U.S. Dairy Forage Research Center

USDA, Agricultural Research Service

Alfalfa: Hay, Haylage, Baleage and Other Novel Products

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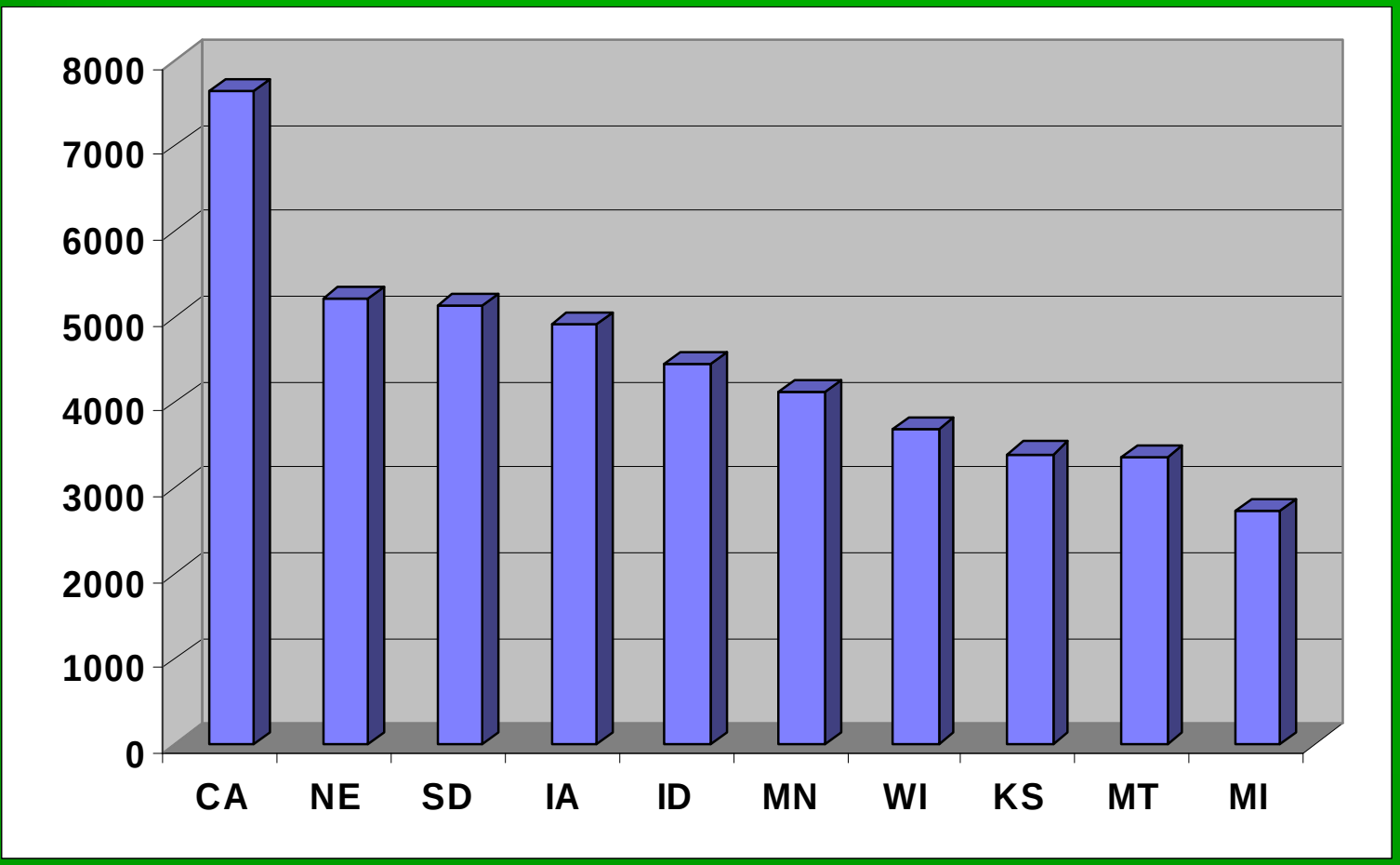
Alfalfa: Hay, Haylage, Baleage, and Other Novel Products

- 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

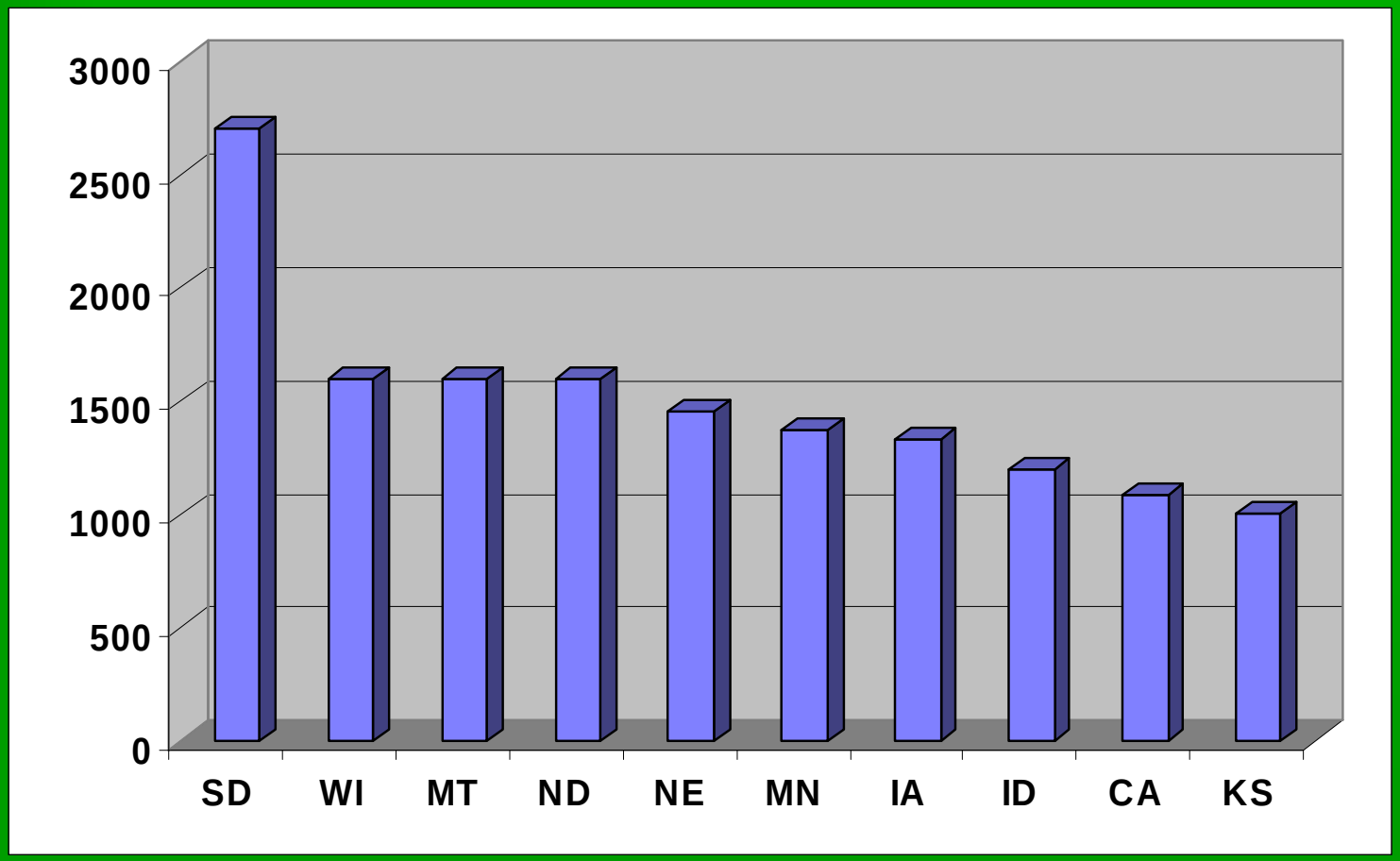
- 76.3 million tons
- $6.9 billion
- 4th following corn, soybeans and wheat
- Idaho ranks 2nd behind CA in value

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



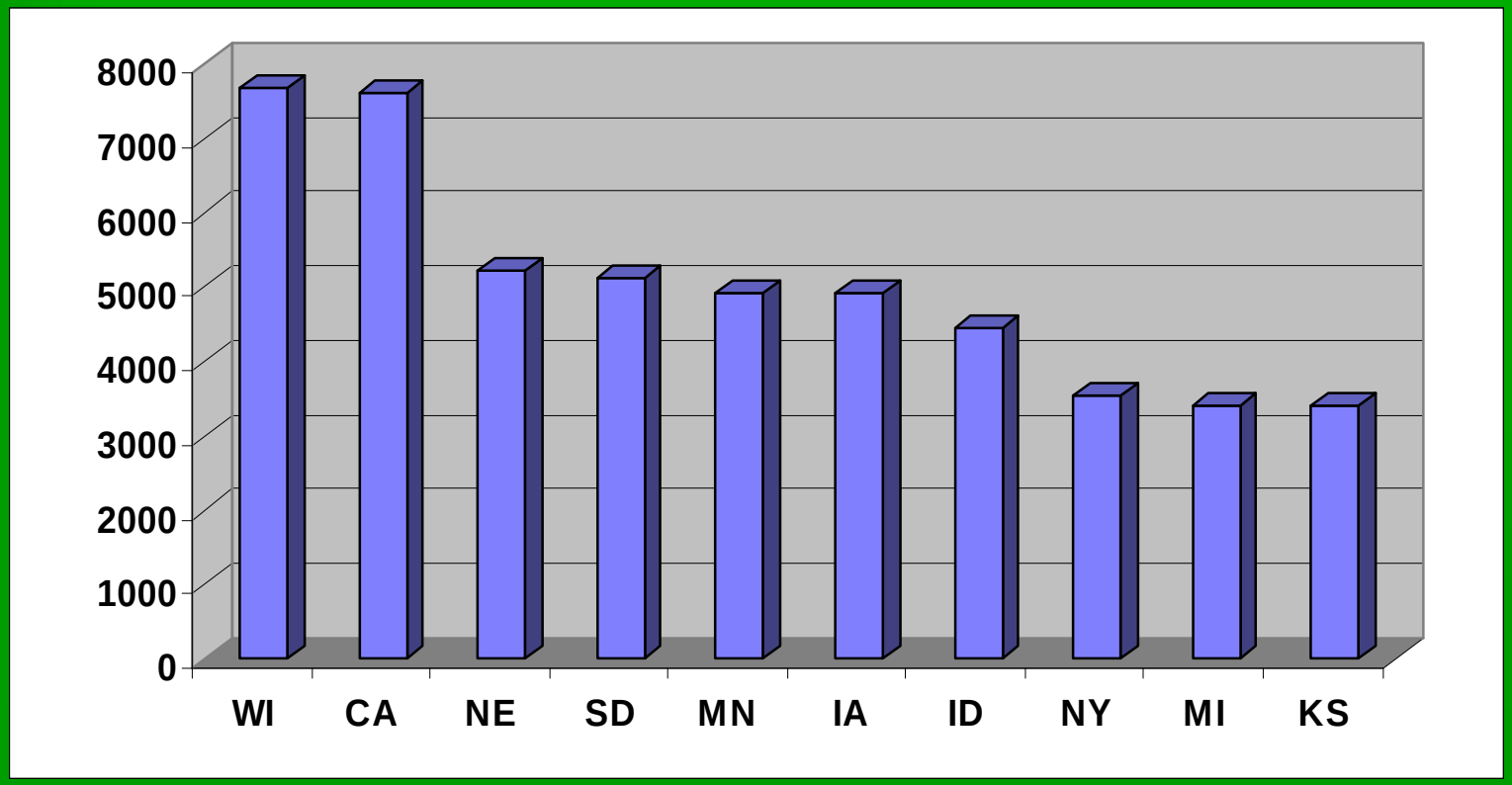
- Top 10 States
  - 58 % of U. S.
  - 60 % of Acre
  - 4 states NC
  - 6 states West
  - 5 Lead Dairy

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



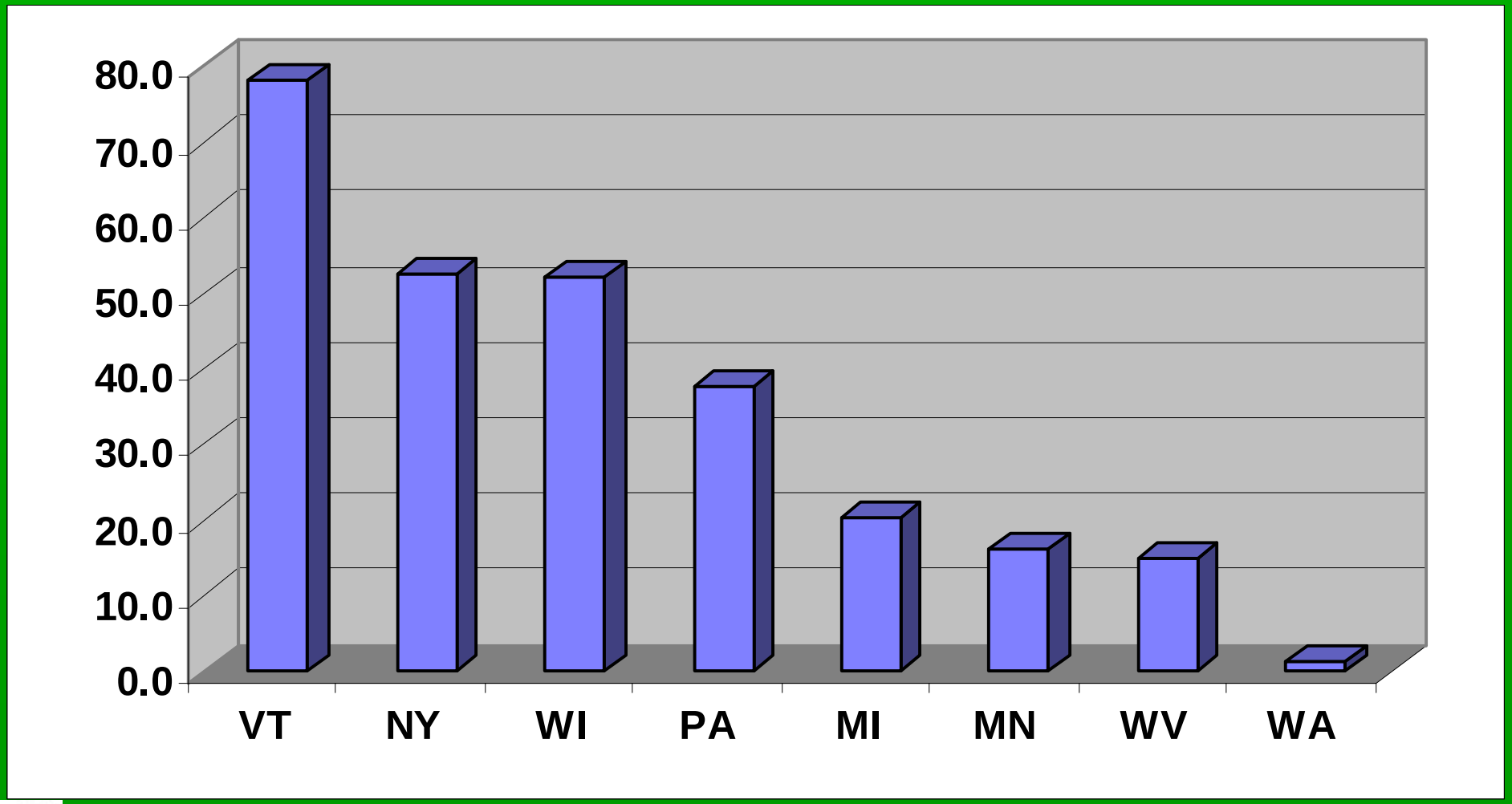
- Top 10 States
  - 58% of U. S.
  - 63 % of Acre
  - 3 states NC
  - 7 states West
  - 4 Lead Dairy

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

- 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

Peter Robinson, University of Davis - CA

Alfalfa:Corn Silage

50% forage: 50 % concentrate

Item	AS[1]	2/3 AS	1/3 AS
Milk production			
Mature cows, lb/hd/305	21,148	22,422	22,100
1st calf cows, lb/hd/305	17,911	18,546	18,008
3.5 % FCM, lb/d	68.2	72.4	70.0
Milk protein, lb/d	2.09	2.22	2.18

[1] (AS) Alfalfa silage: % DM, 40.2; CP, 19.5; ADF, 33.9; and NDF, 40.1. (CS) corn silage: % DM, 35.5; CP, 7.8;; ADF, 25.3; and NDF, 45.3

SOURCE: Dhiman and Satter. 1997. J. Dairy Sci 80: 2069.

High Alfalfa Haylage Diet

Item	Control	Protein	Fat
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]

[abc] Means in same row with different superscripts differ ($p<0.01$)

SOURCE: Dhiman and Satter, 1993.

Protein Use of Alfalfa

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

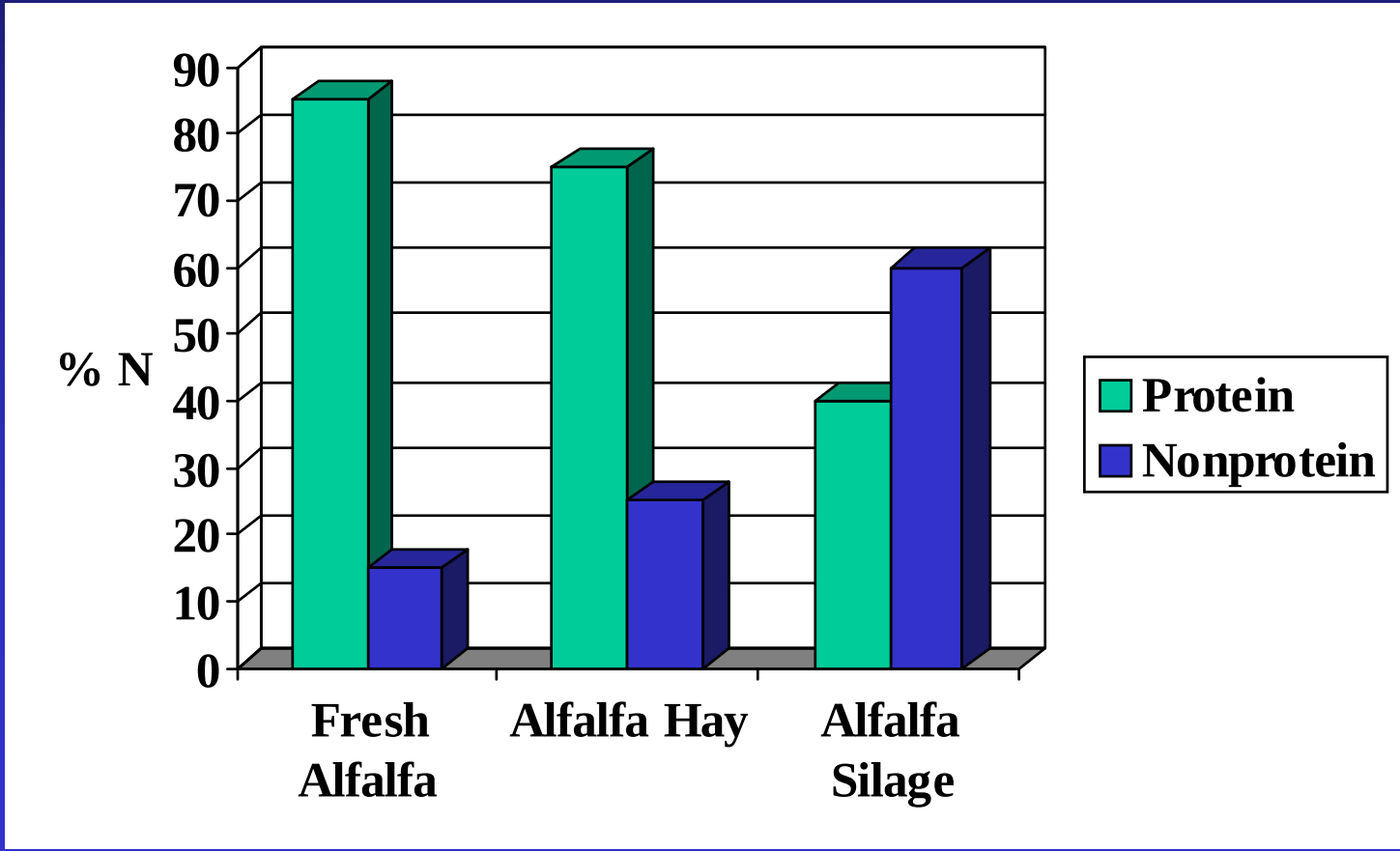
[abc] Means in same row with different superscripts differ ($p<0.05$)

[1] Diets supplemented with 3 % (DM basis) low-soluble fish meal.

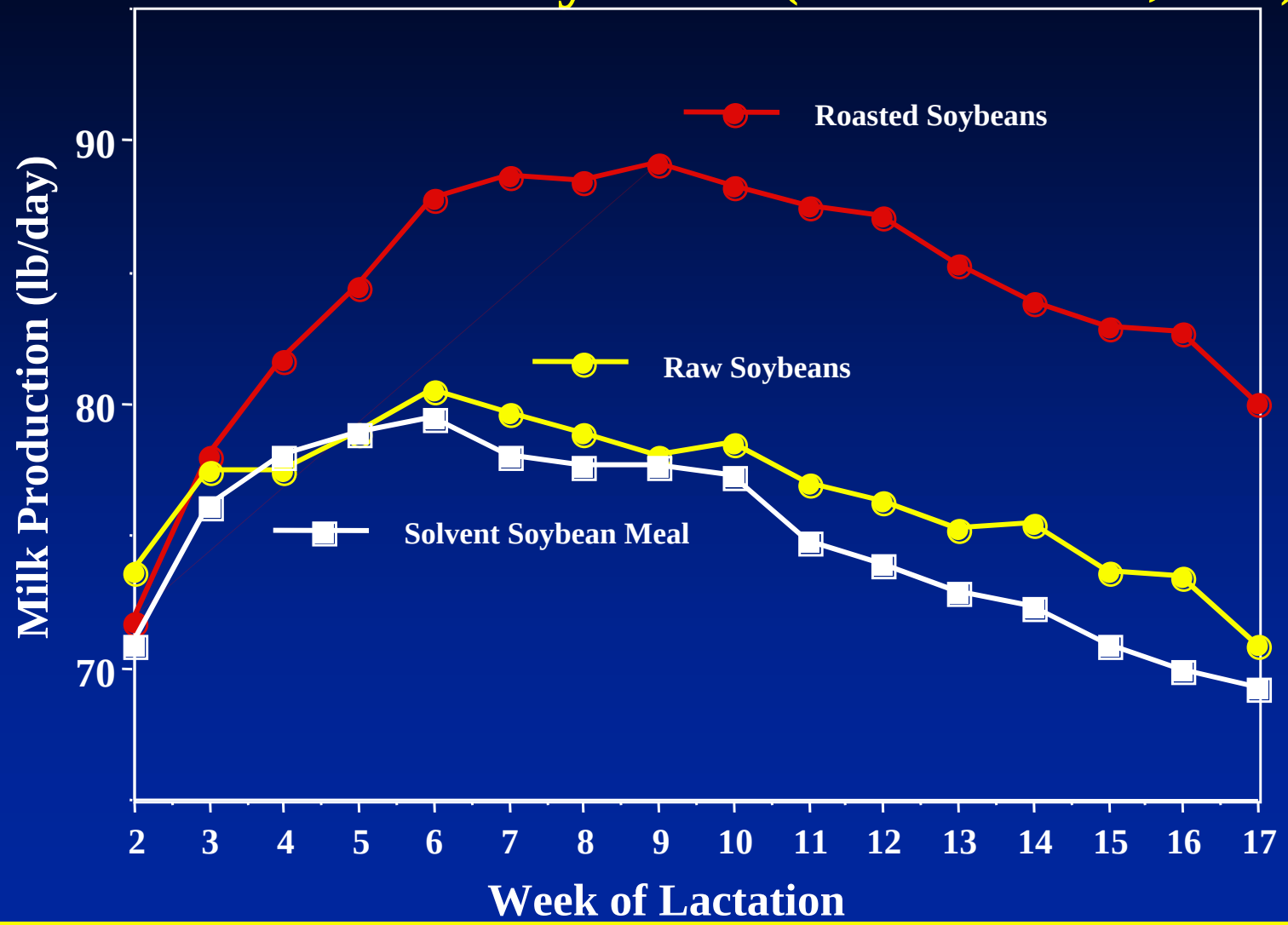
SOURCE: Broderick, 1995.

Feed Storage Problems

- However in alfalfa, our primary forage:



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



USDFRC

Effect of Silage Preservation on Alfalfa

Item	Control C[3]	Formic acid F[4]	Grainmax G[5]
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, %	38.9	41.2	41.3

[3]Control silage was ensiled untreated

[4]Silage ensiled after treatment of 2 gal/T of 90 % formic acid

[5]Silage ensiled after treatment with 1.5 gal/T of Grainmax & 16% formaldehyde.

Broderick and Satter. 1998. Proc. 4-State DFFMC

Effect of Silage Preservation on Alfalfa

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

[3]Control silage was ensiled untreated

[4]Silage ensiled after treatment of 2 gal/T of 90 % formic acid

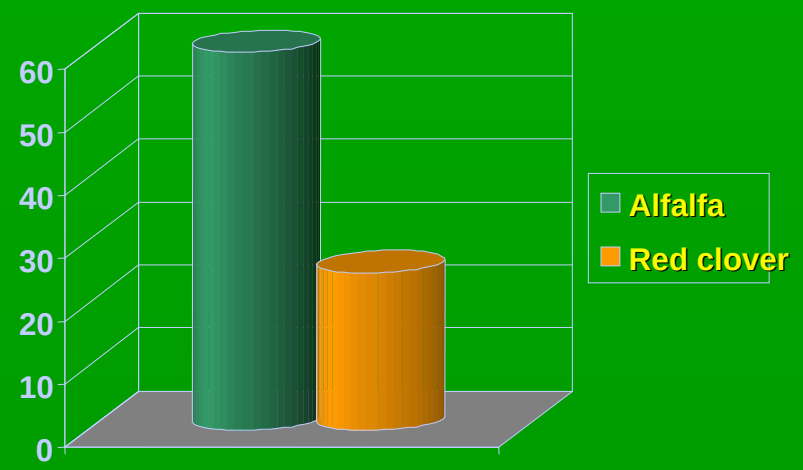
[5]Silage ensiled after treatment with 1.5 gal/T of Grainmax & 16% formaldehyde.

Broderick and Satter. 1998. Proc. 4-State DFFMC

Post Harvest Proteolysis in Alfalfa Impact on dairy production

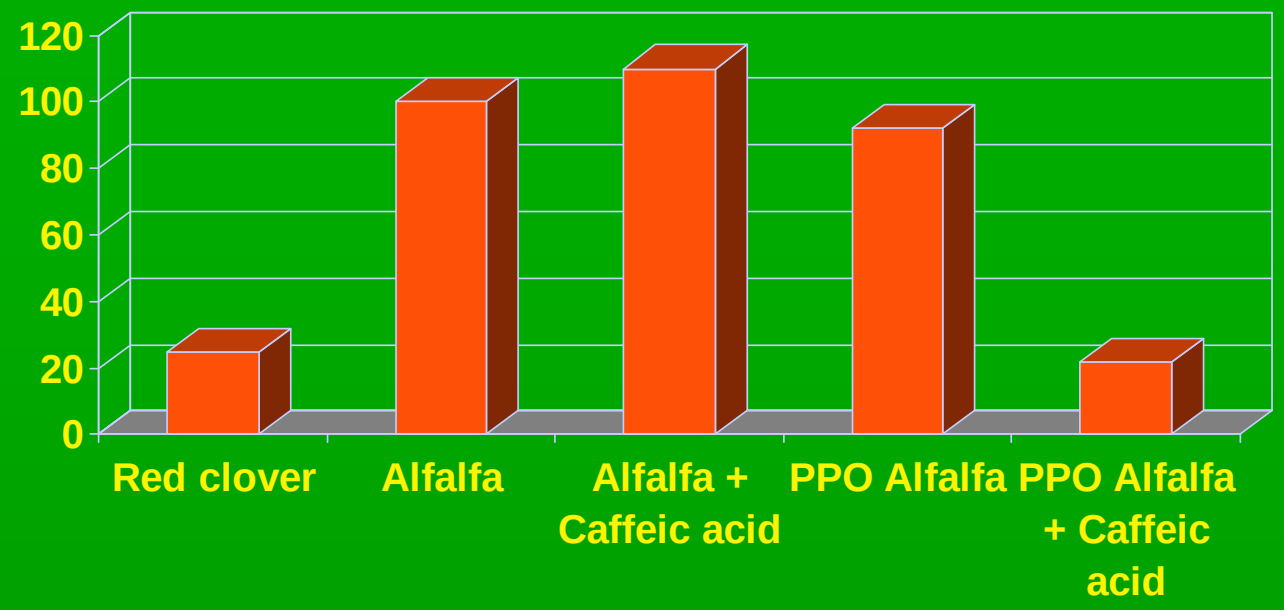
- **Increased NPN decreases the efficiency of protein utilization in ruminants**
  - **Inefficient utilization of alfalfa protein requires the feeding of supplemental protein with high RUP to maximize milk production.**
  - **Inefficient utilization of alfalfa protein also results in the excretion of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

Typical NPN content of silage



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

- 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
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
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	Alfalfa Silage	Hi-Qual Alfalfa
NDF	28	43	43	28
ADF	19	24	33	19
AD Lignin		3.0	8.6	4.0
NDF digestion rate		.06	.10	.15
Physically effective NDF	22	38.7	40.8	25.2

Ideal Alfalfa – Sole Diet

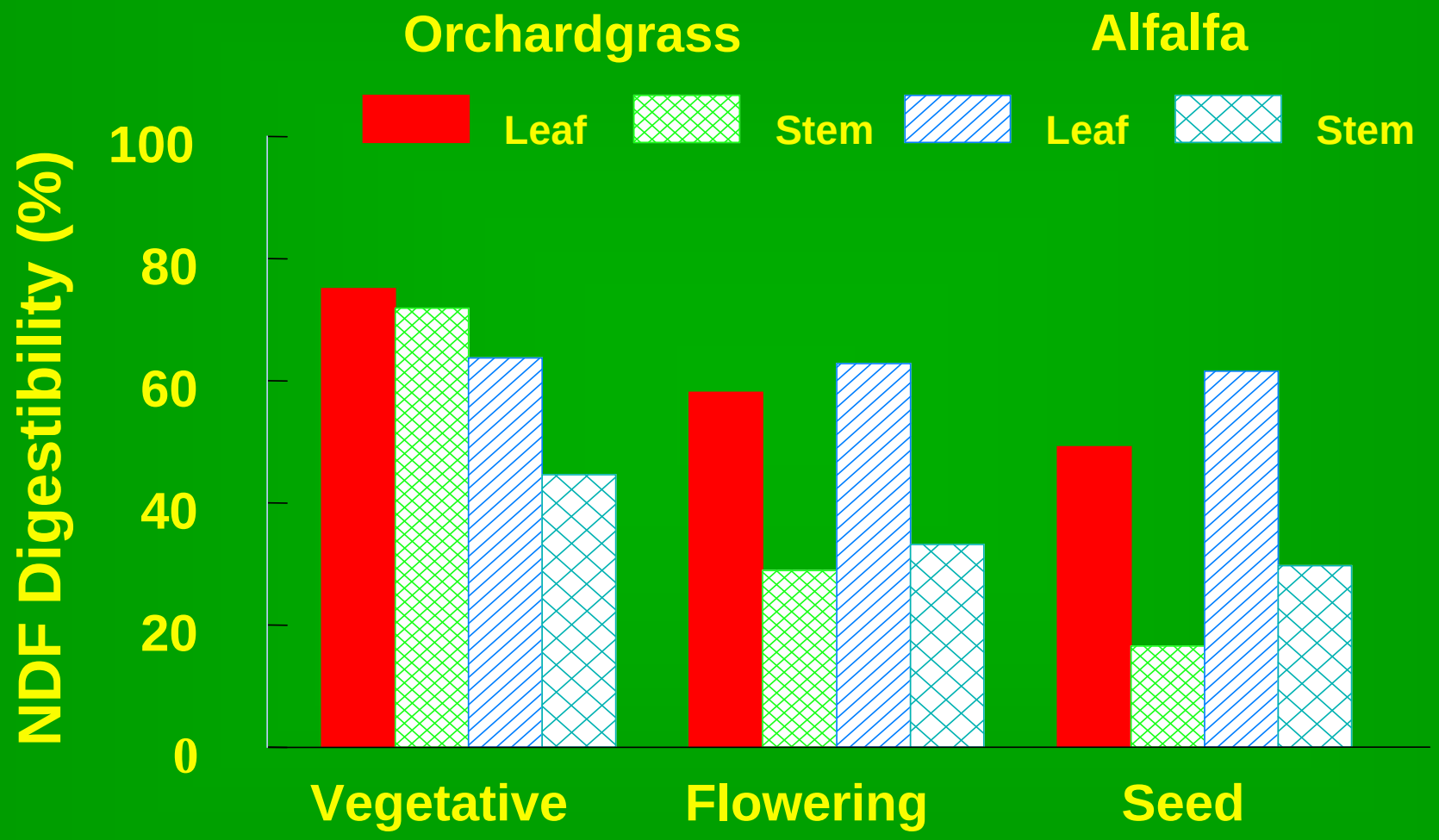
Soluble CHO	Cow Req.	Corn Silage	Alfalfa Silage	Hi-Qual Alfalfa
Nonfibrous CHO	45	42.0	25.0	28.0
Nonstructural CHO		40	10	11
Starches	30	36	3	4
Pectins+		2	15	18

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
% 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	68.3

SOURCE: Mertens, 2003.

Forage Fiber Digestibility



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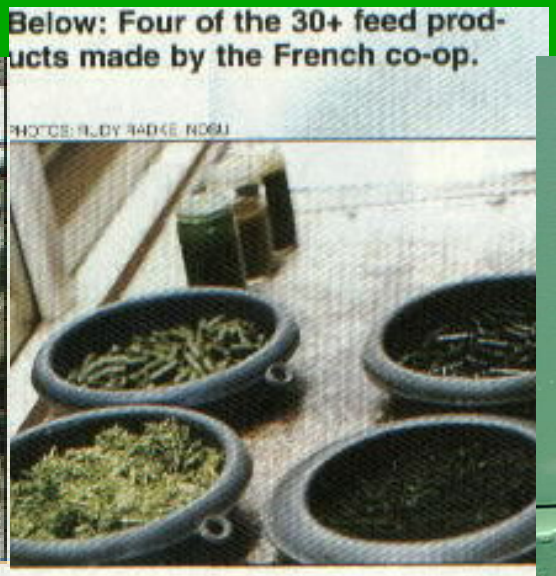
New Alfalfa Products of high value are needed to expand acreage…

- **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.

10 Hay & Forage Grower / February 200

Novel Products of Alfalfa

- 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

- 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

- 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

Wet

Herbage

Juice → Enzymes (Transgenic)

"Fiber"

Dry

Herbage

Leaves → Enzymes (Transgenic)

Stems

Animal

Herbage

"Digestibles" (to animal)

Fibrous Fraction → Hardwood, "Masonite", Biofilters, Bio plywood

Development of Green Genes

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

PHYTASE	4lb @ $150/lb = $600
XANTHOPHYLL	1.2lb @ $175/lb = $245
PROTEIN CONC.	1375lb x $0.10/lb = $137
	Total $982

Potential new uses of alfalfa

- Electric generation

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

- 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	Separation		Mechanical	
	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

Protein Supplement

Dairy, Beef, and Poultry

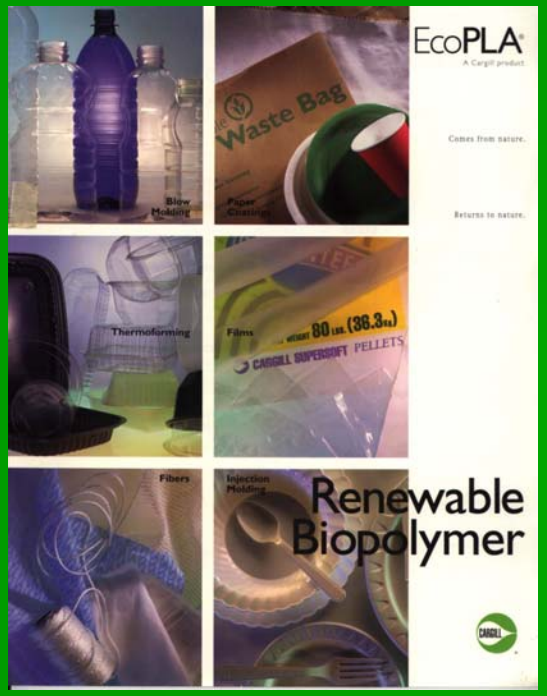
40-50 % of ground hay

High fiber

Combustion, Gasification Or Enzymatic Hydrolysis

50-40 % of ground hay

Bio-degradable plastics made from Lactic Acid



ars Agricultural Research Service

Fiber Board and Filter Mats from Manure

Fresh Alfalfa

Juice

Heat coagulate

Protein Concentrate

Poultry supplement or calf-replacer

25 % of original crop dry matter

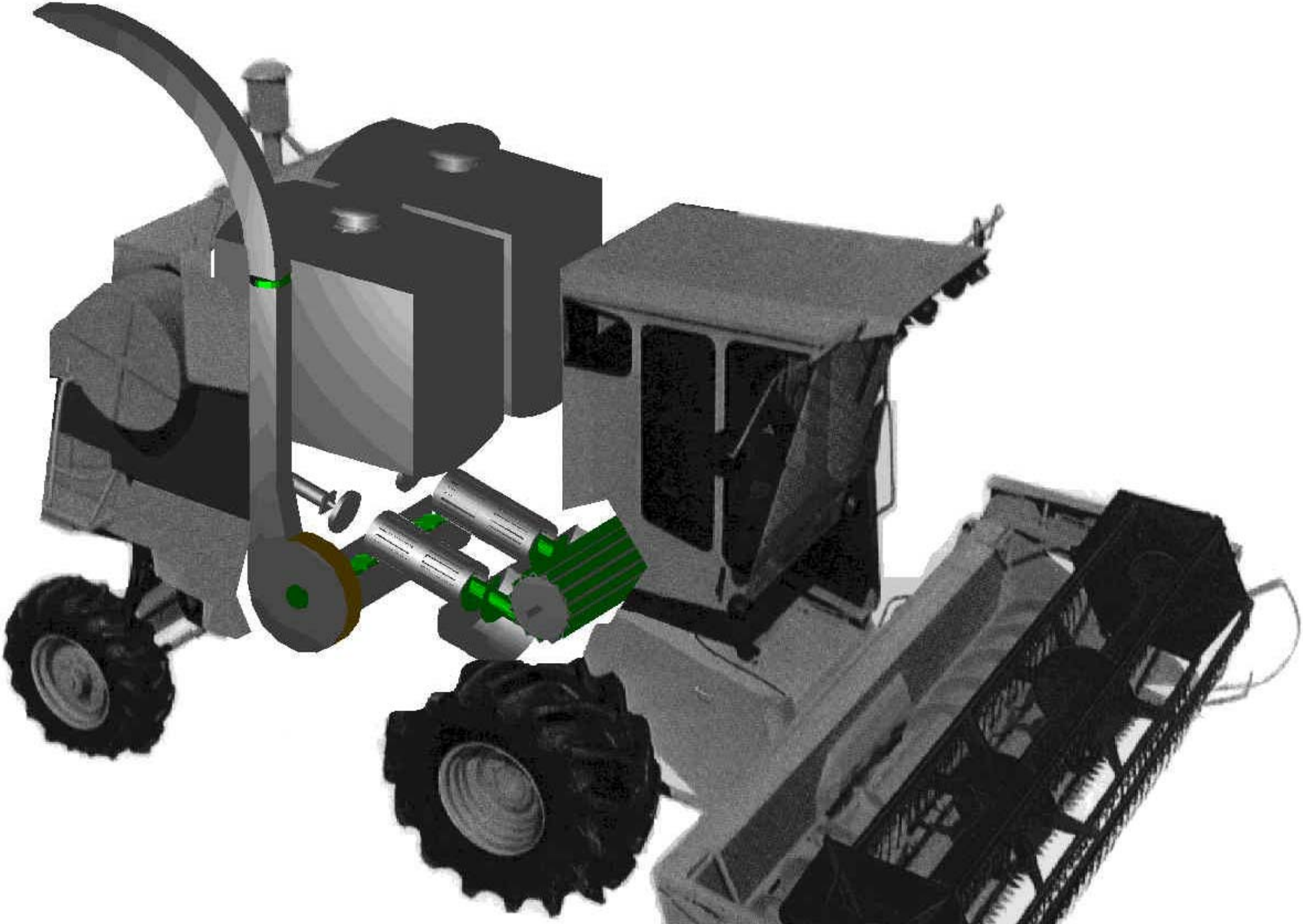
High fiber

Ruminant feed

- Store silage in bunkers
- Process fiber

New products

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.**

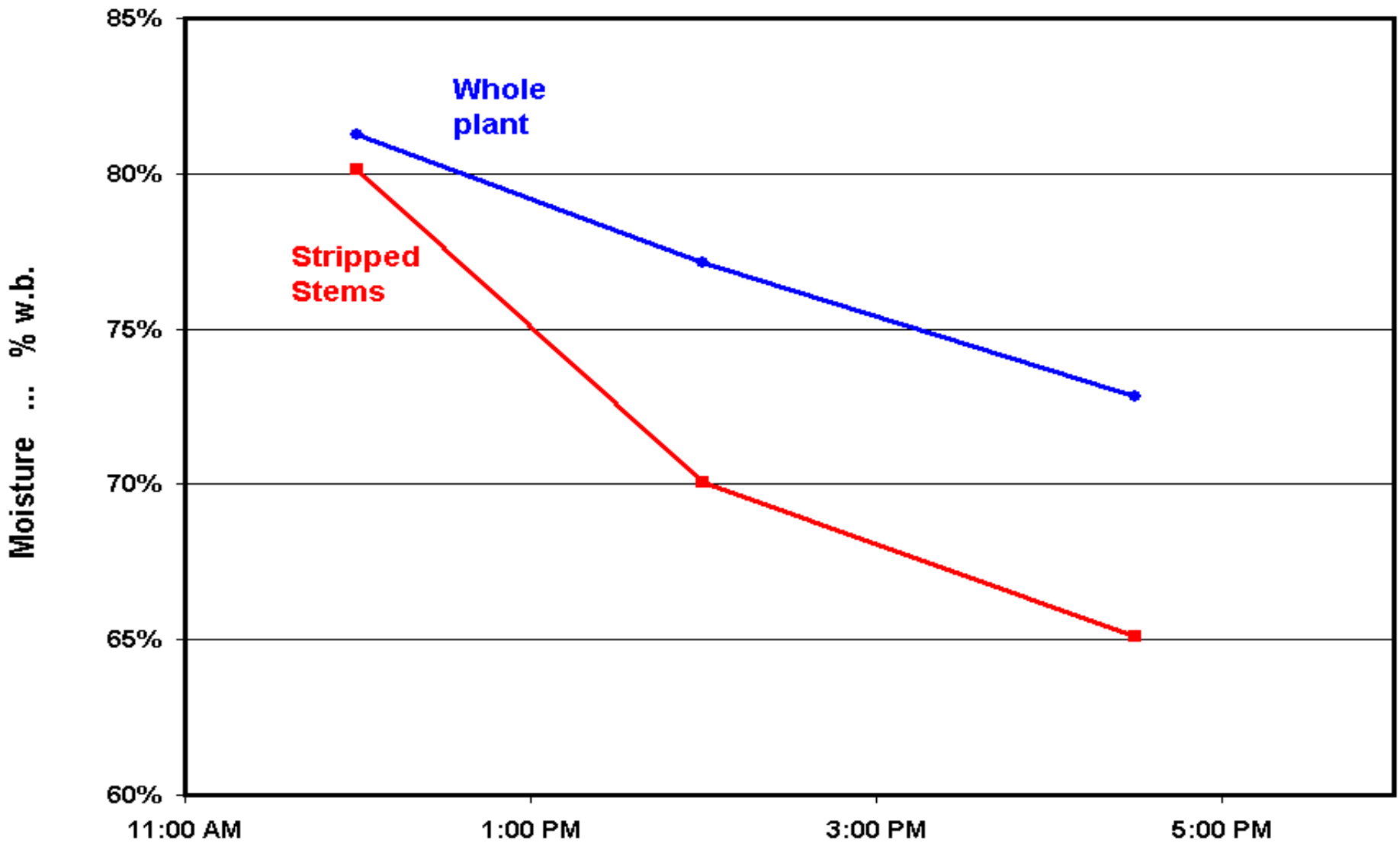
  - **Single day harvesting possible.**

    - **<u>Leaves</u>: direct-ensiled with amendment**

    - **<u>Stems</u>: 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

    - Stems: fiberboard, paper pulp, energy

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

- 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

Farmers 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 850 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

- Electric generation
- Protein production
- Ethanol production

Biomass Conversion to Ethanol

Grind

Pretreatment to Remove Inhibitors

Enzymatic Breakdown of Polysaccharides

Residual Solids

Electricity & Processing Heat

Sugars

Sugars

Fermentation

Ethanol Recovery

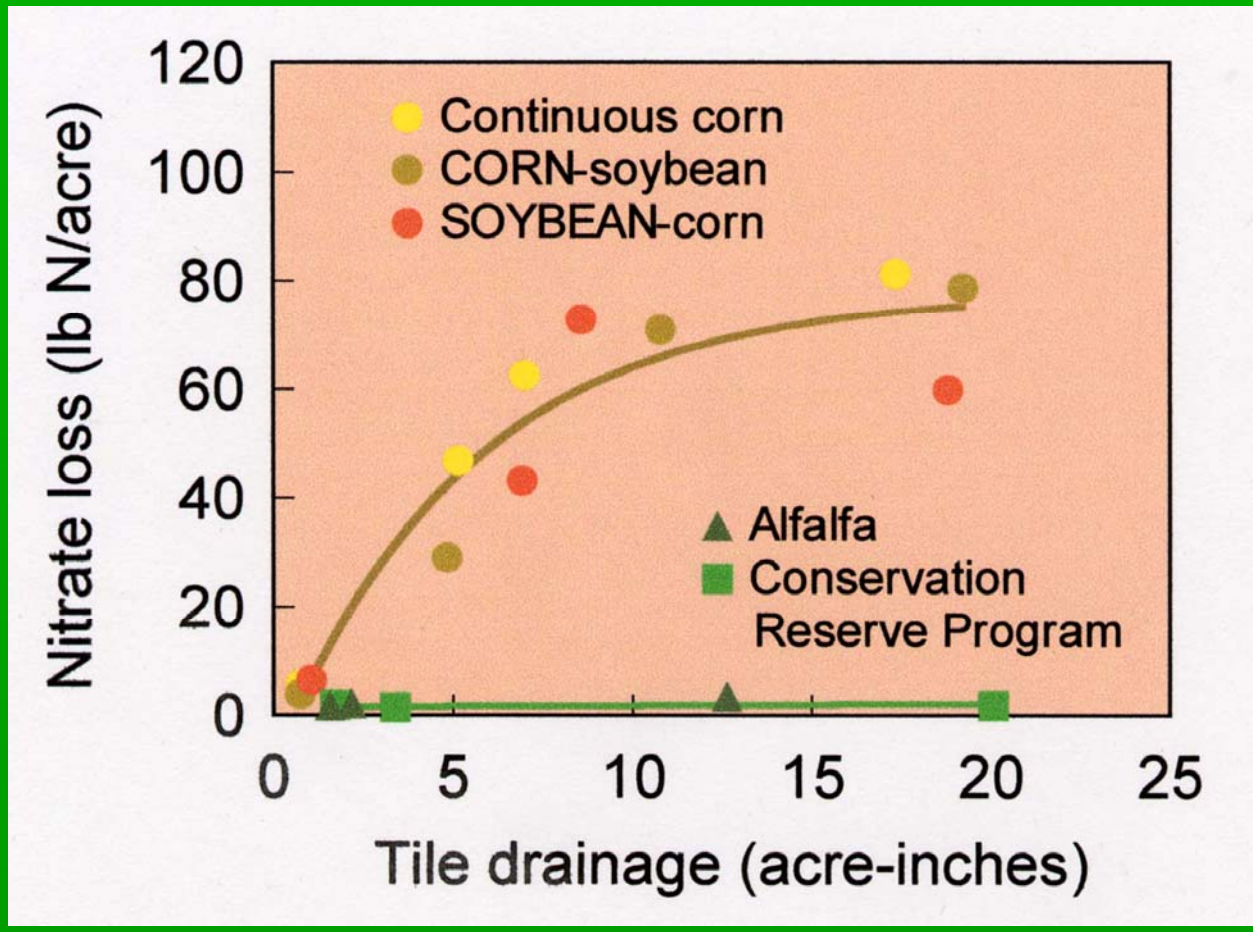
Alfalfa in Crop Rotations:

- 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

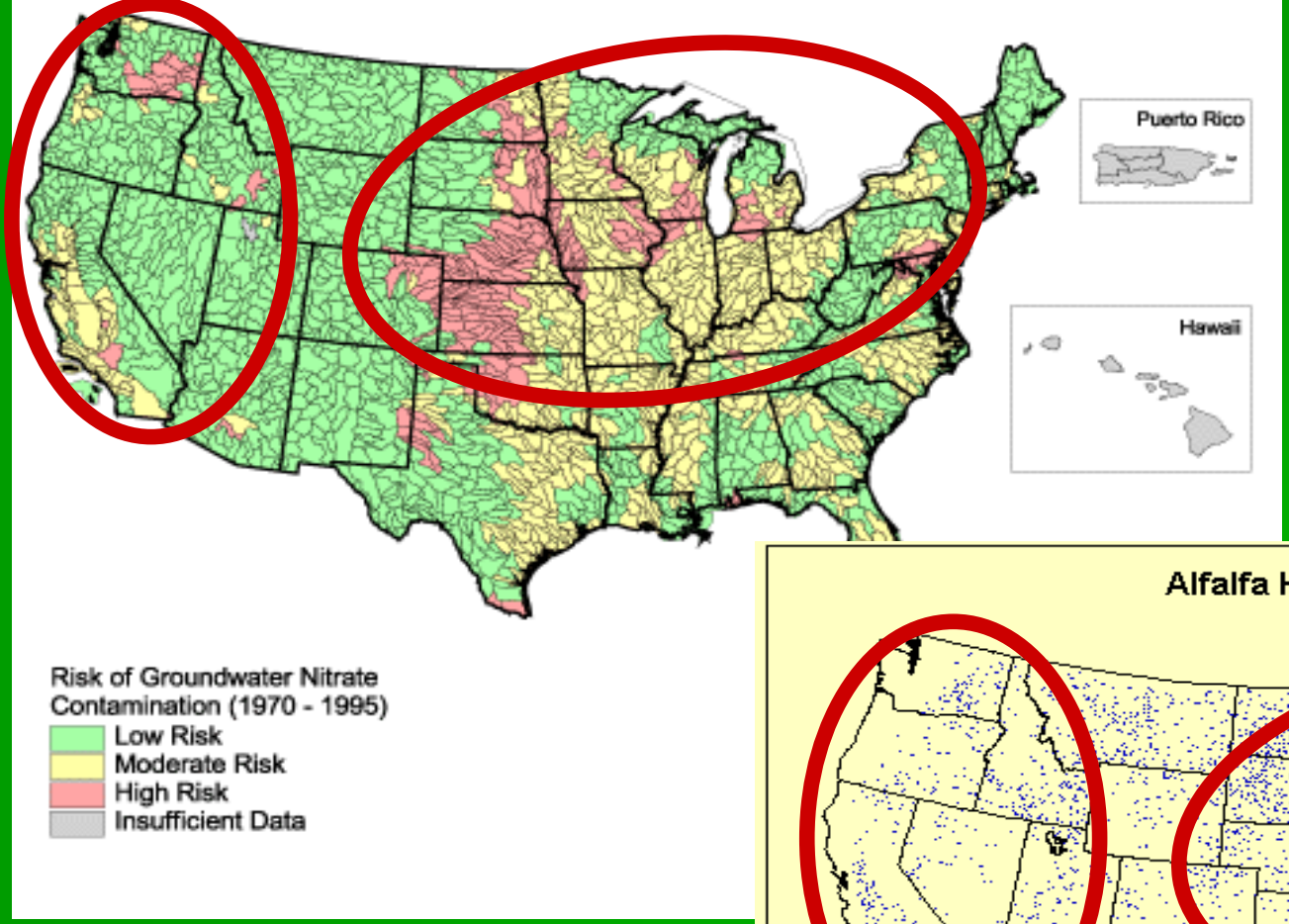
Alfalfa and grass CRP effectively filter tile drain water

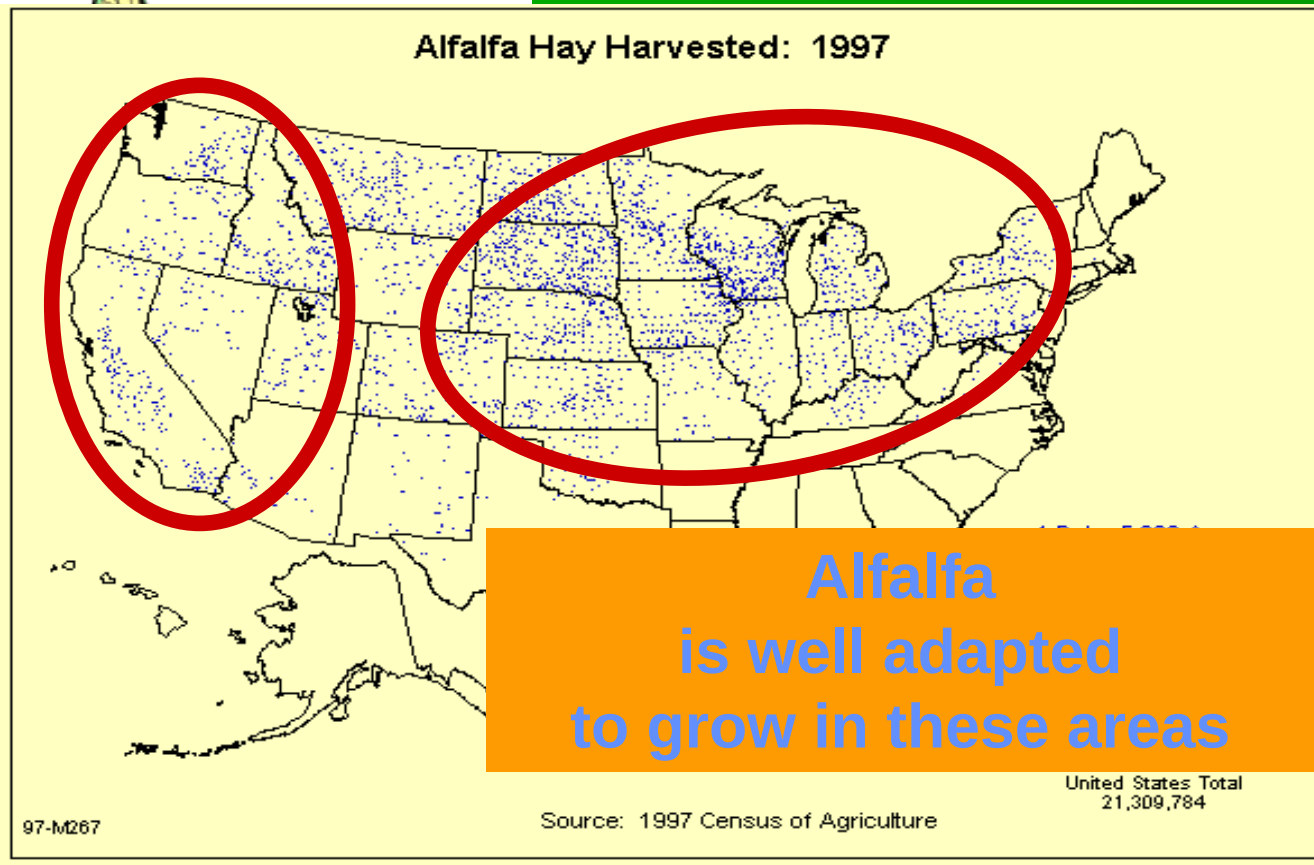


>40 million acres are tile drained in the Upper Midwest

Randall, Huggins, Russelle et al., 1997

Risk of ground water nitrate contamination





Alfalfa is well adapted to grow in these areas

A multidisciplinary collaboration of public and private scientists

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

Novel Products of Alfalfa

- 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.