

# U.S. Dairy Forage Research Center

USDA, Agricultural Research Service

## Alfalfa: Hay, Haylage, Baleage and Other Novel Products

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WI



# Alfalfa: Hay, Haylage, Baleage, and Other Novel Products

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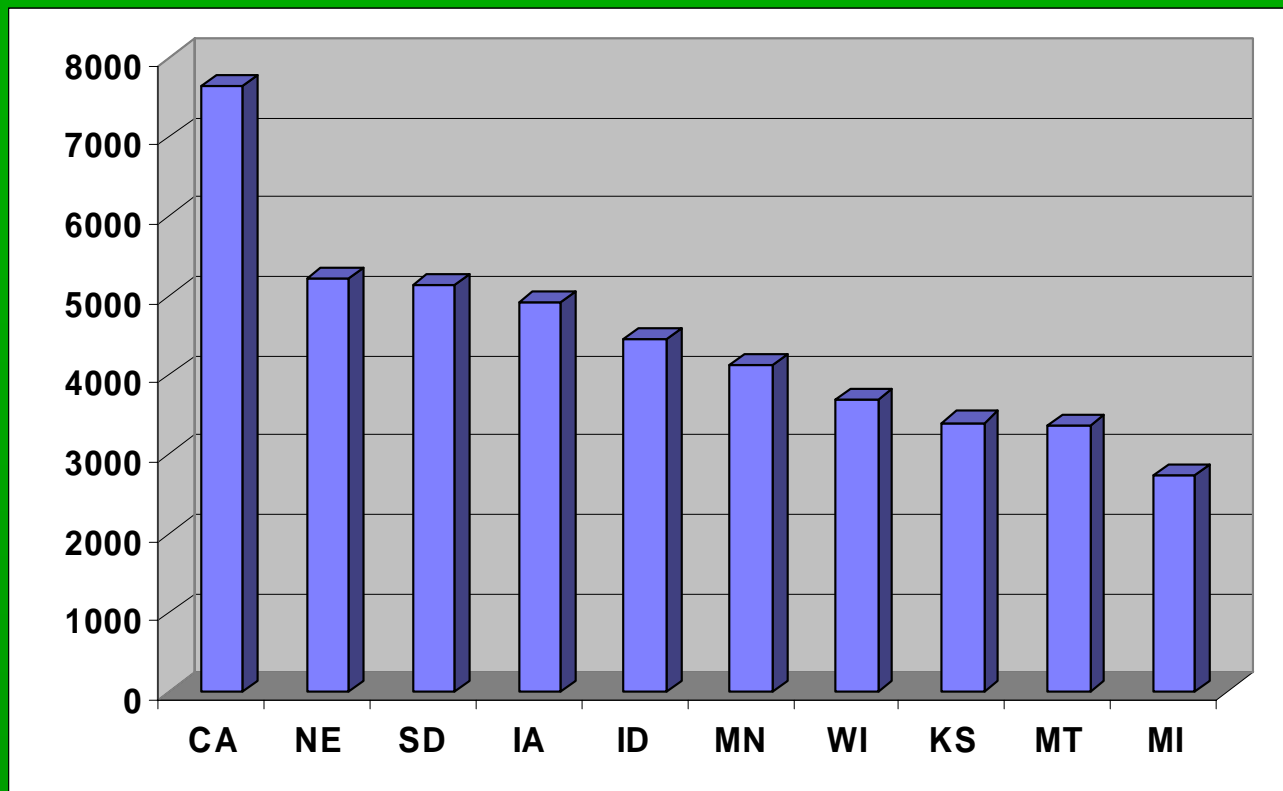
- **Introduction**
- **Alfalfa utilization by dairy cattle**
  - Alfalfa vs corn silage in diets
  - Protein utilization of alfalfa
- **Composition of alfalfa hay and corn silage**
- **Novel alfalfa products**

# 2003 U S Alfalfa Hay Production

- 76.3 million tons
- \$6.9 billion
- 4<sup>th</sup> following corn, soybeans and wheat
- Idaho ranks 2<sup>nd</sup> behind CA in value



# Leading Alfalfa Hay Production States, 1,000 tons, 2003



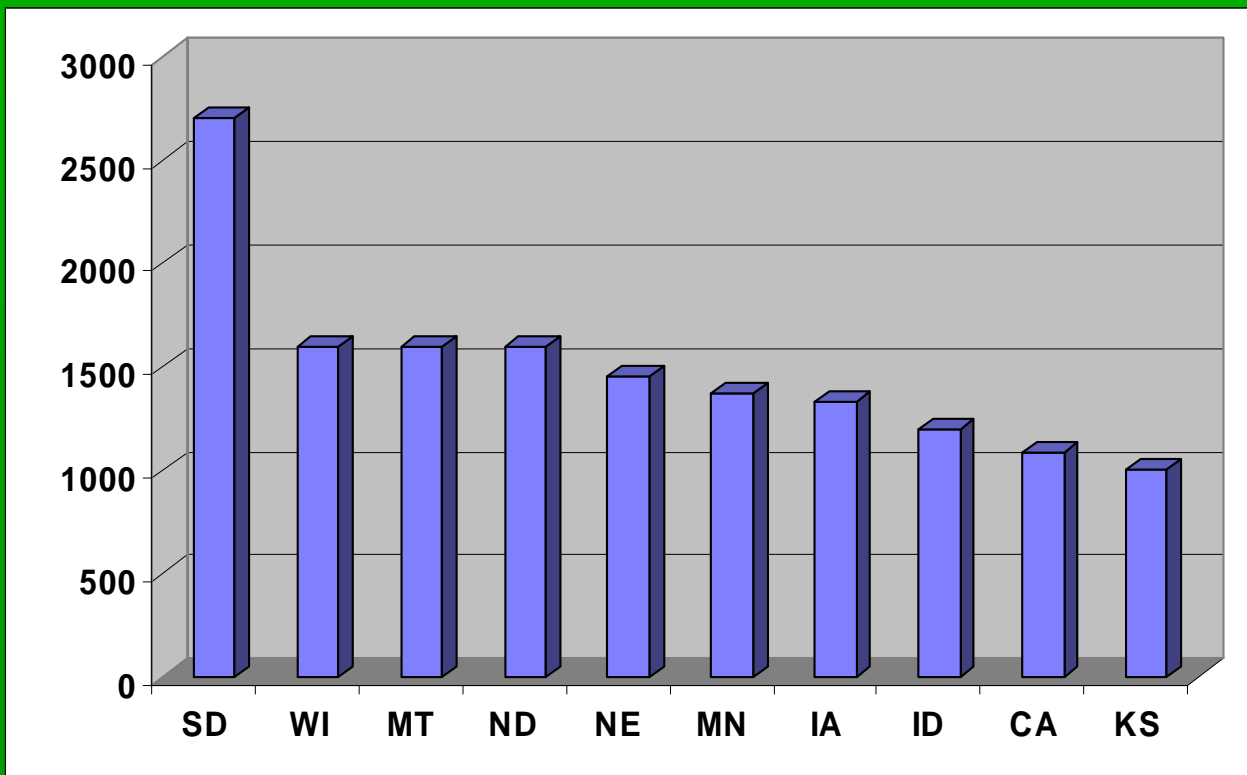
## ■ Top 10 States

- 58 % of U. S.
- 60 % of Acre
- 4 states NC
- 6 states West
- 5 Lead Dairy

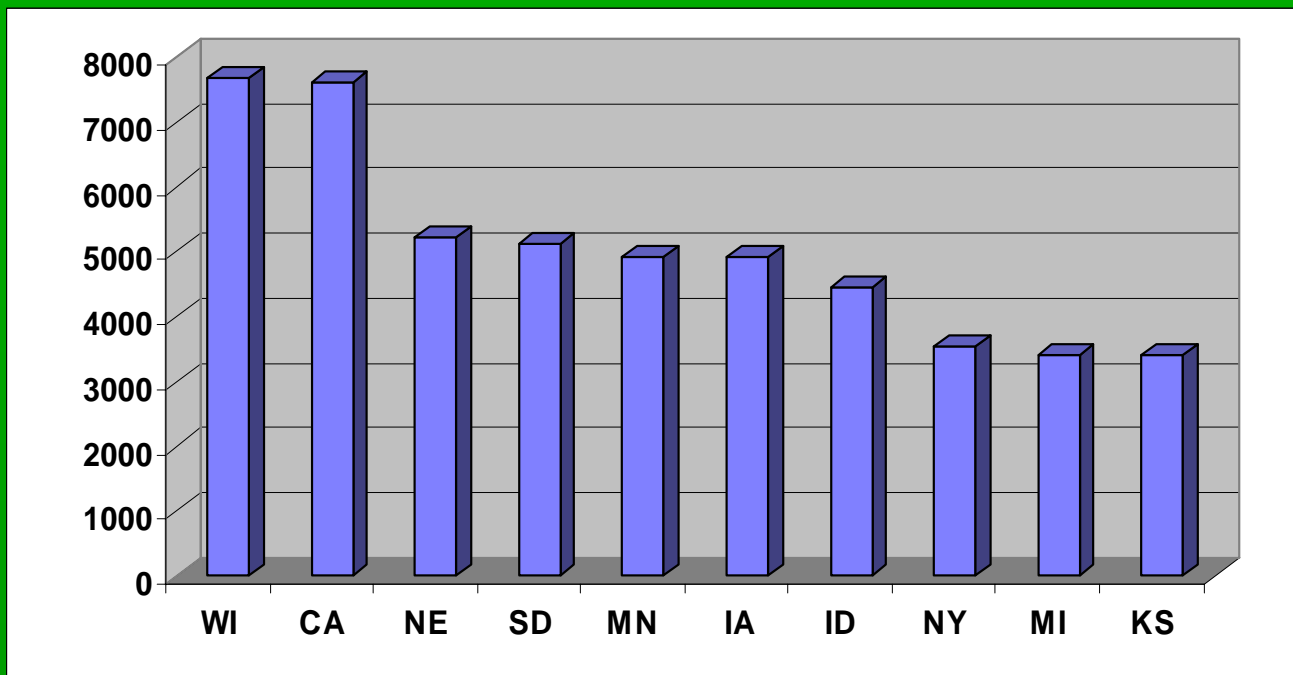
# Leading Alfalfa Hay Acreage States, 1,000 acres, 2003

## ■ Top 10 States

- 58% of U. S.
- 63 % of Acre
- 3 states NC
- 7 states West
- 4 Lead Dairy



# Leading Alfalfa Forage Production States, 1,000 tons, 2003



## ■ Top 10 States

- 59% of U. S.

- 59 % of Acre

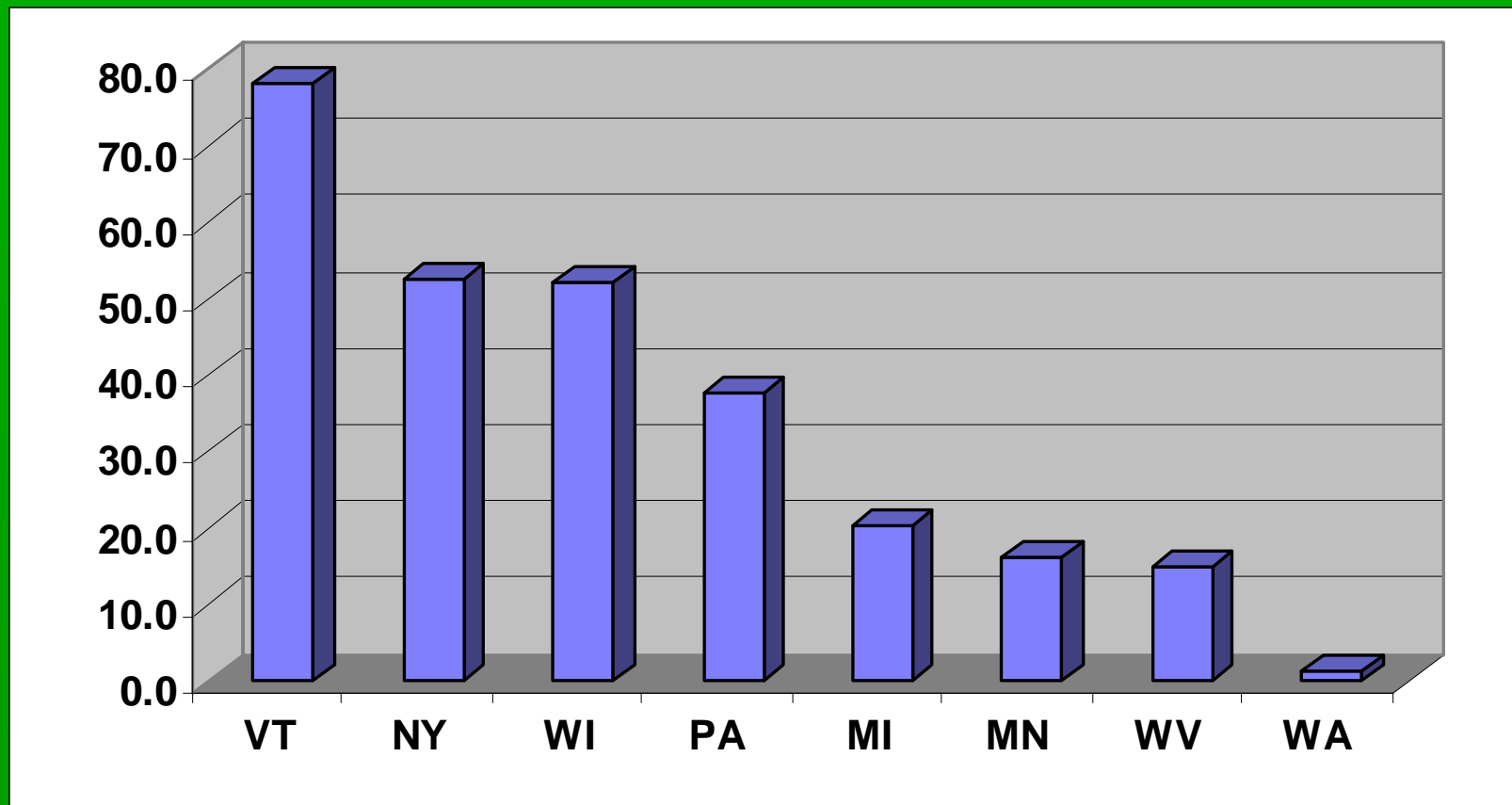
- 4 states NC

- 1 state NE

- 5 states West

- 6 Lead Dairy

# Percent of Total 2003 Alfalfa Production - Haylage



# California Dairy Nutritionists Value Alfalfa Hay

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- High energy value
- Its rapid ruminally digested structural fiber which stimulates intake
- Coarse structural fiber that stimulates chewing and salivation which results in rumen buffering and buffering capacity
- High protein
- Relatively high proportion of protein that escapes rumen undegraded

Davis - CA

Peter Robinson, University of



# Alfalfa: Corn Silage

50% forage: 50 % concentrate

Item	AS <sup>1</sup>	2/3 AS	1/3
<b>AS</b>			
<b>Milk production</b>			
<b>Mature cows,</b>			
<b>lb/hd/305</b>	<b>21,148</b>	<b>22,422</b>	<b>22,100</b>
<b>0</b>			
<b>1<sup>st</sup> calf cows,</b>			
<b>lb/hd/305</b>	<b>17,911</b>	<b>18,546</b>	<b>18,000</b>
<b>8</b>			
<b>3.5 % FCM, lb/d</b>	<b>68.2</b>	<b>72.4</b>	<b>70.0</b>
<b>Milk protein, lb/d</b>	<b>2.09</b>	<b>2.22</b>	<b>2.18</b>

# High Alfalfa Haylage Diet

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Item	Control	Protein	Fat
DM intake, lb	48.4 <sup>b</sup>	55.9 <sup>a</sup>	49.5 <sup>b</sup>
BW gain, lb	50.6	48.4	33.0
3.5 % FCM, lb	63.4 <sup>c</sup>	75.0 <sup>a</sup>	67.5 <sup>b</sup>
Milk protein, lb	1.89 <sup>b</sup>	2.29 <sup>a</sup>	1.94 <sup>b</sup>

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<sup>abc</sup> Means in same row with different superscripts differ (p<0.01)

# Protein Use of Alfalfa

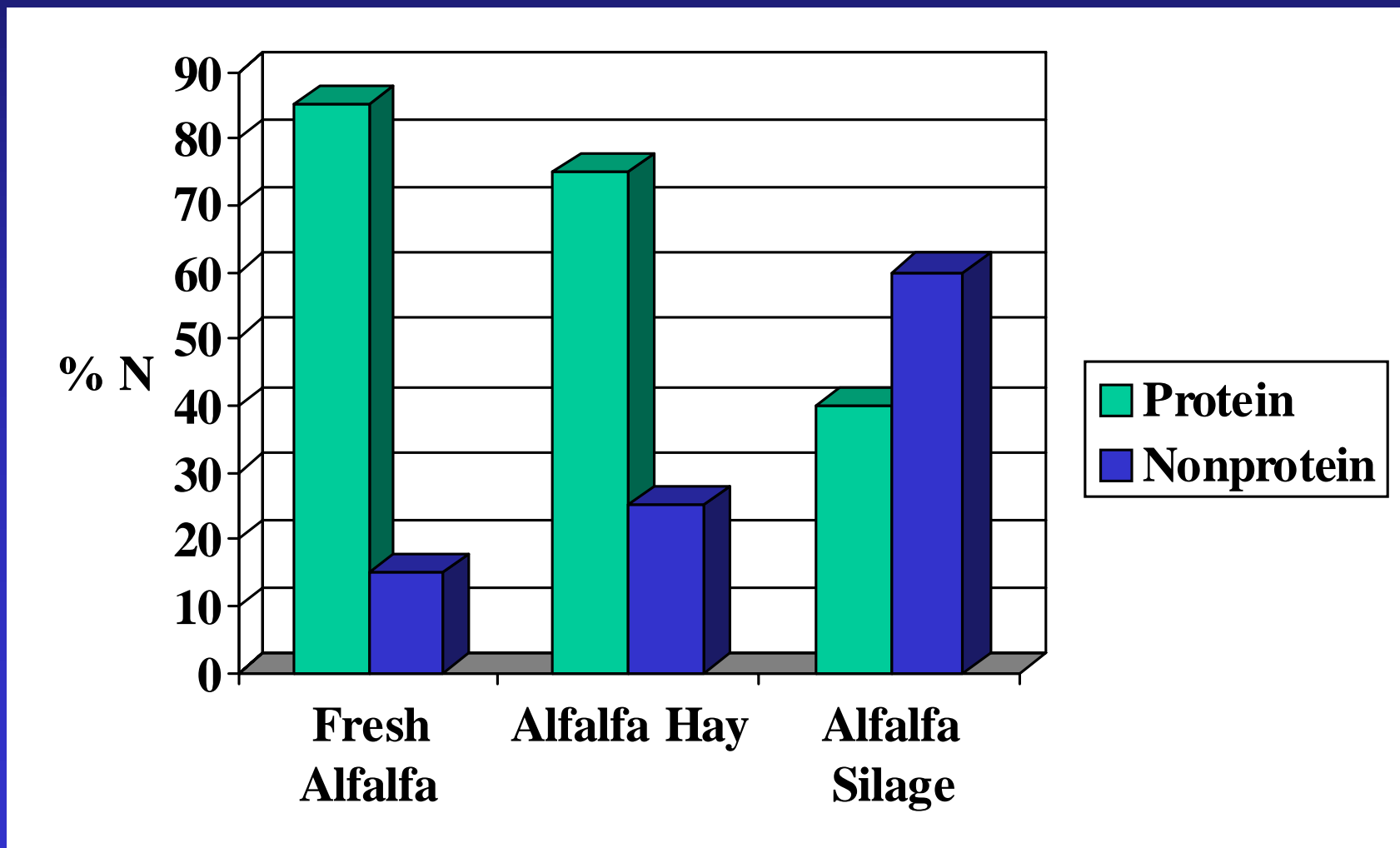
Item	silage	hay	silage	
+FM <sup>1</sup>	hay +FM <sup>1</sup>			
CP,% of DM	17.1	15.4	18.6	17.0
	pounds DM per day per cow			
DM intake	49.2 <sup>c</sup>	52.9 <sup>a</sup>	51.4 <sup>b</sup>	53.4 <sup>a</sup>
BW change	-0.86 <sup>c</sup>	0.99 <sup>a</sup>	0.18 <sup>b</sup>	1.08 <sup>a</sup>
Milk	77.8 <sup>c</sup>	79.6 <sup>b</sup>	82.5 <sup>a</sup>	81.4 <sup>a</sup>
Fat	2.65 <sup>b</sup>	2.60 <sup>b</sup>	2.82 <sup>a</sup>	2.69 <sup>b</sup>
Protein	2.29 <sup>c</sup>	2.43 <sup>b</sup>	2.51 <sup>a</sup>	2.49 <sup>a</sup>
SNF	6.64 <sup>c</sup>	6.81 <sup>b</sup>	7.05 <sup>a</sup>	7.01 <sup>a</sup>

<sup>abc</sup> Means in same row with different superscripts differ (p<0.05)

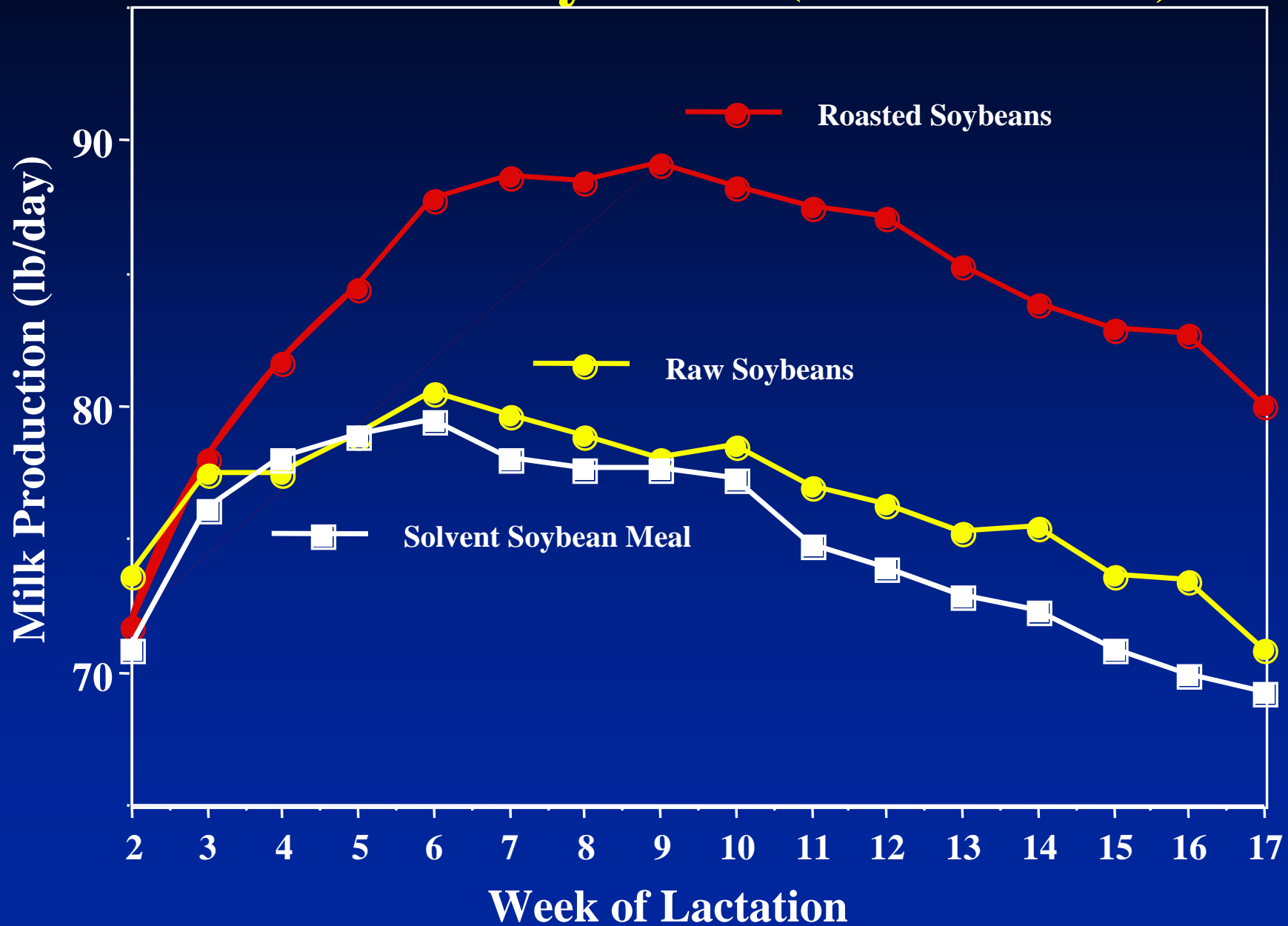
<sup>1</sup> Diets supplemented with 3 % (DM basis) low-soluble fish meal.

# Feed Storage Problems

- However in alfalfa, our primary forage:



# Supplementation of a 50% Alfalfa Silage Diet with Raw or Roasted Soybeans (Faldet & Satter, 1991)



# Effect of Silage Preservation on Alfalfa

Item	Control	Formic acid	Grainmax
ax	C <sup>3</sup>	F <sup>4</sup>	G <sup>5</sup>
Silage comp			
Moisture, %	61.7	64.8	64.1
Crude protein, %	21.4	20.8	21.1
NPN, % of N	43.1	29.1	35.5
NDF, %	38.0	41.2	41.3

<sup>3</sup>Control silage was ensiled untreated

<sup>4</sup>Silage ensiled after treatment of 2 gal/T of 90 % formic acid

<sup>5</sup>Silage ensiled after treatment with 1.5 gal/T of Grainmax & 16% formaldehyde.

# Effect of Silage Preservation on Alfalfa

Item	Control	Formic acid	Grainmax
ax	C <sup>3</sup>	F <sup>4</sup>	G <sup>5</sup>
<b>Intake and milk</b>			
DM intake, lb/day	40.3	40.1	43.4
Milk, lb/day	64.4 <sup>b</sup>	71.1 <sup>a</sup>	71.4 <sup>a</sup>
Fat, lb/day	2.4 <sup>b</sup>	2.9 <sup>a</sup>	2.9 <sup>a</sup>
Protein, lb/day	1.8 <sup>b</sup>	2.0 <sup>a</sup>	1.9 <sup>ab</sup>

<sup>3</sup>Control silage was ensiled untreated

<sup>4</sup>Silage ensiled after treatment of 2 gal/T of 90 % formic acid

<sup>5</sup>Silage ensiled after treatment with 1.5 gal/T of Grainmax & 16% formaldehyde.

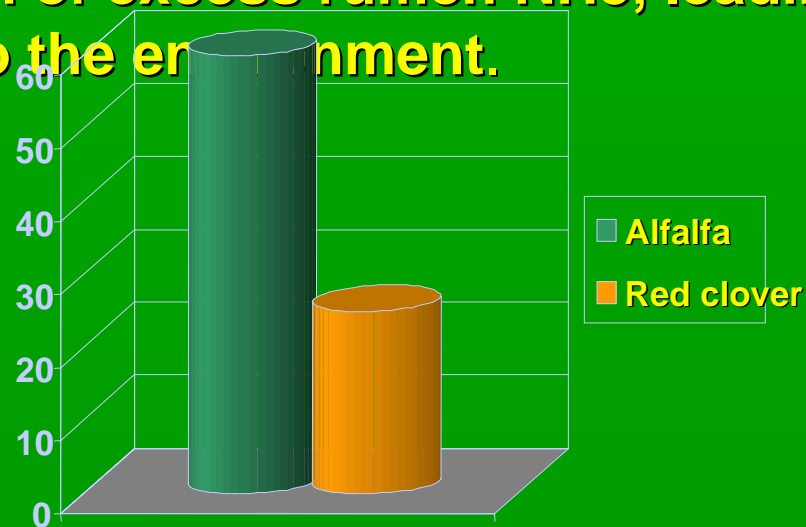
# Post Harvest Proteolysis in Alfalfa

## 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  $\text{NH}_3$ , leading to increased N losses to the environment.

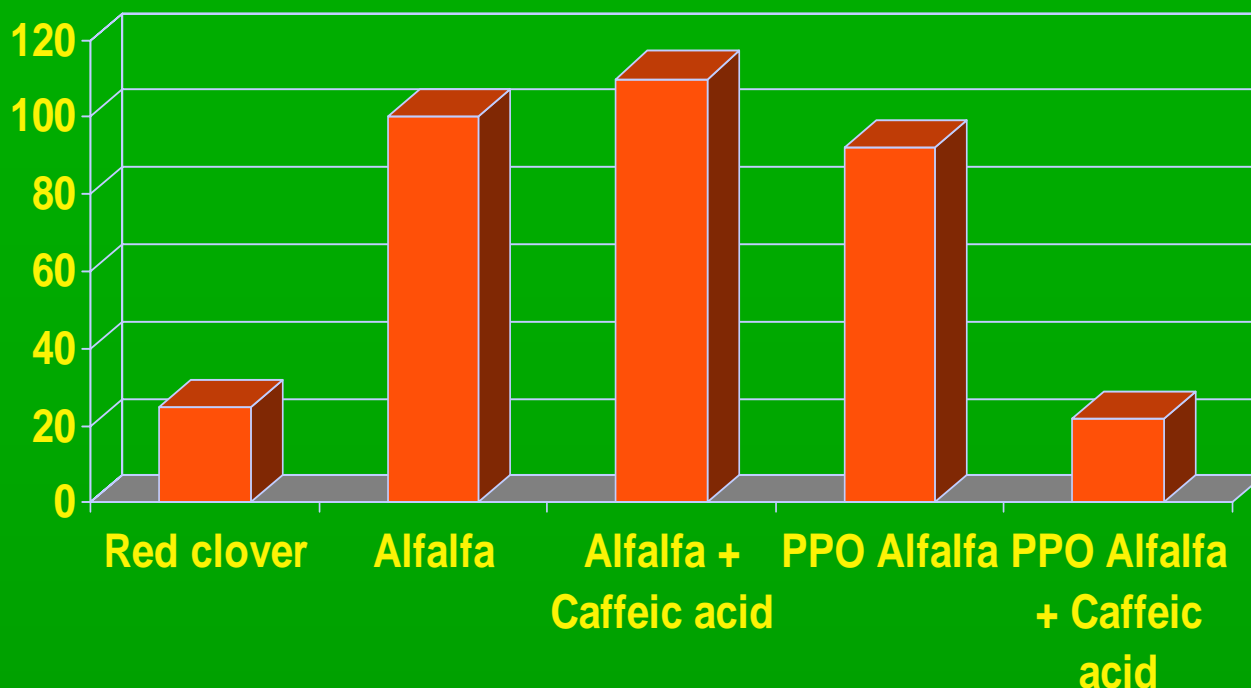
Typical NPN content of silage





# 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

# Improving Alfalfa for Dairy Rations

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- **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**

# Impact of Harvest Management on Forage Quality

Description	CP	EE	Ash	Starch	Pectin	aNDF	ADF	ADL
<b>ALFALFA HAY</b>								
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
<b>CORN SILAGE</b>								
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
Very low grain	9.3	2.7	6.2	15.3	1.3	54.0	33.0	2.93

# Ideal Alfalfa – Sole Diet

Insoluble CHO and Lignin	Cow Req.	Corn Silage	Alfalf a Silage	Hi- Qual Alfalfa
<b>NDF</b>	<b>28</b>	<b>43</b>	<b>43</b>	<b>28</b>
<b>ADF</b>	<b>19</b>	<b>24</b>	<b>33</b>	<b>19</b>
<b>AD Lignin</b>		<b>3.0</b>	<b>8.6</b>	<b>4.0</b>
<b>NDF digestion rate</b>		<b>.06</b>	<b>.10</b>	<b>.15</b>
<b>Physically effective NDF</b>	<b>22</b>	<b>38.7</b>	<b>40.8</b>	<b>25.2</b>

# Ideal Alfalfa – Sole Diet

<b>Soluble CHO</b>	<b>Cow Req.</b>	<b>Corn Silage</b>	<b>Alfalf a Silage</b>	<b>Hi- Qual Alfalfa</b>
<b>Nonfibrous CHO</b>	<b>45</b>	<b>42.0</b>	<b>25.0</b>	<b>28.0</b>
<b>Nonstructural CHO</b>		<b>40</b>	<b>10</b>	<b>11</b>
<b>Starches</b>	<b>30</b>	<b>36</b>	<b>3</b>	<b>4</b>
<b>Pectins+</b>		<b>2</b>	<b>15</b>	<b>18</b>

# Apparent Dry Matter Digestibility of AH and CS

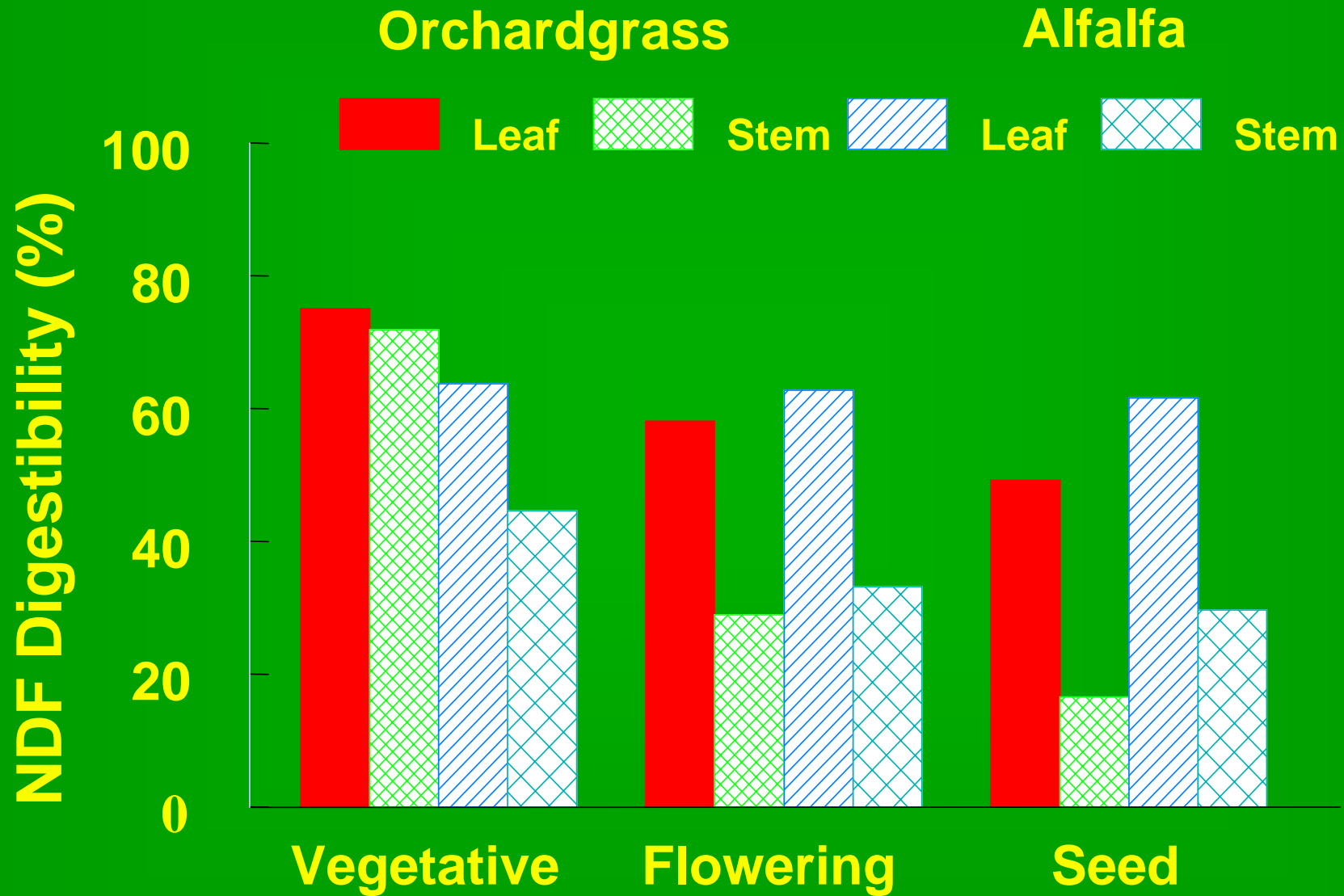
Item proc	AH	AH	CS proc	CS
	<del>24%ADF</del>	<del>27%ADF</del>	<del>24%ADF</del>	<del>27%</del>
ADF				
% aNDF	30.0	34.1	40.5	45.0
% NDFD	52.1	46.8	61.4	60.6
% dNDF	15.6	16.0	24.9	27.3
% NDS	70.0	65.9	59.5	55.0
% dNDS	68.6	64.6	58.3	53.9
% True DM digestibility	84.2	80.6	83.2	81.2
% Endo fecal DM excr	-12.9	-12.9	-12.9	-12.9
% Apparent DMD	71.3	67.7	70.3	66.6

USDFRC



ARS

# Forage Fiber Digestibility



# New Alfalfa Products of high value are needed to expand acreage...

- Research efforts underway to:
  - Develop alfalfa with value-added traits
  - Develop new processing technologies



Reconstituted bales are sold year-round to French dairy farmers.

Below: Four of the 30+ feed products made by the French co-op.

PHOTOS: ILIY RADKE (2001)





# Novel Products of Alfalfa

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## ■ Three methods of forage fractionation exist:

- Wet fractionation; separation into a juice and a fiber fraction
- Dry fractionation; separation into leaves and stems
- Animal fractionation; passage of whole plant through digestive systems of ruminant animals, leaving a high fiber residue.

# Novel Products of Alfalfa

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- **Two important conditions must be met for alfalfa fractionation to be feasible and sustainable:**
  - **Total value of resulting products must be greater than the original forage plus the cost of processing;**
  - **All fractions must have economic value to avoid creating a waste stream.**

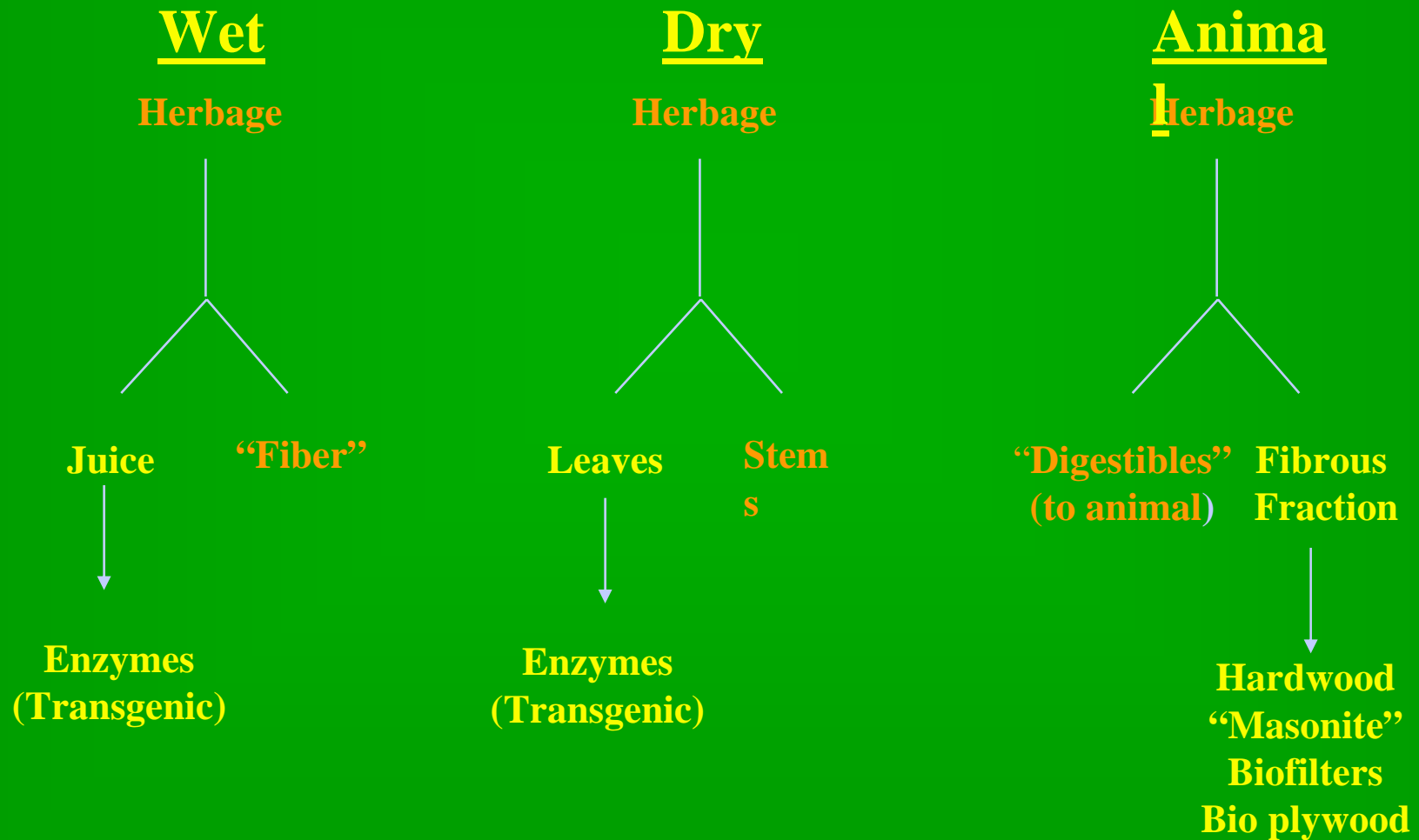
# Novel Products of Alfalfa

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- **Wet-fractionation process has two advantages for agriculture:**
  - **Forage crops can be harvested almost independent of weather, since moisture is removed mechanically rather than by mother nature**
  - **A versatile protein concentrate is obtained which can be fed to non-ruminants, including humans, as well as dairy cattle.**

# FRACTIONATION METHODS

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# Development of Green Genes

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## Transgenic Phytase-rich Alfalfa

- Phytase enzyme makes P in grain ration of monogastric diets more available (poultry, swine, and fish)
- Less P excreted in feces
- Phytase enzyme levels of 1 - 2 % of soluble protein possible
- Phytase extraction with wet fractionation gives added value of xanthophyll & high protein
- Phytase is stable - alfalfa leaf meal

# Alfalfa - Produced Phytase in Poultry Rations:

- ❖ Eliminates need for phosphorus supplementation
- ❖ Reduces the phosphorus content of feces to less than half



# VALUE OF PHYTASE-PROTEIN- PIGMENT CONCENTRATE PER ACRE-YEAR

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**PHYTASE**  
**\$600**

**4lb @ \$150/lb =**

**XANTHOPHYLL**  
**\$245**

**1.2lb @ \$175/lb =**

**PROTEIN CONC.**  
**\$137**

**1375lb x \$0.10/lb =**

**Total**

**\$982**

# Potential new uses of alfalfa

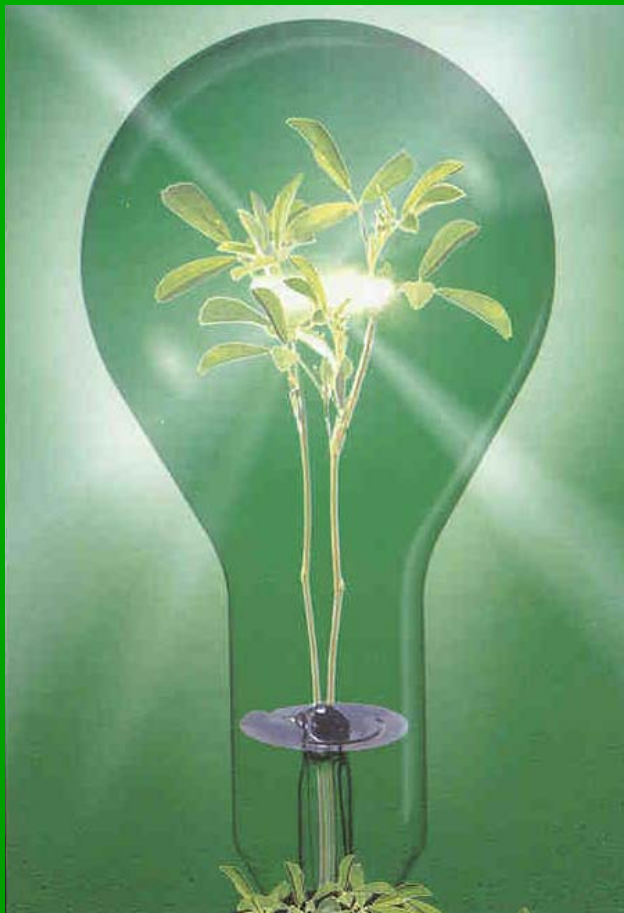
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- **Electric generation**



# Minnesota Agri-Power: Project to Produce Electricity and Livestock Feed (and Improve the Environment) with Alfalfa

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- Separate alfalfa hay into leaf and stem fractions.
- Produce electricity from the low-value stems.
- Utilize the leaves as a feed supplement for livestock.

# Composition of Leaf Meal - Fractionation

Component	<u>Separation</u>		<u>Mechanical</u>	
	Lab	'96	'98	'98
	-----% of dry weight----			
Crude protein	25.2	21.9	25.8	28.2
NDF	36.0	36.5	43.6	34.4
ADF	21.5	21.9	26.6	
25.	1			
Ash	--	11.3	12.4	14.8

**SOURCE: DiCostanzo et al. 1999.**

# Dry Alfalfa

**Leaf Meal**

**High fiber**

**Protein Supplement**

**Dairy, Beef, and Poultry**

**40-50 % of ground hay**

**Combustion, Gasification  
Or Enzymatic Hydrolysis**

**50-40 % of ground hay**

**EcoPLA**  
A Cargill product.

Comes from nature.

Returns to nature.

Blow Molding

Paper Coatings

Thermoforming

Films

WASTE 80 (38.3%)  
CARGILL SUPERSOFT PELLETS

Fibery

Injection Molding

**Renewable Biopolymer**

# Bio-degradable plastics made from Lactic Acid

**RENEWABLE BIOPOLYMER**

**ECO-PLA™**  
The renewable bioplastic from Cargill

Day 0      Day 12      Day 33      Day 45

EcoPLA™ Renewable Bioplastic is a new material made from lactic acid, a natural food ingredient processed from corn and other annually renewable resources. The fork in the above photo was exposed to a lab scale simulation of a composting process\*. Grades of EcoPLA have been shown to degrade in 30 to 90 days, depending on the compost conditions.

\*ASTM Test #D 5538

**Truly Compostable.  
Clearly Acceptable.**

**Check These Features:**

- Compostable - biodegrades like leaves, grass and kraft paper at about the same rate.
- Clear - You can see what's inside.
- Ideal for commercial and municipal composting.
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Why? Because EcoPLA bags are derived primarily from lactic acid, a natural food ingredient that readily decomposes during managed composting and is consumed by microorganisms found in the environment.  
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# Fiber Board and Filter Mats from Manure

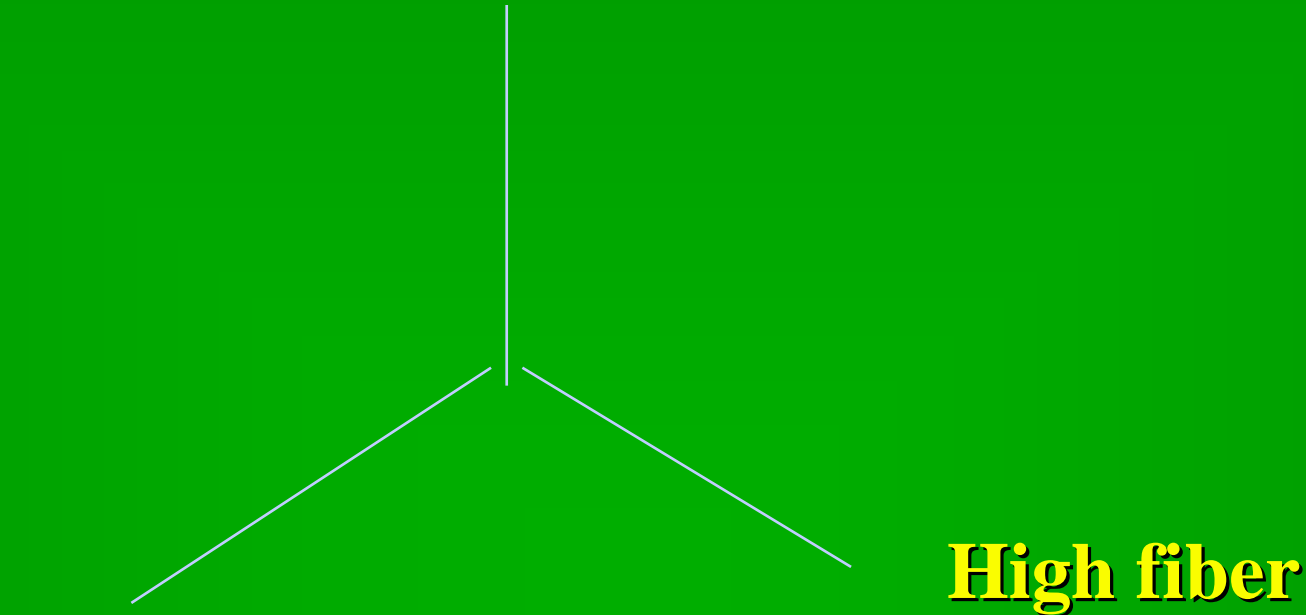


Thick Filter Mat

Fiber Board

Thin Filter Mat

# Fresh Alfalfa



**Juice**

**Heat coagulate**

**Protein Concentrate**

**High fiber**

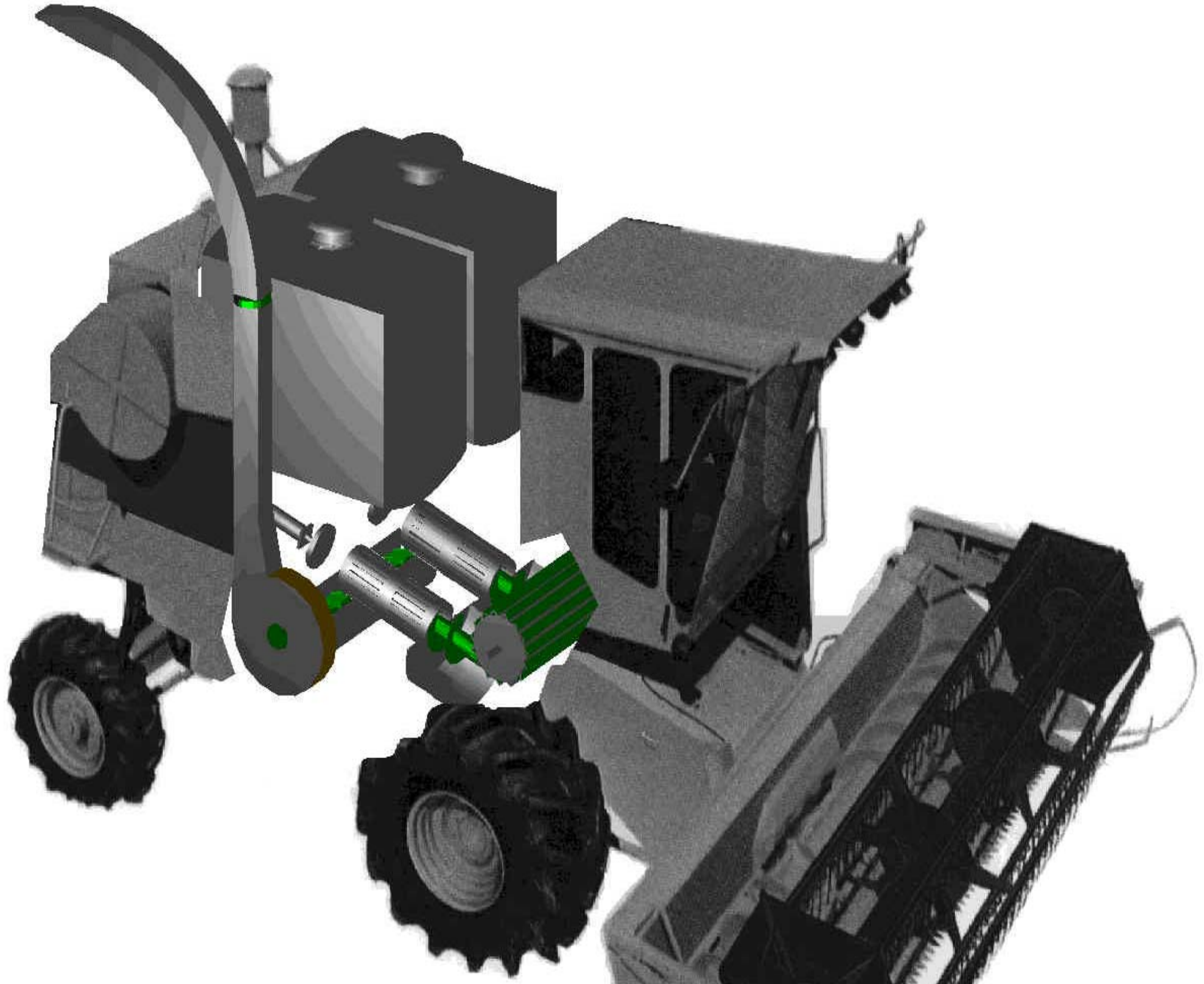
**Ruminant feed**

- **Store silage in bunkers**
- **Process fiber**

**Poultry supplement or calf-replacer**

**New products**

**25 % of original crop dry matter    75 % of original crop dry matter**



# Fractionating for Quality

## ■ Alfalfa fractionating at harvest:





# Fractionating for Quality

- Alfalfa fractionating at harvest:



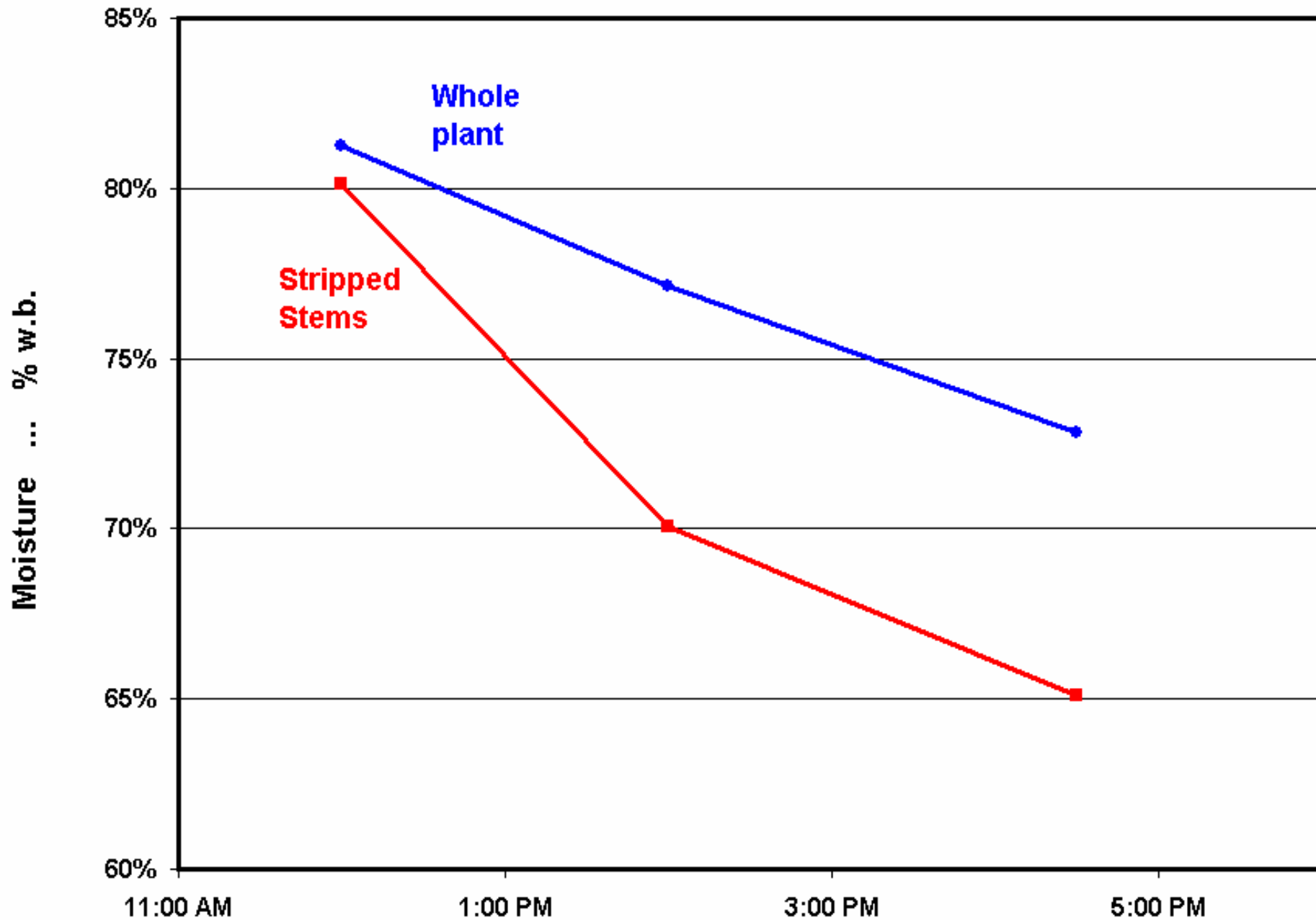
# Fractionating for Quality

- **Why fractionate alfalfa at harvest:**
  - **Leaf yield and quality relatively unaffected by maturity.**
  - **Stem quality diluted with age.**
  - **Conventional practices co-mingle high- and low-quality.**

# Fractionating for Quality

- *Why fractionate alfalfa at harvest:*
  - Fractionated leaves and stems can be target fed more optimally.
  - Single day harvesting possible.
    - Leaves: direct-ensiled with amendment
    - Stems: wilted and chopped on same day
  - Fewer cutting possible

# Fractionating for Quality



# Fractionating for Quality

- **Why fractionate alfalfa at harvest:**

- **Value-added products possible:**

- **Leaves: protein concentrates, pigmenting agents**

# Fractionating for Quality

- **What is the big hurdle with alfalfa harvest fractionation:**
  - **Direct ensiling with amendment:**
    - About 1 ton ground corn grain or DDG needed for every acre

# Potential new uses of alfalfa

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- **Electric generation**
- **Protein production**

# Biotechnology Applications in Alfalfa

- Insertion of BT gene to deter insect feeding
- Coat protein for control of viruses
- Improved winterhardiness
- Balanced animal diets
- Alfalfa bioremediation
- Alfalfa root & nodules
- **Human proteins**

## French May Produce Hemoglobin In Alfalfa Plants

**F**armers in France may soon be growing alfalfa to produce human hemoglobin.

Viridis, a subsidiary of Alfalis, which specializes in alfalfa production, hopes to begin manufacturing various proteins, especially hemoglobin.

"Alfalfa is a true protein factory," says Damien Levesque, Viridis' managing director. "It is the plant that can produce the largest quantity of proteins per acre – far ahead of soybeans. Alfalfa produces 2,200 lbs of protein per acre, compared with 650 to 890 lbs for soybeans."

His company specializes in the extraction of alfalfa juice for pigments and other products.

"The special characteristic of alfalfa is storing the proteins in the leaves and not in the seeds like soybeans or peas," says Levesque. "Extraction is therefore carried out by pressing the green foliage in order to recover proteins in the alfalfa juice without altering its quality. We have developed a specific technology for pressing."

Viridis has acquired Medicago, a Quebec biotechnology company that successfully introduced the gene for hemoglobin production in alfalfa plants.

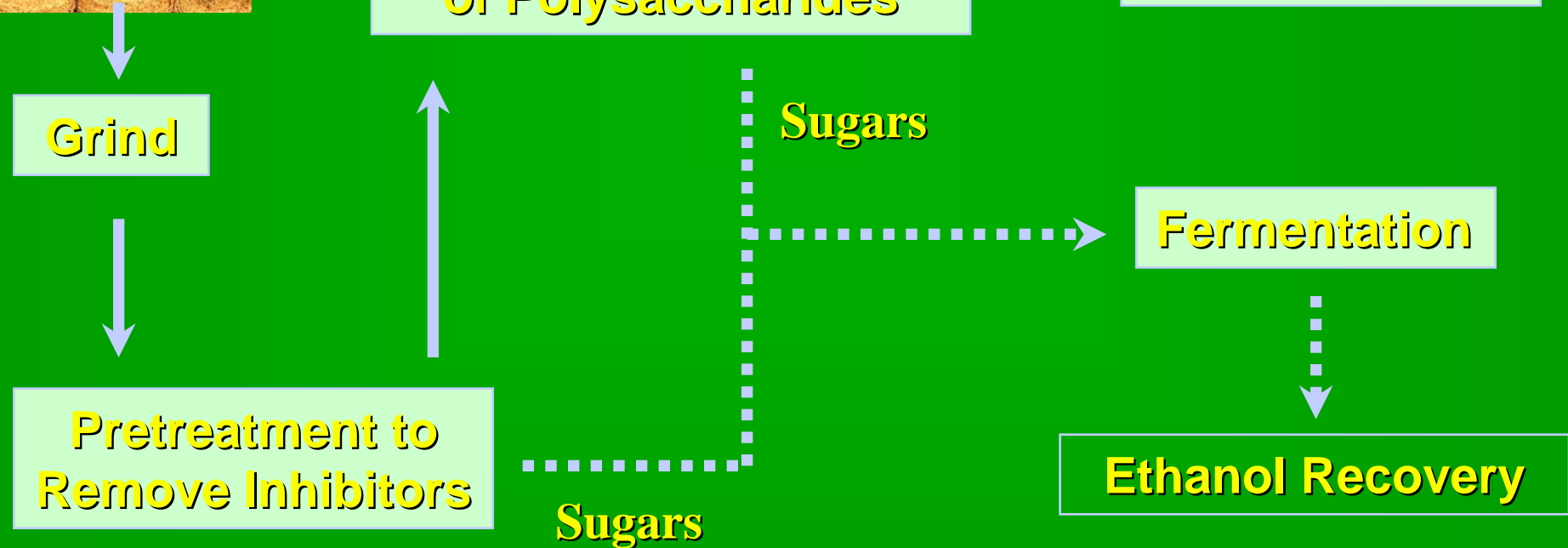


# Potential new uses of alfalfa

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- **Electric generation**
- **Protein production**
- **Ethanol production**

# Biomass Conversion to Ethanol



# Alfalfa in Crop Rotations:

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- 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:

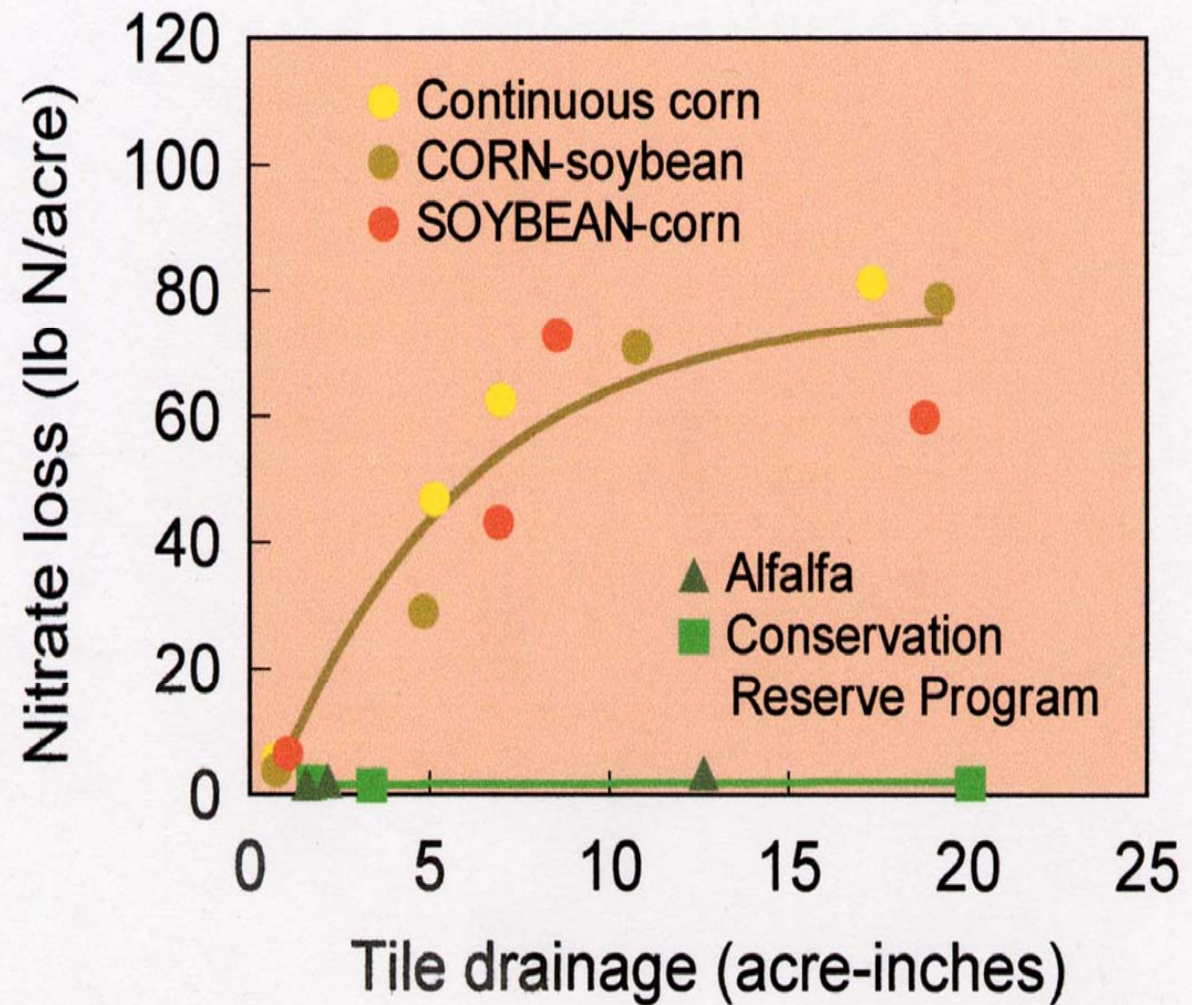
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- Helps protect surface and ground water
- Acts as waste-water recycler

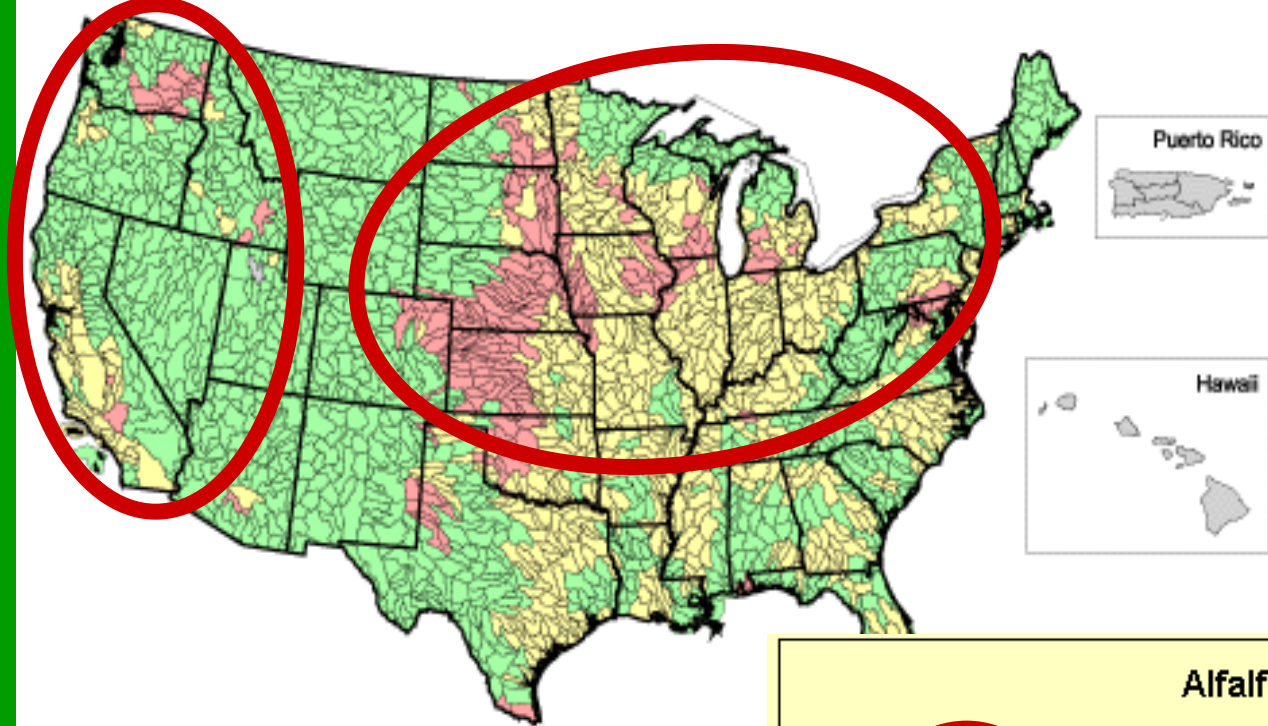


# Alfalfa and grass CRP effectively filter tile drain water

## tile drain water



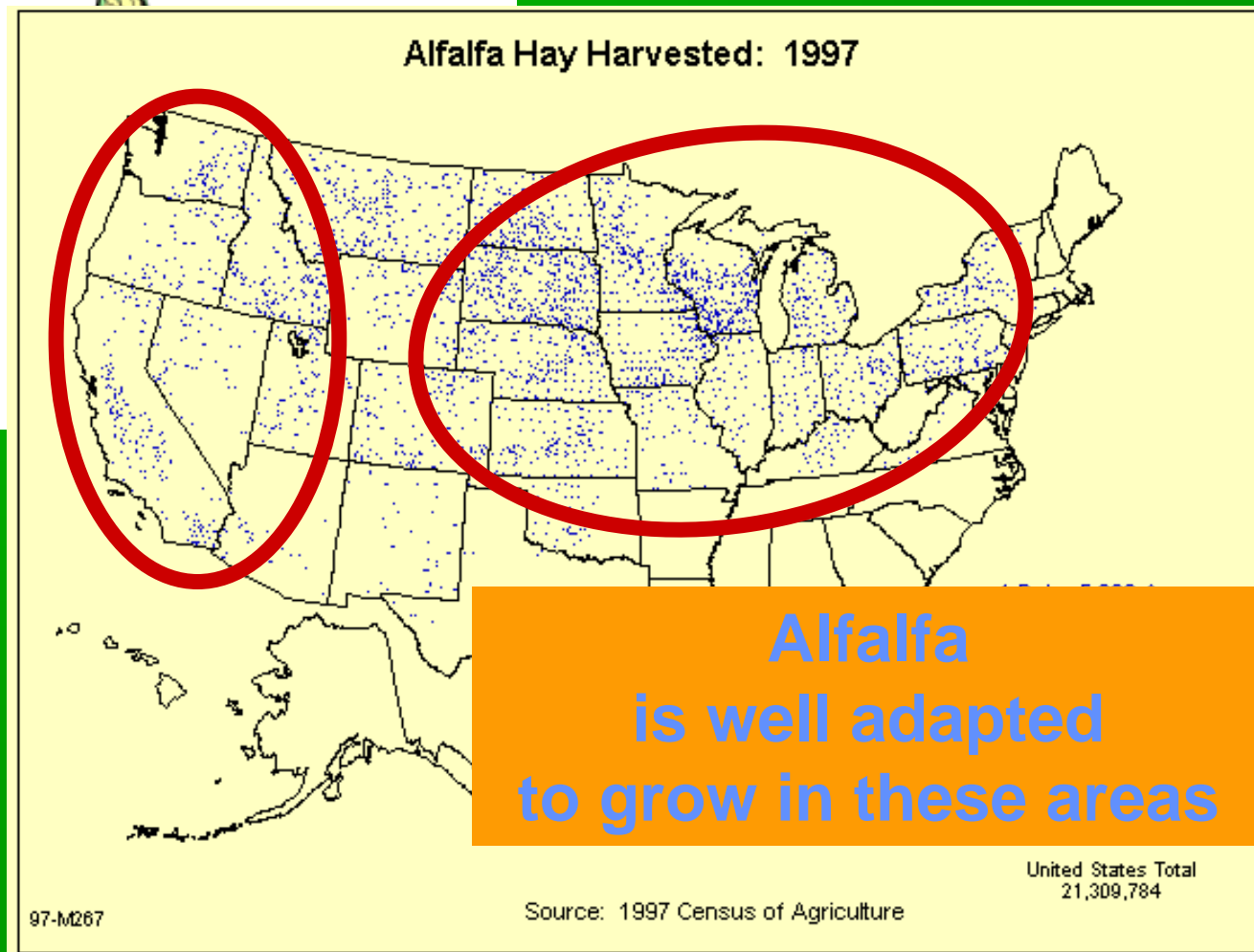
40 million acres are tile drained in the Upper Midwest



# Risk of ground water nitrate contamination

Risk of Groundwater Nitrate Contamination (1970 - 1995)

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



**Alfalfa**  
is well adapted  
to grow in these areas

# A multidisciplinary collaboration of public and private scientists

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- Dairy Nutrition (USDFRC)
- Biochemistry (Noble Foundation and USDFRC)
- Molecular/cell biology (Noble, FGI and DowAgro)
- Agronomy
- Plant breeding (FGI)

# Novel Products of Alfalfa

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## ■ Summary and Conclusions

- Alfalfa can be processed to provide products of higher value.
- Processing green alfalfa via wet fractionation removes effects of weather on harvest
- Corn and soybean cash farmers will benefit from all types of fractionation discussed.
- The Alfalfa Industry must cooperate to support research and development to obtain new products from alfalfa.