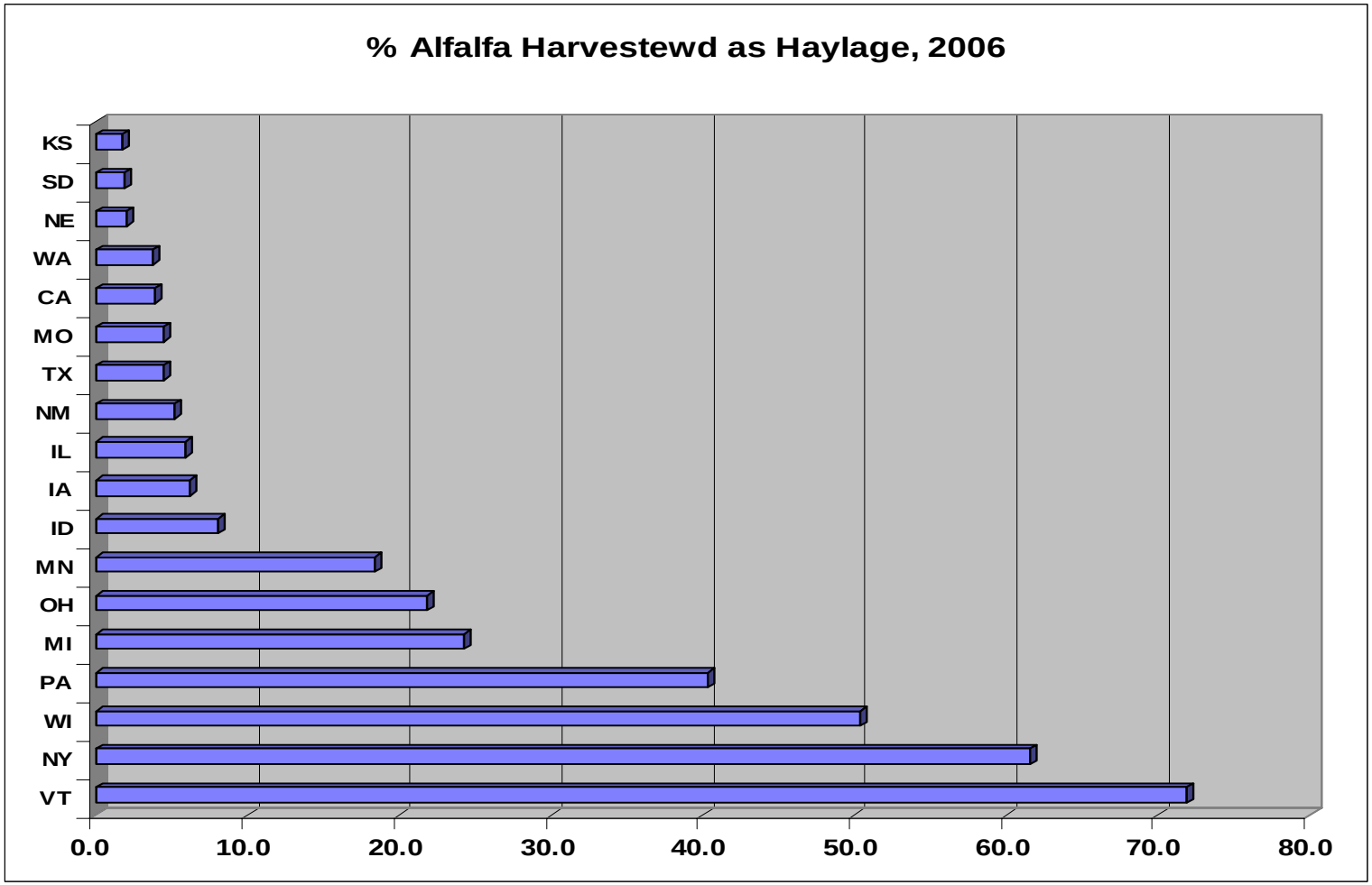


Trends . . .

Alfalfa Hay Production



Trends . . . Alfalfa Silage Production

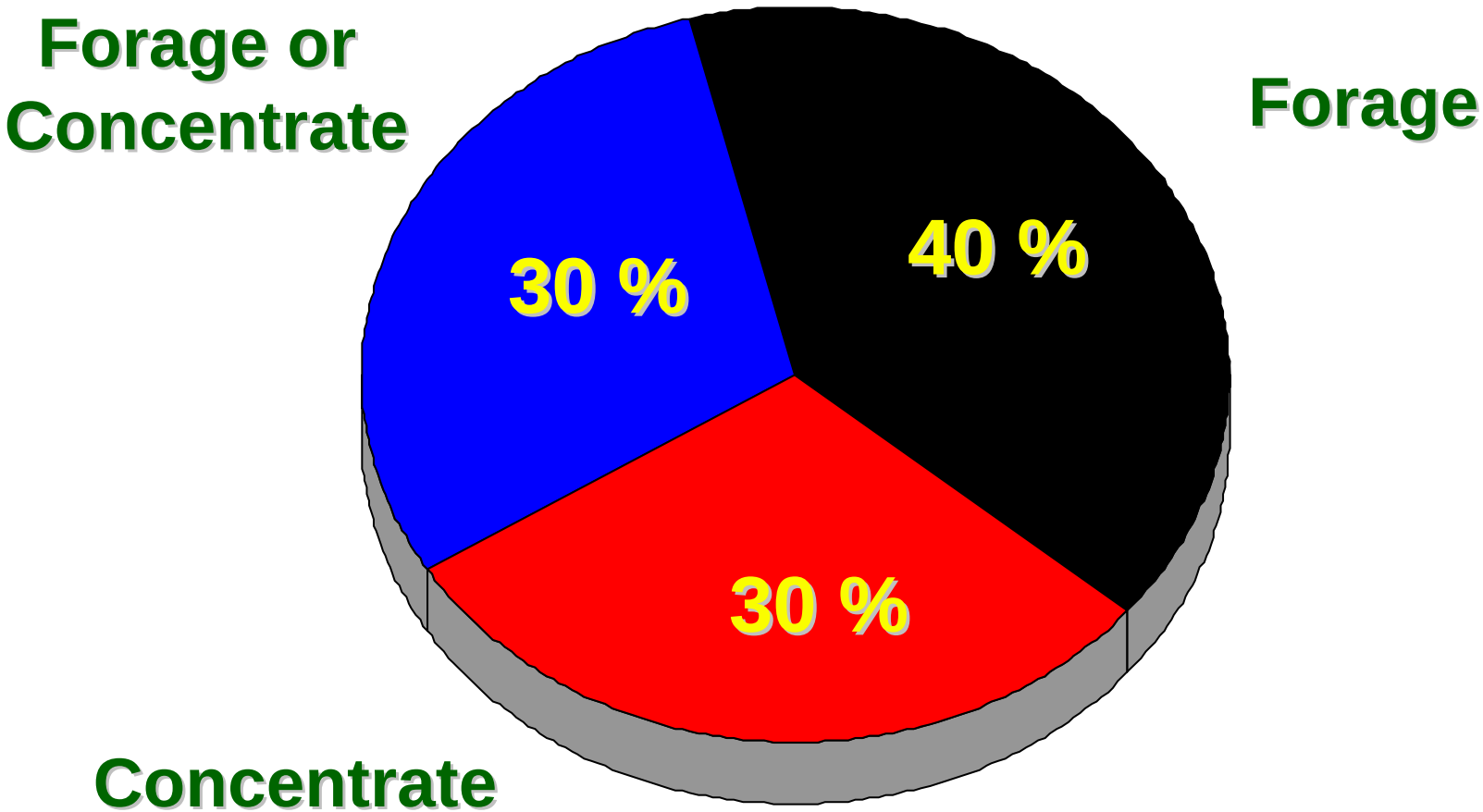


Trends . . .

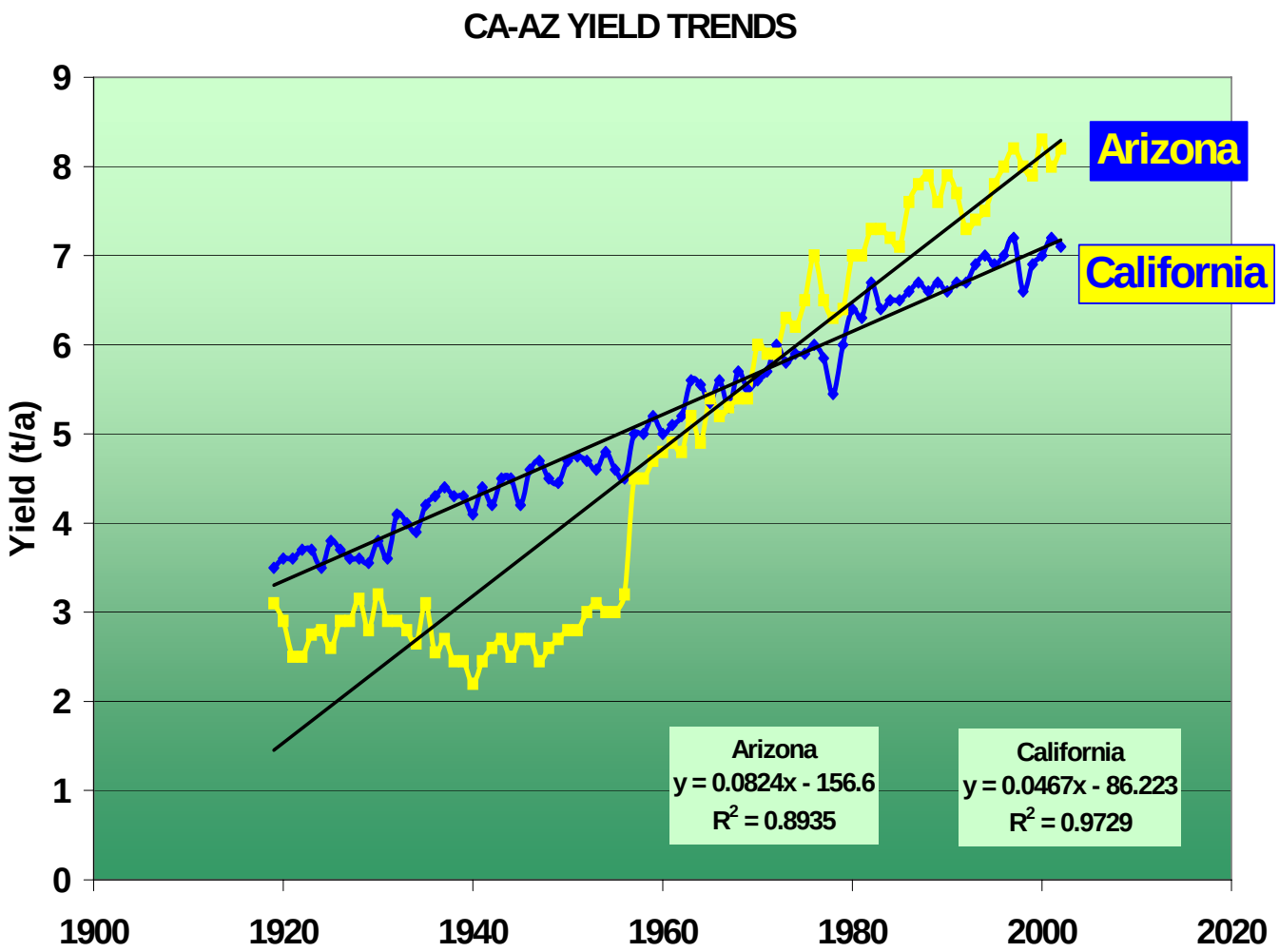
- **Hay acreage remains unchanged**

- **Dairy cattle feeding – declining amounts**

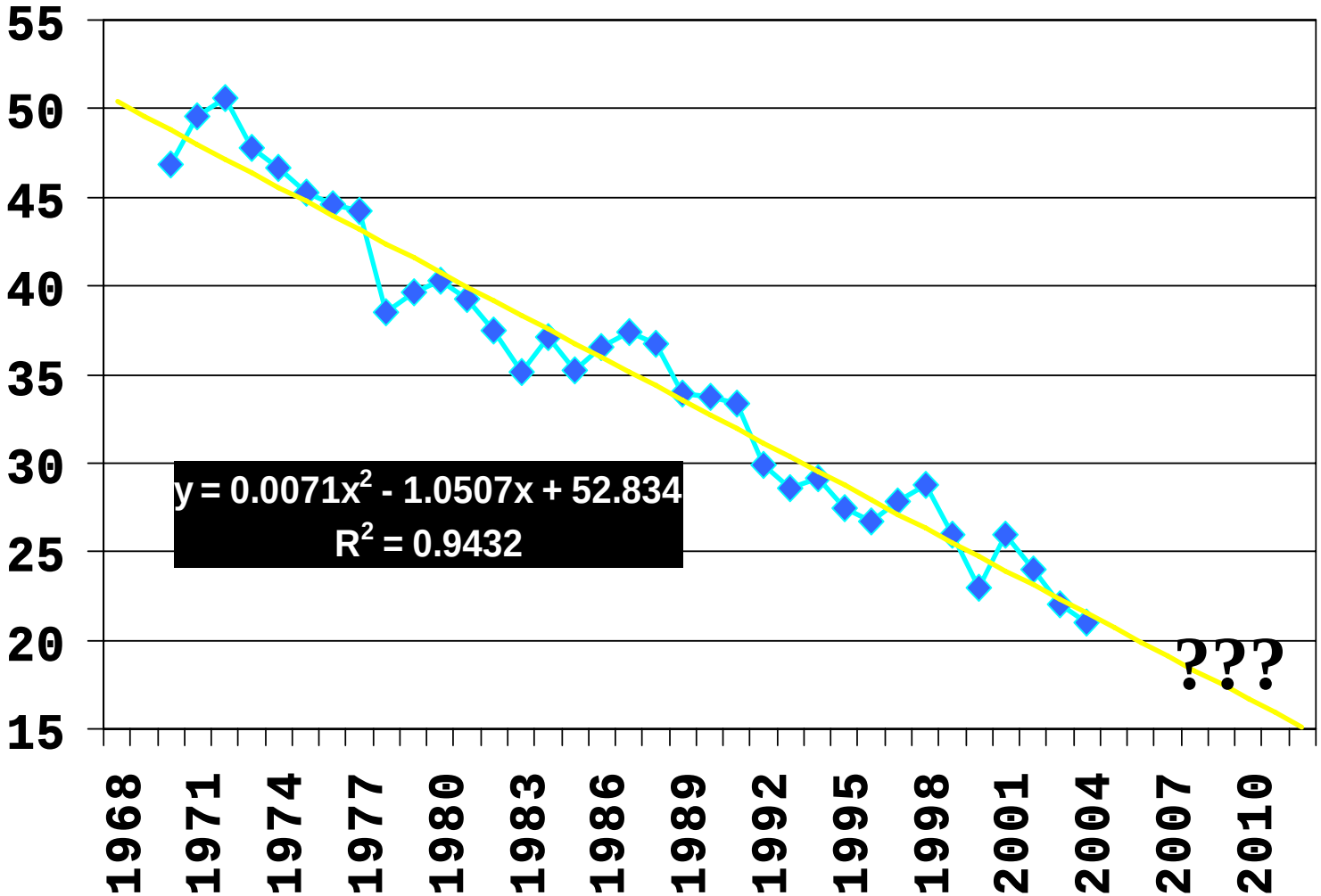
For many years the **Rule of Thumb** for feeding alfalfa to dairy cattle was. . .



Alfalfa Yield Trends . . .



CA Hay Production Per Dairy Cow (lbs alfalfa/cow/day)

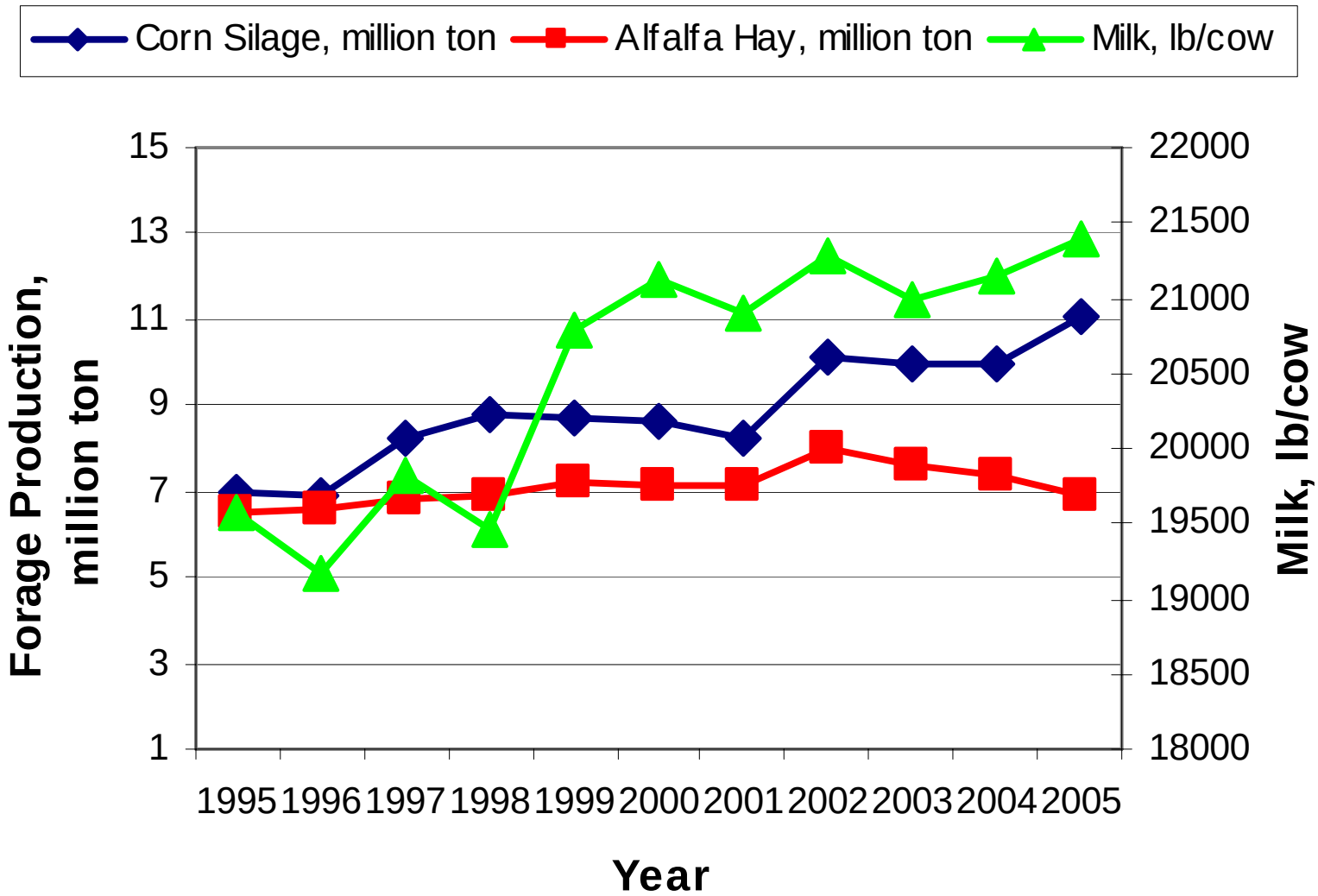


Source: Dan Putnam, 2005 Consortium for Alfalfa Improvement

Why this declining trend?

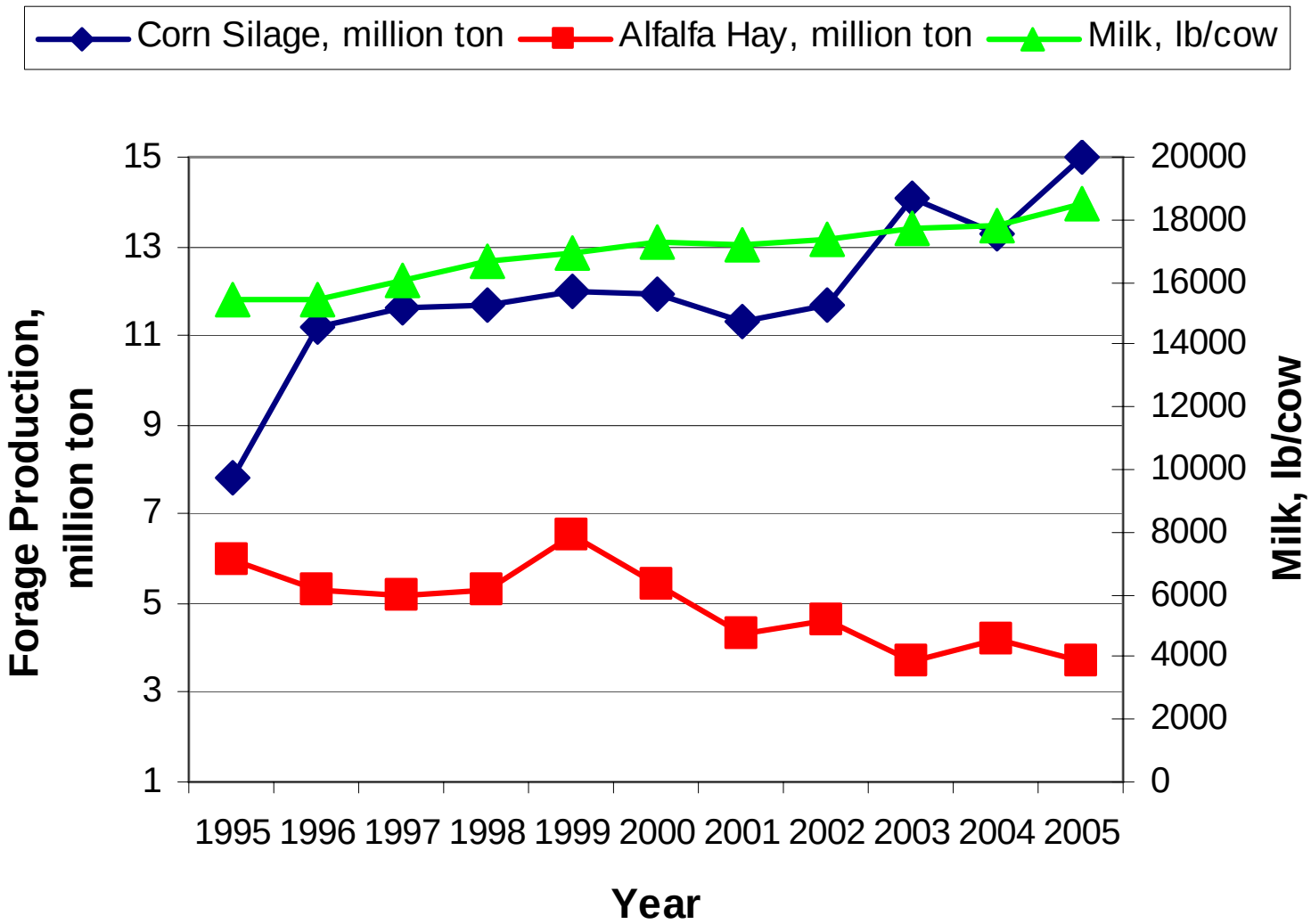
Competition with corn silage

California



SOURCE: Jim Linn, 2006 NAAIC

Wisconsin



SOURCE: Jim Linn, 2006 NAAIC

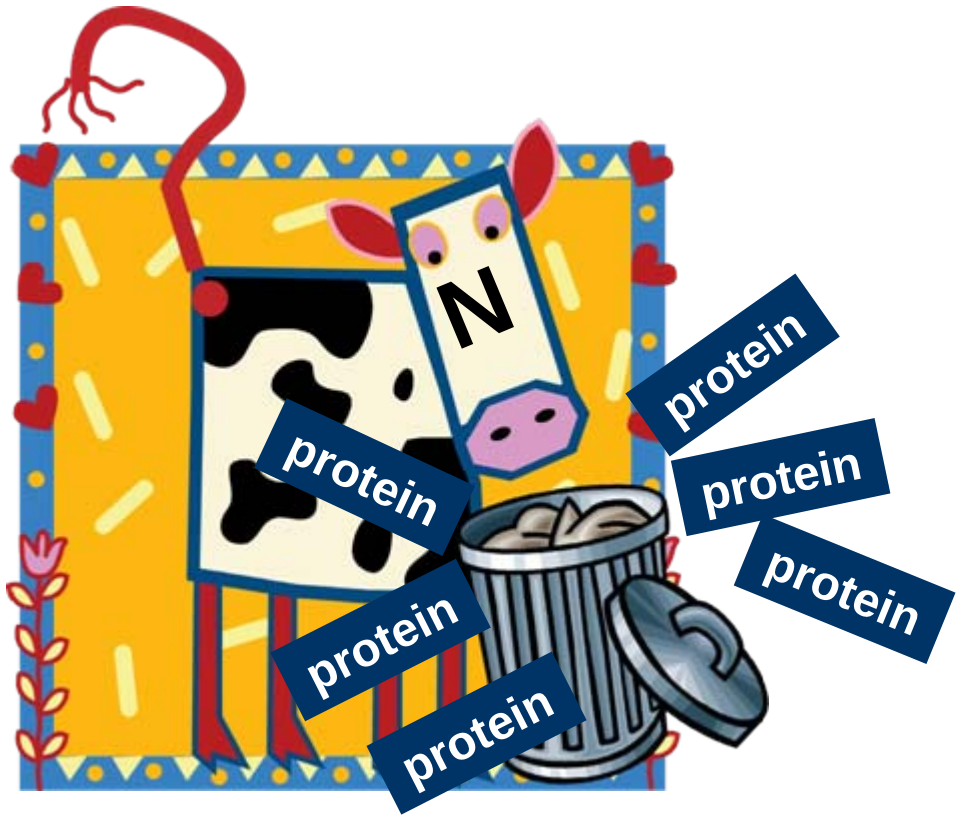
Why this declining trend?

Competition from byproducts

- Canola Meal
- Soybean Meal
- Cottonseed
- Distillers Grains
- Bakery By-Products
- Almond Hulls
- Citrus Pulp
- Tomato Pumice
- Etc. Etc. Etc. Etc. Etc.

Why this declining trend?

Many of these byproducts are high in protein

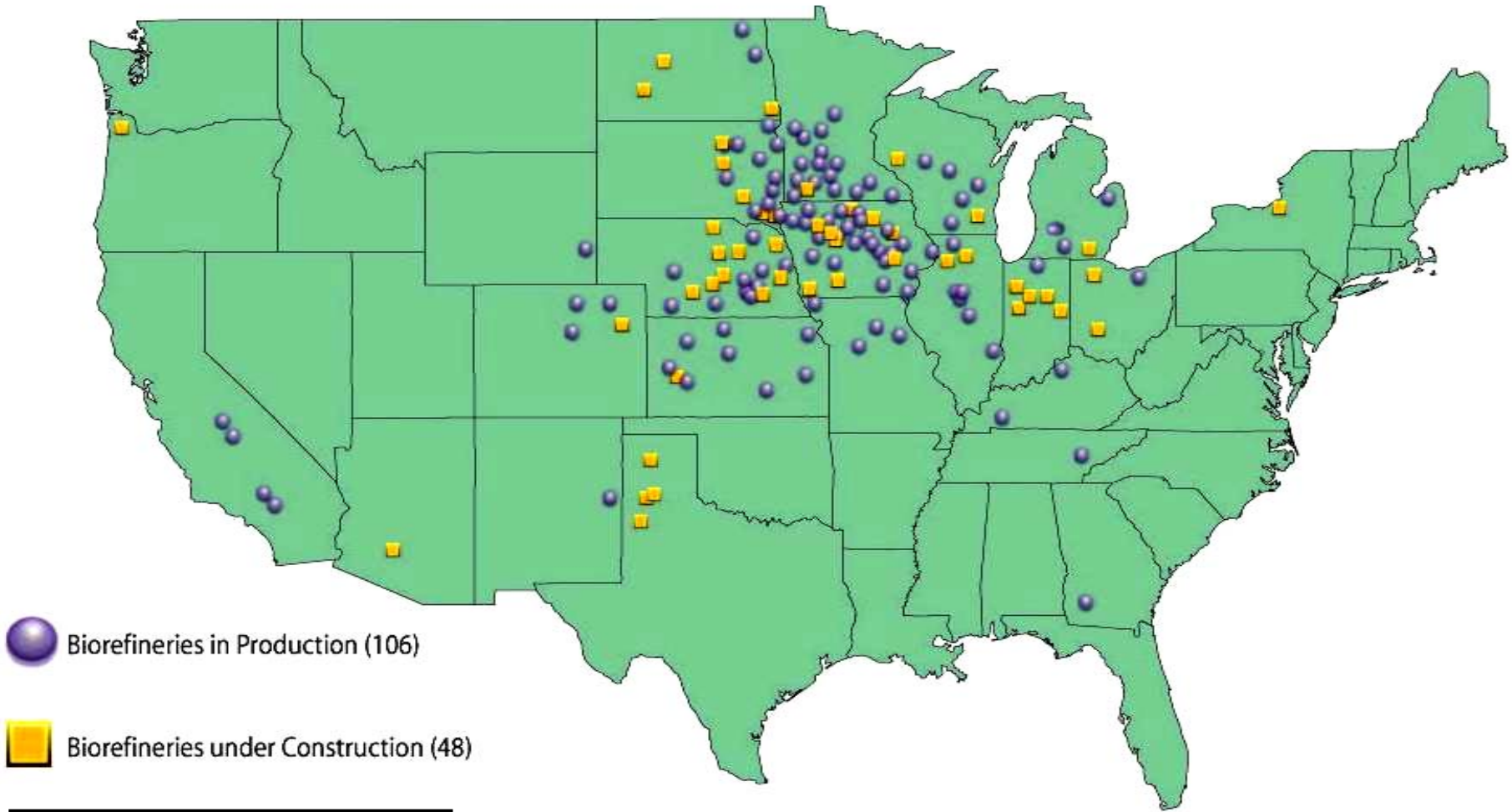


Protein Sources

	CP, %	RDP, % CP
Alfalfa	20+	70
Dist grains - ethanol	30	60
SBM – biodiesel	50	65
Corn gluten feed	22	70
Corn gluten meal	67	45
Wheat midds	19	75
Blood	87	30
Corn silage	8	65
Corn grain	10	50
Dairy Cow Ration	<17	65

SOURCE: Jim Linn, 2006 NAAIC

U.S. Ethanol Biorefinery Locations



Last updated: Oct. 30, 2006

Source: Renewable Fuels Association

Forage Fiber Sources – Dairy Rations

Straw – Use is increasing

- Low nutrient value
- Effective fiber

Hay Price, Particle Size and $

- Ground hay
  - Quality (125 – 175 RFV) may not have extra value
- Long hay - Unchopped
  - Quality has value ($)

SOURCE: Jim Linn, 2006 NAAIC

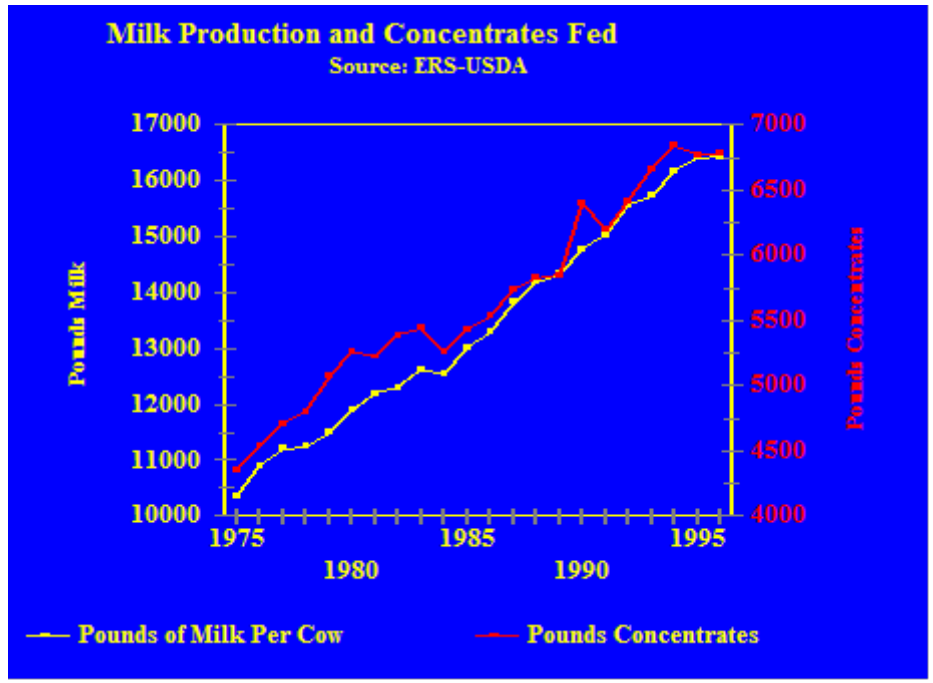
Key Issues with alfalfa quality/value

- It must be measured
- Breaking the yield/quality tradeoff
- Problems with rapid lignification of alfalfa stems under hot conditions
- Enhancing/complementing other feeds
- Solving Waste Problems

SOURCE: Putnam, Dan. 2005

Less alfalfa being fed in dairy rations

- Lower yield of alfalfa than other crops
- Increased use of corn silage
- Minimized forage in ration
  - Cheap grain
  - Greater quality consistency of grain
  - Inability to accurately estimate energy of forage



Dairy Nutritionist Survey

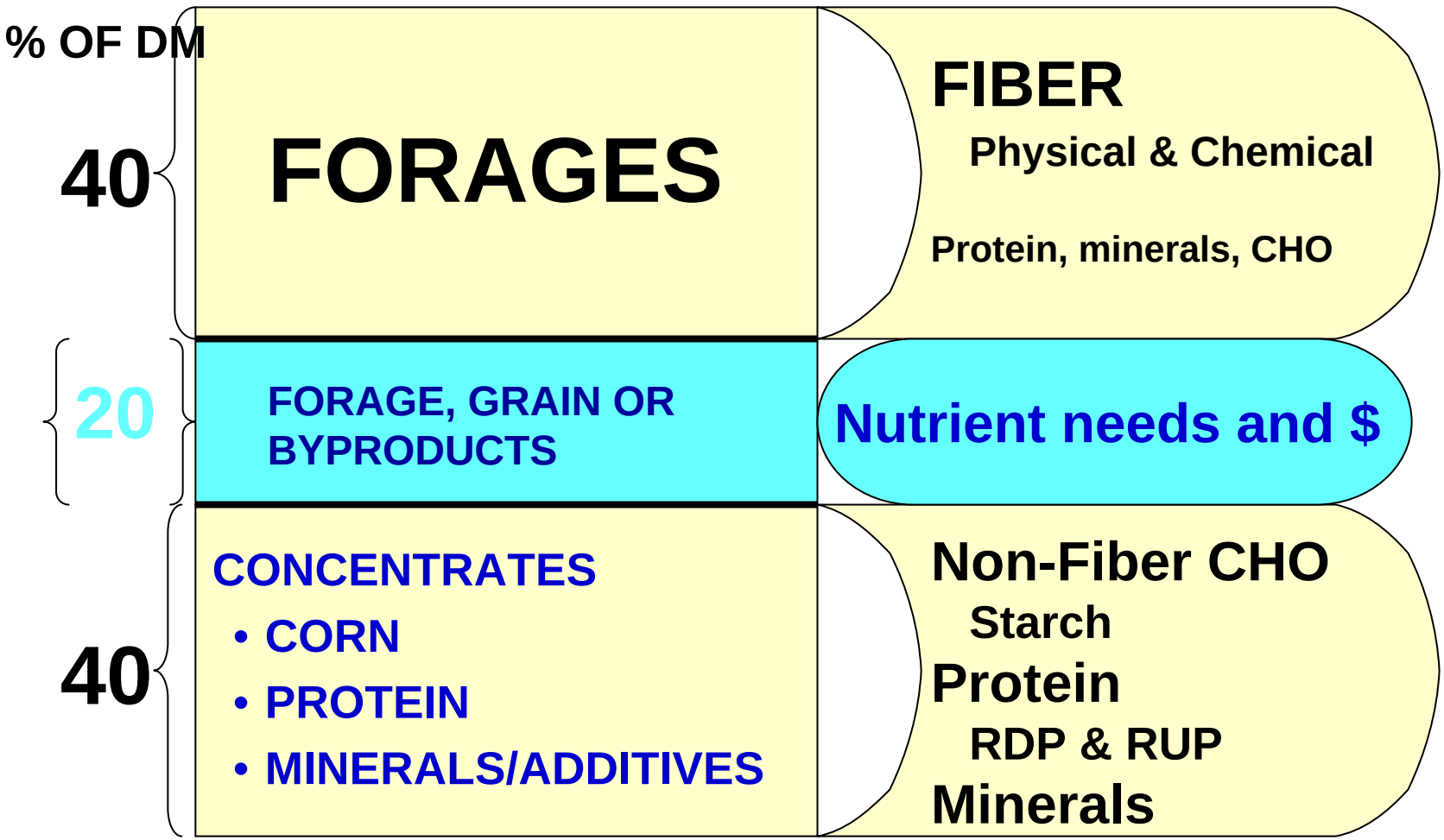
MAJOR CHALLENGES

1. **Forage quality - consistency**
2. **N and P excretion**
3. **Transition cows**
4. **Ethanol – starch and Distillers Grains**
5. **Ration formulation – modeling**
6. **Fiber digestion**
7. **Milk price and feed cost**

WATER AVAILABILITY

Source: Hutjens – 2006 ADSA meeting

Dairy Ration Overview



We don’t want to see reduced perennial forage crops in rotation because . . .

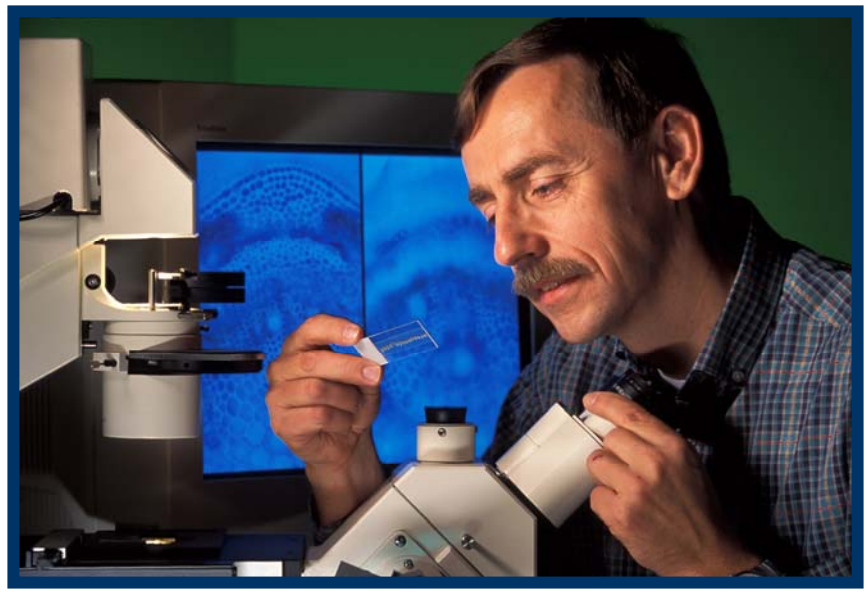
- Perennial forage crops are good for environment
- Good for cow health

Challenges . . .

. . . of the dairy forage industry

Research strategies and opportunities . . .

. . . of the U.S. Dairy Forage Research Center



Barriers to increasing alfalfa in dairy diets

Redesigning alfalfa for dairy cows

- Improve protein utilization
  - Increase fiber digestion
    - Increase yield

Forage Quality…

Description	CP	EE	Ash	Starch	Pectin	aNDF	ADF	ADL
ALFALFA HAY								
Exceptional	25.4	2.7	10.4	3.1	14.2	30.0	24.0	4.53
Very high	24.0	2.6	9.9	2.9	13.2	34.1	27.0	5.38
High quality	22.5	2.5	9.5	2.7	12.3	38.2	30.0	6.23
Good quality	21.0	2.4	9.1	2.5	11.4	42.2	33.0	7.08
Fair quality	19.5	2.2	8.7	2.3	10.5	46.3	36.0	7.93
CORN SILAGE								
V. high grain	8.3	3.2	4.1	31.1	1.7	36.0	21.0	1.57
High grain	8.6	3.1	4.6	27.2	1.6	40.5	24.0	1.91
Normal	8.8	3.0	5.1	23.2	1.5	45.0	27.0	2.25
Low grain	9.0	2.8	5.7	19.2	1.4	49.5	30.0	2.59
V. low grain	9.3	2.7	6.2	15.3	1.3	54.0	33.0	2.93

Source: Mertens, 2003.

Apparent Dry Matter Digestibility of AH and CS

Item	AH 24% ADF	AH 27% ADF	CS proc 24% ADF	CS proc 27% ADF
% aNDF	30.0	34.1	40.5	45.0
% dNDF	15.6	16.0	24.9	27.3
% NDS	70.0	65.9	59.5	55.0
% dNDS	68.6	64.6	58.3	53.9
% True DMD	84.2	80.6	83.2	81.2

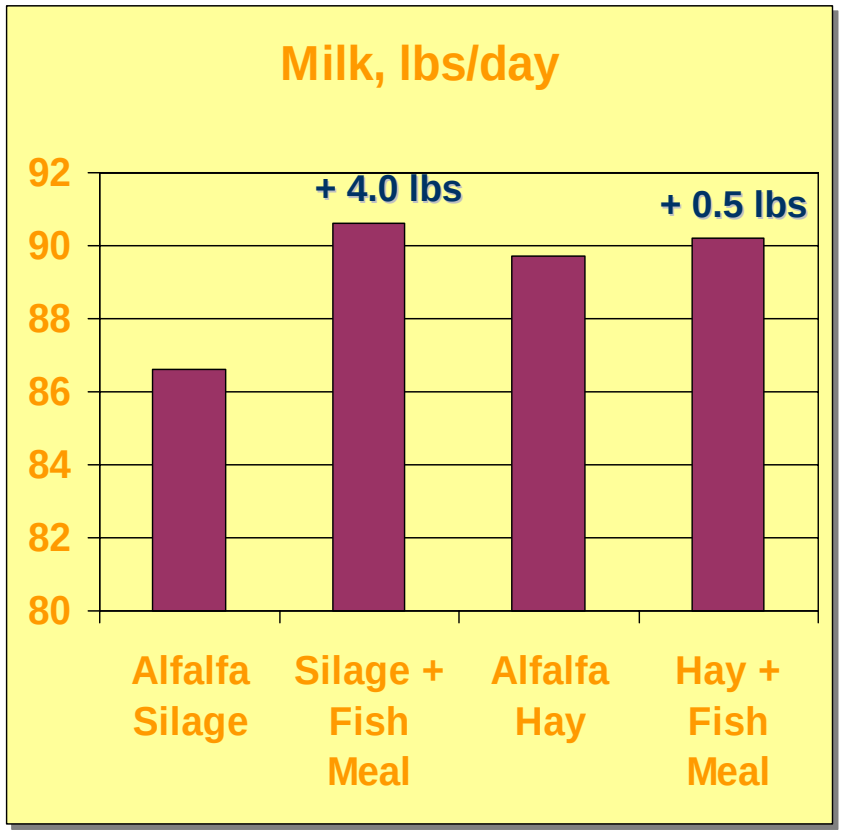
Source: Adapted from Mertens, 2003.

Alfalfa for Dairy Rations

- **Currently using harvesting management to improve alfalfa quality**
  - **Immature alfalfa has many appealing nutritional properties**
    - **Low in fiber**
      - **High digestibility**
      - **High intake potential**
    - **Rapid rate of digestion**
    - **High in crude protein**

Source: Adapted from Mertens, 2003.

Milk Yield from Alfalfa Silage and Hay Diets

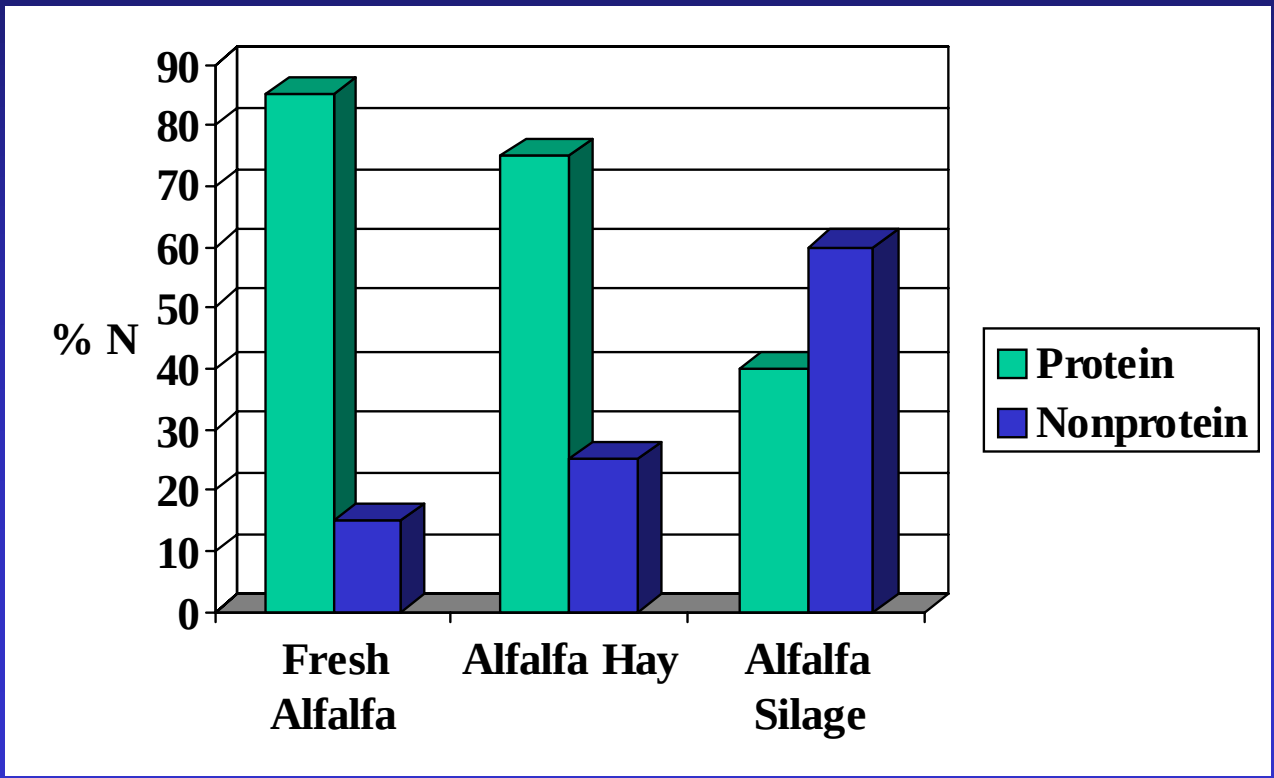


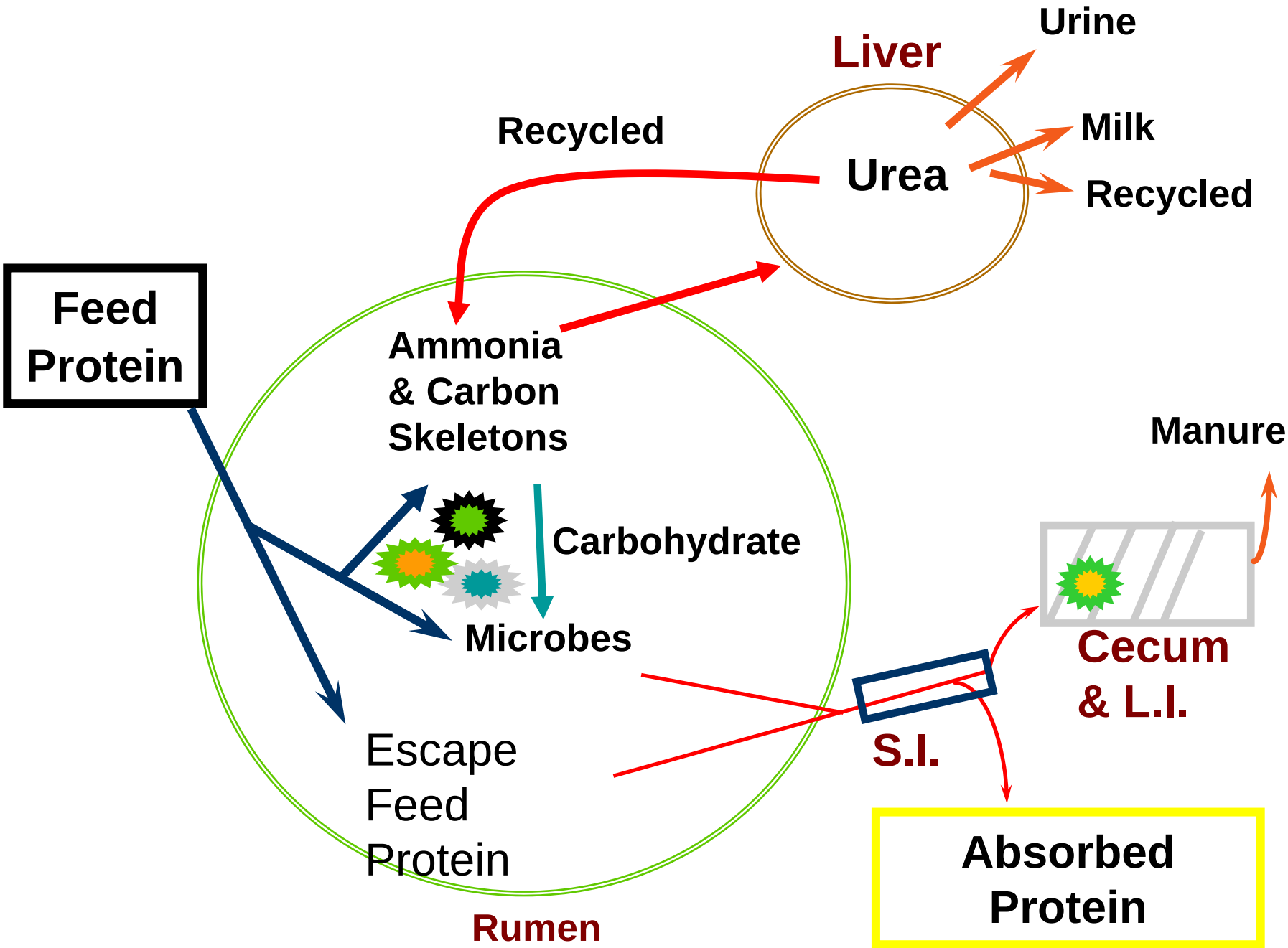
- Fish meal is beneficial in alfalfa silage diets, but not alfalfa hay diets.
- Bottom line: alfalfa silage nitrogen is not efficiently used by the cow

Source: Vagnoni and Broderick, 1997

Feed Storage Problems

- However in alfalfa, our primary forage:





Source: Mary Beth Hall

Research Challenge / Opportunity . . .

- **Protein utilization:**
  - **high-quality forage reduces N use efficiency . . .**
  - **leading to higher manurial N loading back to fields . . .**
  - **creating an increased risk of N leaving farm via runoff, leaching, or ammonia emissions.**

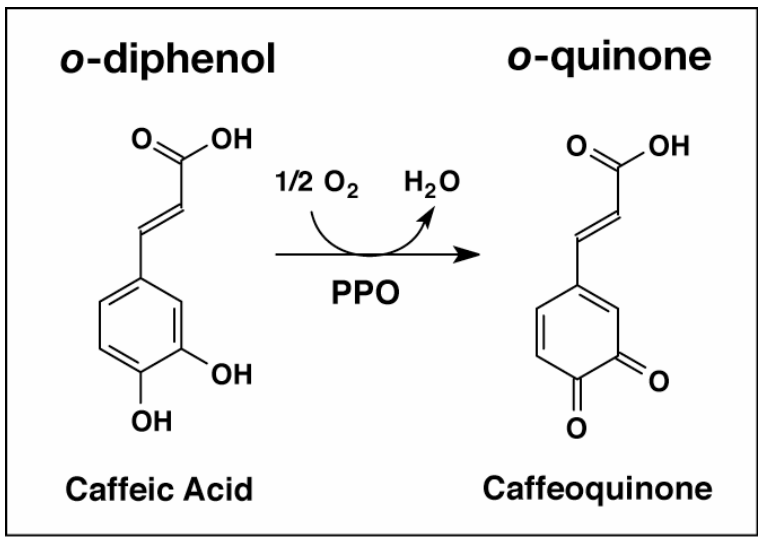
Protein utilization: PPO

Polyphenol oxidase (PPO) and *o*-diphenols

--A process for preserving protein in ensiled forages

Polyphenol oxidase (PPO) and *o*-diphenols in red clover

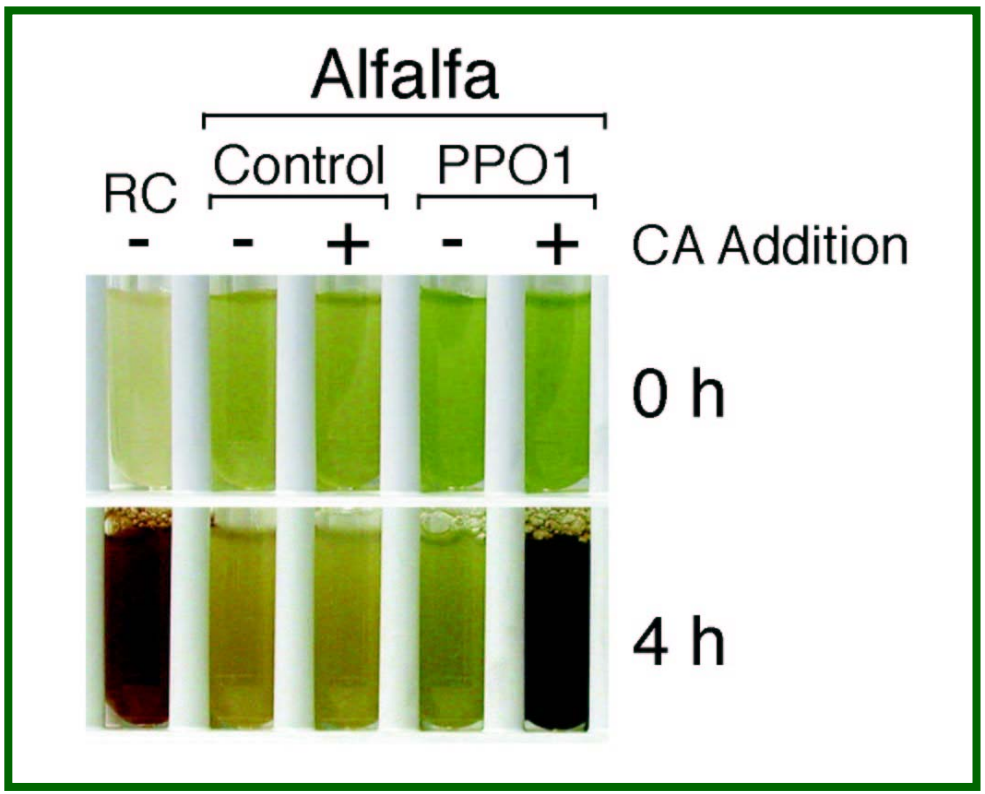
- PPO oxidizes *o*-diphenols to *o*-quinones
- Responsible for post harvest browning
- PPO and o-diphenols are abundant in red clover



PPO and *o*-diphenols prevent post-harvest proteolysis

- **Evidence for PPO/*o*-diphenol role**
  - **Alfalfa lacks PPO/*o*-diphenols**
  - **Proteolytic inhibition O_2-dependent**
    - » Inhibition involves a heat labile factor
- **Experimental demonstration**
  - **Loss-of-function in red clover**
  - **Gain-of-function in alfalfa**

Expression of red clover PPO1 in transgenic alfalfa



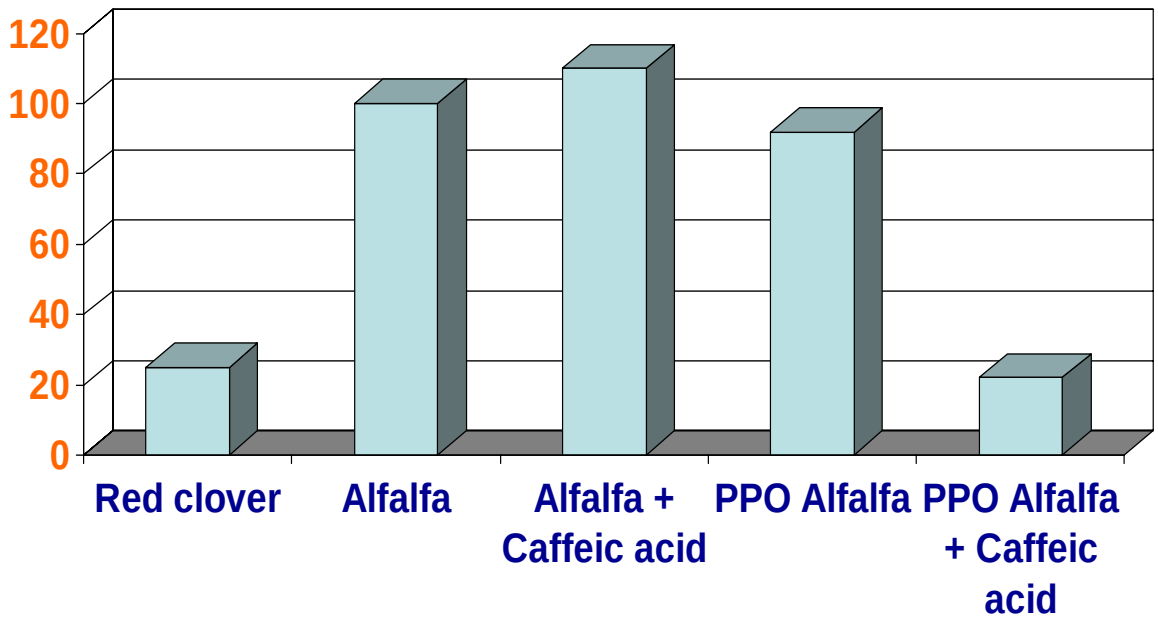
In alfalfa, browning is dependent on:

- **A PPO transgene**
- **Exogenous o-diphenol, e.g. caffeic acid**

SOURCE: Sullivan, Michael L. and Ron D. Hatfield. 2003 DFRC Research Report

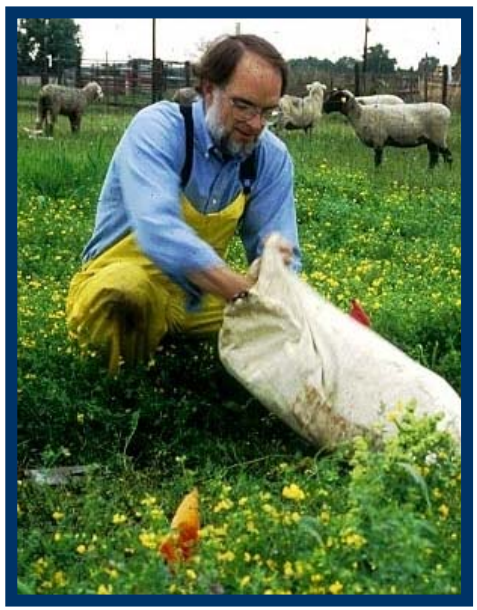
Red Clover vs. Alfalfa Silage

Protein breakdown (% of alfalfa)

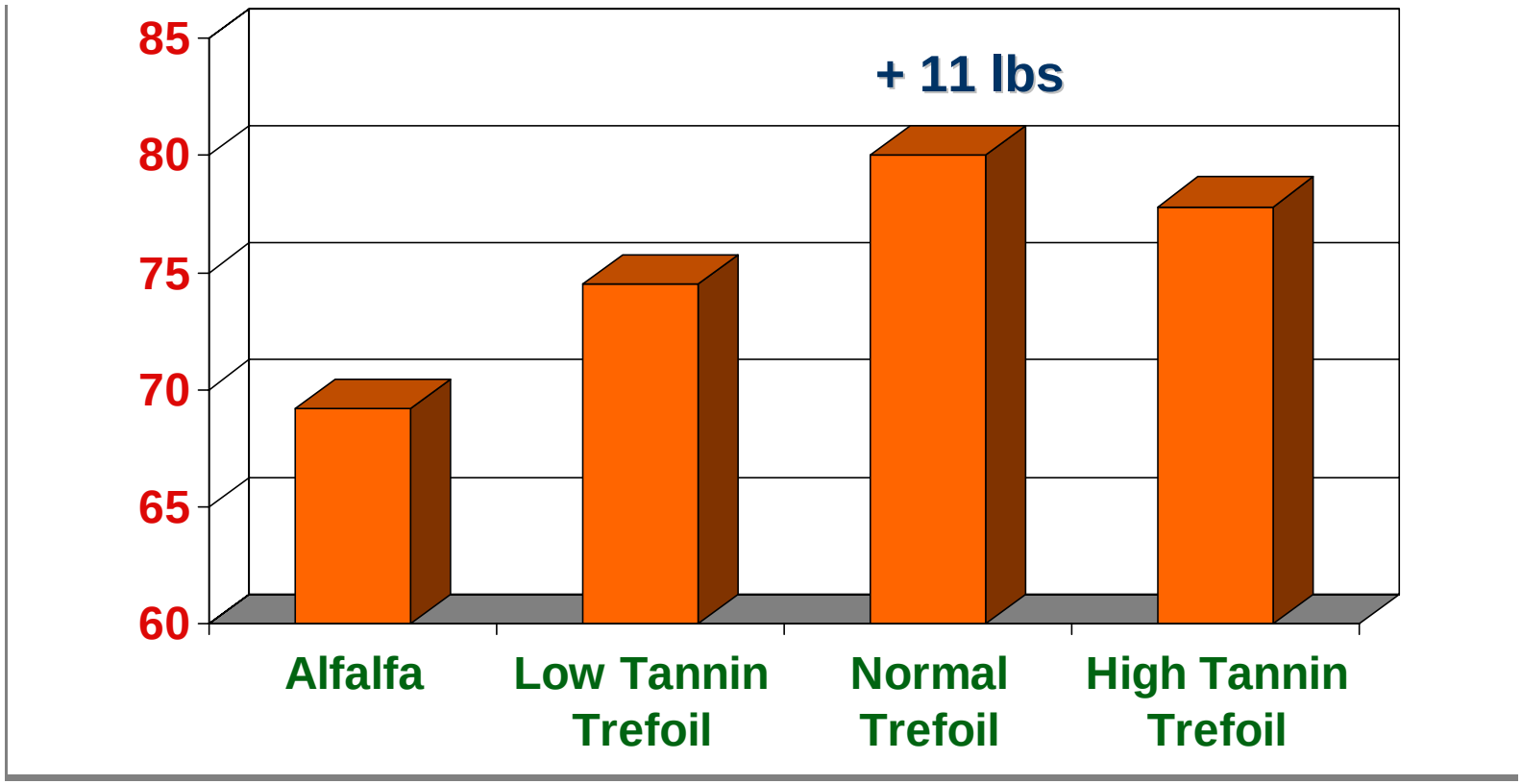


Protein Utilization: Tannins

- **Tannins have been shown to improve protein utilization and animal performance.**

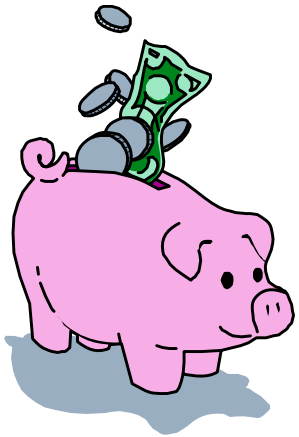


Milk Yield (lbs/day)-Alfalfa and Birdsfoot Trefoil Silages



Hymes-Fecht et al., 2005

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



Alfalfa silage	$ 23
Alfalfa hay	$ 11

Strategies: reducing 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)

Research Challenge / Opportunity . . .

. . . fiber digestion

Apparent Dry Matter Digestibility of AH and CS

Item	AH 24ADF	AH 27ADF	CS proc 24ADF	CS proc 27ADF
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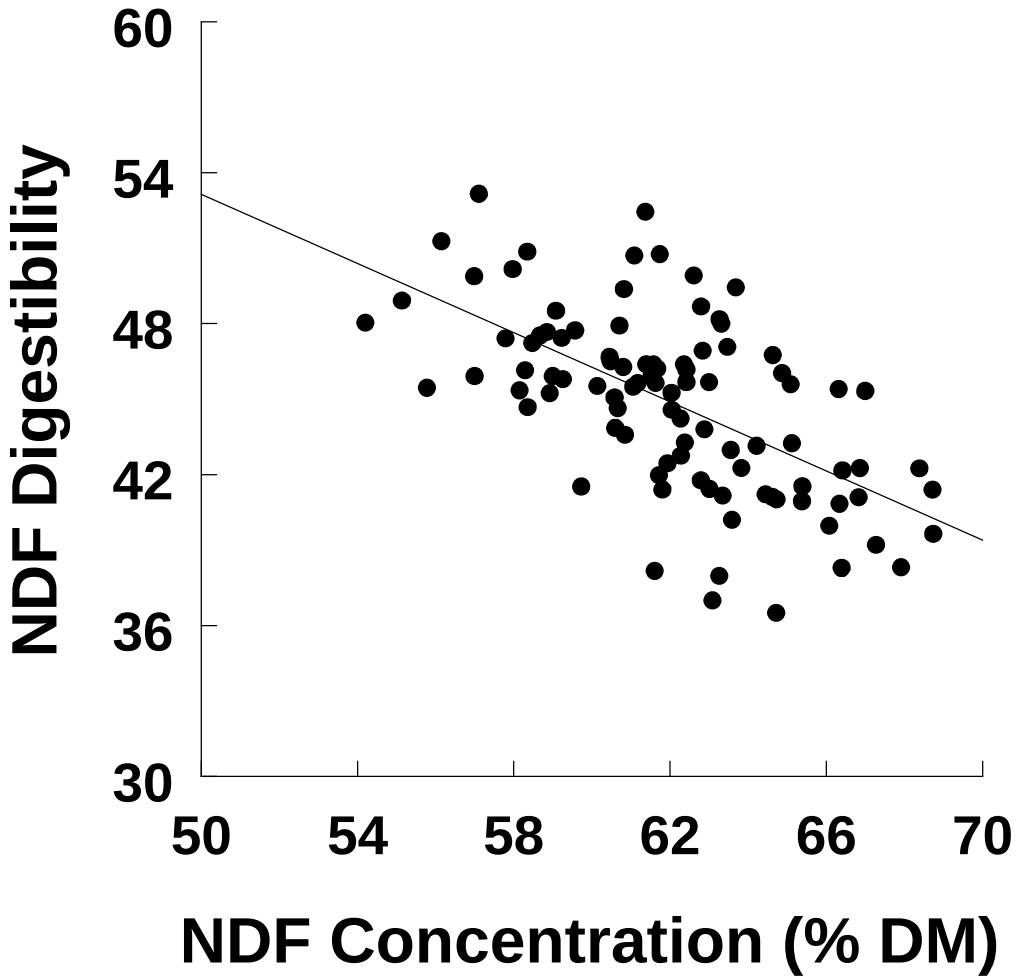
Source: Adapted from Mertens, 2003.

NDF Digestibility of Alfalfa Stems



Source: Jung and Lamb, 2002. Unpub USDA-ARS. St. Paul, MN

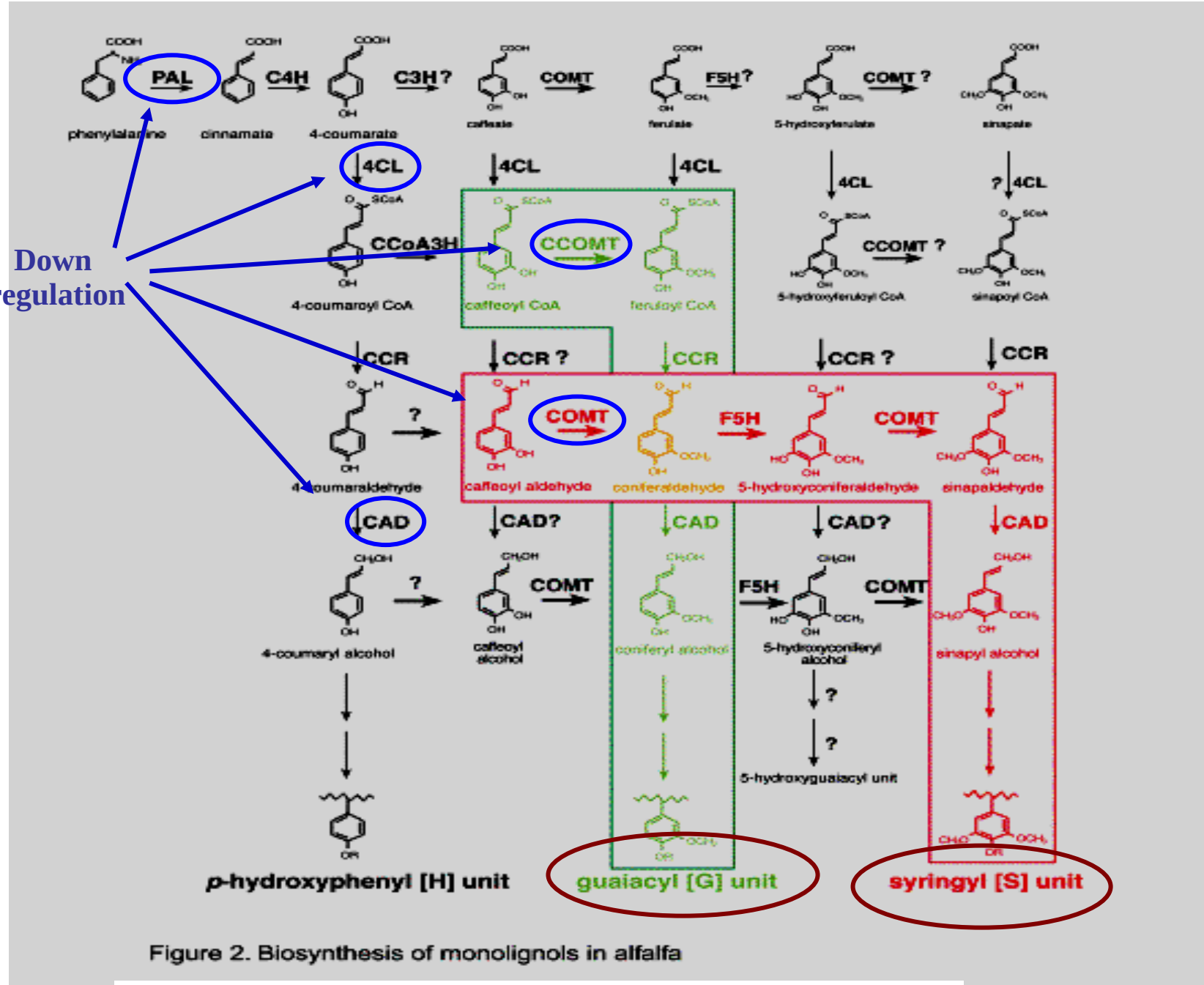
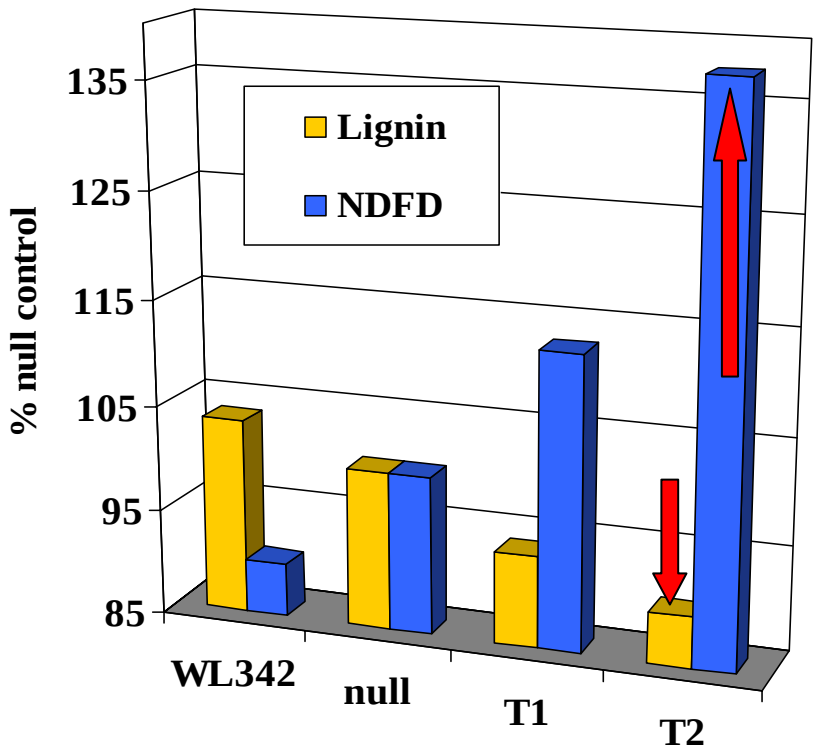


Figure 2. Biosynthesis of monolignols in alfalfa

Engineering the lignin biosynthetic pathway in alfalfa

Low Lignin Alfalfa… Higher Fiber Digestibility

Fiber digestibility of alfalfa stems in transgenic lines at Nampa, ID.



Transgenic plants have been generated that show decreased lignin content and increased fiber digestibility.

Source: McCaslin et. al., 2002

Alfalfa Improvement Opportunities

- Modify fiber composition
  - Replace with soluble CHO (pectin, etc.)
- Improve fiber digestibility
  - Lower lignin
  - Modify lignin
  - Replace lignin with cellulose
  - Reduce physical limitations
  - Increase rate of digestion

Redesign Alfalfa for Dairy Cattle

Consortium for Alfalfa Improvement

- Noble Foundation
- Forage Genetics International
- Plant Science Research Unit, USDA-ARS
- US Dairy Forage Research Center, USDA-ARS

Consortium *for* Alfalfa Improvement

Grasses for Hay, Silage, Pasture

Grasses for Hay or Silage

- Badger smooth bromegrass - high digestibility

- Alpha smooth bromegrass - high digestibility and persistence with alfalfa

Pasture grasses

- **Albert orchardgrass**
  - high forage and seed yield, good quality, excellent disease resistance.

- **Spring Green festulolium**
  - **Superior cold tolerance and winter survival.**
  - **Over 1 million pounds of seed sold.**
  - **Will be available in 2005 as certified organic seed.**

New Pasture Grasses for 2006/07 *(Listed by experimental names)*

- **WR00 & WR04 Reed canarygrass - improved, more rapid, stand establishment.**

New Pasture Grasses for 2006/07 *(Listed by experimental names)*

- **WMF1 Meadow fescue - superior forage yield, palatability, acceptance, and intake under management-intensive rotational grazing.**
- **WCO1 Festulolium - improved cold tolerance and winterhardiness, high palatibility and acceptance, excellent disease resistance.**

Summary

- Corn silage, alfalfa and perennial grasses main forage fed to dairy cows
- Determining attributes of ideal forage for harvest or grazing needs holistic approach

Summary

- Ideal attributes – plant modification
  - Those that increase milk potential (per acre or per ton)
  - Enhance digestible NDF
  - Improve protein utilization
  - Increase sugar content
  - Reduce incidence of bloat
  - Improve agronomic traits (insect, weed, virus, drought and cold tolerance)
  - Increase mineral availability
  - Enhance yield
- Progress in attaining these attributes has been slow using traditional plant breeding, but will accelerate with the use of biotechnology

http://ars.usda.gov/mwa/madison/dfrc

Any questions ?