U.S. Dairy Forage Research Center

USDA, Agricultural Research Service

Future of Forage Crops: Alfalfa and Corn Silage

World Ag Expo

February 10, 2005, Tulare, CA

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Research Lab, Madison, WI

Research Farm, Prairie du Sac, WI

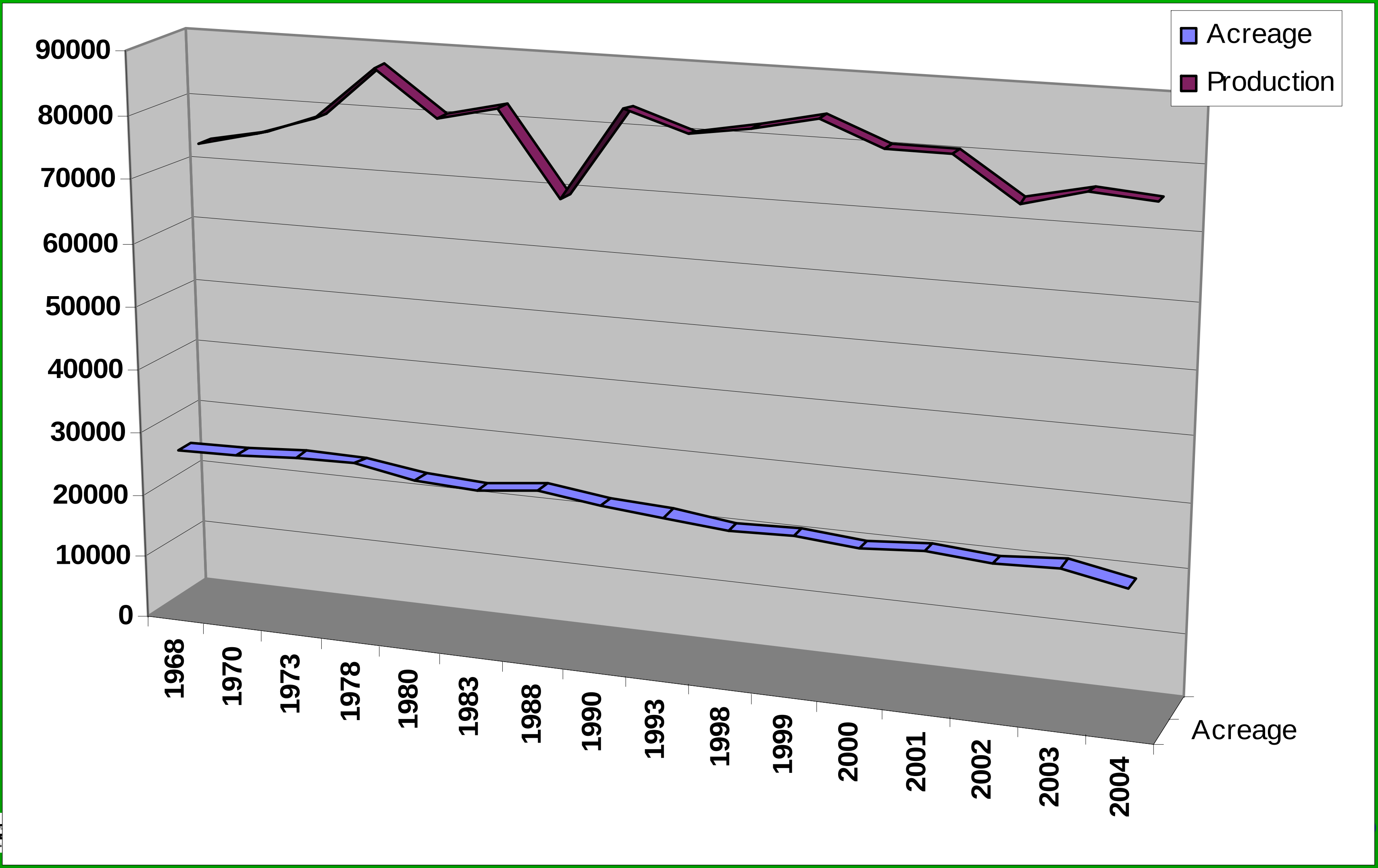
Future of Forage Crops: Alfalfa and Corn Silage

- Alfalfa and Corn Silage production and acreage
- Advantages of alfalfa for dairy operations
  - Forage needed in diets – cow health & production
  - Crop rotations
  - Environmental
  - The perfect alfalfa plant on dairy farms
- Biotechnology in alfalfa and corn silage
- Future innovations needed to maintain or expand alfalfa acreage

2004 U S Alfalfa Production

- Hay
  - 75.4 million tons
  - 21.7 million acre
  - $ 7.0 billion
  - 3rd following corn and soybeans
- Forage
  - 83.9 million tons
  - 24.7 million acres
  - ~$8.2 billion
  - 3rd following corn and soybeans

U. S. Alfalfa Hay in 1,000 tons



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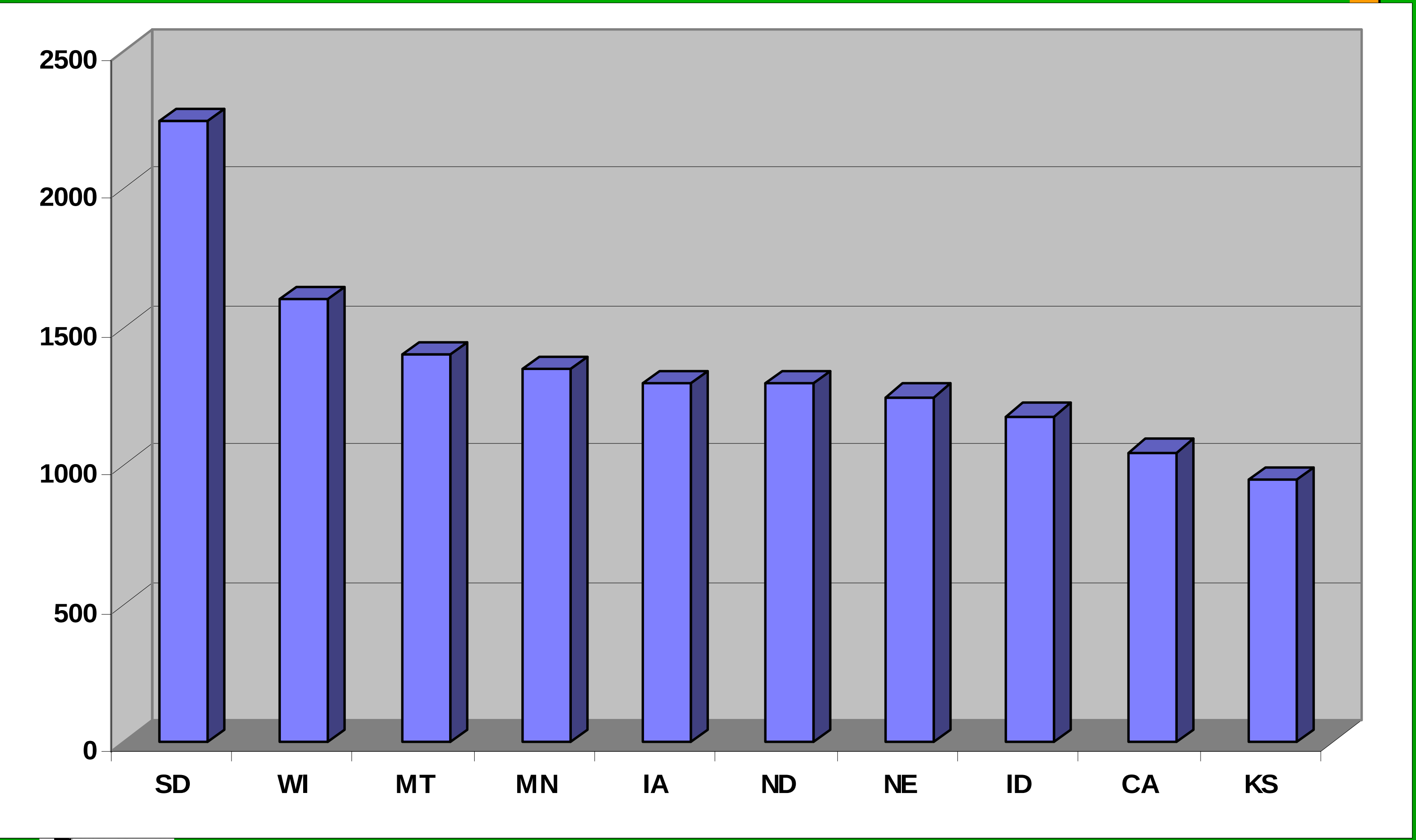
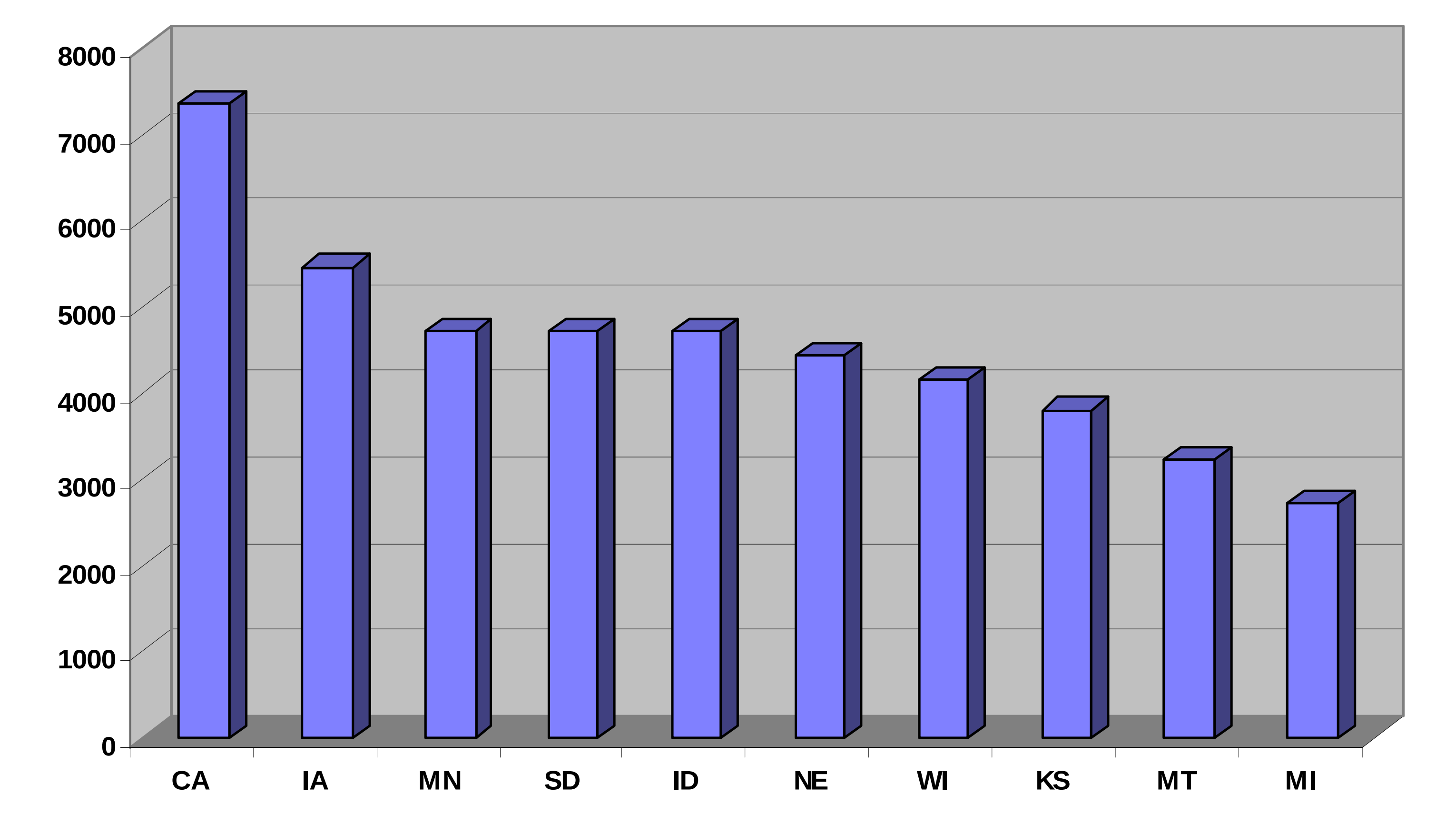
Leading Alfalfa Hay States, 1,000 acres, 2004



- Top 10 States
  - 63 % of U. S.
  - 59 % of Acre
  - 7 states NC
  - 3 states West
  - 4 Lead Dairy

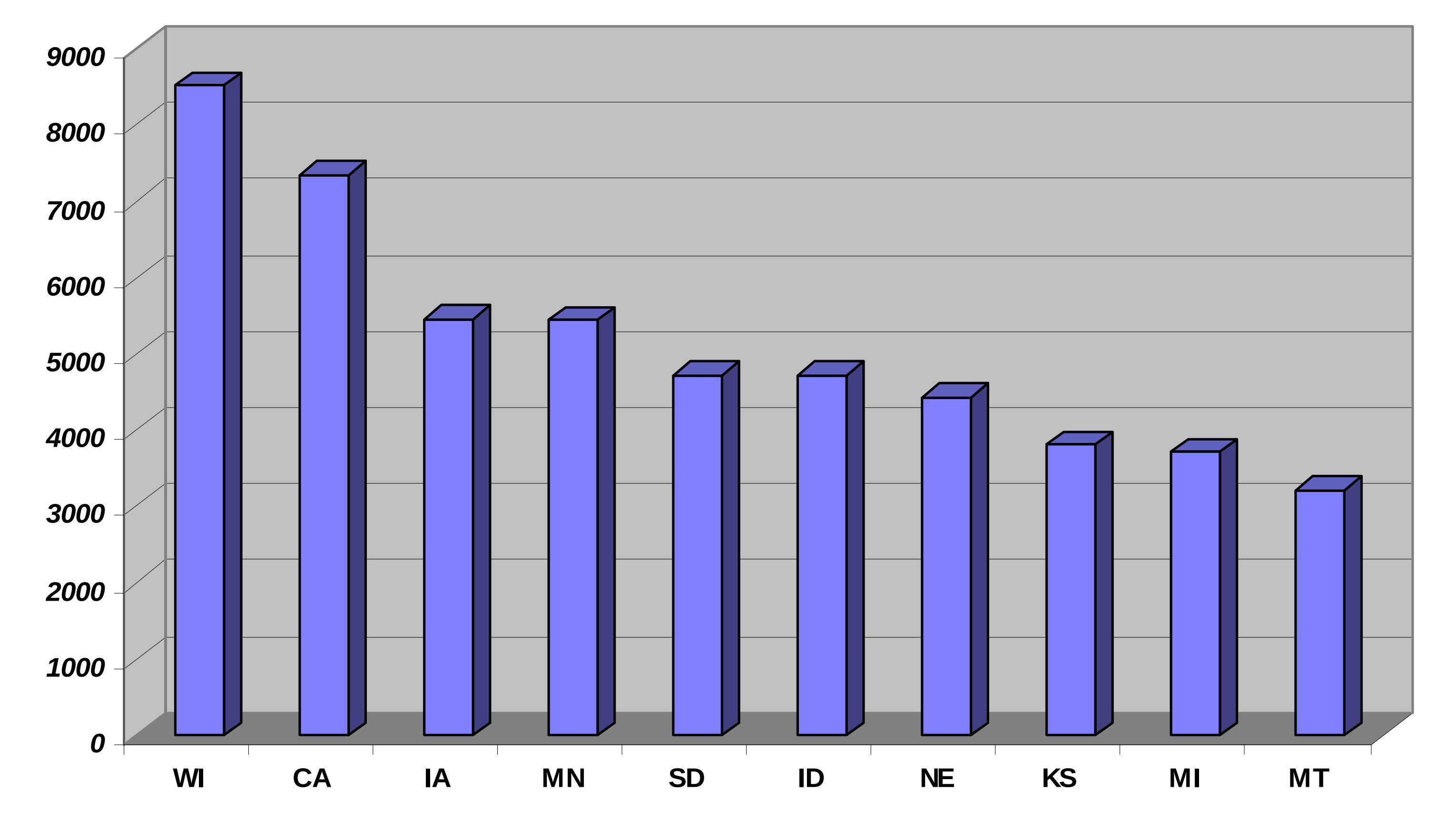
Leading Alfalfa Hay Production States, 1,000 tons, 2004



- **Top 10 States**
  - 60 % of U. S.
  - 61 % of Acre
  - 7 states NC
  - 3 states West
  - 6 Lead Dairy

Acreage – 21.7 mil
Production – 75 mil

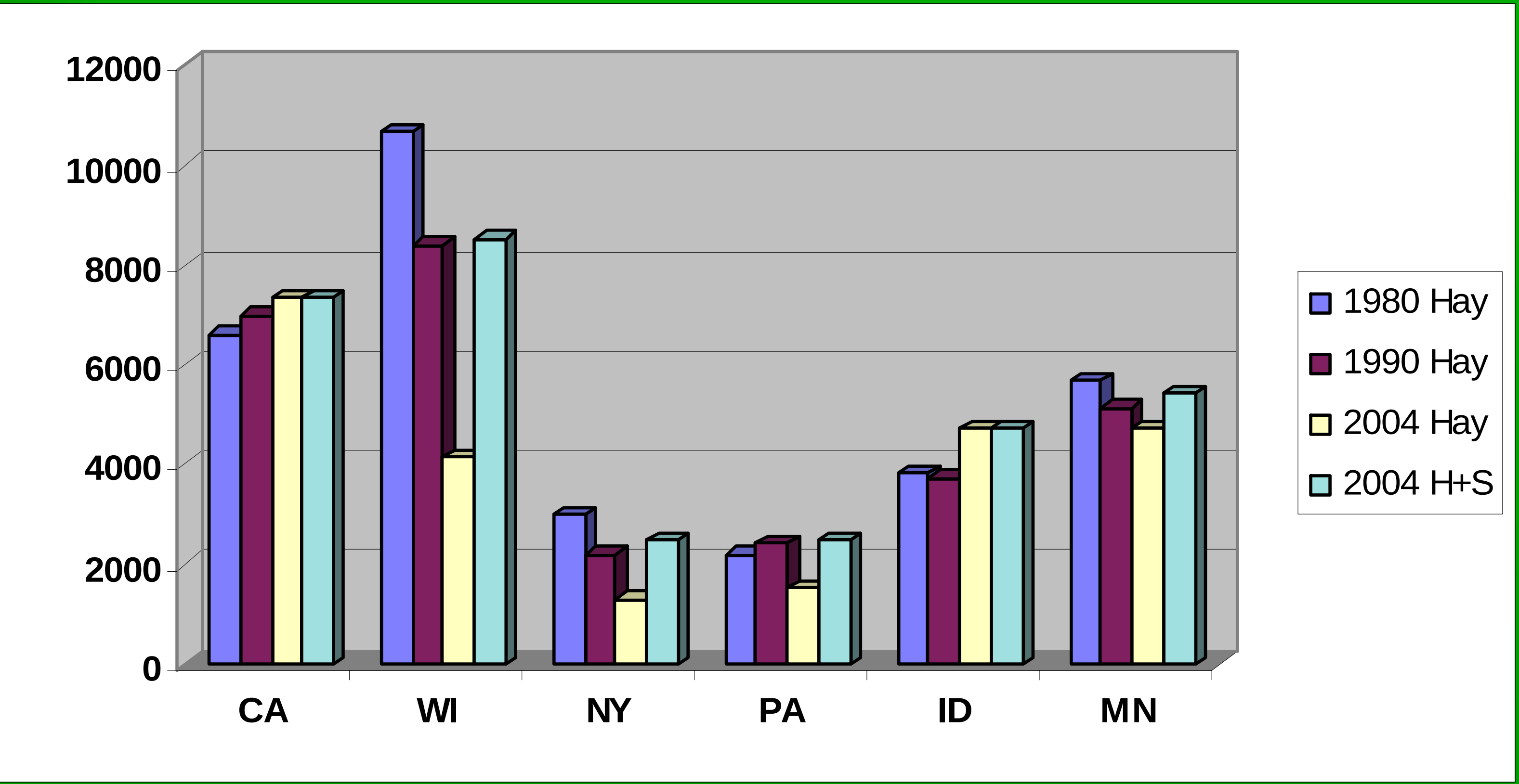
Leading Alfalfa Forage Production States, 1,000 tons, 2004



- Top 10 States
  - 61% of U. S.
  - 61 % of Acre
  - 7 states NC
  - 1 state NE
  - 3 states West
  - 5 Lead Dairy

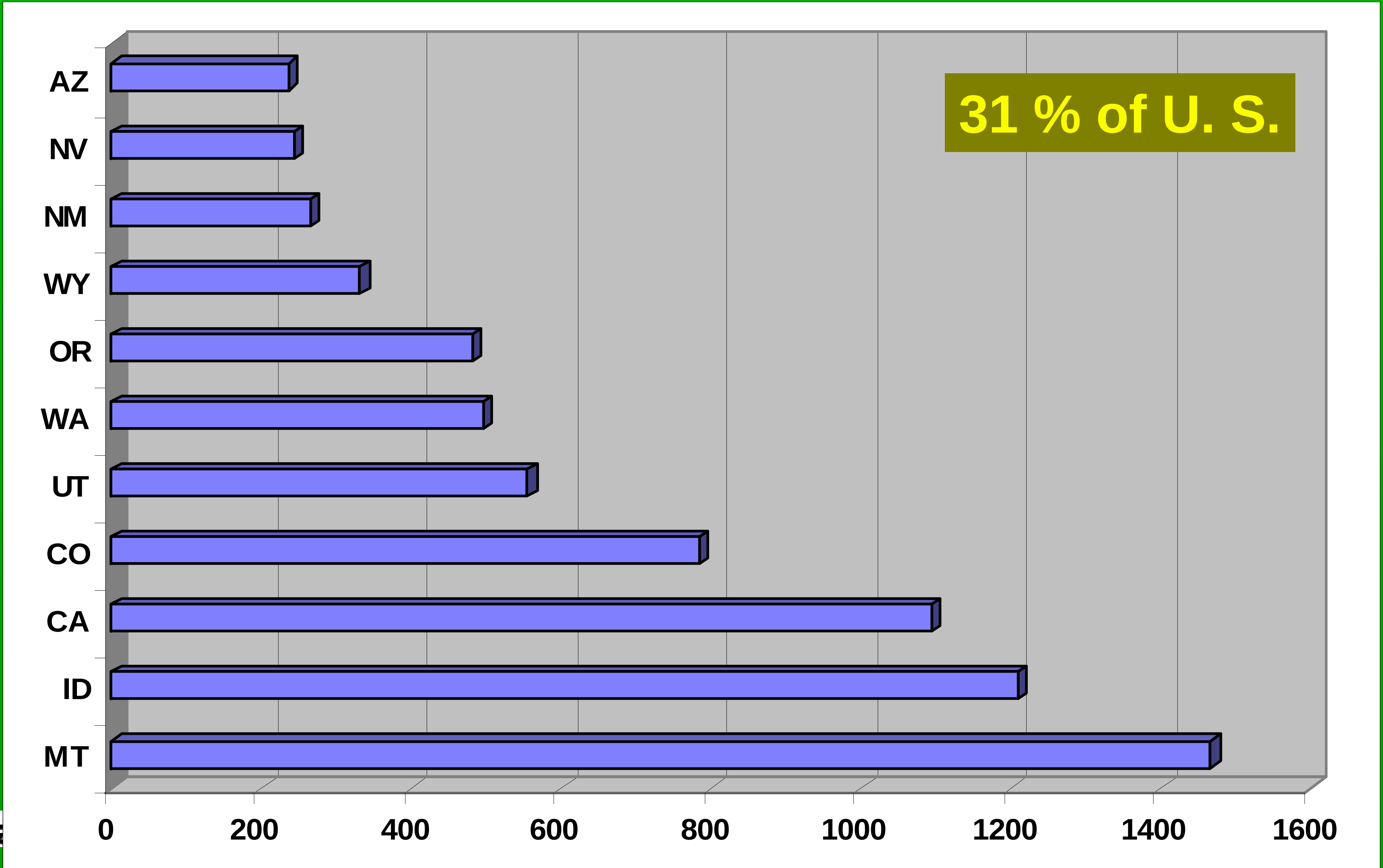
Acreage – 23.3 mil
Production – 84 mil

Alfalfa Hay & Silage Production in Leading Dairy States, 1,000 tons

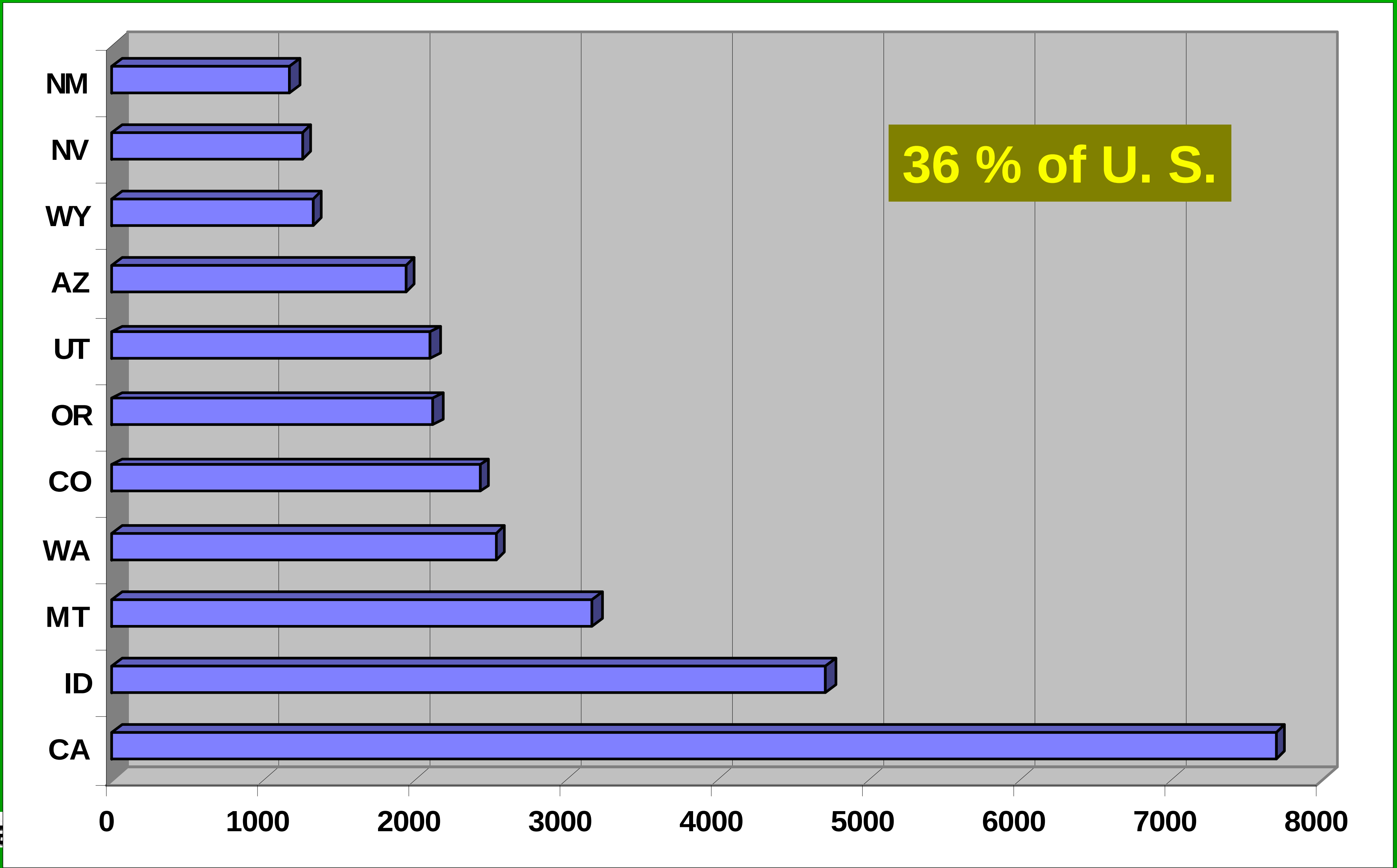


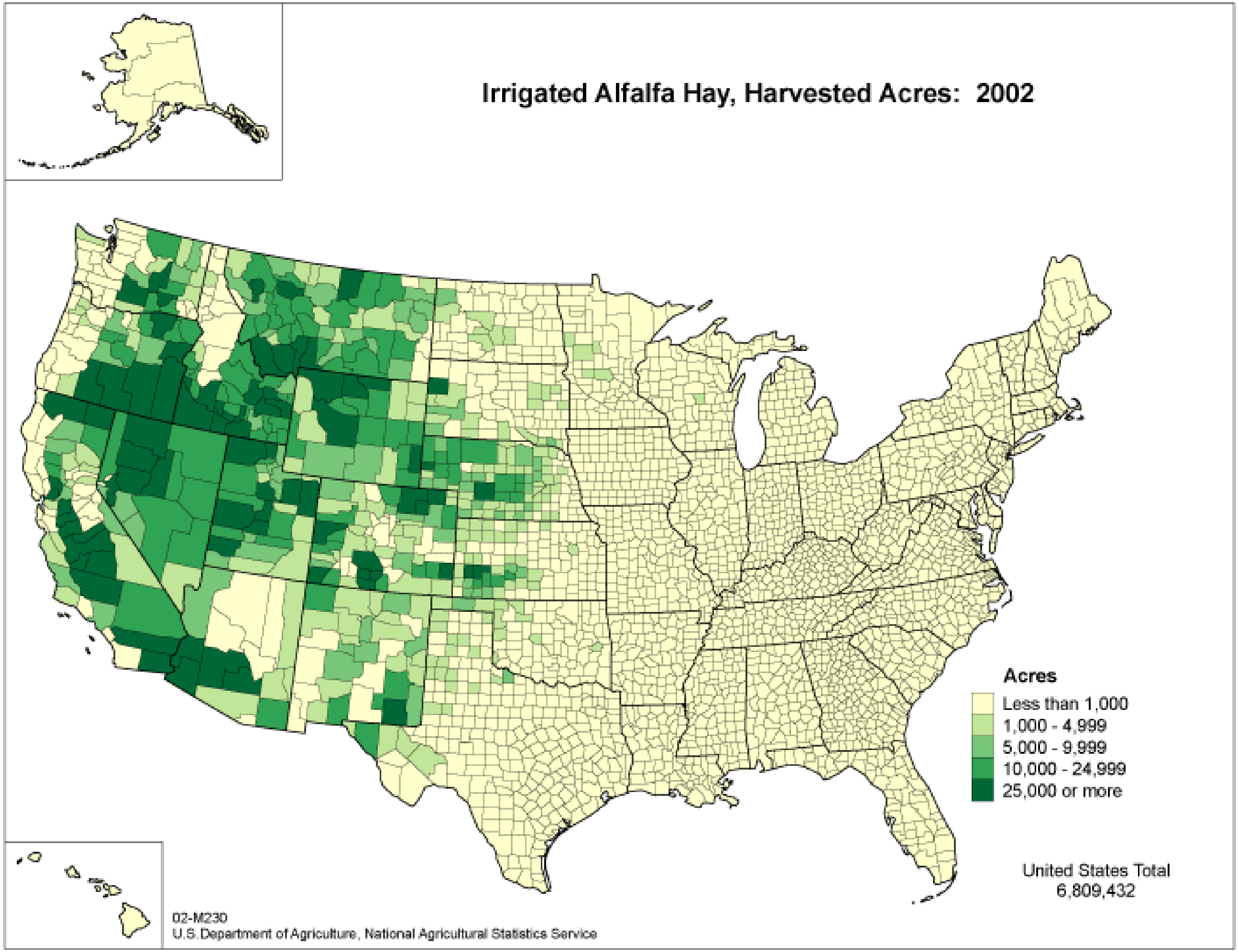
- 6 States
  - % of U. S.
    - 17.8 - 1980
    - 17.7 - 1990
    - 19.9 - 2004
  - % of 1980
    - 0 – 1980
    - -30 – 1990
    - -81 – 2004
    - -9 – 2004 HS

Western Alfalfa Acres, 02-04, 1,000

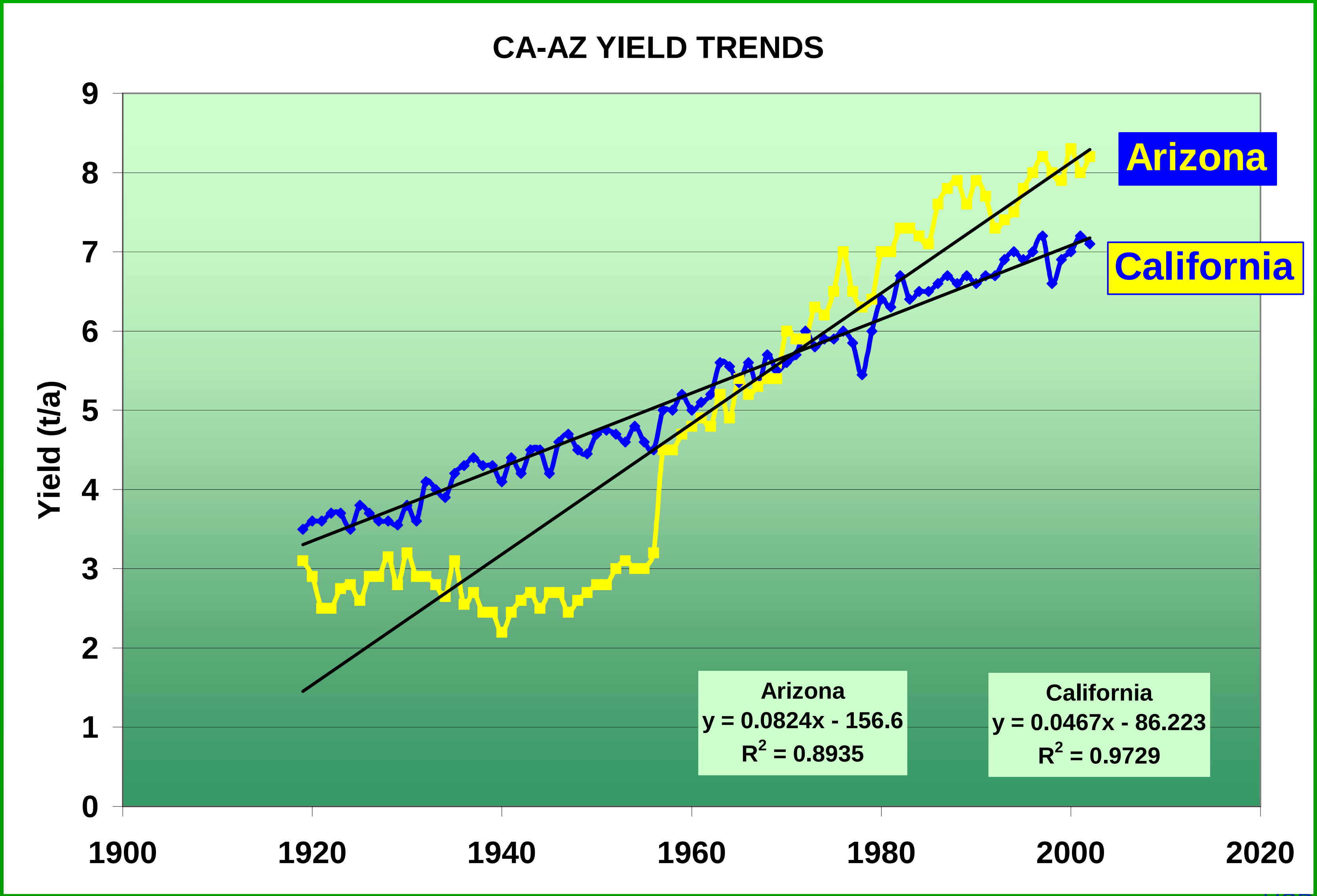


Western Alfalfa, 02-04, 1,000 tons




Irrigated Alfalfa Hay, Harvested Acres: 2002
Acres
Less than 1,000
1,000 - 4,999
5,000 - 9,999
10,000 - 24,999
25,000 or more
United States Total
6,809,432
02-M230
U.S. Department of Agriculture, National Agricultural Statistics Service

Alfalfa Yield Trends



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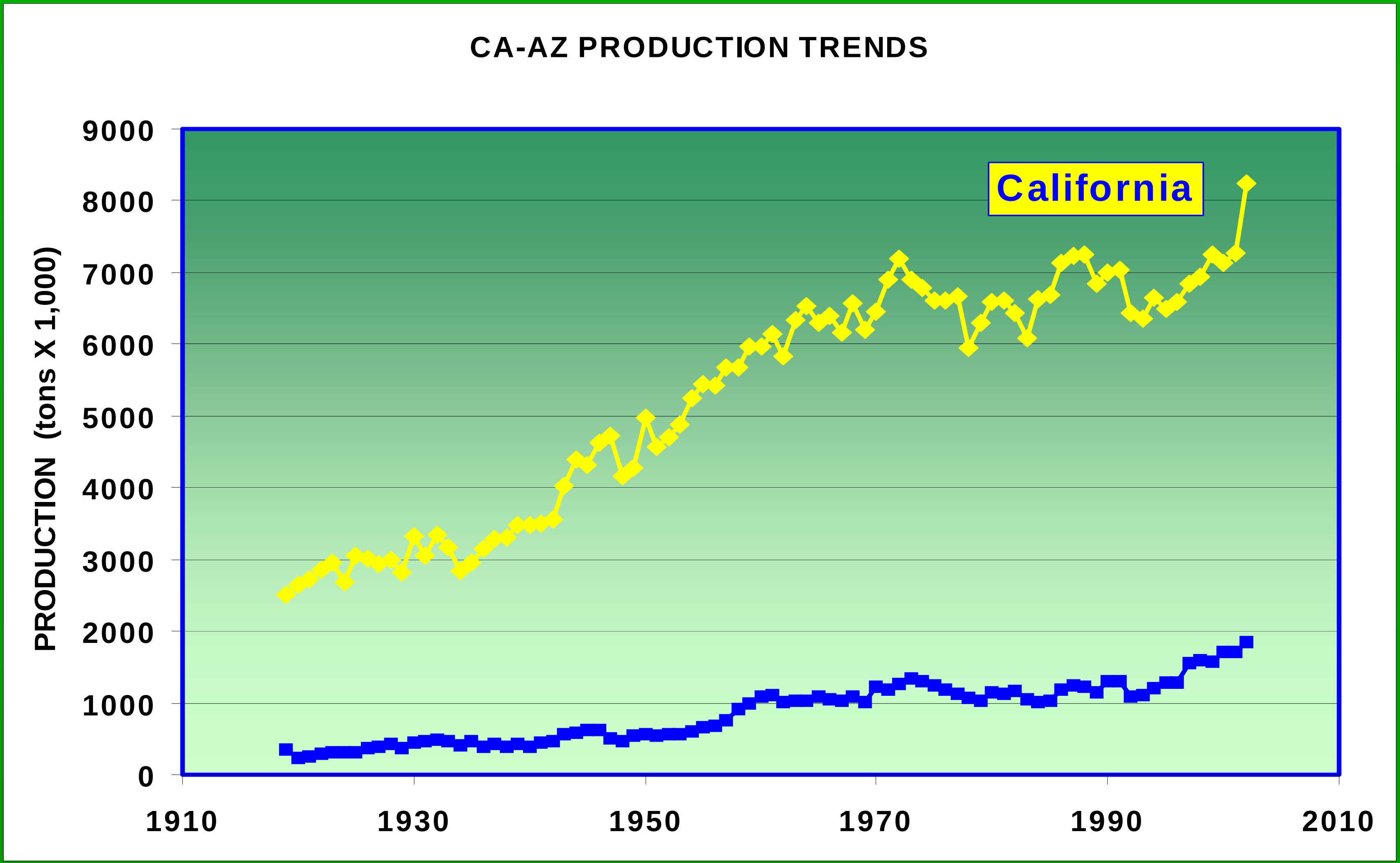
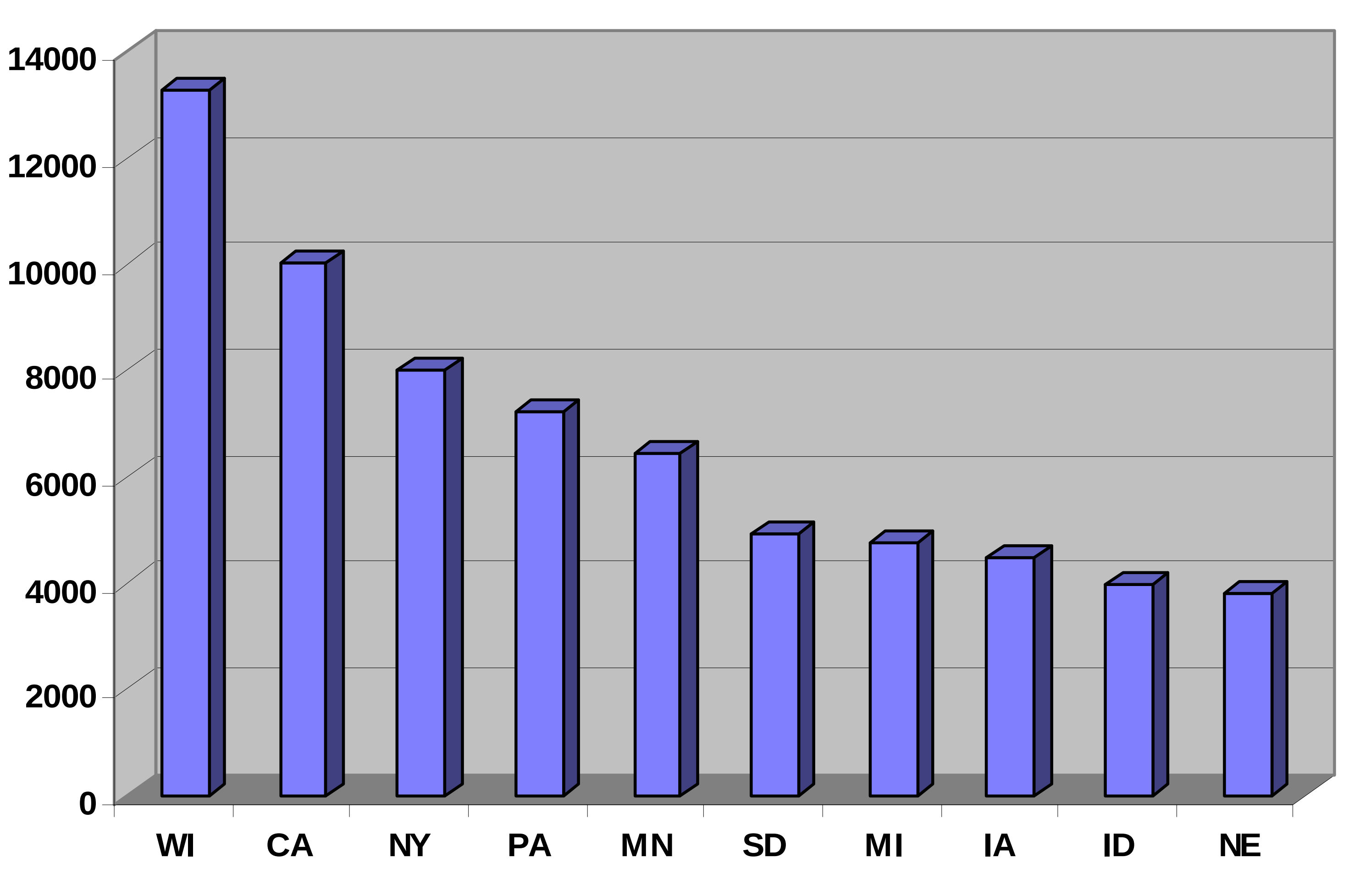
CA-AZ Production Trends



Leading Corn Silage Production, 2004



- Top 10 States
  - 62 % of U. S.
  - 64 % of Acre
  - 6 states NC
  - 2 states NE
  - 2 states West
  - 7 Lead Dairy

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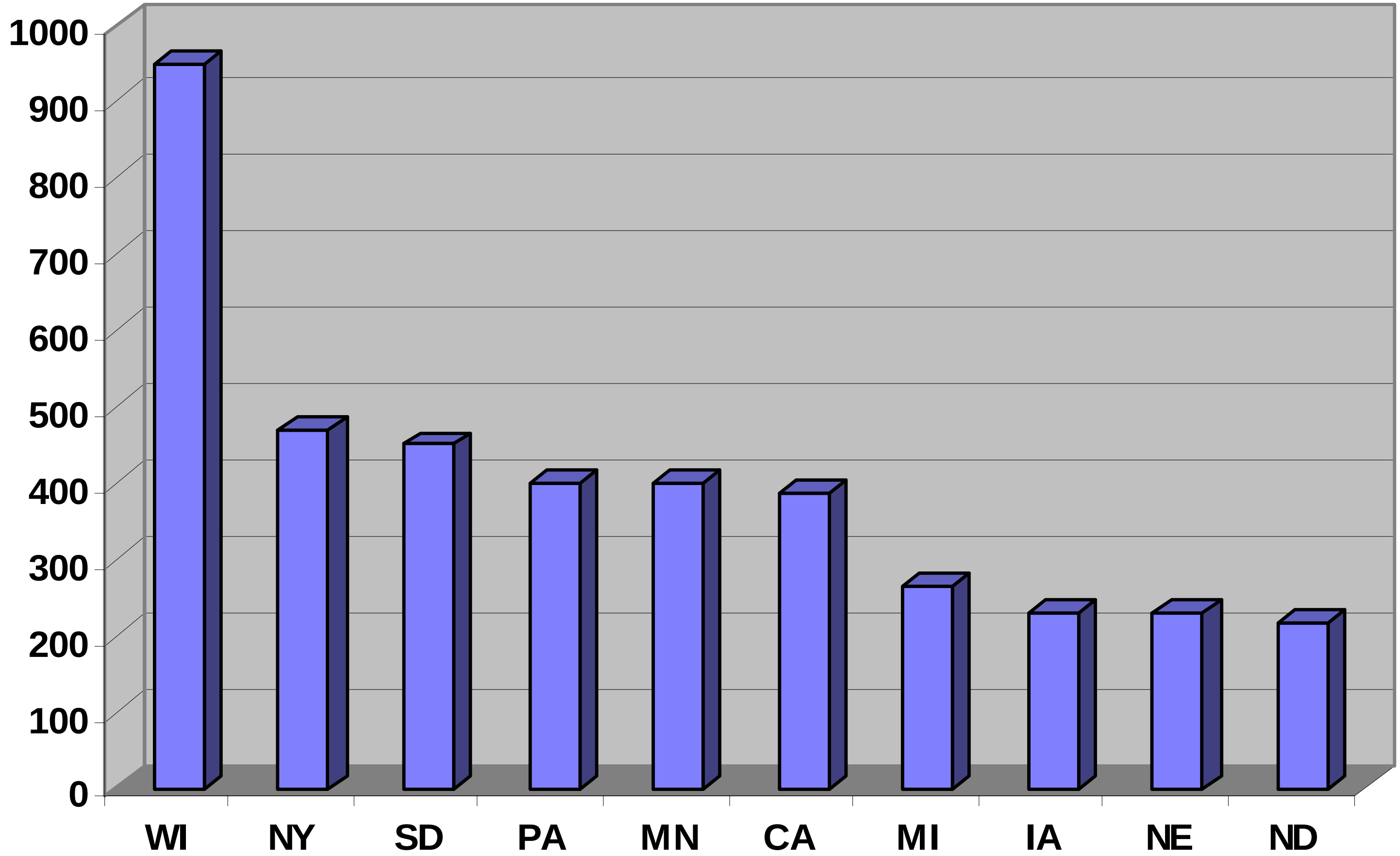
Leading Corn Silage, 1,000 Acres, 2004



- Top 10 States
  - 60 % of U. S.
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  - 7 states NC
  - 2 states NE
  - 1 states West
  - 6 Lead Dairy

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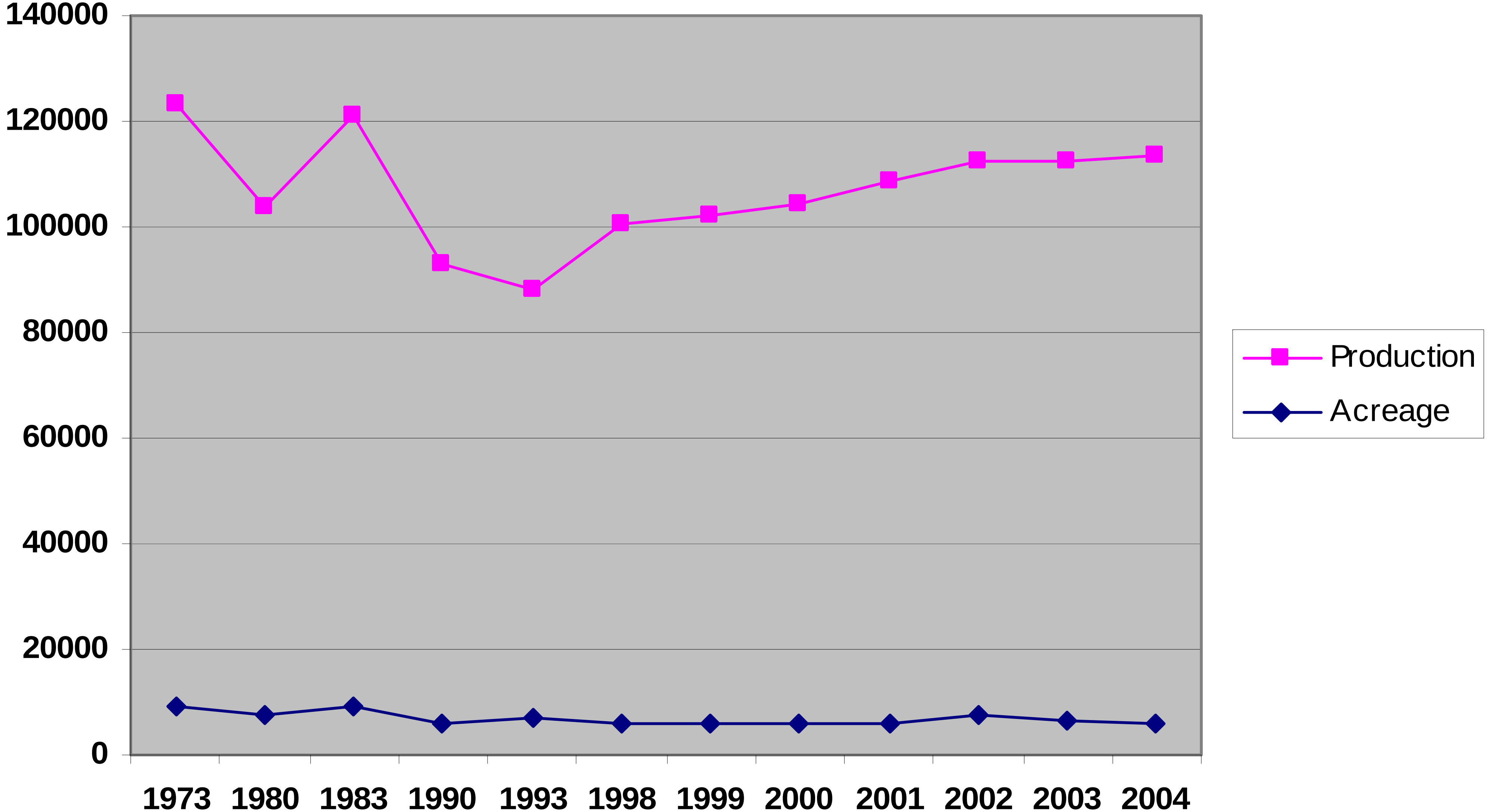
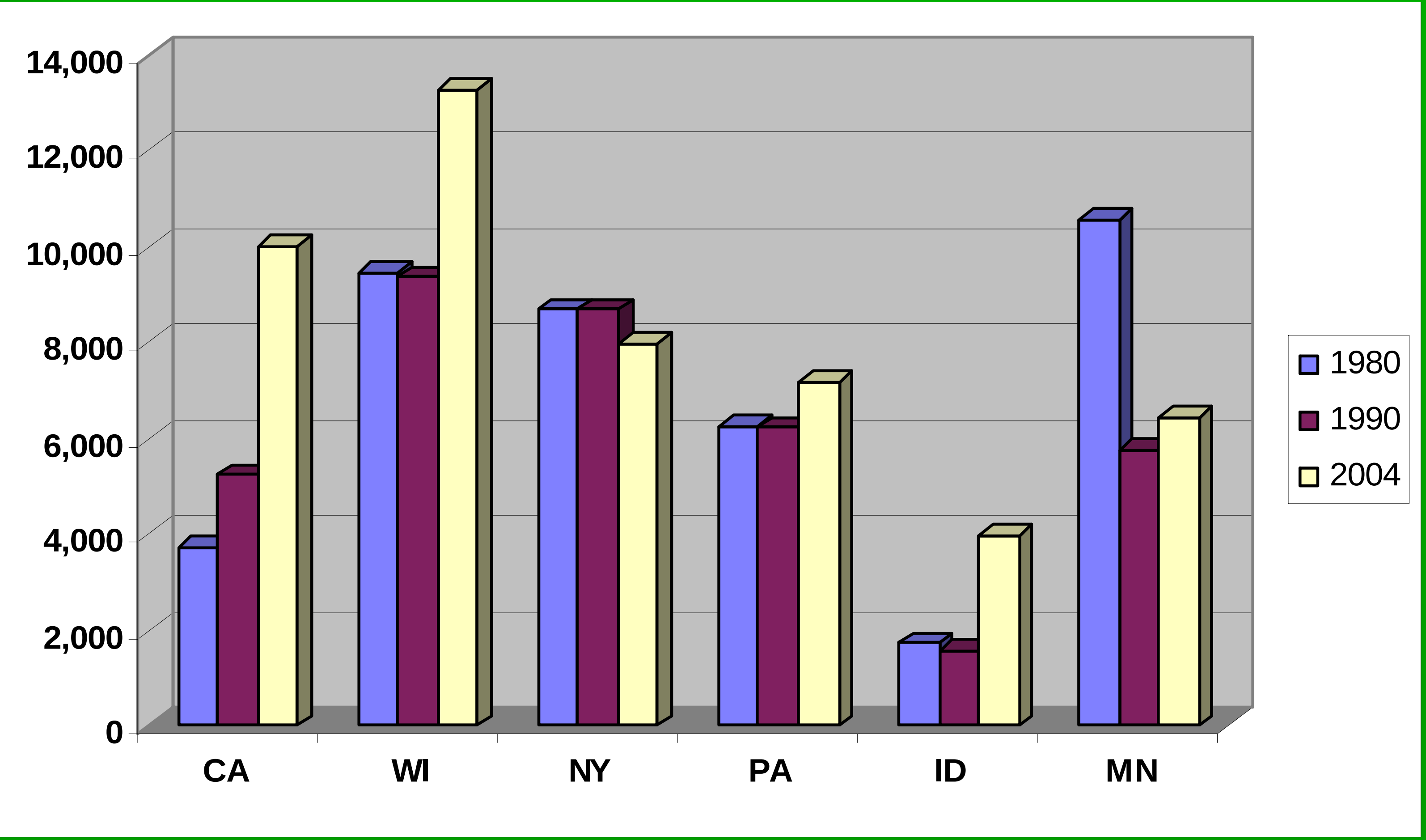
Corn Silage Acreage & Production



Corn Silage Production in Leading Dairy States, 1,000 tons



6 States

- % of U. S.
  - 26 - 1980
  - 16 - 1990
  - 13 - 2004
- % of 1980
  - 0 – 1980
  - -36 – 1990
  - 85 – 2004

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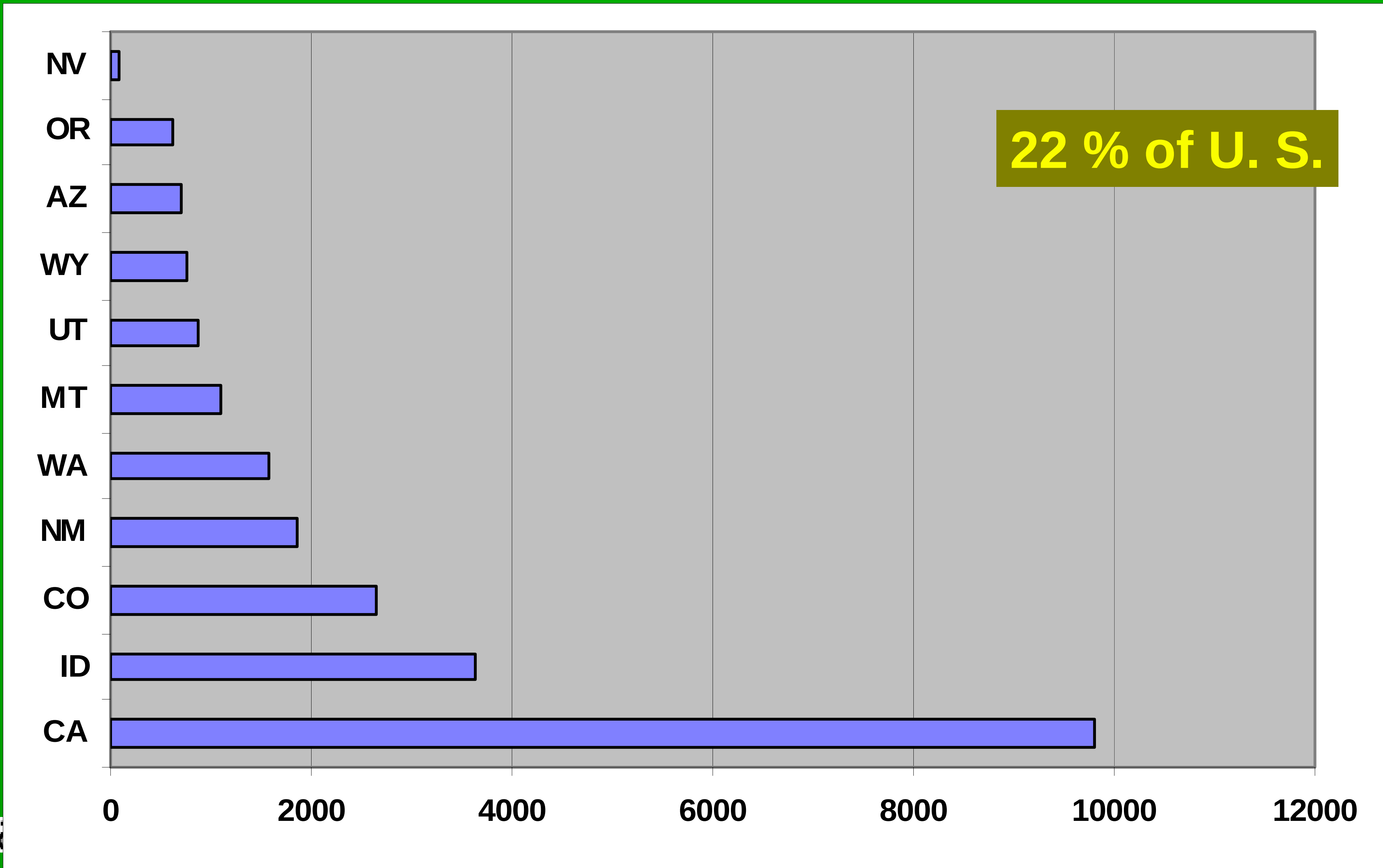
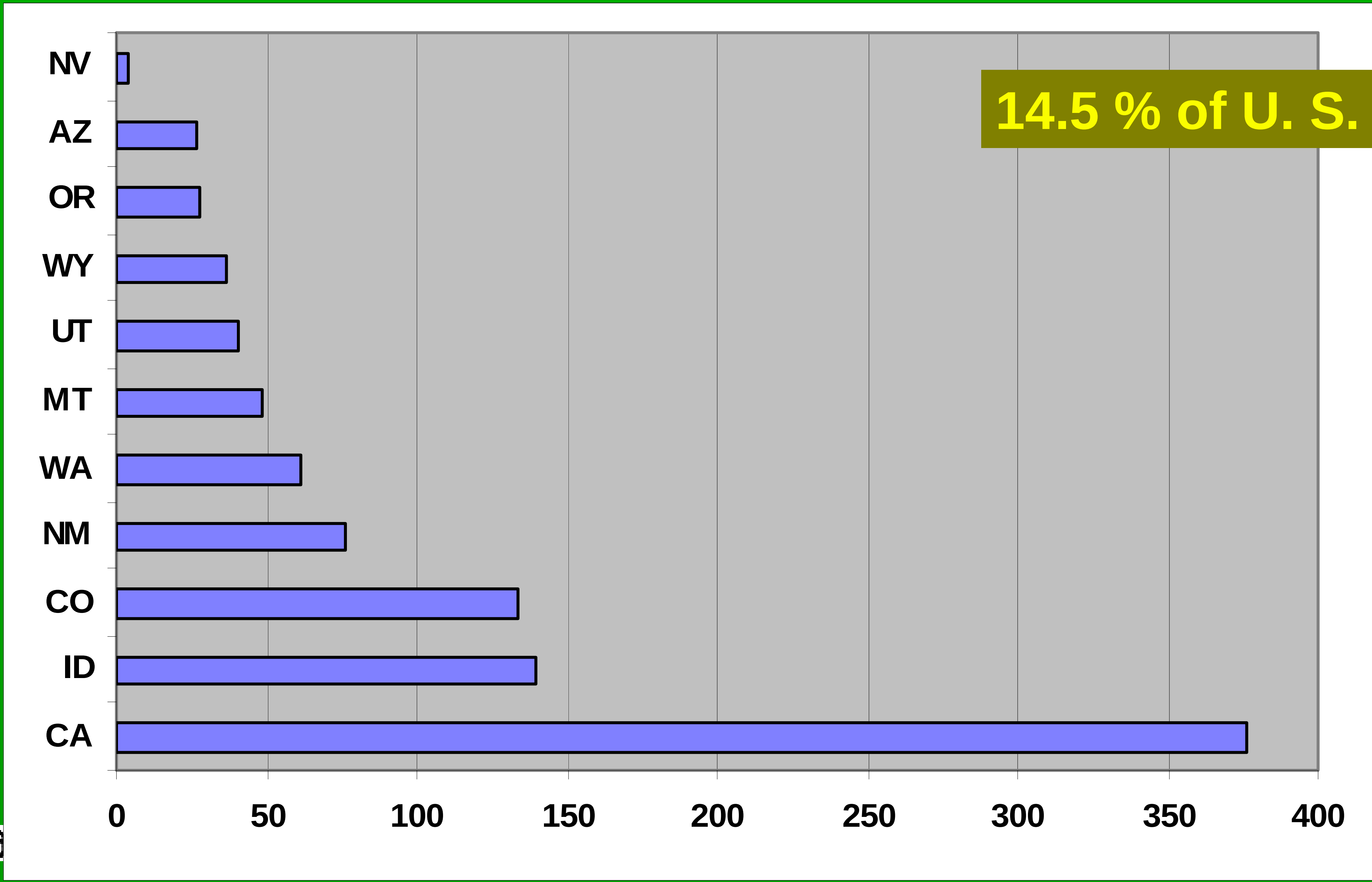
Western Corn Silage, 02-04, 1000 tons



Western Corn Silage Acres, 02-04, 1000



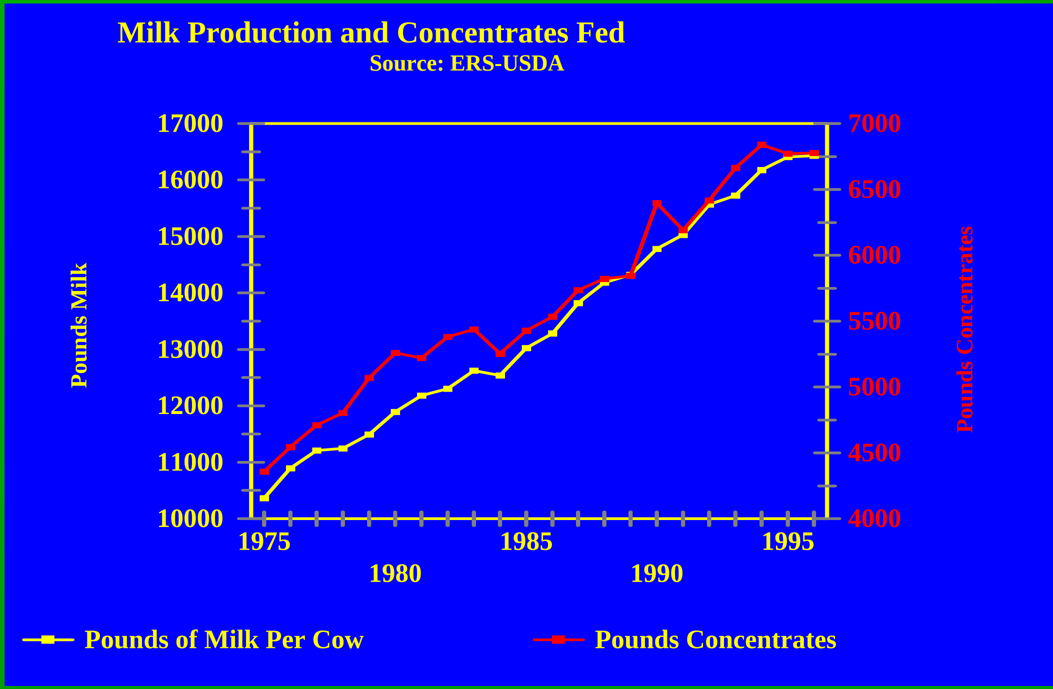
California Dairy Nutritionists Value Alfalfa Hay

- 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

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



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

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

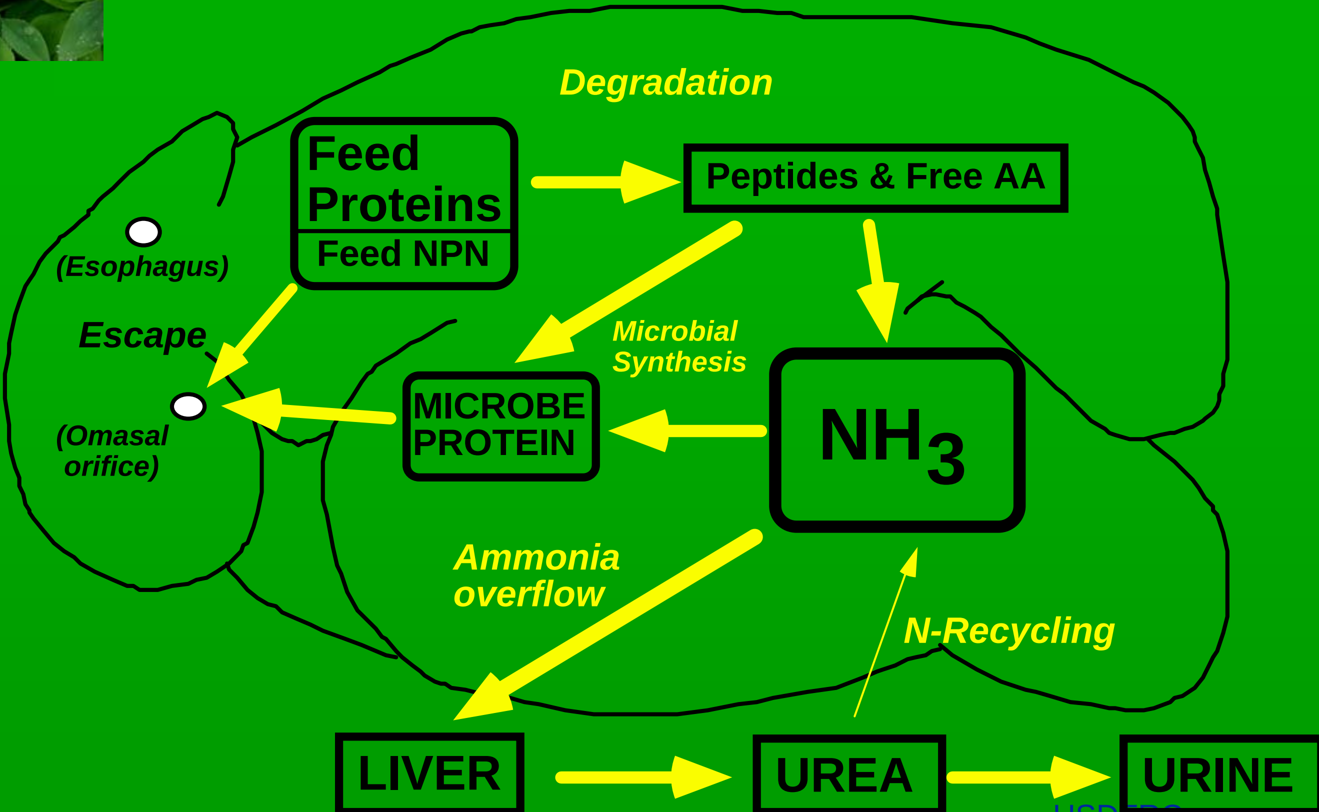
Item	silage	hay	silage +FM[1]	hay+FM[1]
CP,% of DM	17.1	15.4	18.6	17.0
	pounds DM per day per cow			
DM intake	49.2[c]	52.9[a]	51.4[b]	53.4[a]
BW change	-0.86[c]	0.99[a]	0.18[b]	1.08[a]
Milk	77.8[c]	79.6[b]	82.5[a]	81.4[a]
Fat	2.65[b]	2.60[b]	2.82[a]	2.69[b]
Protein	2.29[c]	2.43[b]	2.51[a]	2.49[a]
SNF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

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



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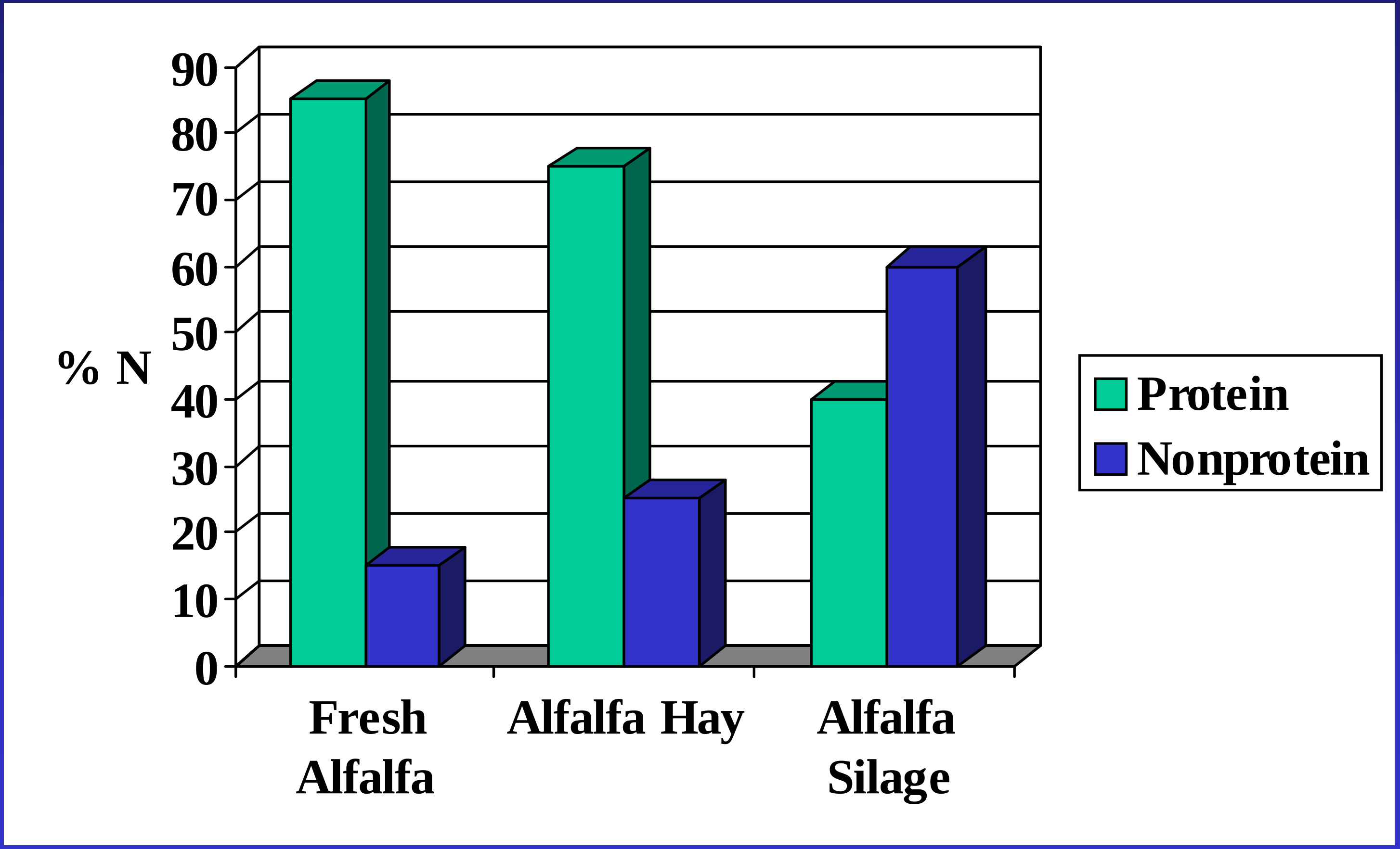
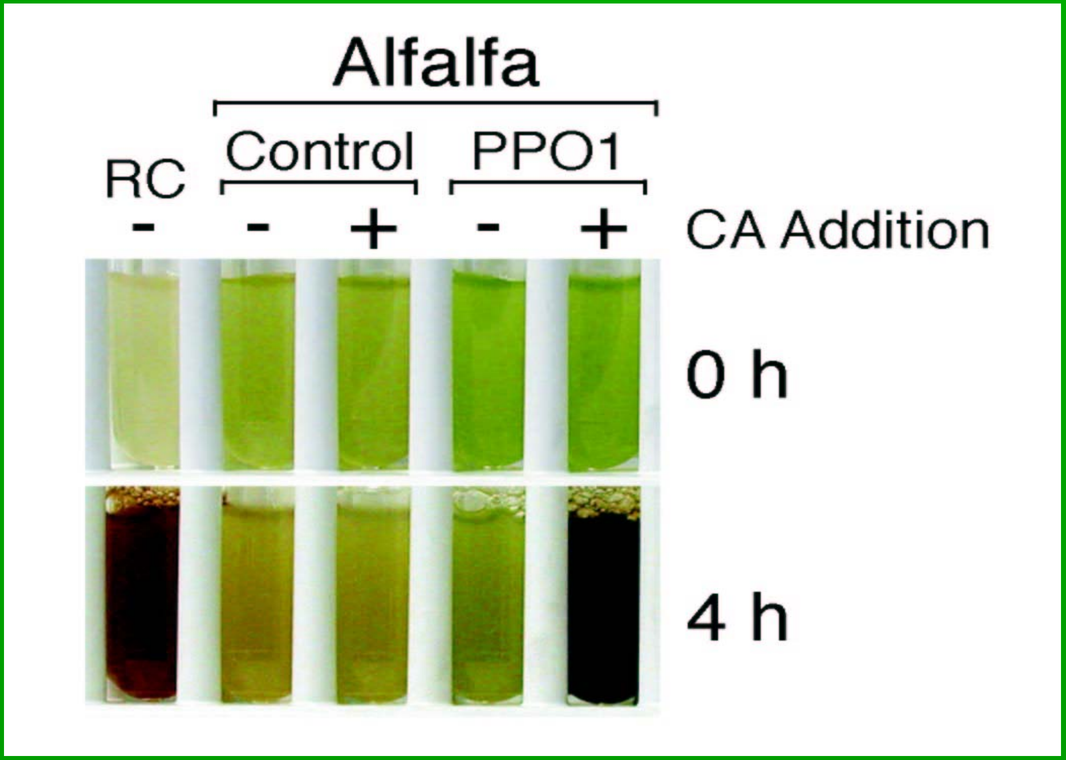
Feed Storage Problems

- However in alfalfa, our primary forage:



Expression of red clover PPO1 in transgenic alfalfa



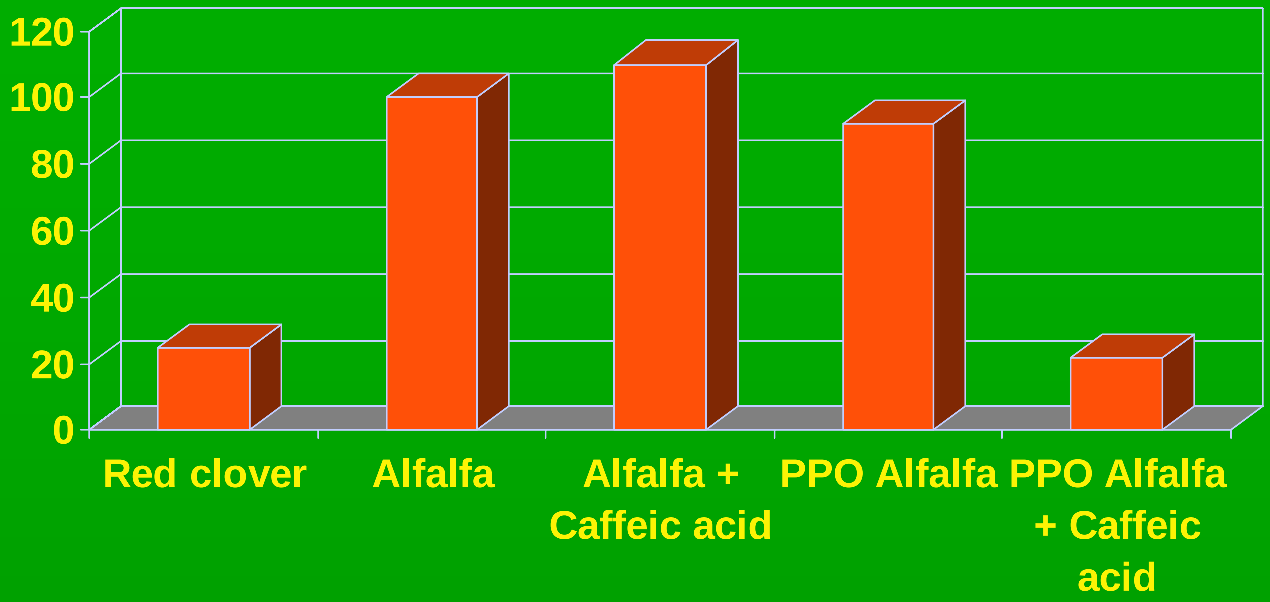
In alfalfa, browning is dependent on:

- 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)



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

PPO = Polyphenol Oxidase gene from red clover

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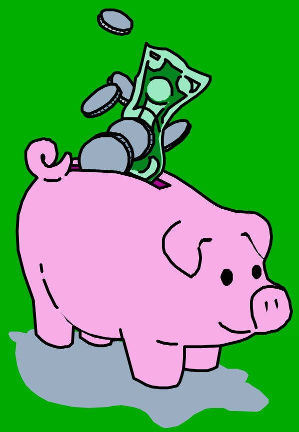
Tannins improve protein utilization

- 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.

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



Alfalfa silage	$ 23
Alfalfa hay	$ 11

Uptake and loss of manure and forage residue N by subsequent annual crops

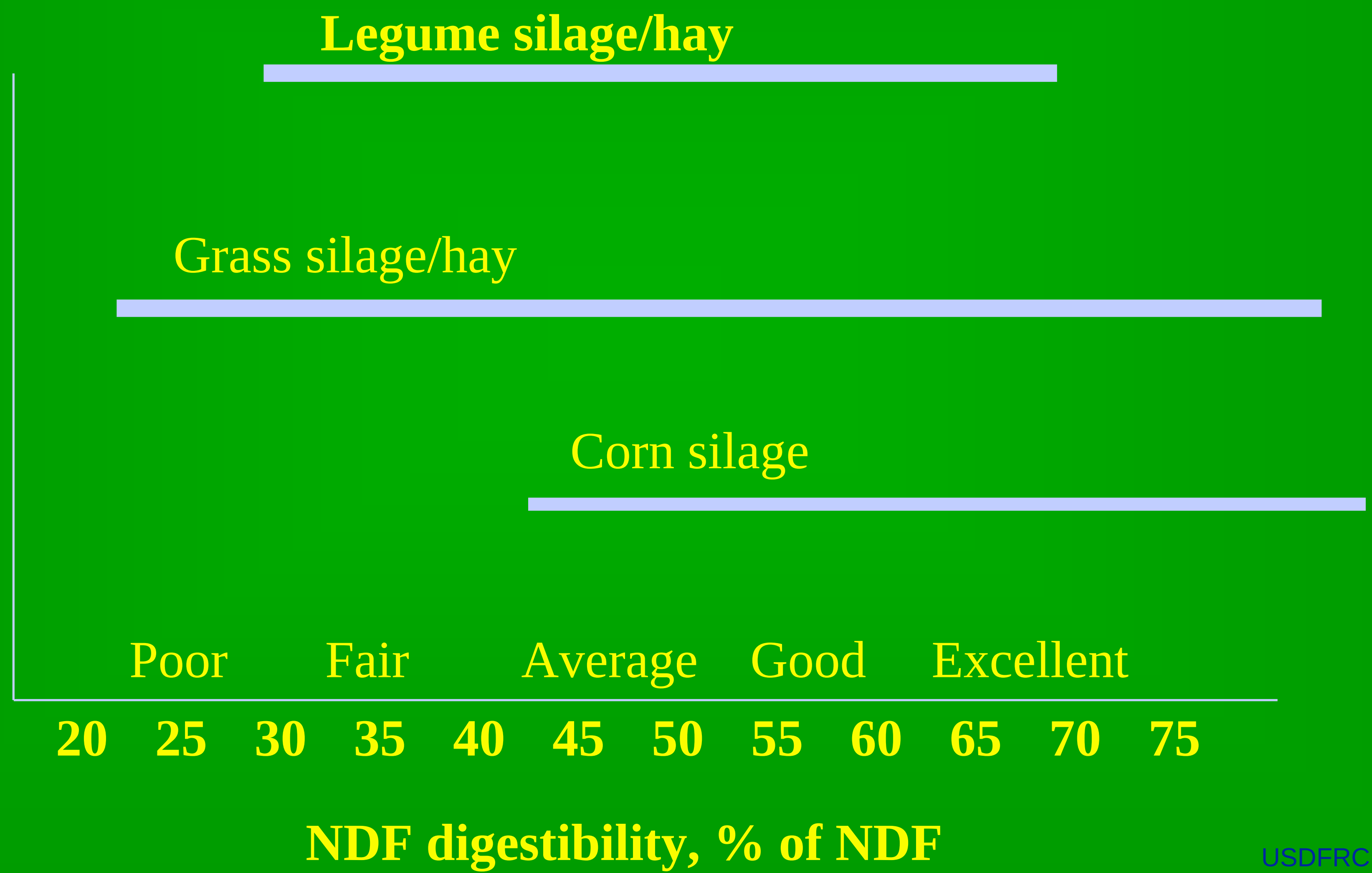





Strategies for decreasing post-harvest proteolysis in alfalfa silage

- 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)

NDF Digestibility of Forages



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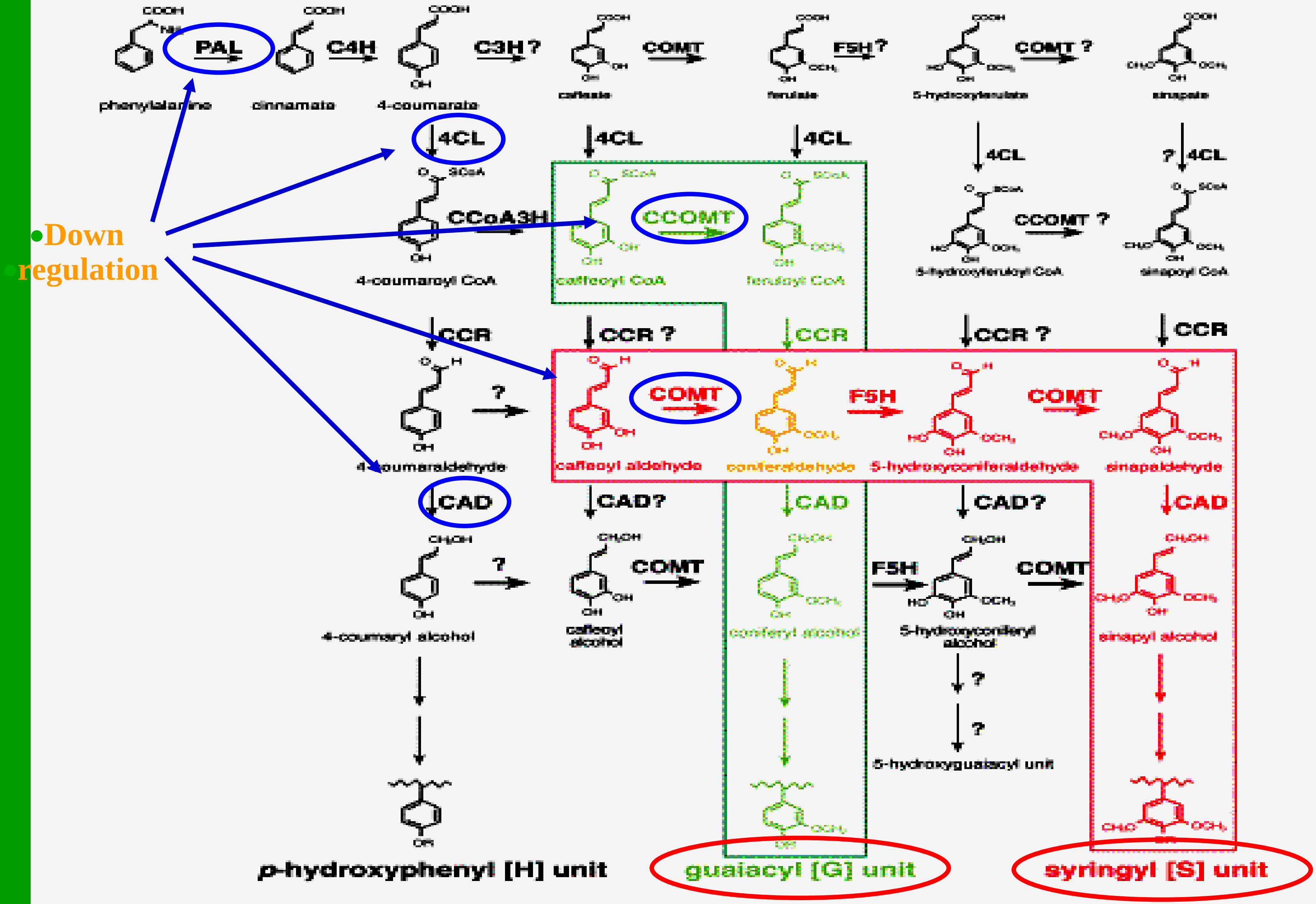


Engineering the lignin biosynthetic pathway in alfalfa

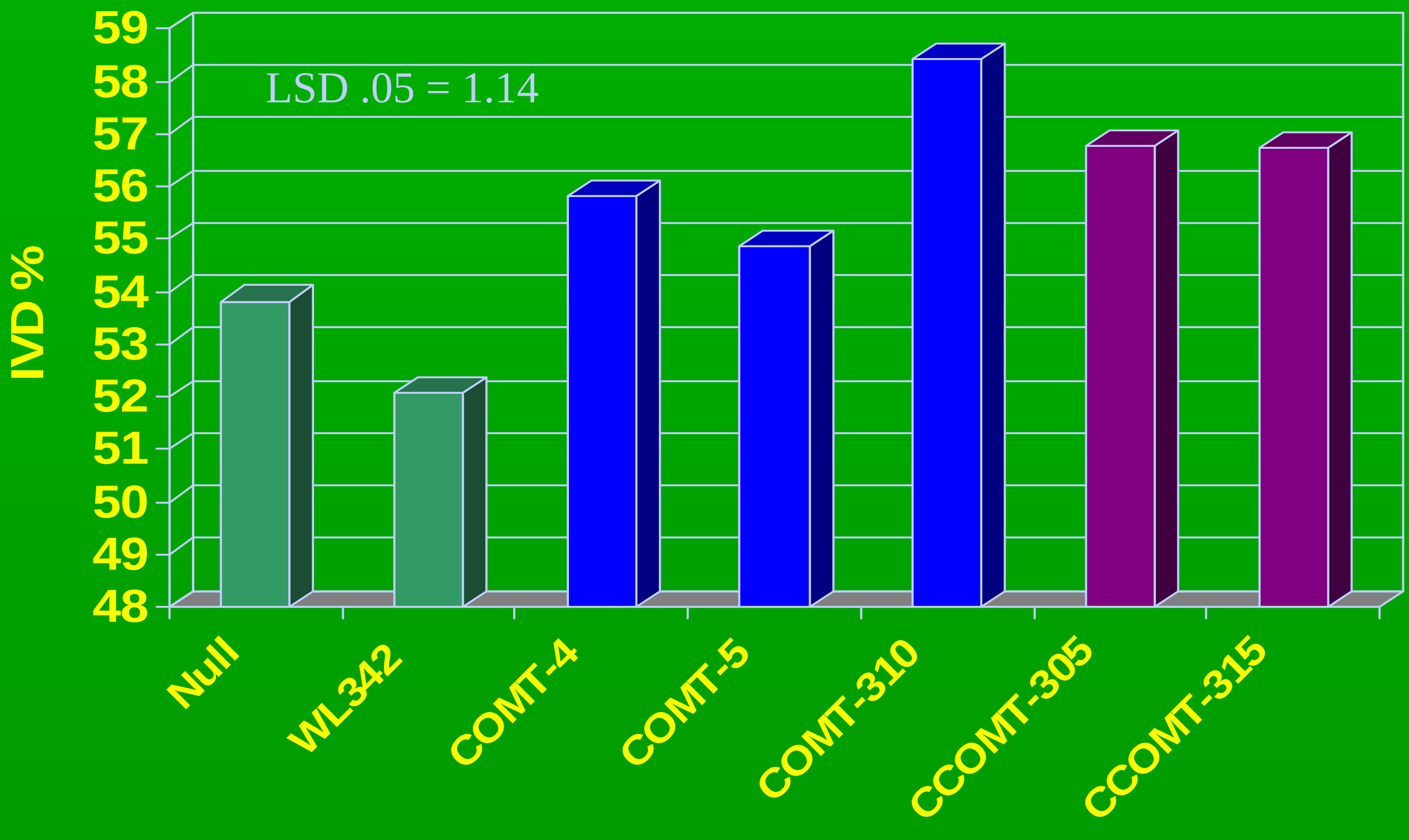
Genetic engineering for improved forage quality in alfalfa

- **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

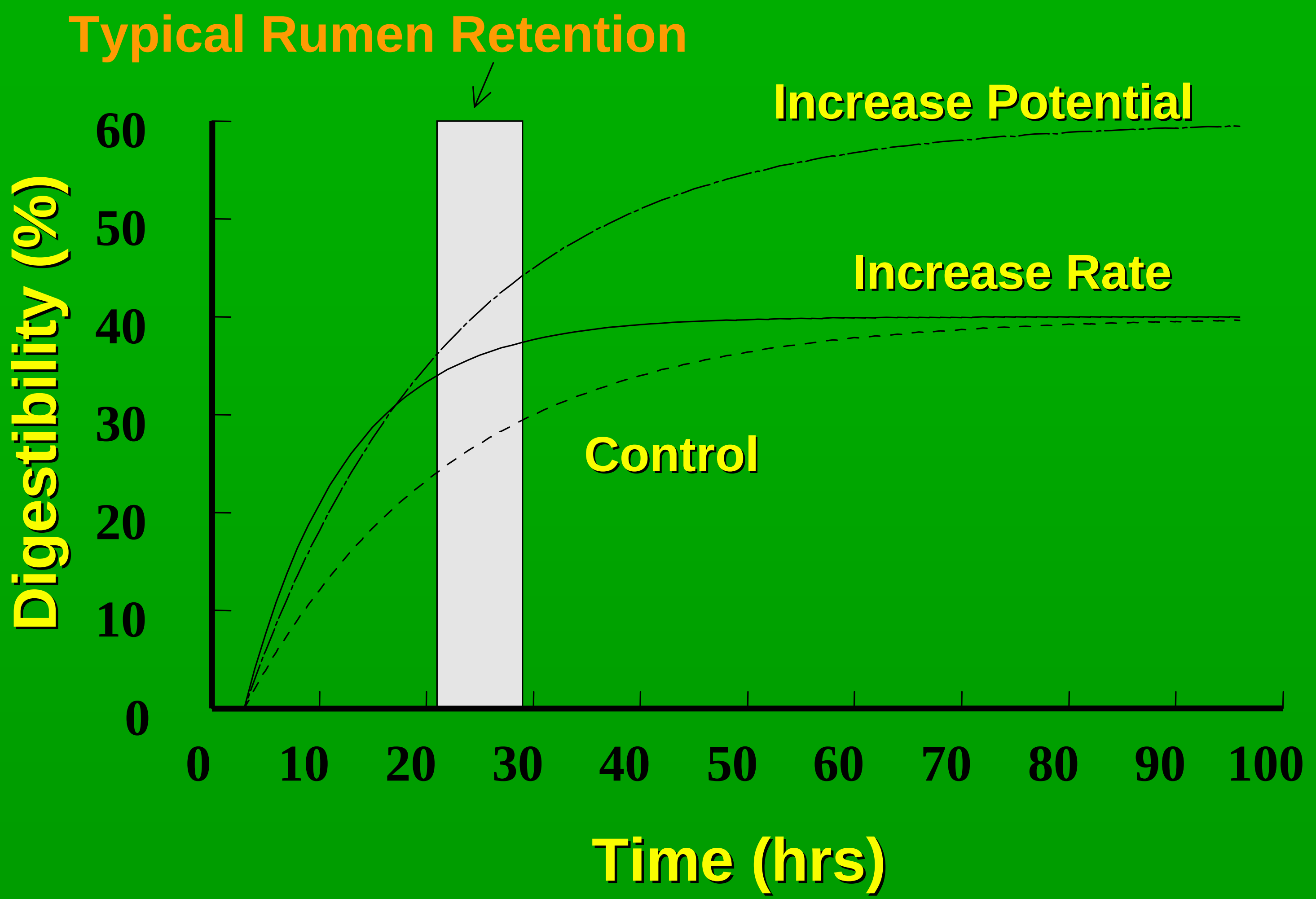
Dixon et. al., 2000

Lower Stem IVD – 2001 summary



McCaslin et al. 2002. Unpublished. Forage Genetics

NDF Digestion Profiles



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Attributes of Idea Alfalfa Plant

- Better balance of protein and rapidly fermentable carbohydrate
- At optimum aNDF of 40 %
  - 18 % crude protein
  - Less ash
  - 30 % nonfiber carbohydrate (NFC)
- Improve current balance of amino acids with slower rate of degradation in ensiling
- Increase fat to 4 %
- Improve the extent of digestion of fiber
- Removal or suppression of bloat causing properties

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 Biotechnology Research

- Over-expression of salt tolerance
- Commercialization of Roundup Ready gene and down regulation of lignin genes to increase digestibility
- Identifying alfalfa genes controlling yield and winter-hardiness
- Identifying genes controlling salt and drought tolerance
- Cloning genes for vegetative storage proteins

SOURCE: Brummer et al., 2004

Alfalfa Biotechnology Research

- Developing molecular markers, studying down regulation of lignin genes, insertion of genes for condensed tannins, identifying and introgression of drought and aluminum tolerance genes
- Developing molecular markers and using markers for identifying genes for yield and winter survival
- Characterize genes controlling post-harvest proteolysis
- Insertion of genes to allow remediation of atrazine and genes to control pectin in cell walls

SOURCE: Brummer et al., 2004 USDFRC

Corn Silage Hybrid Development

- Waxy
- Brown Midrib
- Multi-leaf (Leafy)
- High oil
- Opaque 2 (high lysine)

SOURCE: Hartnell et al., 2005

Corn Silage Hybrid Development

- Biotech – Input traits
  - Insect protection against European corn borer, corn rootworm and others
  - Herbicide-tolerant
  - Traits under development
    - Drought tolerance, cold tolerance
    - Insect-stalk snap resistance
    - Increased grain to stover ratio
    - Slower dry down rate
    - Mycotoxin resistance (primarily aflatoxin)

SOURCE: Hartnell et al., 2005

Corn Silage Hybrid Development

- Biotech – Forage enhanced traits
  - Reduced or altered lignin to enhance stover
  - Altered carbohydrate – improved microbial efficiency & reduced impact on fiber digestion & rumen pH
  - Increased protein quality & amino acid balance
  - Enhance digestible biomass
  - Plant production of enzymes – digestibility
  - Production of fermentation adjuvants in plant that aid in fermentation in the silo & rumen

SOURCE: Hartnell et al., 2005

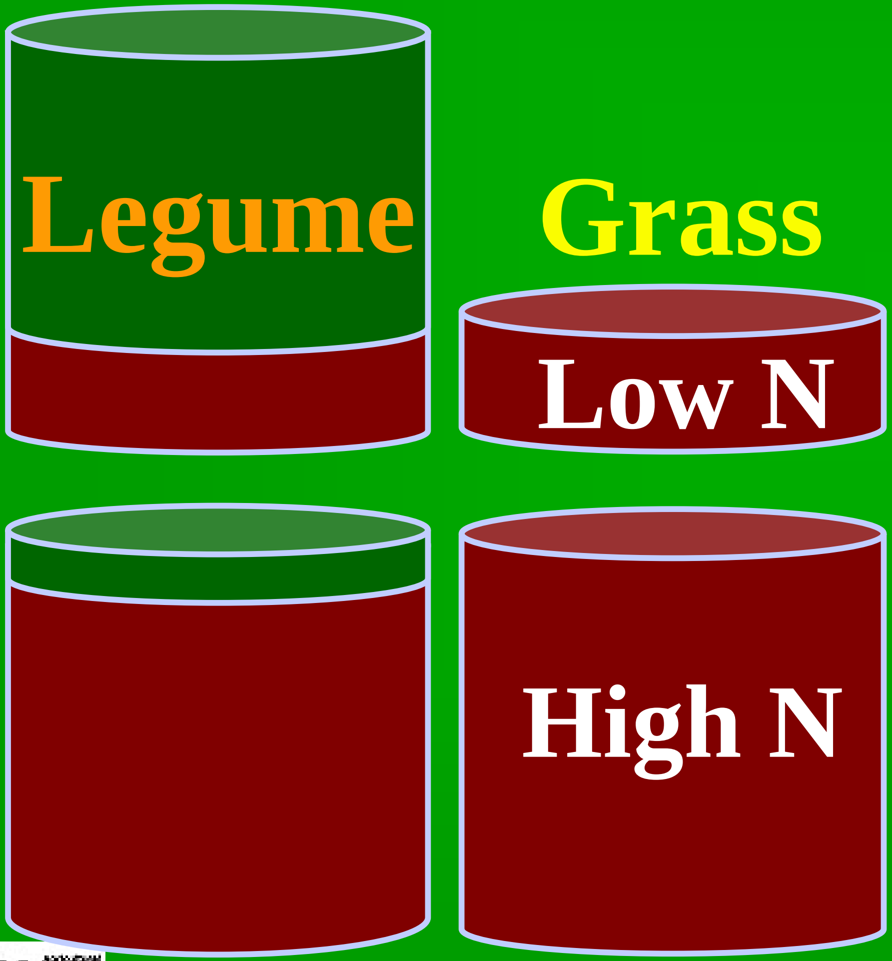
Alfalfa in Crop Rotations:

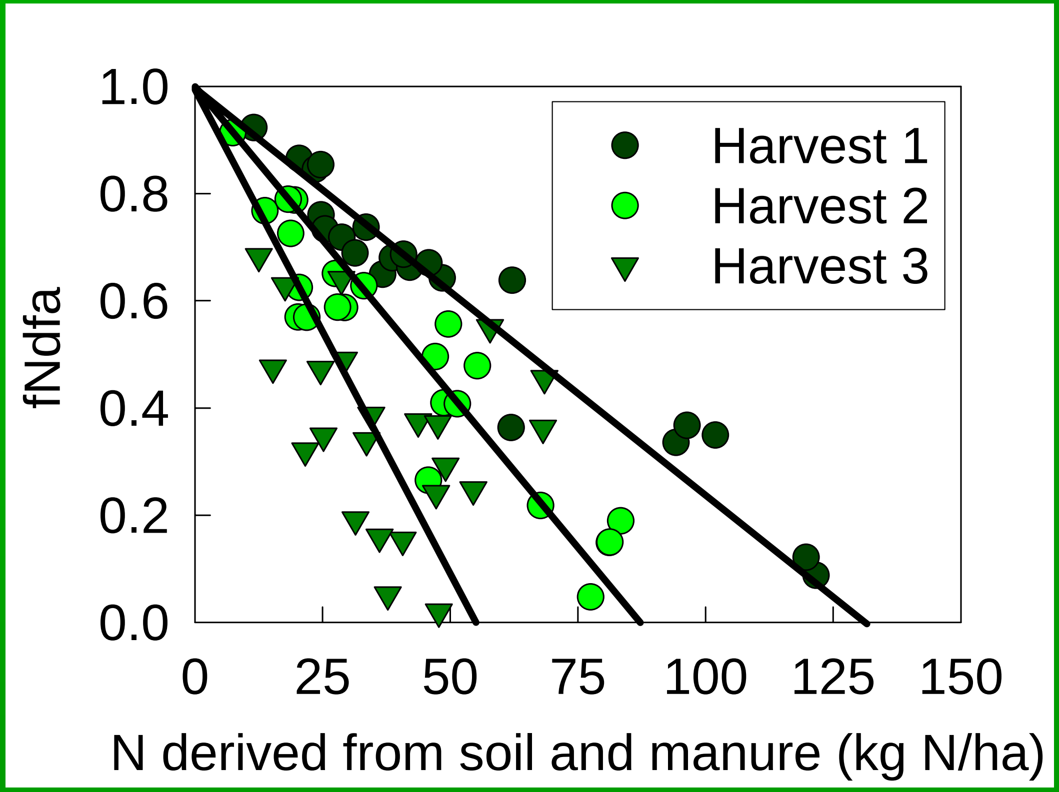
- Adds nitrogen via biological fixation
- Improves water infiltration and soil quality
- Reduces soil erosion from wind and water
- Improves yield of subsequent crop
- Reduces N fertilizer demands of subsequent crops

Alfalfa in Crop Rotations:

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

Legumes serve as N buffers





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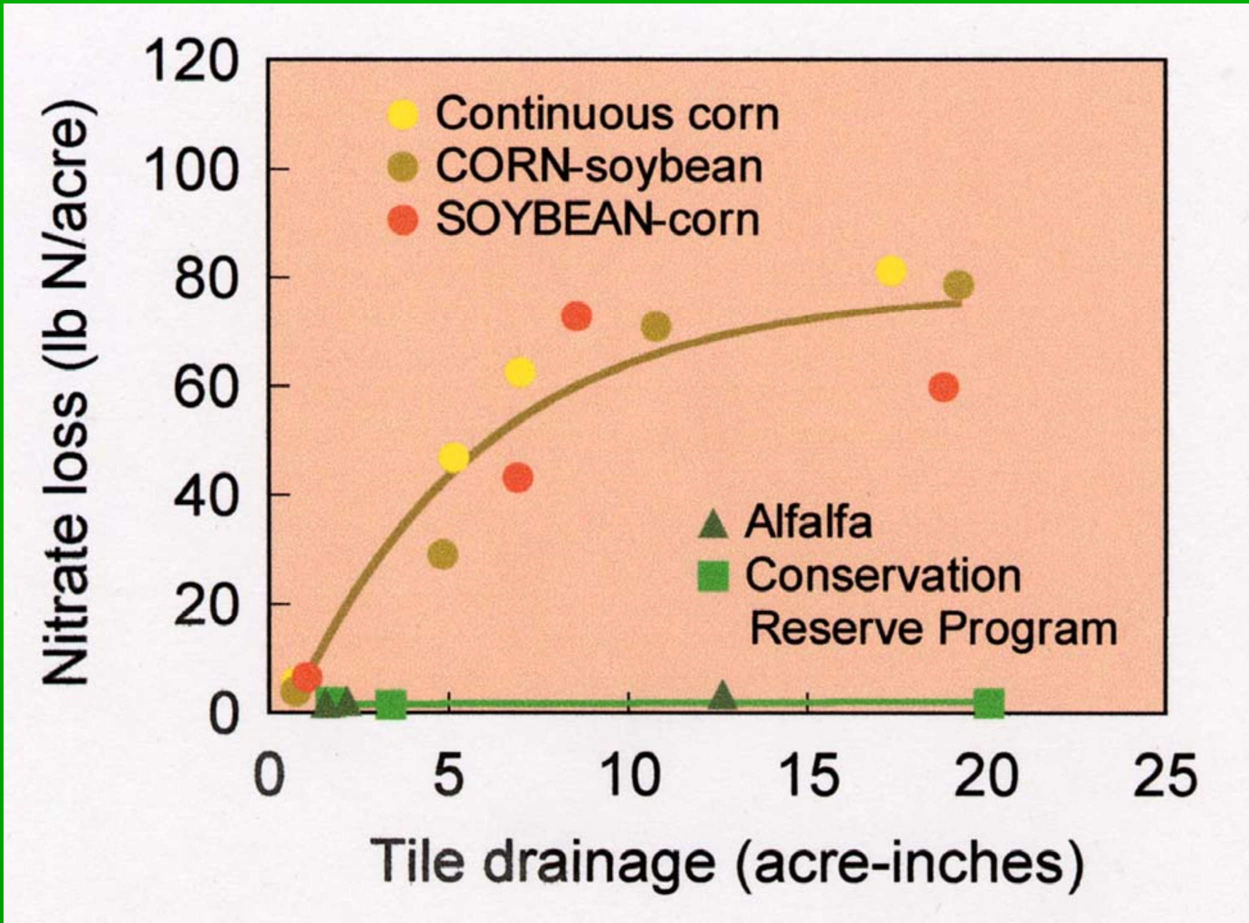
Russelle et al., 2002

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

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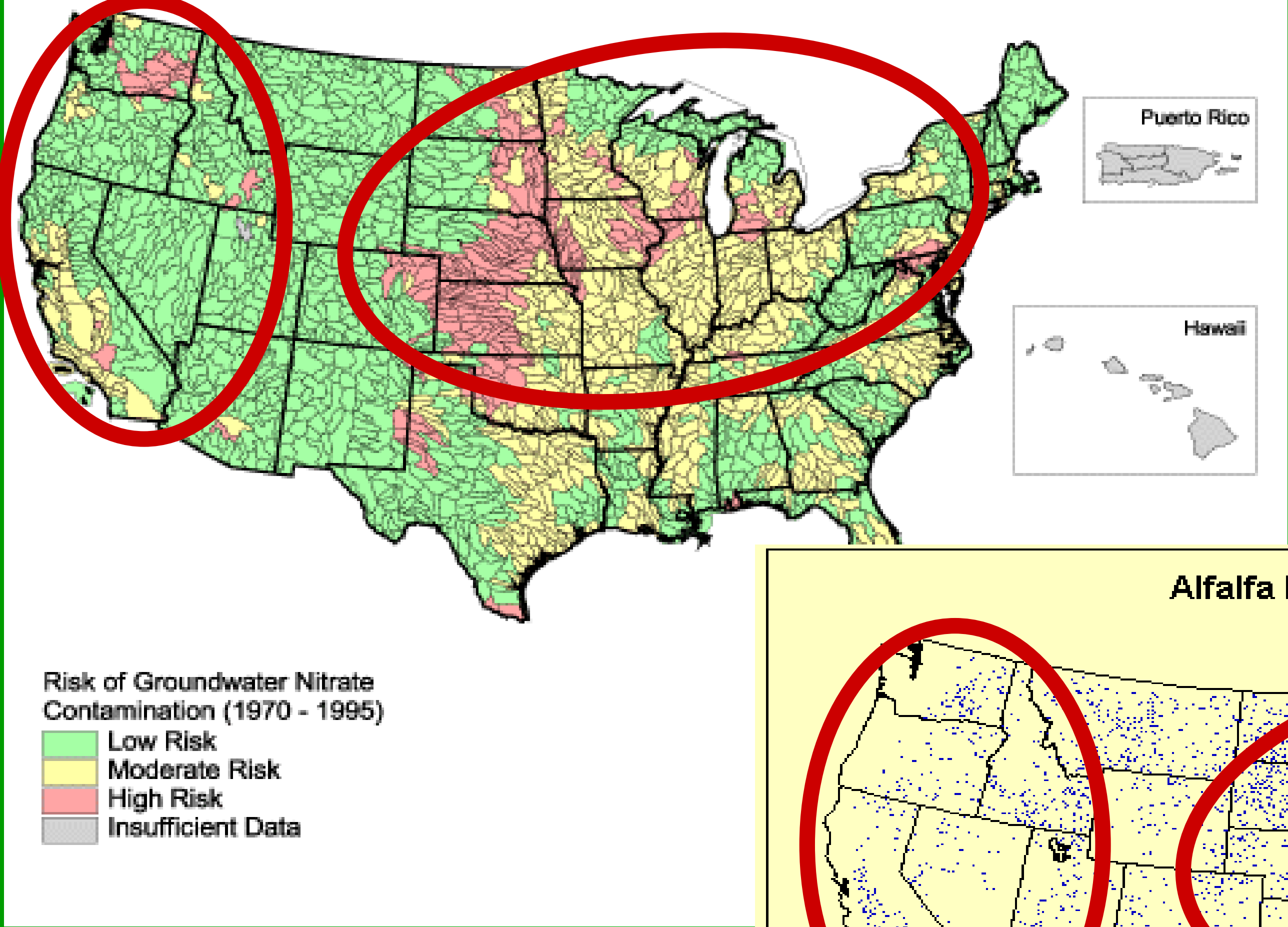
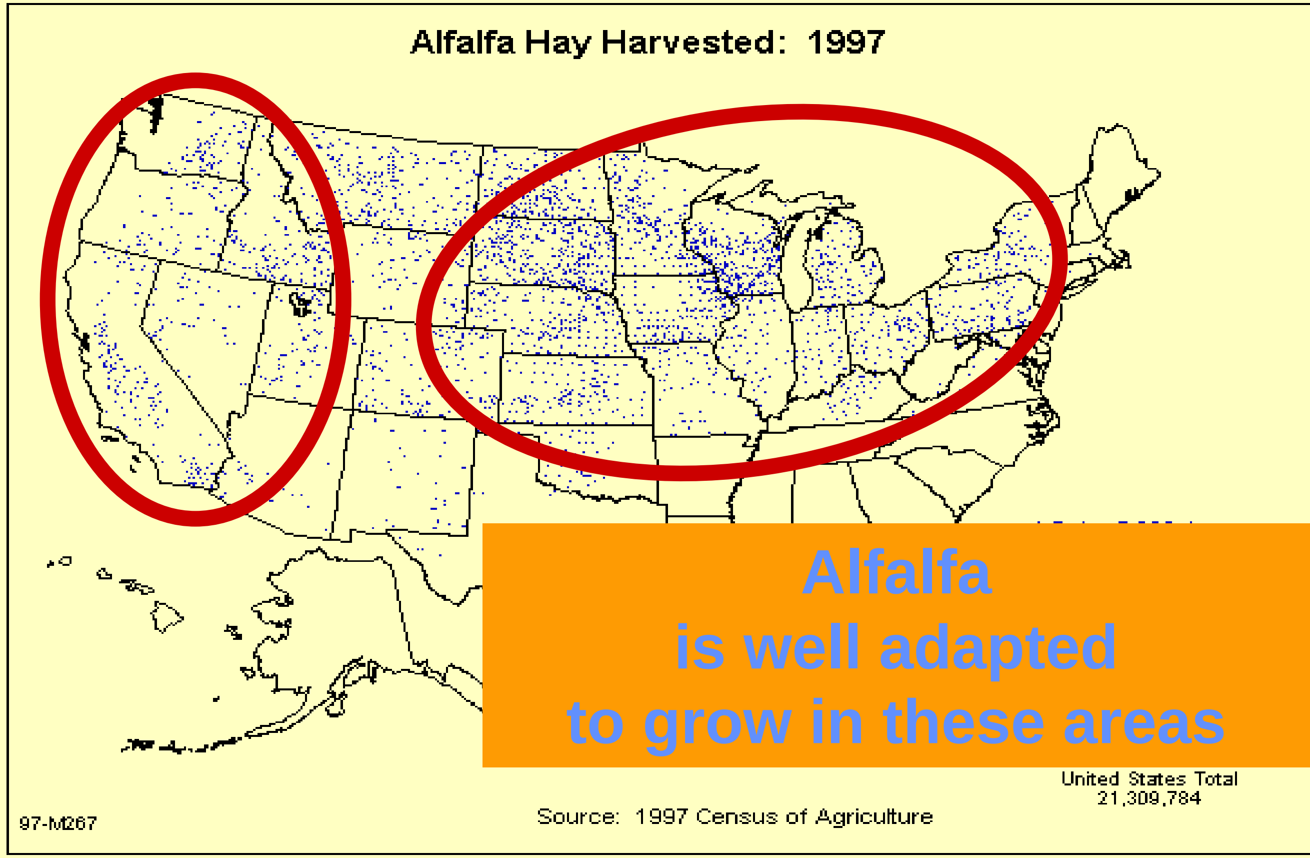
Risk of ground water nitrate contamination





Alfalfa is well adapted to grow in these areas

Consortium for Alfalfa Improvement

- Share expertise of Noble Foundation, Forage Genetics, Plant Science Unit and USDFRC to redesign alfalfa for dairy cattle
  - November 2000 at Noble Foundation
  - September 2002 at Forage Genetics
  - February 2003 at Noble Foundation
  - January 2004 at Noble Foundation
  - August 2004 at USDFRC

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

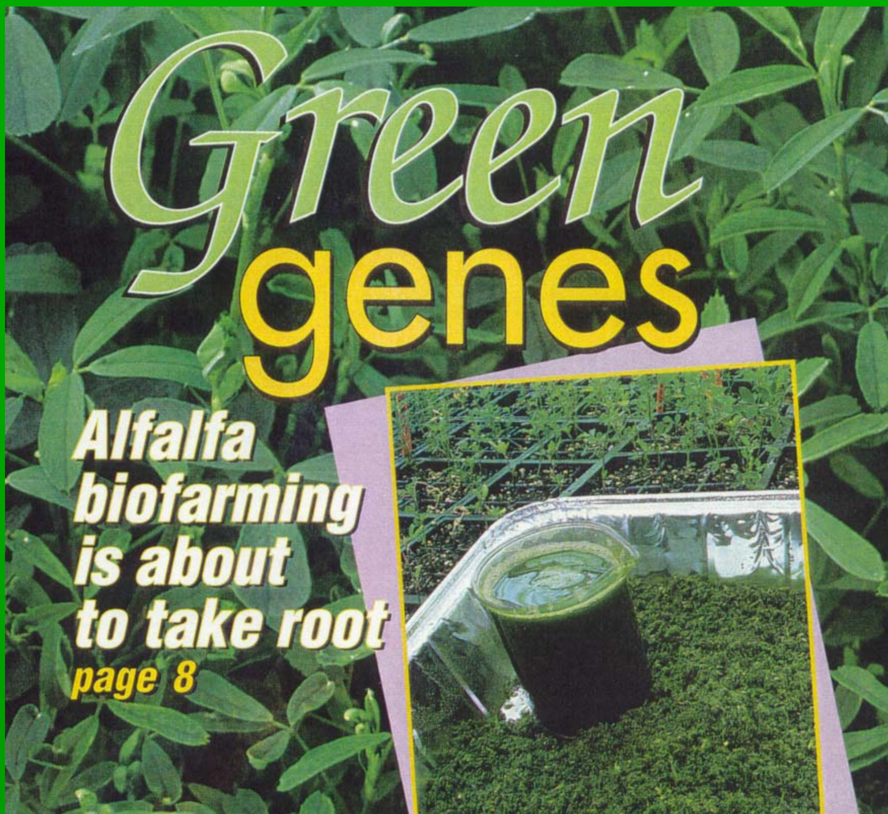
- **Research efforts underway to:**
  - Develop alfalfa with value-added traits
  - Develop new processing technologies

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

Development of Green Genes



- Fractionation of alfalfa
  - dry - electricity
  - wet - phytase
    - cellulase
    - biopluping
    - biobleaching
    - bioremediation

Biomass Conversion to Ethanol

Grind

Pretreatment to Remove Inhibitors

Sugars

Enzymatic Breakdown of Polysaccharides

Sugars

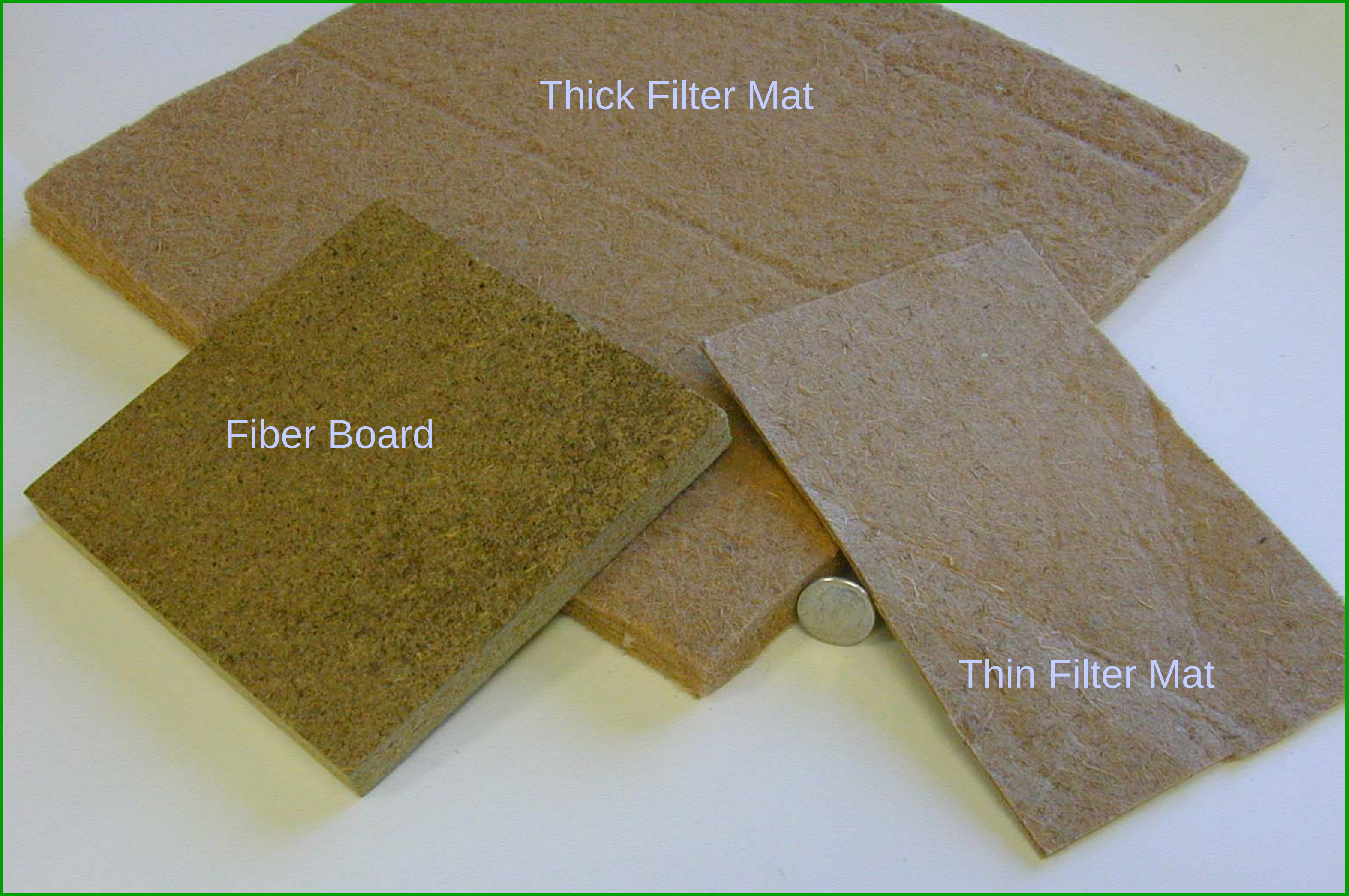
Residual Solids

Electricity & Processing Heat

Fermentation

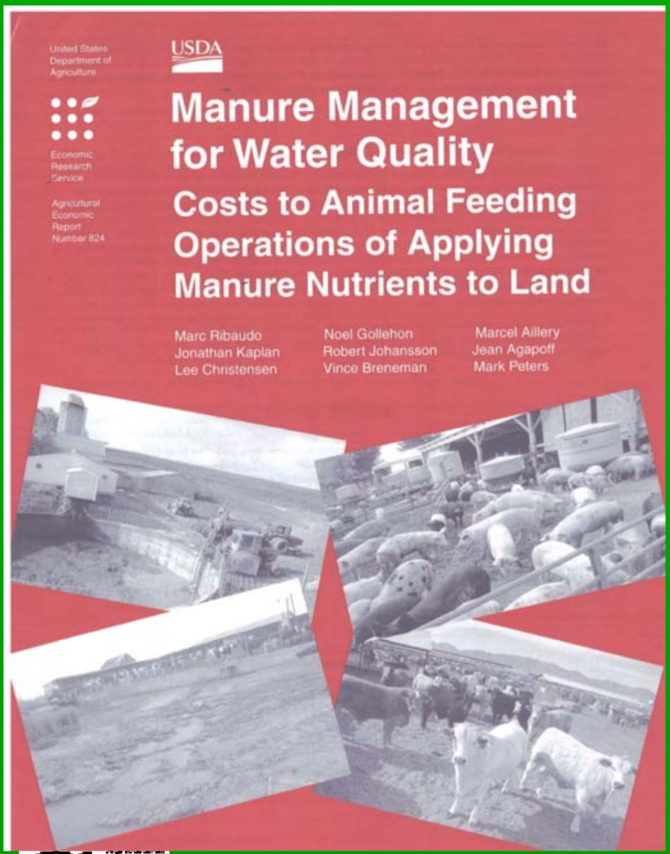
Ethanol Recovery

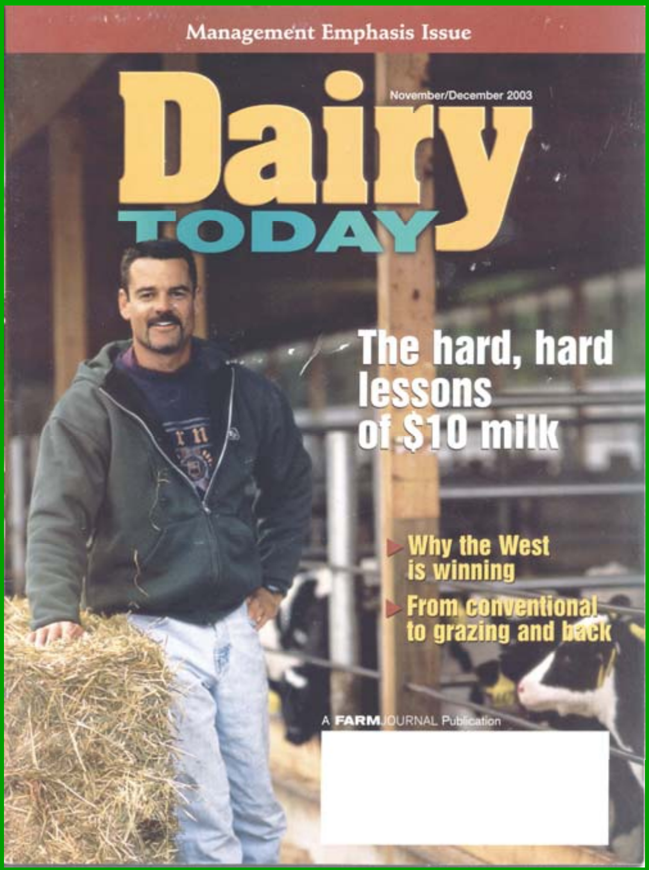
Fiber Board and Filter Mats from Manure



Using Biotech To Keep Alfalfa and Corn Silage Competitive

- Solutions to major challenges in agriculture





Nutrient necessities

Nutrient management planning for 1,300 cows and 1,000 acres takes planning, bucks and persistence

By Kim Bower-Spence

Expanding a dairy from 315 to 1,325 mature cows with a land base of just under 1,000 owned and rented acres, Phil Kulp knew nutrient management would drive decision making from the get-go.

Kulp Family Dairy LLC's two-step expansion began in 1999 with a leap to 600 milking cows. The family added another barn, for a total of 1,100 in 2002. Their 1999 nutrient management plan took into account the second-phase cows. Their five-year concentrated animal feeding operation (CAFO) permit, issued in May 2001, also counted their final total.

The Martinsburg, Pa., operation includes Phil and his wife, Becky; his parents, Larry and Mary Ann; and about 30 employees.

Plethora of permits. Bill Fink, agronomist with the Ephrata, Pa.–based consulting firm Team Ag, devised Kulp's nutrient management plan. He helped them wade through the myriad regulations concerning animal equivalent units, concentrated animal operation (CAO) status, local watershed designation, manure storage needs and township requirements.

The Kulps hit the trigger for both state and federal regulations. Having more than 1,000 animal equivalent units brought them under federal CAFO rules. Since they had more than two animal units per acre, they also needed to meet Pennsylvania standards for CAOs. Kulp Family Dairy also lies within a special protection watershed.

Besides their nutrient management and conservation plans, the Kulps needed a Water Quality Management Part II permit to construct manure storage. Engineering plans by Team Ag included an engineering survey, site map, manure storage and transfer system design, erosion and sediment control plans, and storm water management plans.

Phil Kulp estimates that the operation paid about $25,000 total in permitting costs for everything from storm water management to septic and CAFO. "We got into it early enough that maybe it wasn't as costly," he says.

Fink says permitting can run $5 to $6 an acre for nutrient management, plus $1,000 for state permit applications. CAFO plans range from $1,000 up to $15,000, depending on engineering. And the process takes six to eight months.

Permitting challenges aside, Kulp cites four steps to successful nutrient management.

1. Plan for land. "You have to maintain an adequate land base, and we do that by cooperating with our neighbors," Kulp notes. "As we were talking about building and expanding, I was already talking with other landowners."

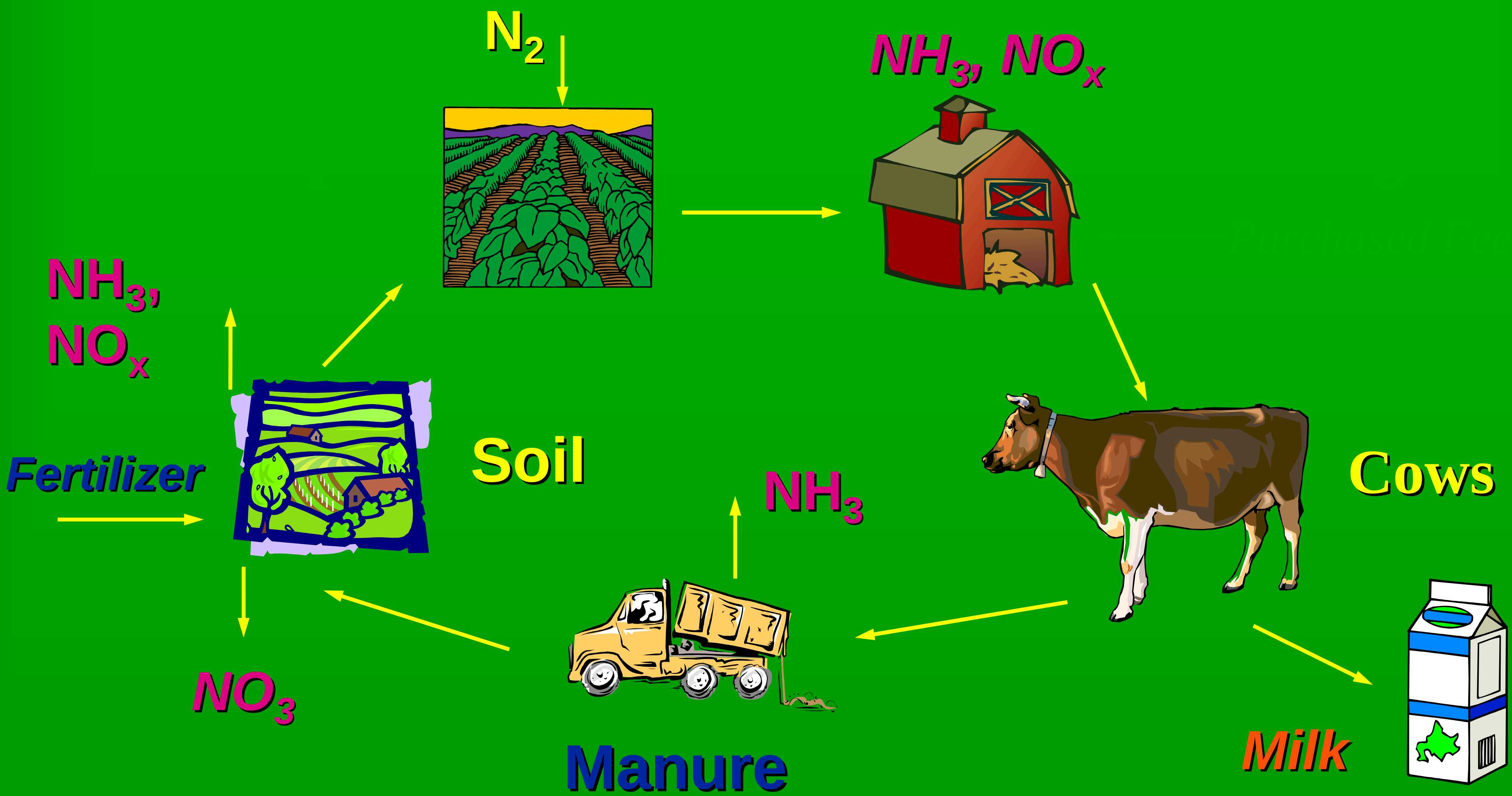
Those conversations yielded three 5-year feed contracts that set price and include import-export agreements for manure. "We buy all the forage from those acres, and we also return the manure in accordance with the nutrient management plan."

Word apparently spread that it's a ▶

Phil Kulp, Martinsburg, Pa., wrote five-year contracts with other local farmers to buy their forages and apply manure from Kulp Family Dairy on their fields.

10 Elite Producer November/December 2003

Nitrogen Cycle on Dairy Farms



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