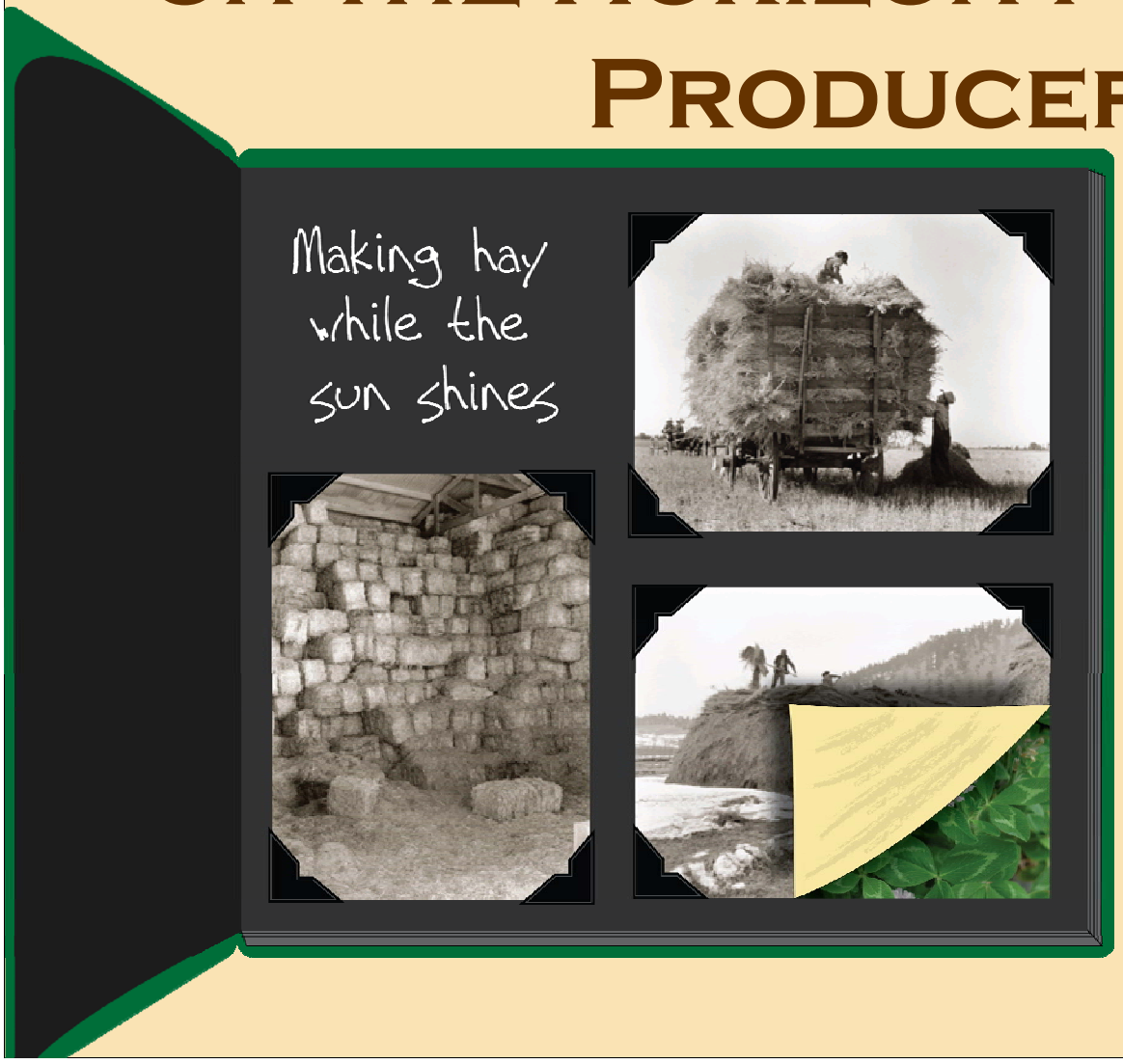
The Future of Forages: What Major New Developments are on the Horizon for Forage Producers?



Neal Martin, M. Casler, H. Riday and G. Brink

U.S. Dairy Forage Research Center, USDA-ARS, Madison, WI

Iowa Forage & Grassland Council Annual Meeting

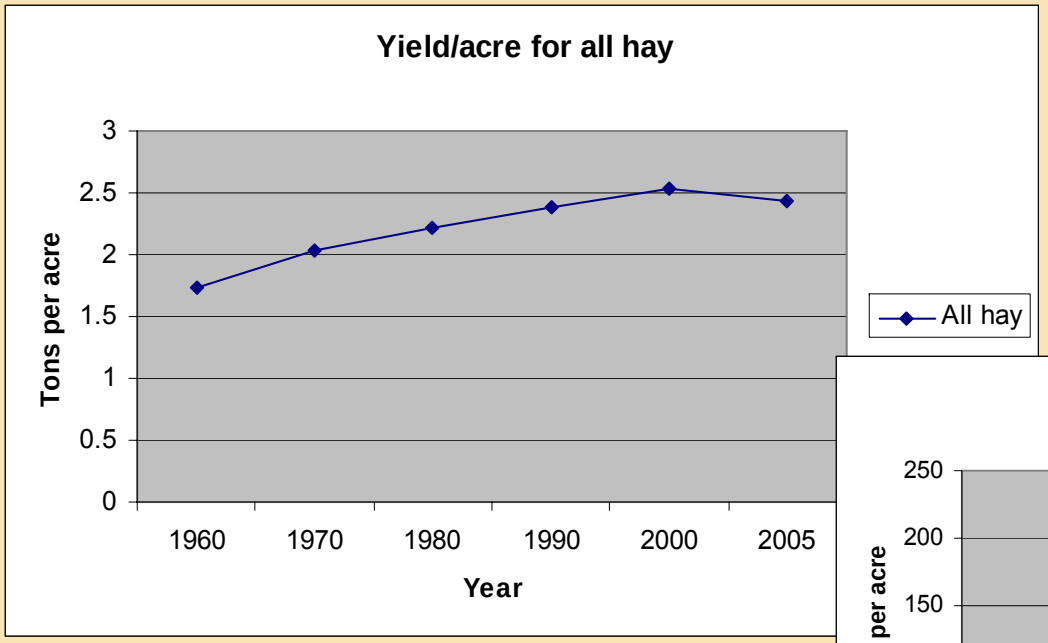
November 24, 2009
Des Moines, IA

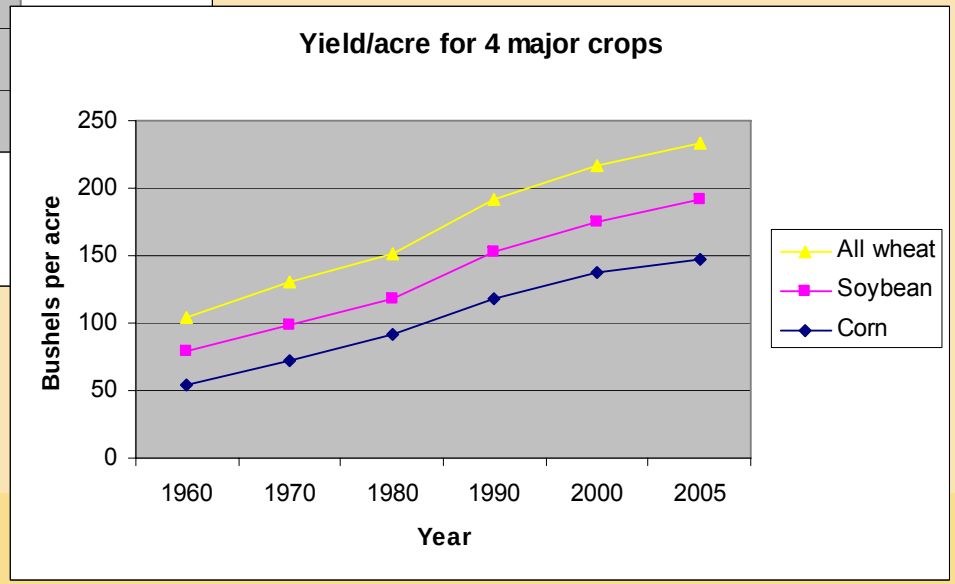
This talk will report. . .

- Forage crop production trends
- Redesigning alfalfa for livestock diets - CAI
- Forage legume breeding - USDFRC
- Forage grass breeding - USDFRC

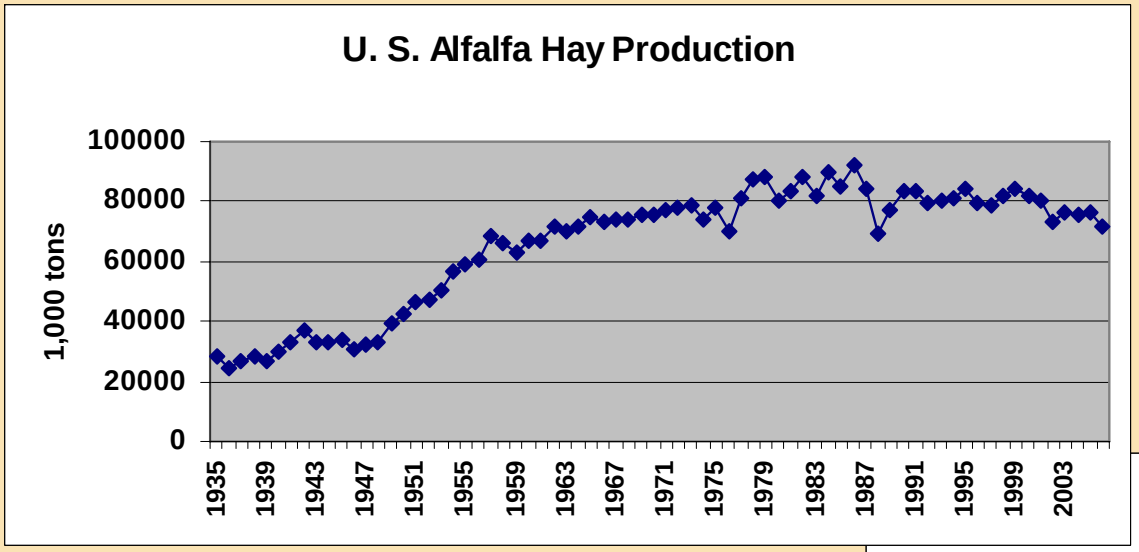
Forage trends . . .

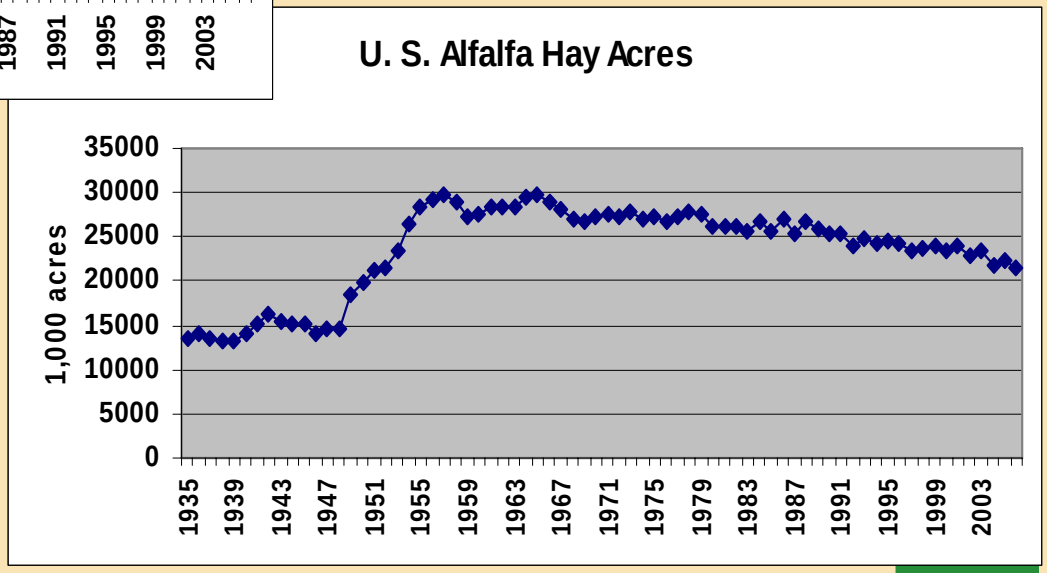
Least aggressive in yield increases





Alfalfa Hay Trends . . .



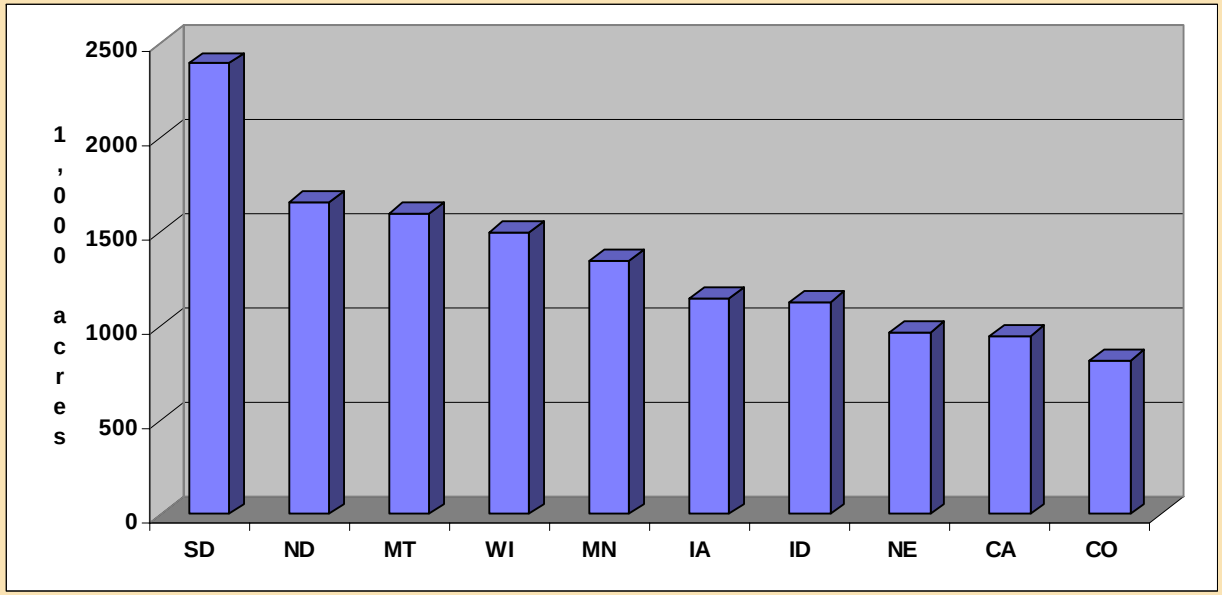


Forage Trends . . .

2008 U.S. Alfalfa Production

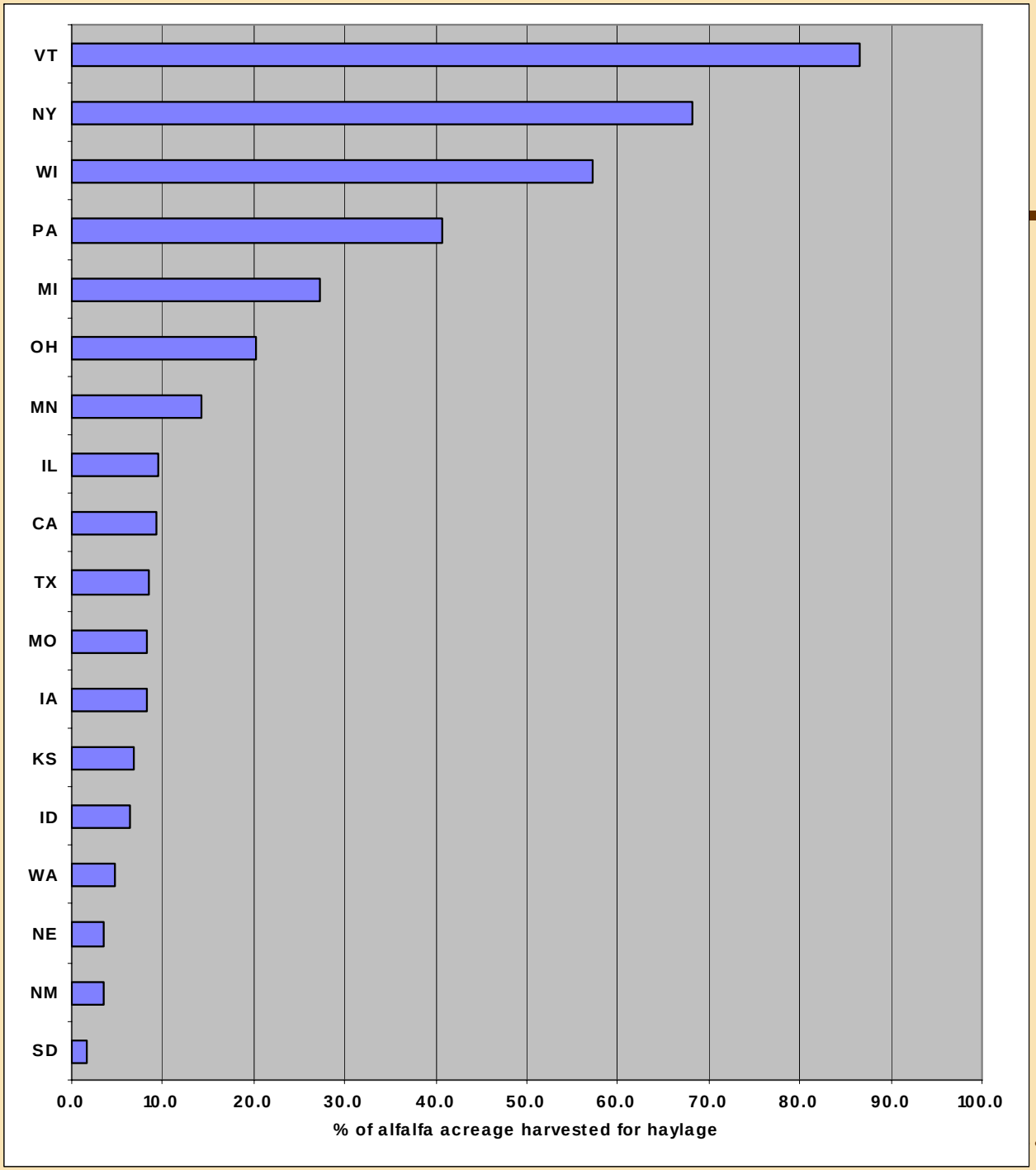
- **Hay**
  - 69.6 million tons
  - 21.0 million acre
  - $10.8 billion
  - 4th following corn, soybeans & wheat
- **Forage**
  - 80.7 million tons
  - 23.1 million acres
  - ~$13.9 billion

Leading Alfalfa Hay States, 1,000 acres, 2008



Top 10 States

- 64 % of U.S. acres
- 60 % of tonnage
- 5 states NC
- 4 states West
- 5 Lead Dairy



HAYLAGE

- 18 states harvest 1 or more cuttings for haylage or green chop
- Leading dairy states
- In NE and Midwest, harvest more than 30% of alfalfa acreage as haylage

Forage Trends . . .

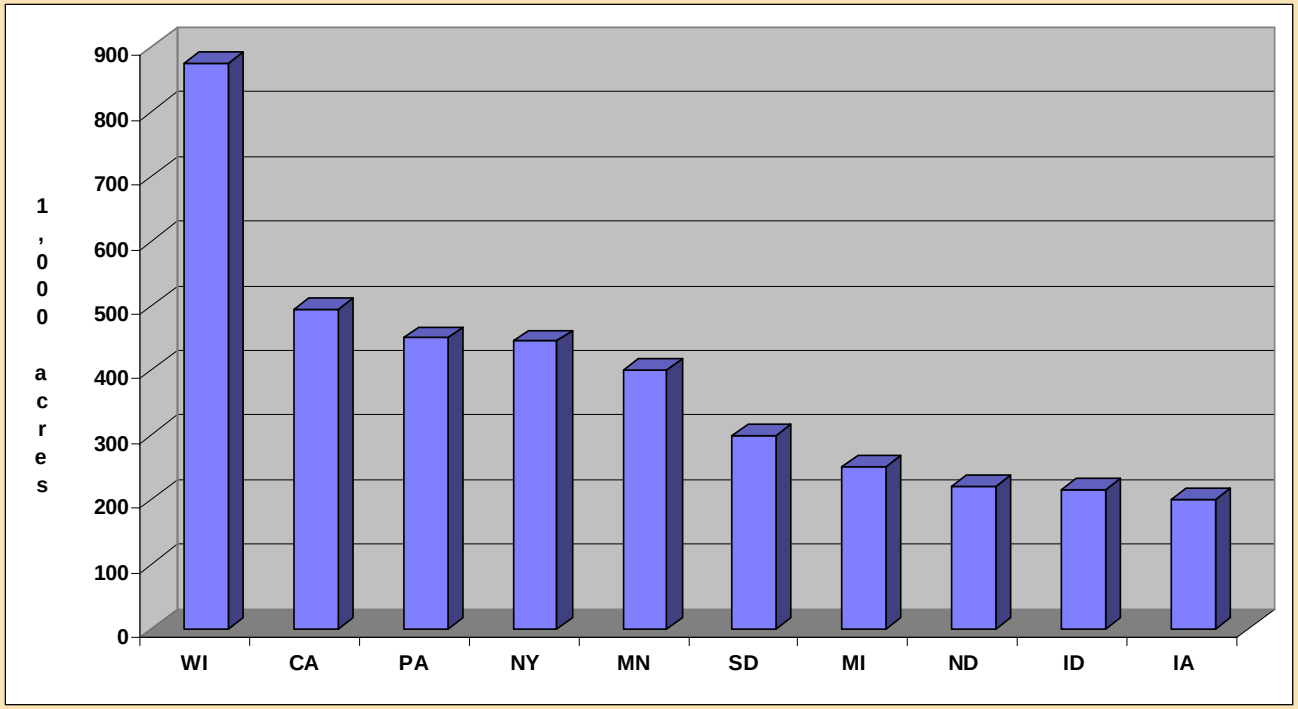
	million acres, 2007
Cropland harvested	406,424,909
Cropland pastured	35,771,154
Woodland pastured	370,297
Permanent pasture & rangeland	408,832,116

Between 2007 & 2002 acreage harvested for hay and haylage declined by 4 %

Acreage grazed declined by 28 %

2007 U.S. Census of Agriculture

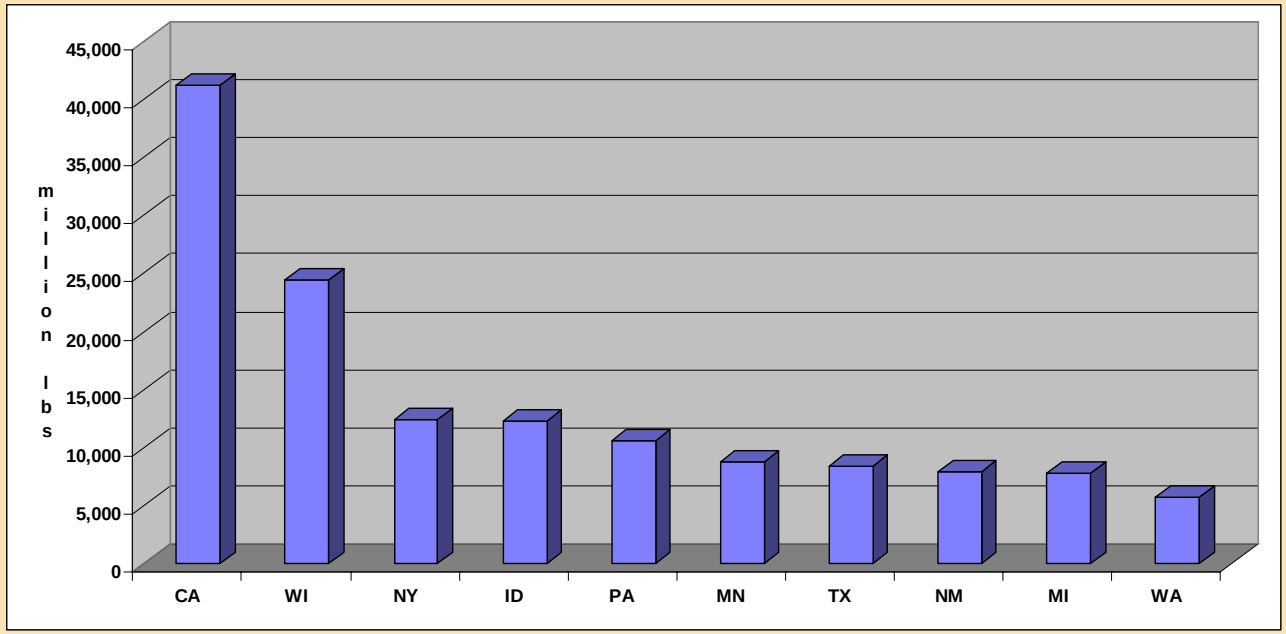
Leading States in Corn Silage production 1,000 tons, 2008



Top 10 States

- 64% of U.S. acres
- 64% of tonnage
- 6 NC
- 2 West
- 2 states NE
- 7 Lead Dairy

Leading Dairy States, million pounds of milk, 2008



Top 10 States

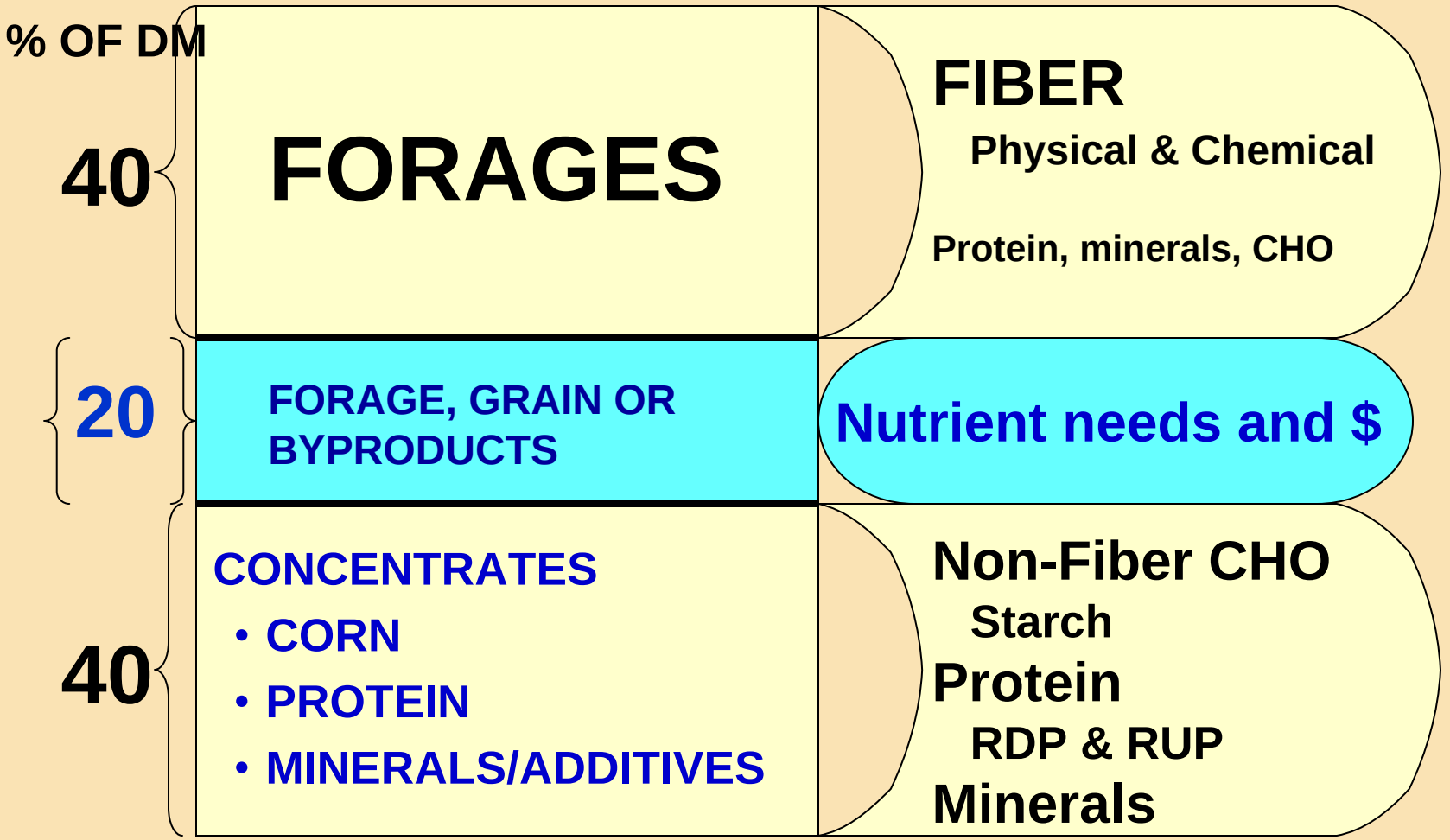
- 73% of U.S. prod
- 71% of cows
- 5 west
- 3 NC
- 2 NE

Trends . . .

- **Hay acreage remains unchanged**

- **Dairy cattle feeding – declining amounts**

Dairy Ration Overview

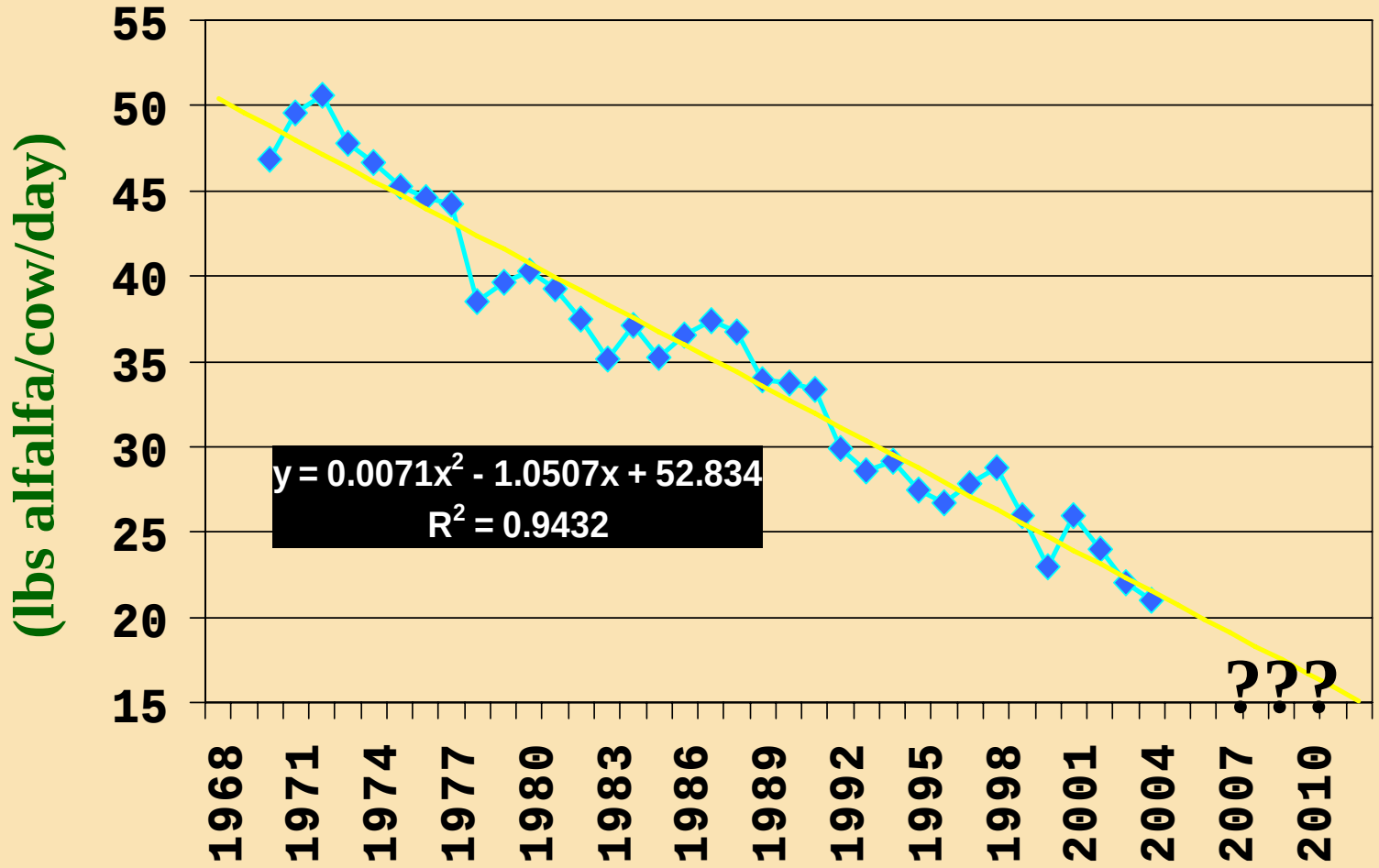


Barriers to increasing forage usage . . .

They've become great consumers of byproducts from the food, fiber and fuel industries.

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

CA Hay Production Per Dairy Cow



Source: Dan Putnam, 2005 Consortium for Alfalfa Improvement

Barriers to increasing alfalfa usage . . .

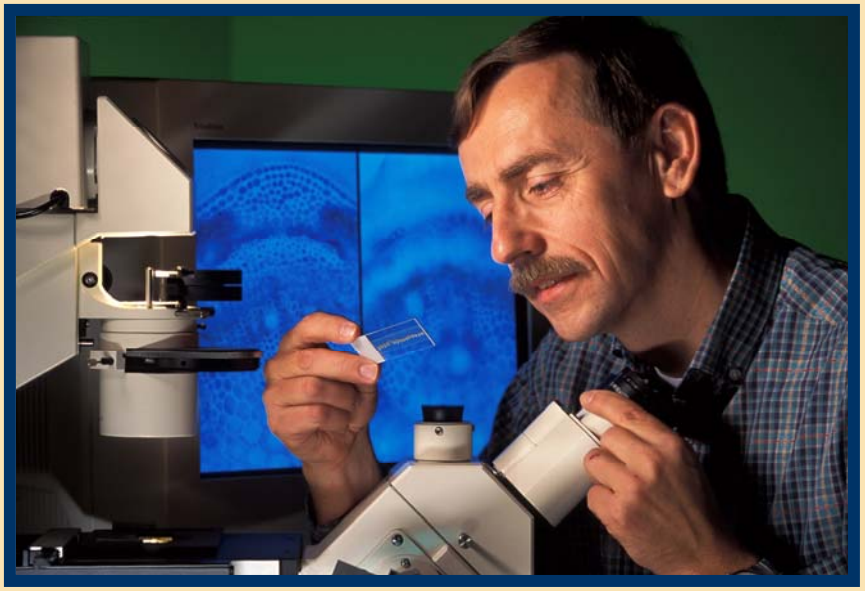
- Increasing use of corn silage
- Forage quality of alfalfa haylage, alfalfa hay and corn silage
  - Low fiber
  - Excessive crude protein resulting in excessive ruminal degradable protein
  - Less consistent quality of hay and haylage
- Relative to corn, alfalfa yields have lagged

Challenges . . .

. . . of the dairy forage industry

Research strategies and opportunities . . .

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



THE FUTURE OF FORAGES...

Forage & Livestock Industries Need

Perennial Legumes and Grasses

- Increased yield and persistence
  - Improved forage digestibility of legumes
  - Enhanced protein utilization of alfalfa

Redesigning Alfalfa

Two goals:

1. Reduce the amount of protein degraded in silage and in the rumen.
2. Increase the availability of carbohydrates in the plant cells.

Redesigning forages: The DFRC Team

David Mertens
dairy scientist

Ron Hatfield
plant physiologist

John Grabber
Agronomist

John Ralph
chemist

Heathcliffe Riday
geneticist

Mike Sullivan
molecular geneticist

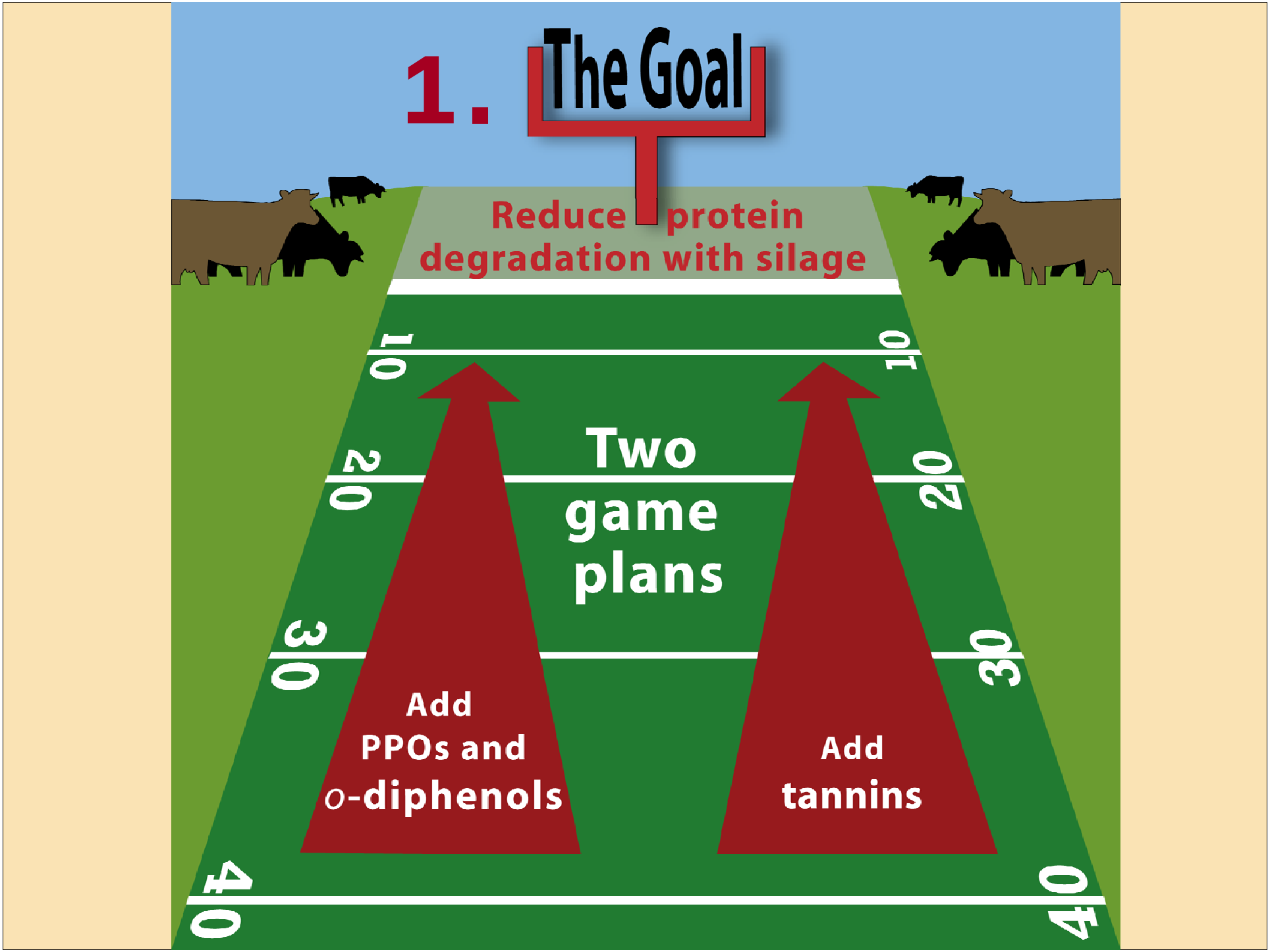
THE FUTURE OF FORAGES...

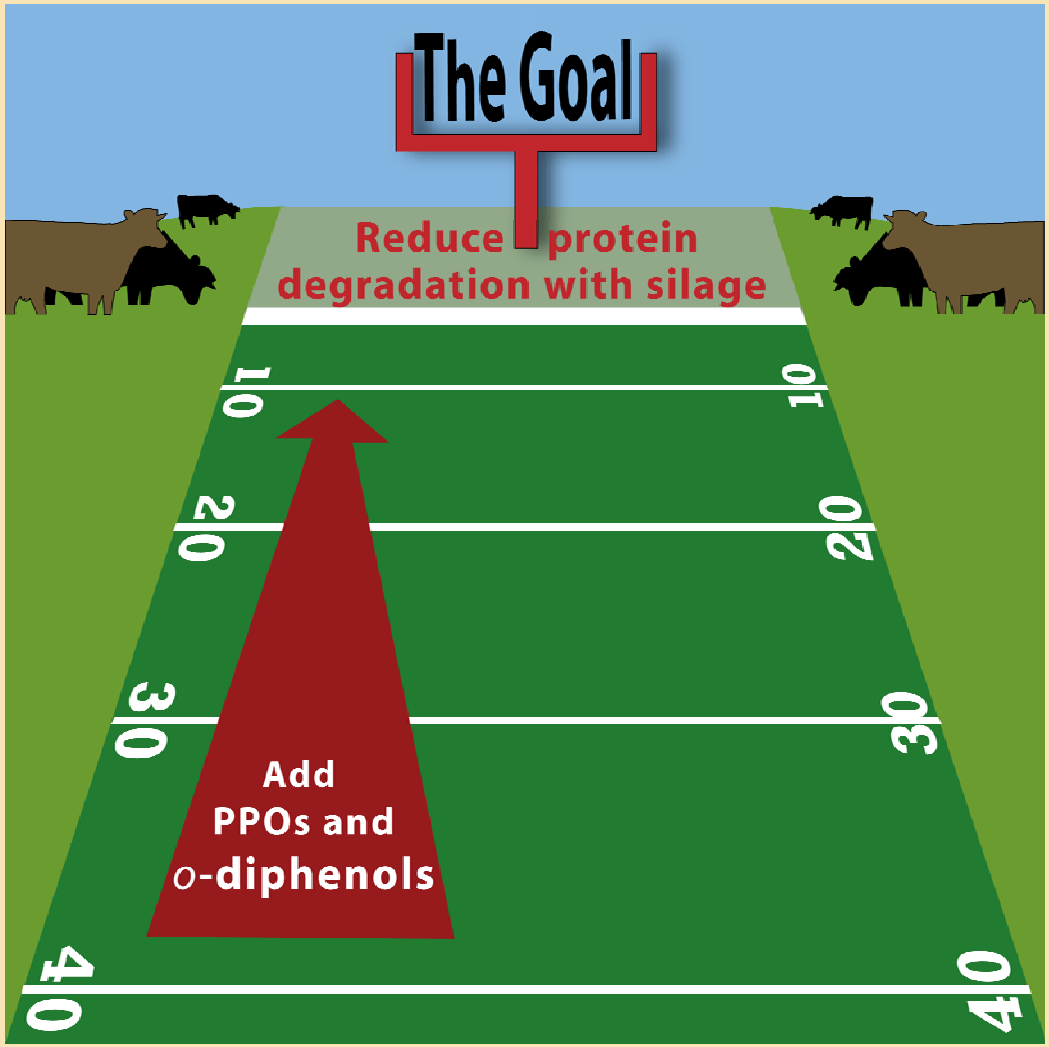
Redesign Alfalfa for Dairy Cattle

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


1.
The Goal
Reduce protein degradation with silage
10
10
20
20
30
30
40
40
Two game plans
Add PPOs and o-diphenols
Add tannins



(PPO is an enzyme, found in many plants, that causes browning and loss of quality.)

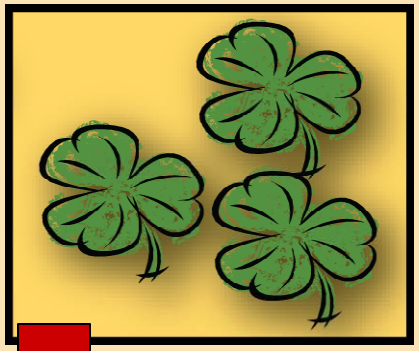
Consortium *for* Alfalfa Improvement

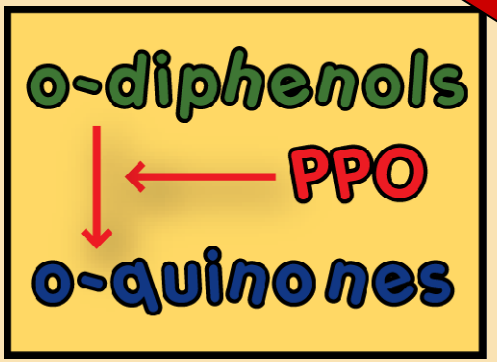
Redesigning Alfalfa

Goal #1: Reduce protein degradation

Save protein

Unlike alfalfa, red clover contains PPOs (polyphenol oxidase) and *o*-diphenol.





The PPO acts on the *o*-diphenols to produce *o*-quinones.

Redesigning Alfalfa

Goal #1: Reduce protein degradation

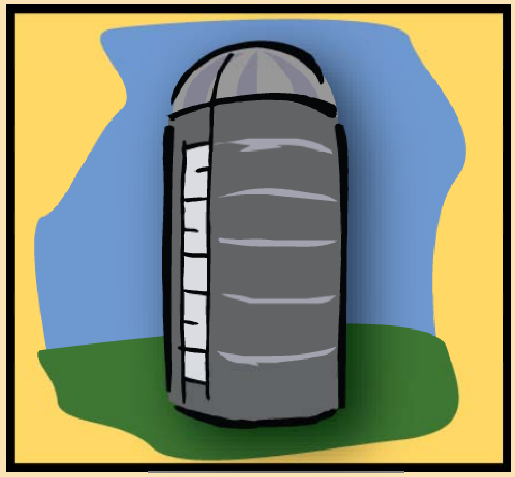
The highly reactive *o*-quinones bind with protein.

Proteases, which want to degrade protein, cannot do this when *o*-quinones are bound to the protein.

Redesigning Alfalfa

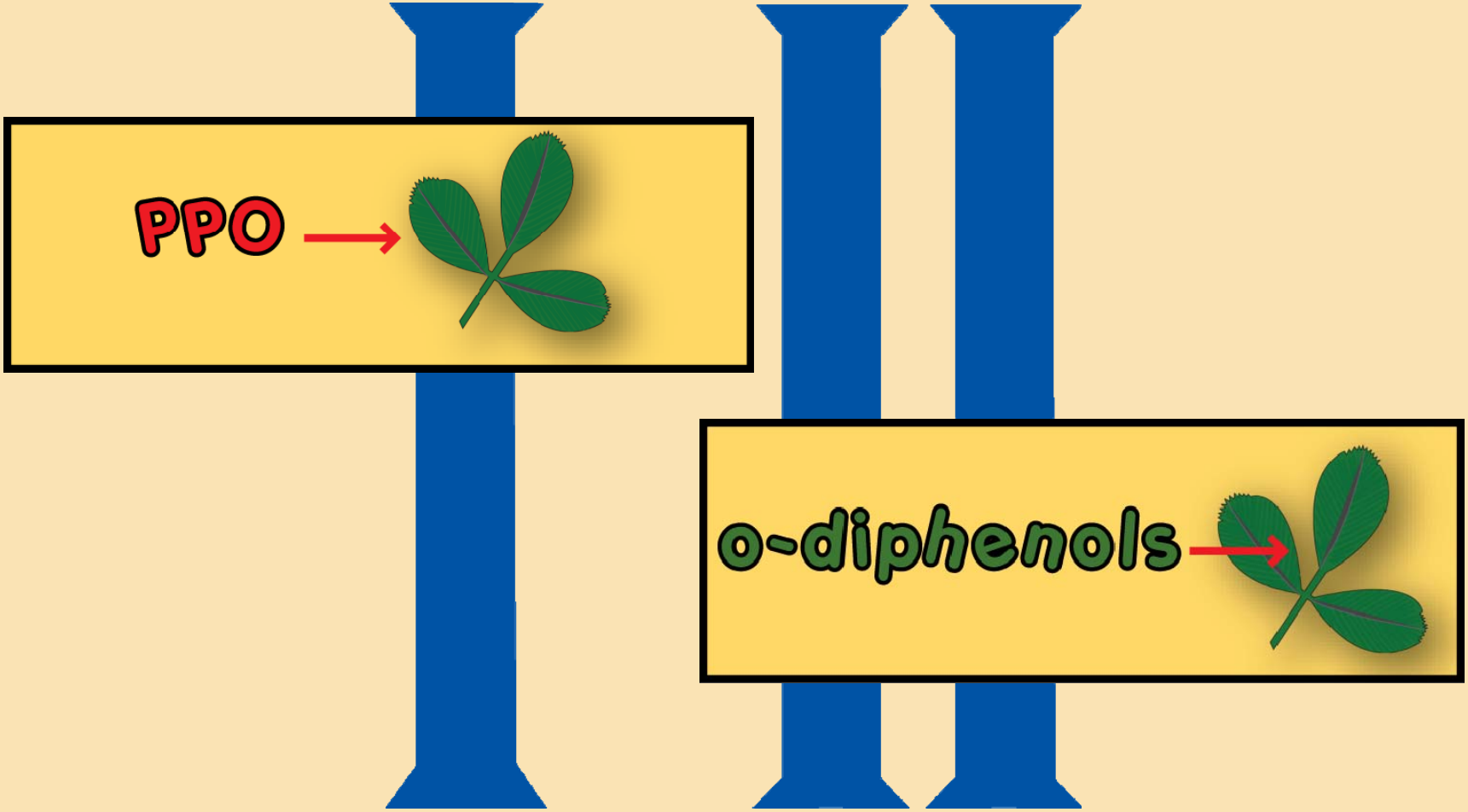
Goal #1: Reduce protein degradation

Therefore, red clover, compared to alfalfa, loses much less protein when ensiled.



Can we take what works in red clover and transfer it to alfalfa?

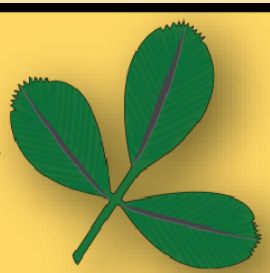
Redesigning Alfalfa



The Future of Forages...

Redesigning Alfalfa

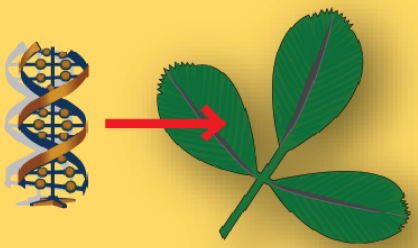
PPO →



PPO genes occur naturally in some variety of alfalfa?

NO.

Insert red clover gene into alfalfa?



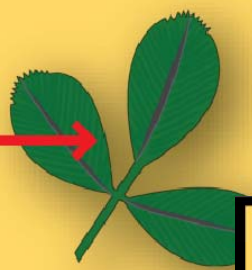
YES.

DFRC has successfully done this.

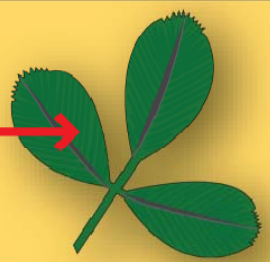
THE FUTURE OF FORAGES...

Redesigning Alfalfa

o-diphenols



Introduce genes for the enzymes needed to produce *o*-diphenol?



Currently being researched.

Add plant material that contains *o*-diphenols at the time of ensiling?

Currently being researched.

Redesigning Alfalfa

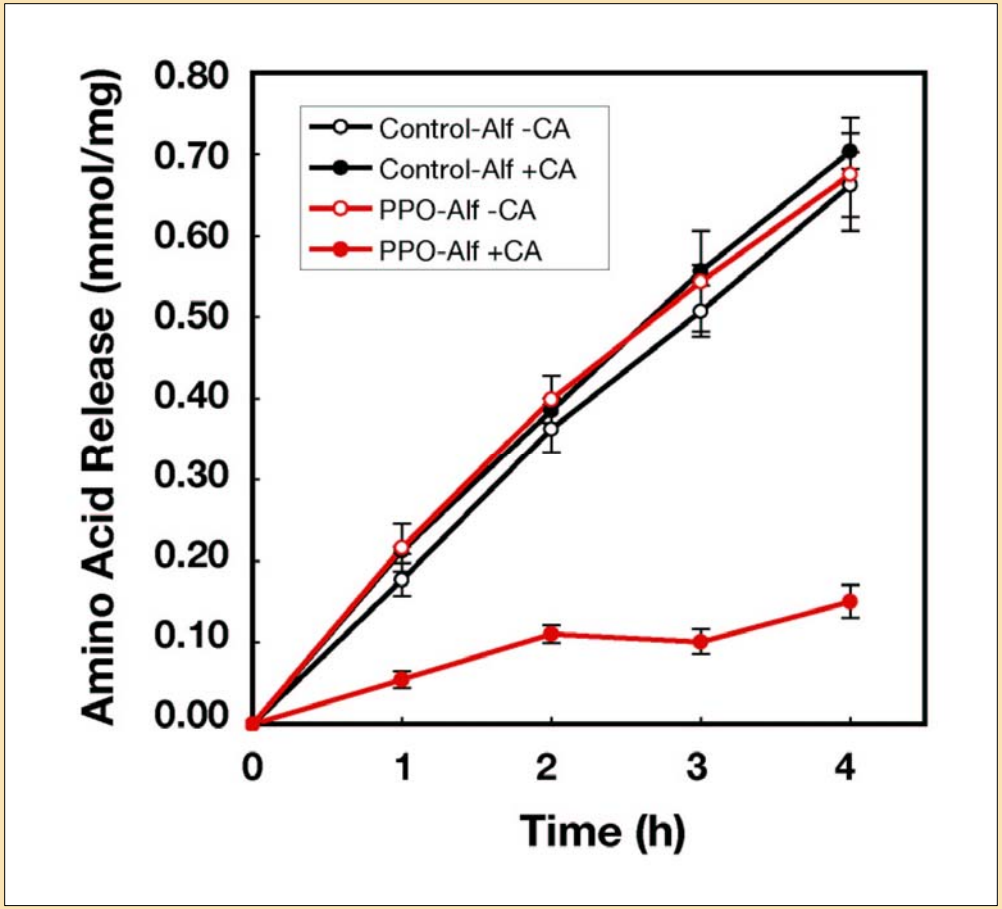
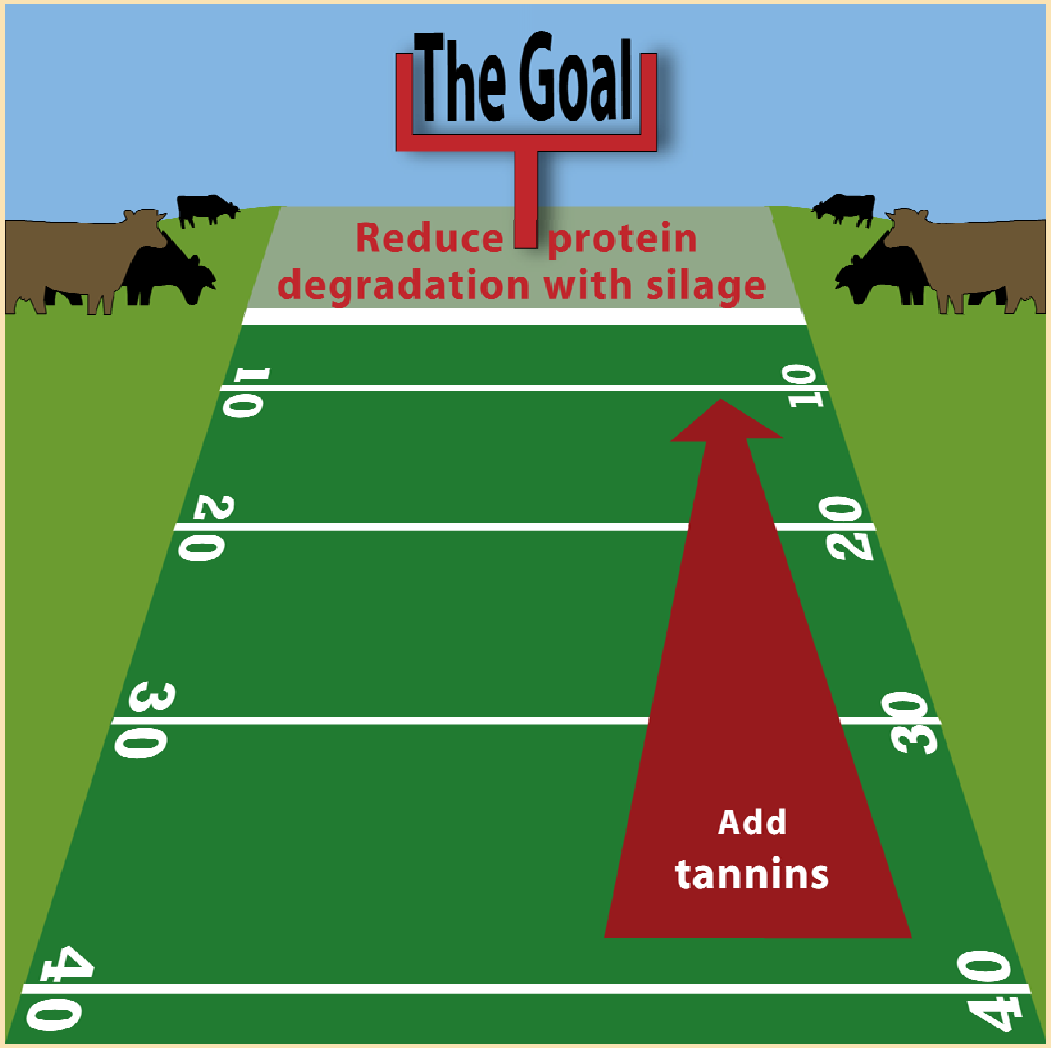


Chart shows how much less protein is degraded in alfalfa silage when alfalfa has PPO gene and *o*-diphenol* is added at time of ensiling.

***caffeic acid in these studies**

Tannin is found naturally in some forages such as birdsfoot trefoil.

Tannins bind to protein and protect it during ensiling and in the cow's rumen.



THE SAMUEL ROBERTS NOBLE FOUNDATION

Consortium *for* Alfalfa Improvement

Research Challenge / Opportunity . . .

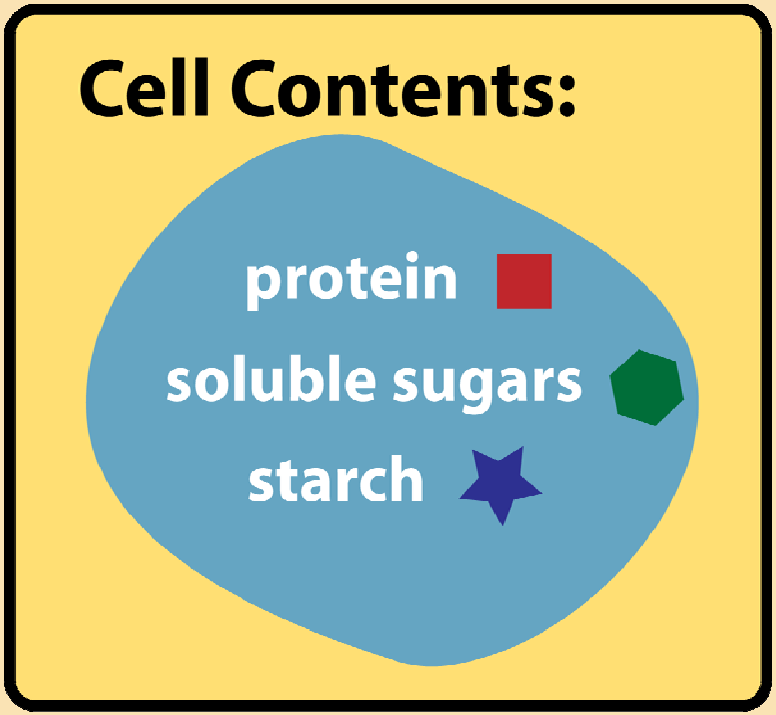
. . . fiber digestion

Redesigning alfalfa . . .

First: A lesson on cell walls

Cell contents are completely digestible.

But sometimes intact cell walls keep them from being available to the cow.



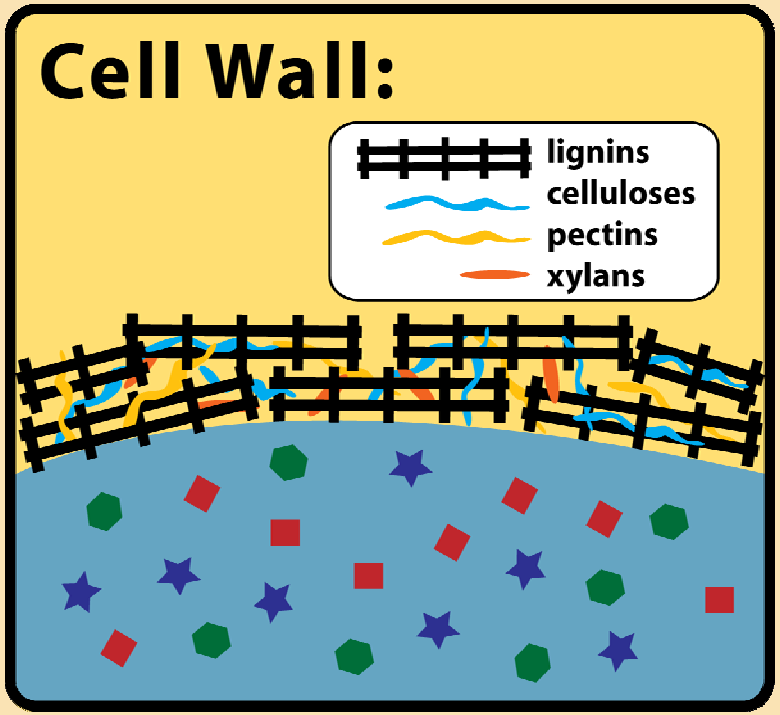
Redesigning Alfalfa

Cell walls contain carbohydrates such as:

- **celluloses**
- **pectins**
- **xylans**

that are partially available to the cow.

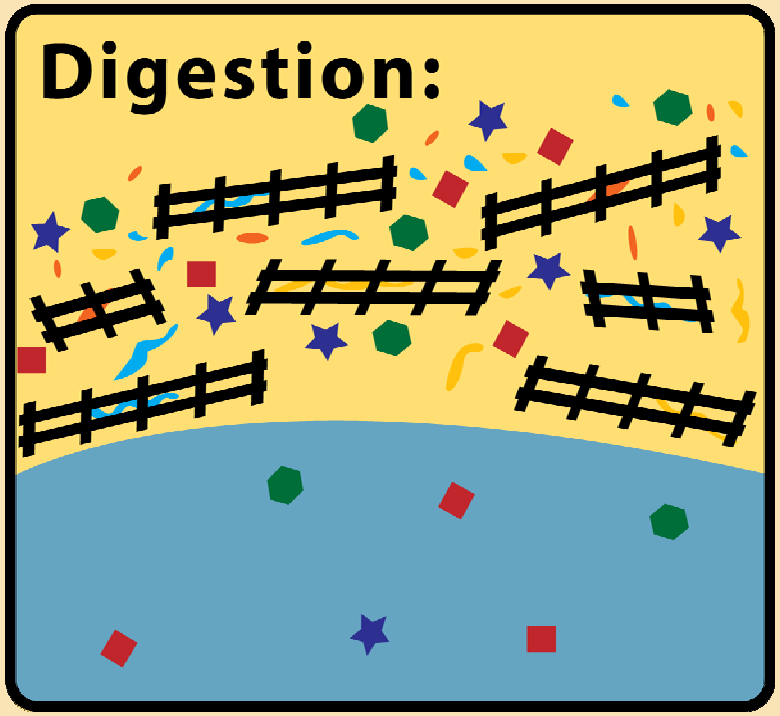
Cows cannot digest lignin.

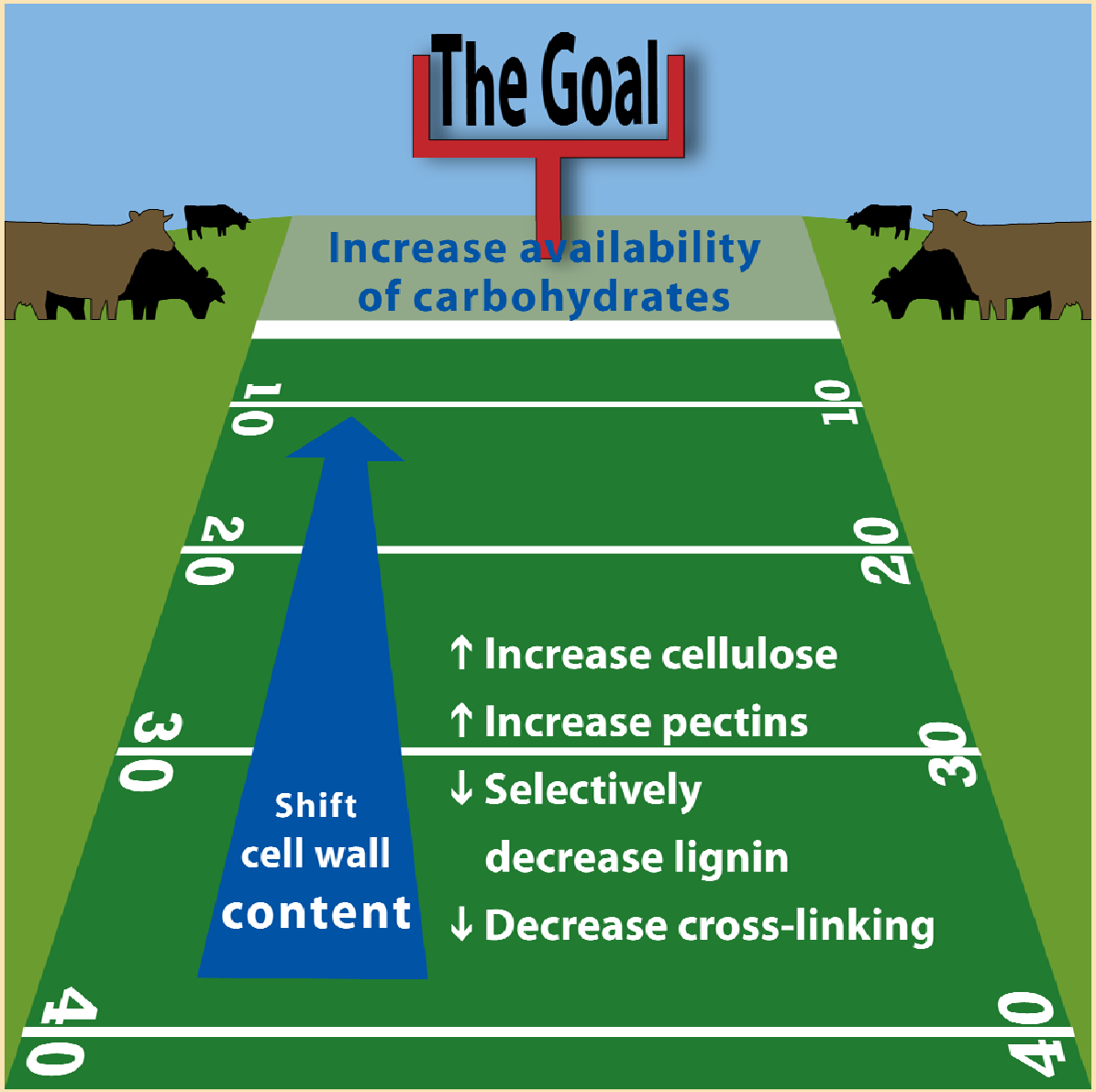


Redesigning Alfalfa

During digestion, lignin remains intact. But enzymes and microbes eat away at the other carbohydrates which break up and become available to the cow.

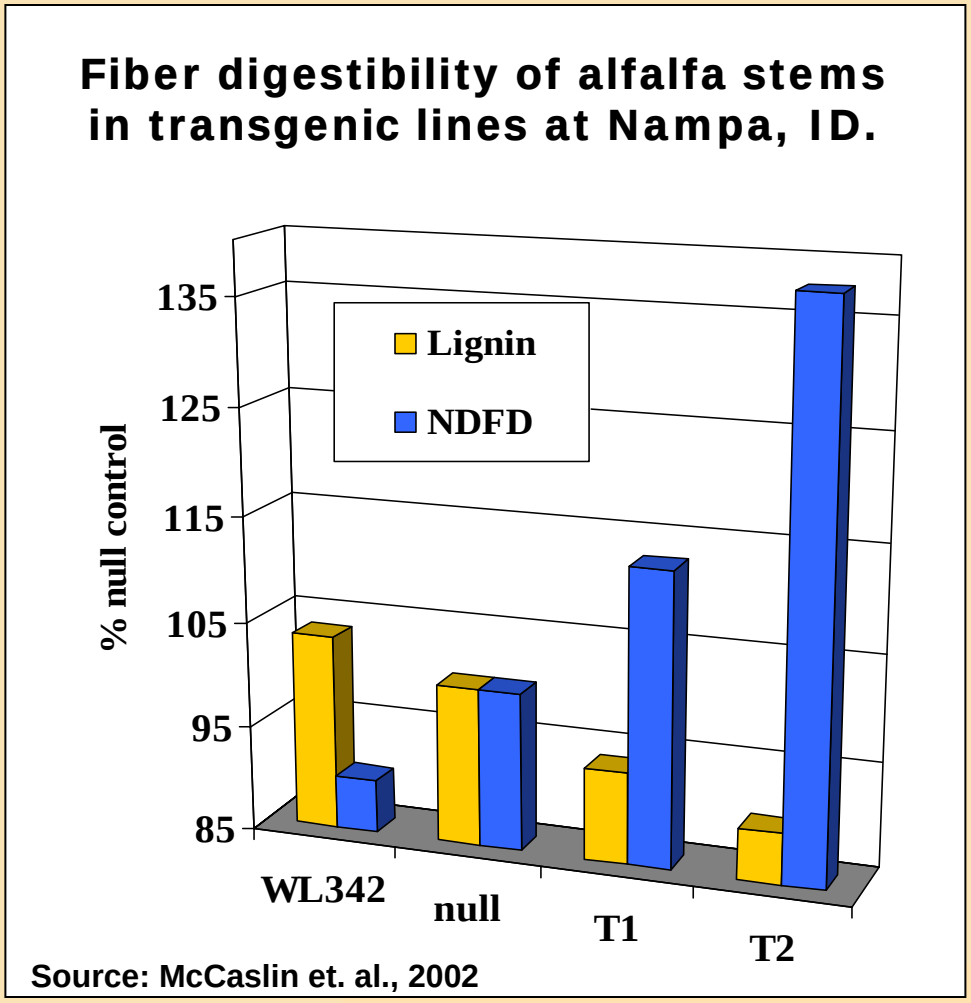
This also weakens the foundation around the lignin allowing the cell wall to break open so that cell content nutrients can be utilized by the cow.





Can't get rid of lignin . . . So research goal is to decrease the percentage of it in the cell wall by increasing celluloses and pectins.

Redesigning Alfalfa



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

Forage Genetics International

Consortium for Alfalfa Improvement

The Future of Forages...

The Future of Forages...

The Future of Forages...

Lactating Cow Response

Alfalfa hay in diet!	CP	NDF	NDFD	Milk
	----% DM----		-% NDF-	lb/day
COMT Inactive	18.1	31.1	53.5**	84.7*
COMT Active (Control)	18.4	29.3	42.5	82.1
CCOMT Inactive	18.1	42.5	48.6**	84.5
CCOMT Active (Control)	18.3	31.1	44.5	86.7

! TMR diets - 50 % alfalfa hay, 10 % corn silage, 40 % concentrate

*Significant, P < 0.10; ** significant P <0.01

SOURCE: Weakley et al. 2008. J. Dairy Sci. Supple. 1

Digestibility in Lambs

100% Alfalfa Hay Diet	aNDF	ADL	NDFD	DMD
	-----%DM-----		-%NDF-	-%DM-
COMT Inactive	38.2	5.3	57.5*	67.5*
COMT Active (Control)	39.0	5.8	49.1	64.5
CCOMT Inactive	39.4	5.2	50.1*	65.3*
CCOMT (Control)	39.4	5.9	46.4	63.7

*Significant, P < 0.05

SOURCE: Mertens et al. 2008. J. Dairy Sci. Supple. 1

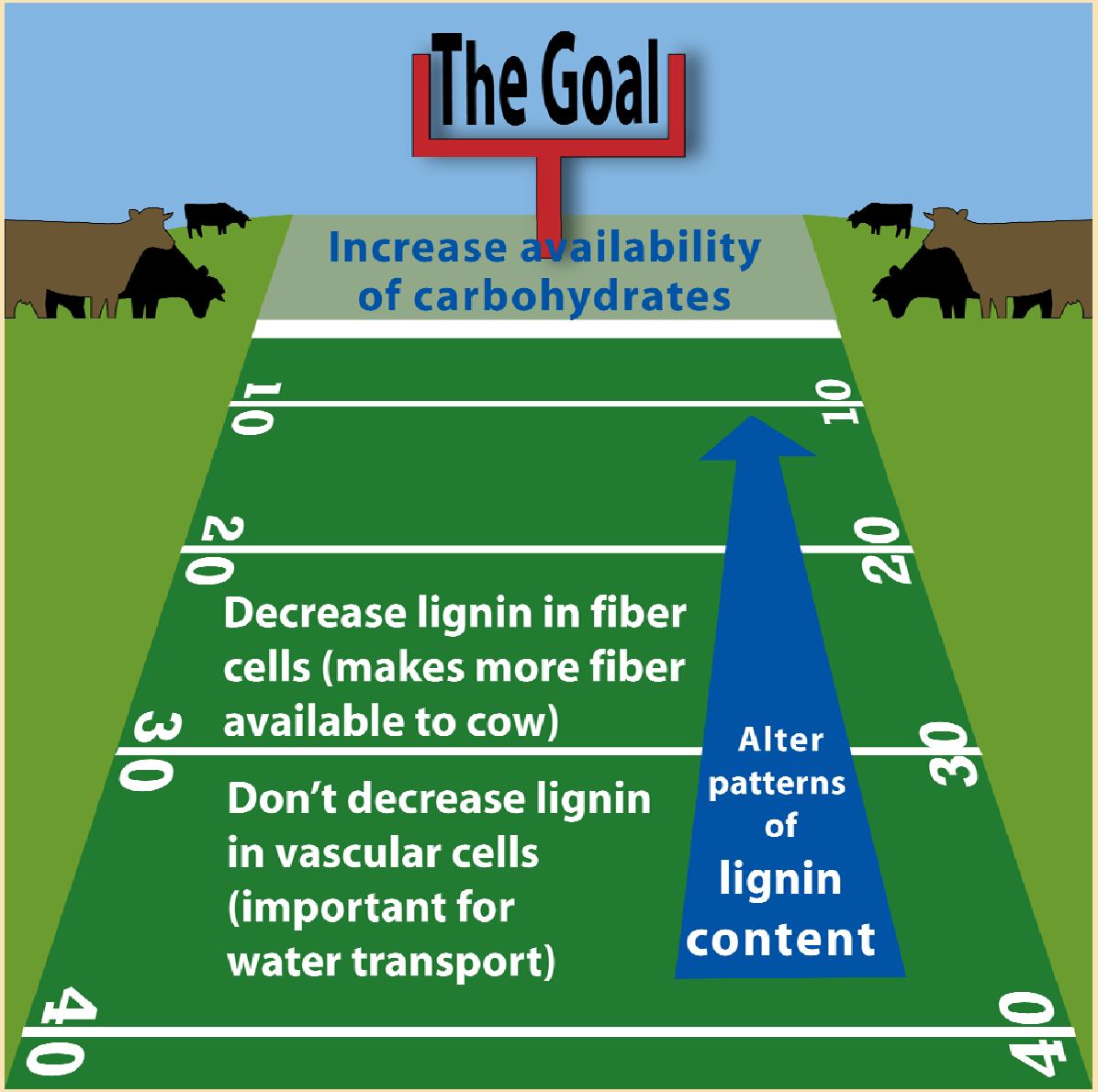
Need for Updated NIRS Equations

Test	Alfalfa Type		
	Regular	COMT Inactive	CCOMT Inactive
NIRS breeder equation	---------- % ----------		
ADL (%DM)	12.5b	11.2a	10.9a
NDFD (%NDF)	31.8a	35.8a	35.3a
Chemical analysis			
ADL (%DM)	10.2c	9.6b	7.9a
NDFD (%NDF)	30.6c	41.0a	36.2b

Values within row differ significantly, P < 0.05

SOURCE: Riday et al. 2008. Abstract. Proceedings Joint Meeting of the 41st North American Alfalfa Improvement Conference & 20th Trifloium Conference, June 1-4, 2008. Dallas, TX. Abstract # 18.

Lignin is more crucial in some cells than others . . . So research goal is to selectively decrease lignin in some cells and leave it intact in others.



Lignin Composition - Analysis

Test	Null	COMT	CCOMT
NIRS breeder equation	---------- % ----------		
ADL, DM	12.5b	11.2a	10.9a
NDFD, NDF	31.8a	35.8a	35.3a
Chemical analysis			
ADL, DM	10.2c	9.6b	7.9a
T. Thioacidolysis, DM	6.1c	3.8a	5.0b
S-lignin, DM	2.7b	0.7a	2.7b
G-lignin, DM	3.3b	3.1b	2.2a
H-lignin, DM	0.7a	0.7a	0.9b
NDFD, NDF	30.6c	41.0a	36.2b

Values within row differ significantly, P < 0.05

SOURCE: Riday et al. 2008. Abstract. Proceedings Joint Meeting of the 41st North American Alfalfa Improvement Conference & 20th Trifloium Conference, June 1-4, 2008. Dallas, TX. Abstract # 18.

Redesigning Alfalfa

Potential high value alfalfa

1. Allow us to feed lower protein diets
2. Allow for digestion of complex carbohydrates – new feeding approach
3. Reduce the number of cuttings per season

Red Clover Breeding

Prairie du Sac, WI –
Breeding Nursery

Red Clover

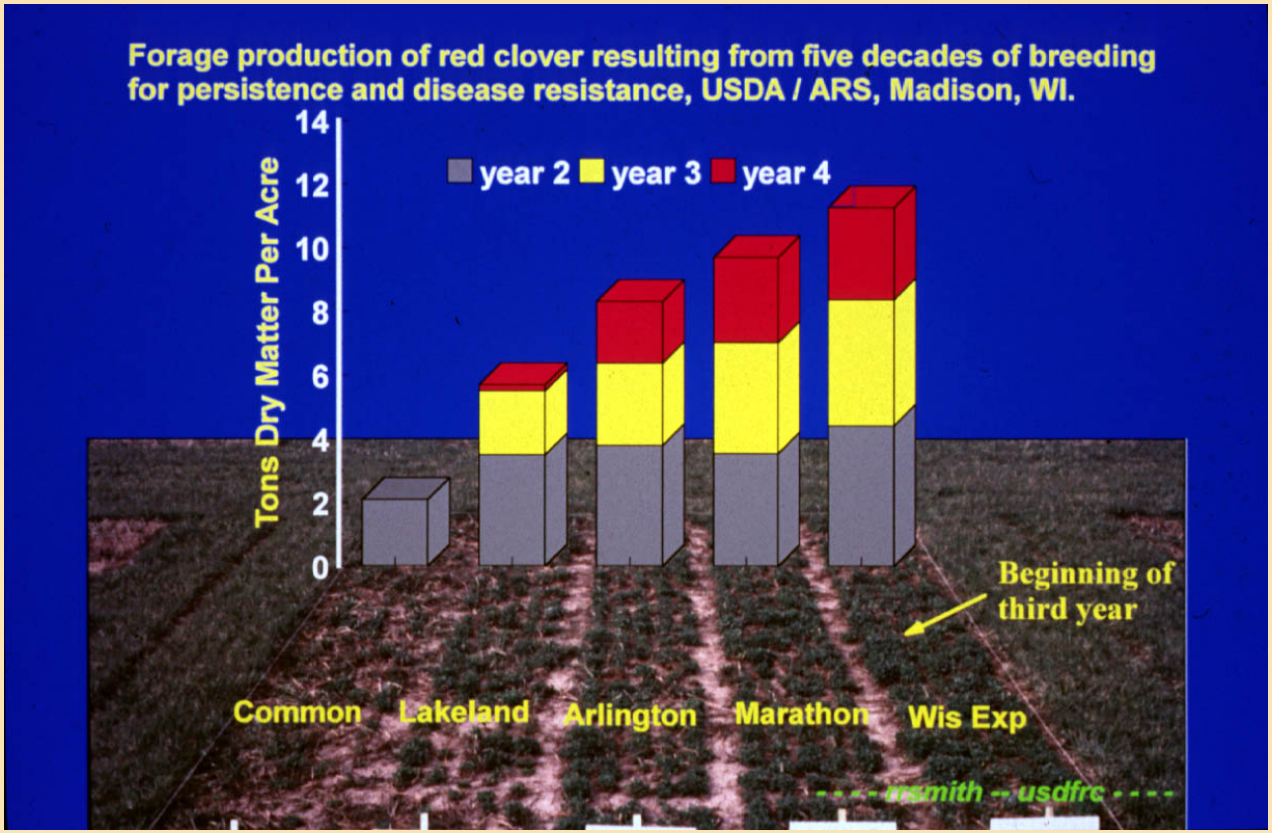
- Establishment and Management Versatility
- Less Persistent

Breeding Targets

- Increased Persistence
- Increased Yield
- Plant Vigor

Redesigning forages: Clover

- Arlington and Marathon red clover were developed & released. These varieties have increased persistence, longevity, yields, and disease resistance.
- Annually save $140/acre/year on at least 250,000 acres in the Midwest.



Kura Clover Breeding

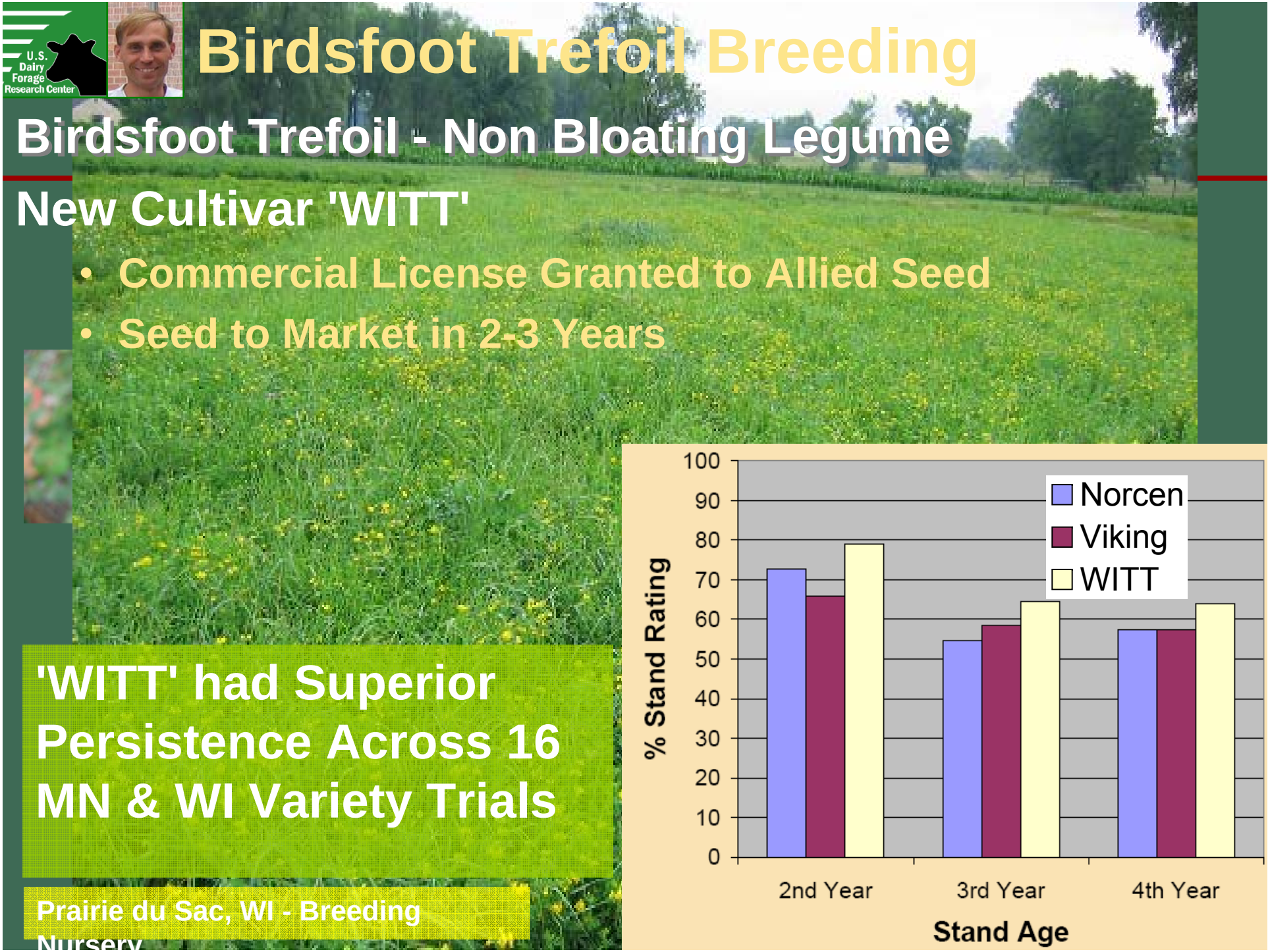
Prairie du Sac, WI – Breeding Nursery

Kura Clover

- Very Persistent
- Difficult to Establish

Breeding Targets

- Seedling Establishment
- Seed Production and Yield
- Plant Vigor


U.S. Dairy Forage Research Center
Birdsfoot Trefoil Breeding
Birdsfoot Trefoil - Non Bloating Legume
New Cultivar 'WITT'
• Commercial License Granted to Allied Seed
• Seed to Market in 2-3 Years
'WITT' had Superior Persistence Across 16 MN & WI Variety Trials
Prairie du Sac, WI - Breeding Nursery
% Stand Rating
100
90
80
70
60
50
40
30
20
10
0
Norcen
Viking
WITT
2nd Year
3rd Year
4th Year
Stand Age

Redesigning forages: Grasses

While genetic engineering is used with alfalfa, it is not used with other legumes and grasses. Why?

- **Small market and very small profit margins with each individual grass species makes it difficult for company to recoup R&D costs.**
- **The traits that are most desired – better yield and persistence – are not easy traits to genetically engineer by 1 gene.**
- **A lot of producers who want to grow grasses are philosophically opposed to genetic engineering.**

Redesigning forages: Grasses

Recent pasture/grazing research

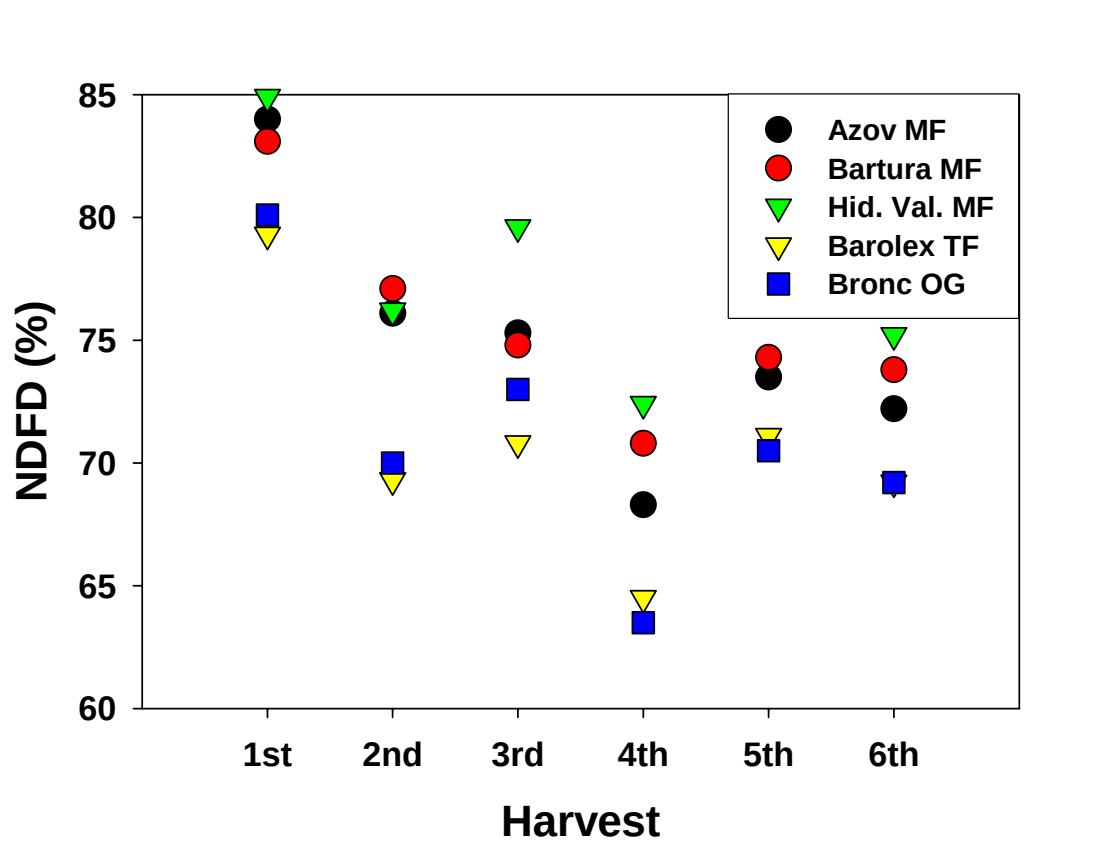
Geoff Brink, DFRC Agronomist

Agronomic potential of meadow fescue

Response to N rate and defoliation management at grazing maturity by:

- Bronc orchardgrass
- Barolex soft-leaf tall fescue
- Azov, Bartura, and Hidden Valley meadow fescue.

Redesigning forages: Grasses

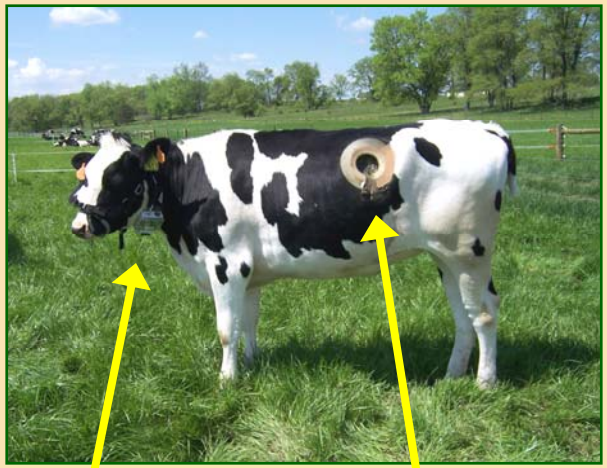


- Tall fescue and orchard-grass yielded 500-1000 lb DM/acre/year more than meadow fescue.
- NDFD of meadow fescue > tall fescue and orchardgrass through-out growing season at similar maturity.

Redesigning forages: Grasses

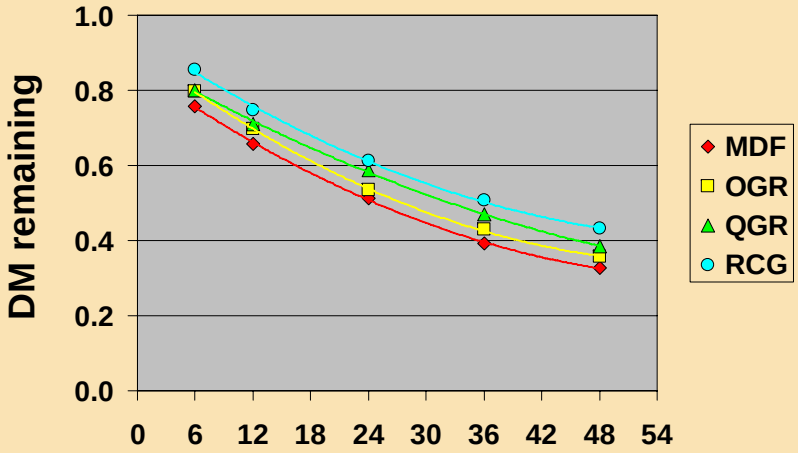
Animal response to meadow fescue

Compare intake, digestibility, and behavior of bred dairy heifers grazing meadow fescue, orchardgrass, reed canarygrass, and quackgrass (grasses that differ in sward structure and quality).

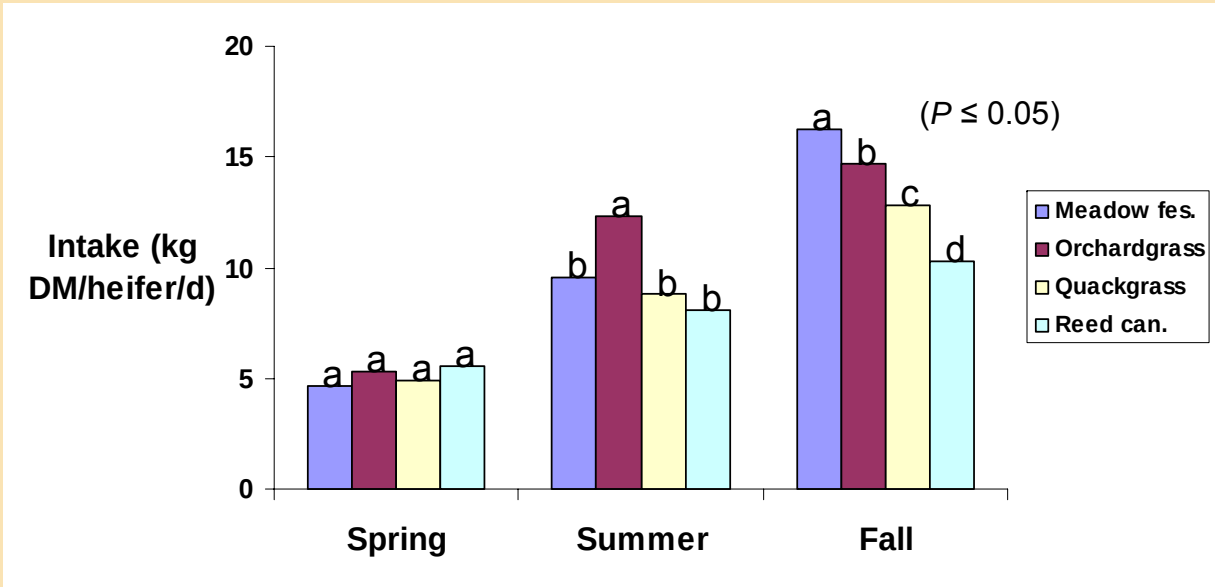


Collaborative with Dr. Kathy Soder, USDA-ARS Pastures Systems and Watershed Management Research Unit.

Redesigning forages: Grasses



- **Meadow fescue had greater *in situ* digestibility than tall fescue or orchardgrass, but greater intake in fall only.**



THE FUTURE OF FORAGES...

Redesigning forages: Grasses

Targets for Grass Breeding

- **<u>The past:</u> hay/silage production**
  - **The focus of grass breeding since its beginning.**
  - **Many excellent, well-adapted varieties exist.**

Redesigning forages: Grasses

- **<u>The present:</u> management-intensive grazing & pastures**
  - **Virtually no grass breeding efforts until 1990.**
  - **Most breeding programs have shifted toward this goal.**
  - **The best hay types are not necessarily the best pasture types and vice versa.**

Redesigning forages: Grasses

Recent grass breeding activities

(Mike Casler, ARS-U.S. Dairy Forage Research Center, Madison, WI)

- **Timothy and bromegrass:**
  - **Breeding grazing-tolerant varieties**
- **Reed Canarygrass:**
  - **New cultivar with improved establishment by selection and breeding**
  - **Determining the mechanism for improved establishment**

Original germplasm taken from natural, undisturbed locations such as cemeteries and ditches.

Redesigning forages: Grasses

- **'Spring Green' Festulolium**
  - **Meadow fescue x perennial ryegrass hybrid**

X

  - **Quality & establishment similar to ryegrass**
  - **Drought tolerance similar to fescue**
  - **Selected for winter survival on-farm**

Redesigning forages: Grasses

- **'Spring Green' Festulolium**
  - **Tested in 8 states from Minnesota and Iowa to New York and Virginia . . .**
  - **. . . and compared to previous fescue x rye varieties, Tandem and Kemal**
  - **Spring Green showed a 31% increase in survival (52 vs. 40%). . .**
  - **. . . and a 2% increase in tons/ acre (3.98 vs. 3.91)**

Redesigning forages: Grasses

- **Meadow Fescue:**
  - **New cultivar, 'Hidden Valley,' selected from Charles Opitz farm, WI**
  - **Drought tolerance and highly palatable**

Opitz Farm, Wisconsin

Redesigning forages: Grasses

- **Non-heading Orchardgrass**
  - A management technique, not breeding
  - Designed to simplify grazing management in the spring
  - Orchardgrass flowering genes turned off in cold weather, but not in warm weather
  - Take seeds produced in warm Oregon and plant them in hardiness zones 3, 4, and 5 where winters are cold.

Redesigning forages: Grasses

Grass and legume breeding summary:

- We have changed the focus of our grass and legume breeding program from hay harvesting to grazing.
- We are developing new varieties with unique traits that will simplify and enhance the grazing operation.
- There is a growing interest and market for these varieties.