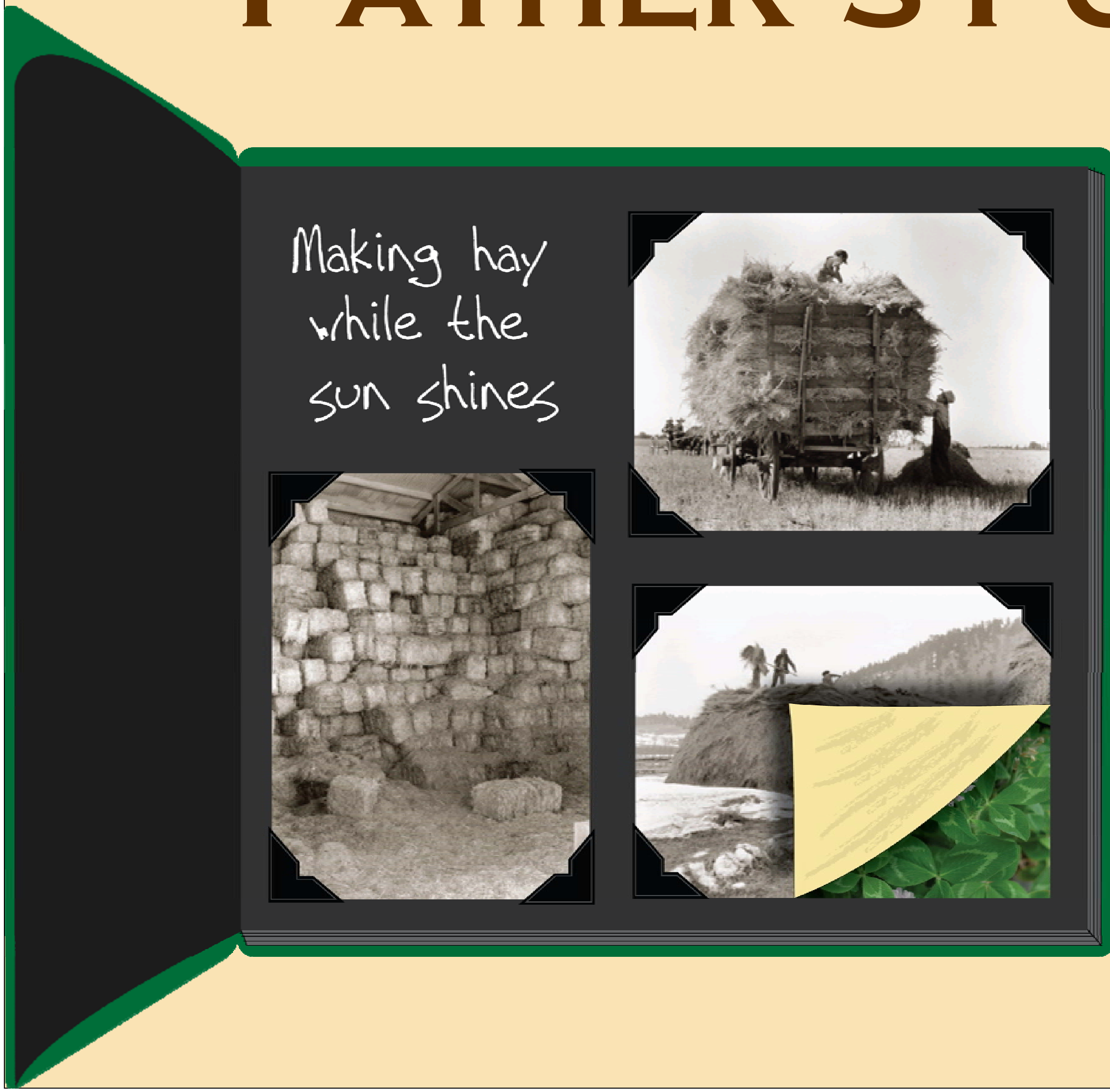
These Aren't Your Father's Forages



Neal Martin
Director

U.S. Dairy Forage Research Center
Madison, WI

AFGC Annual Meeting

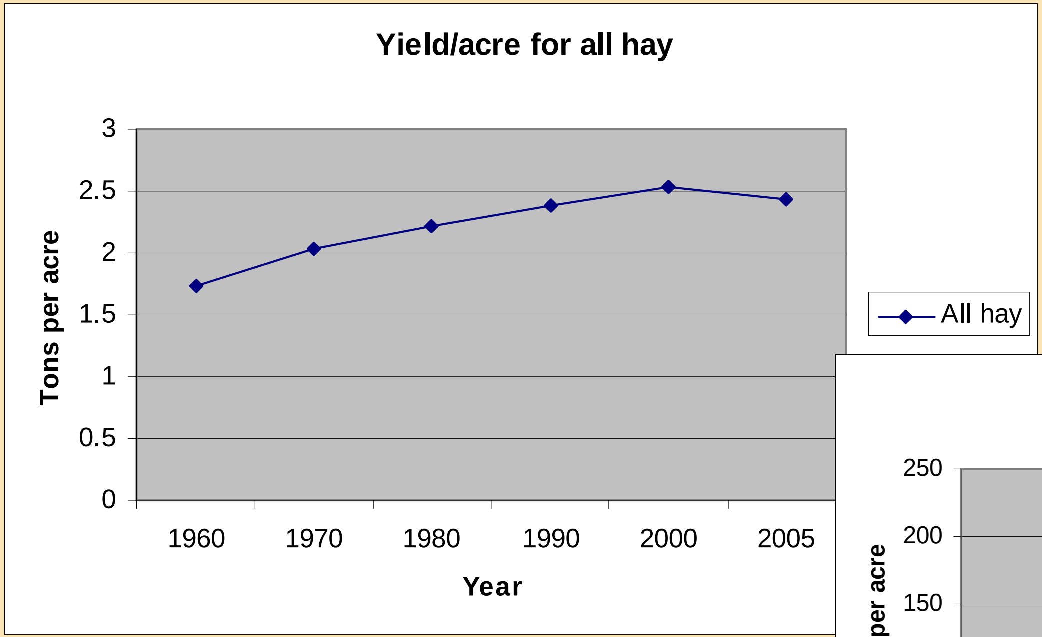
June 26, 2007
State College, PA

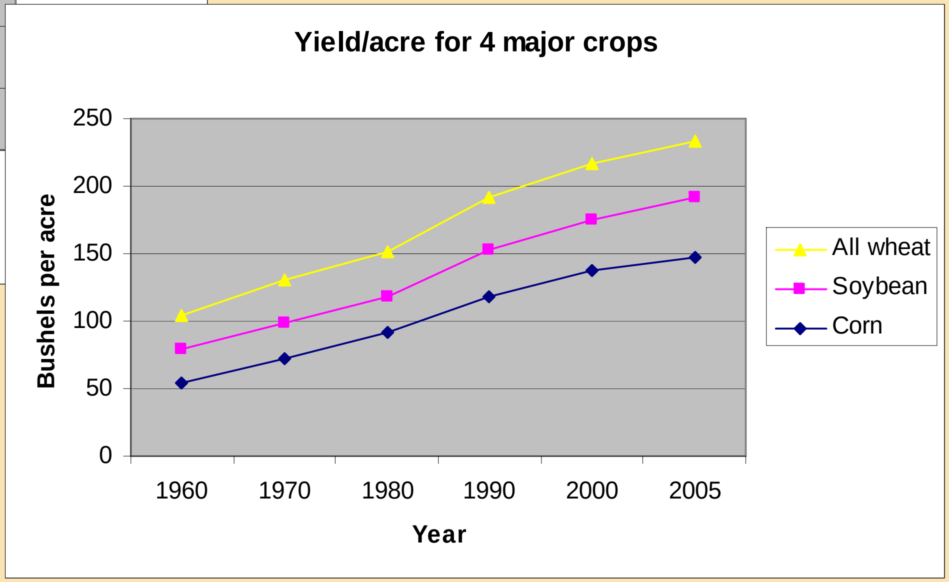
This talk will explore . . .

- Trends in forage production and use
- Barriers to increasing forage in livestock diets
- Redesigning forages for livestock diets
- Growing forages for renewable energy

Forage trends . . .

Least aggressive in yield increases



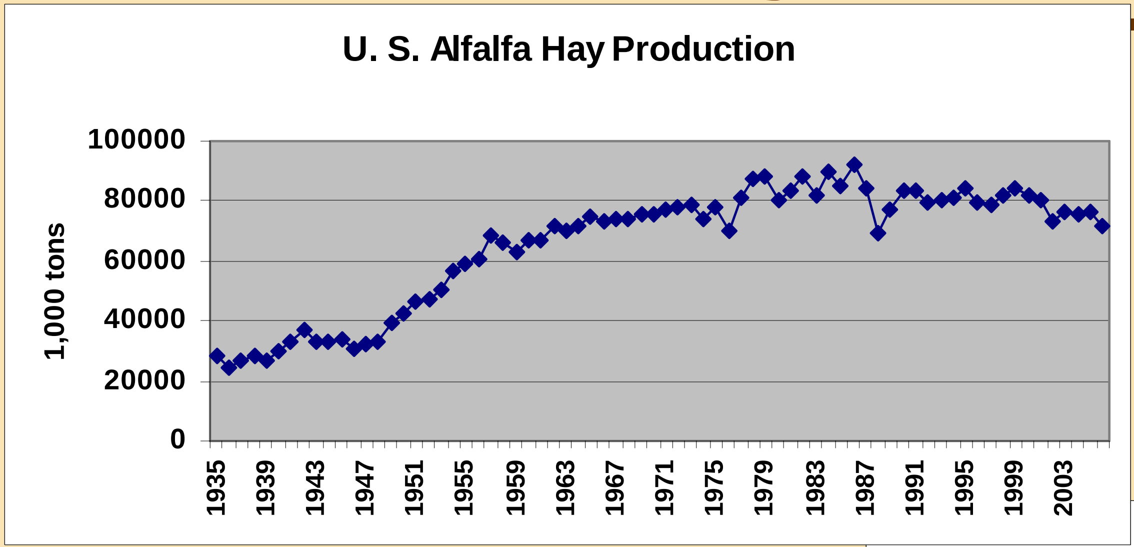


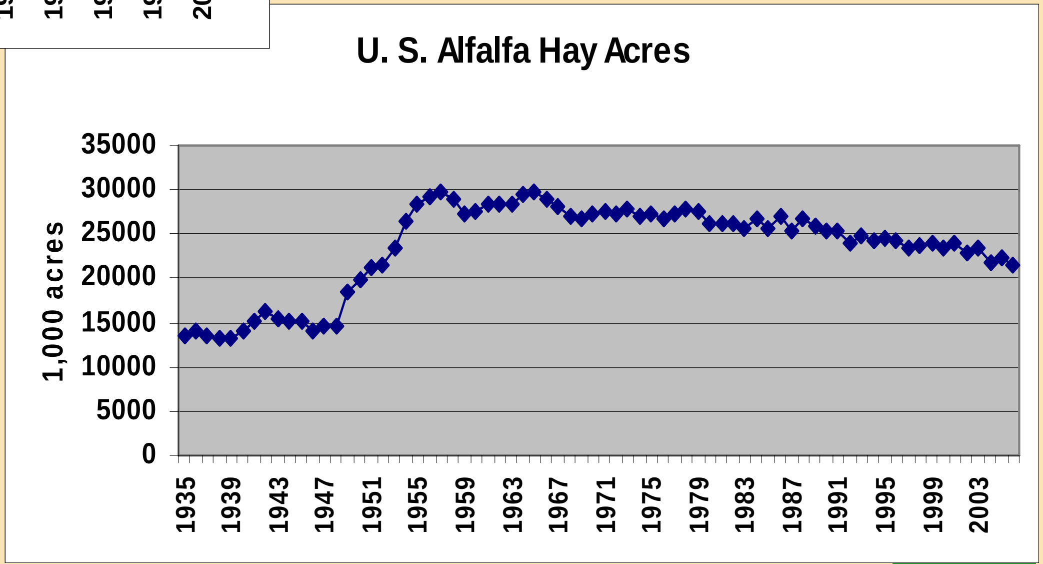
Forage Trends . . .

2006 U.S. Alfalfa Production

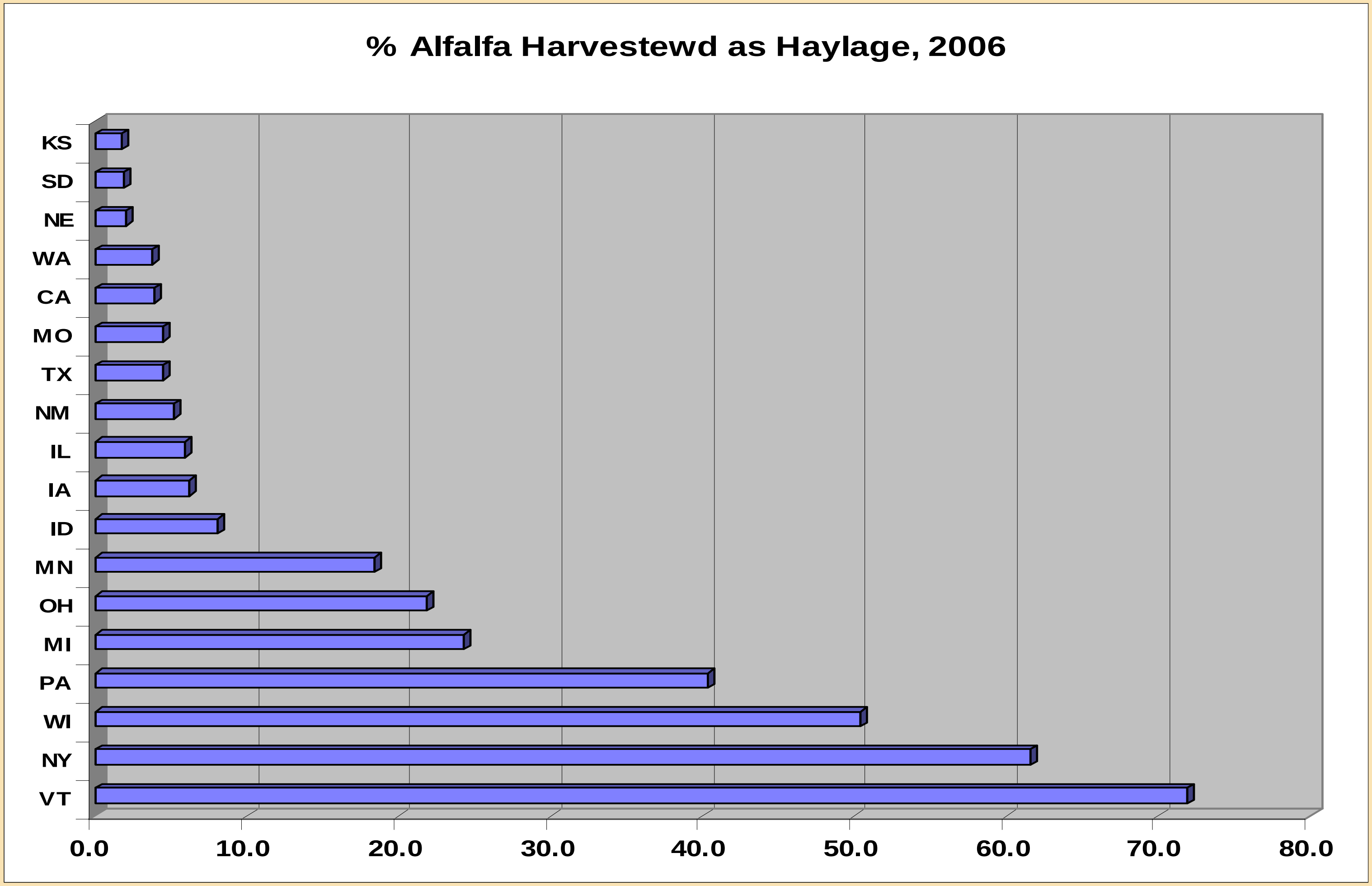
- **Hay**
  - 71.7 million tons
  - 21.4 million acre
  - $7.5 billion
  - 3rd following corn and soybeans
- **Forage**
  - 83.3 million tons
  - 23.2 million acres
  - ~$9.4 billion
  - 3rd following corn and soybeans

Alfalfa Hay Trends . . .

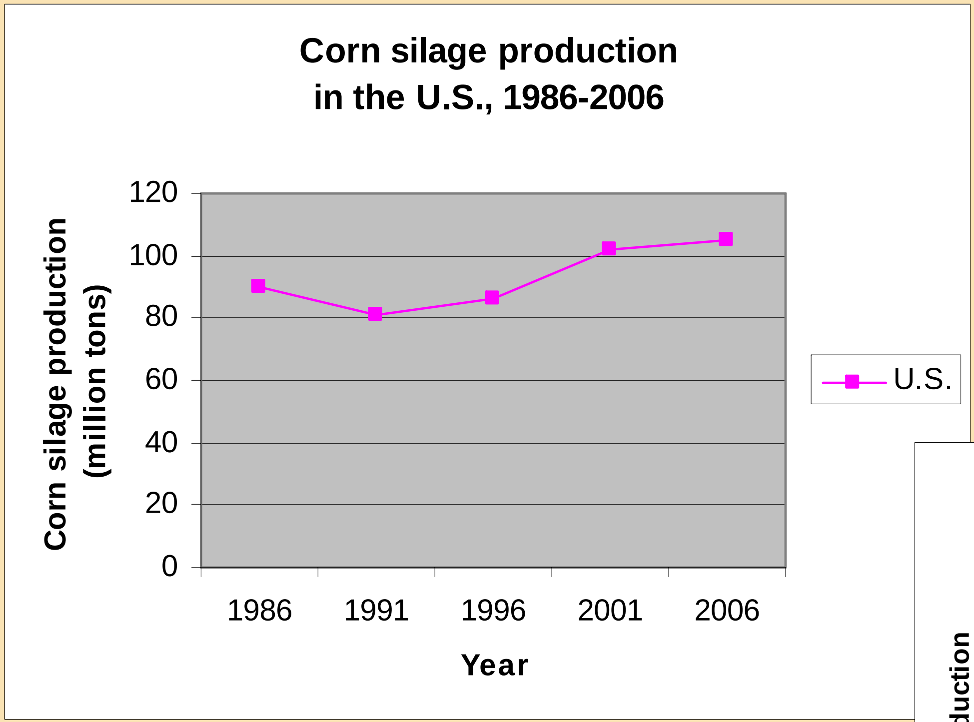


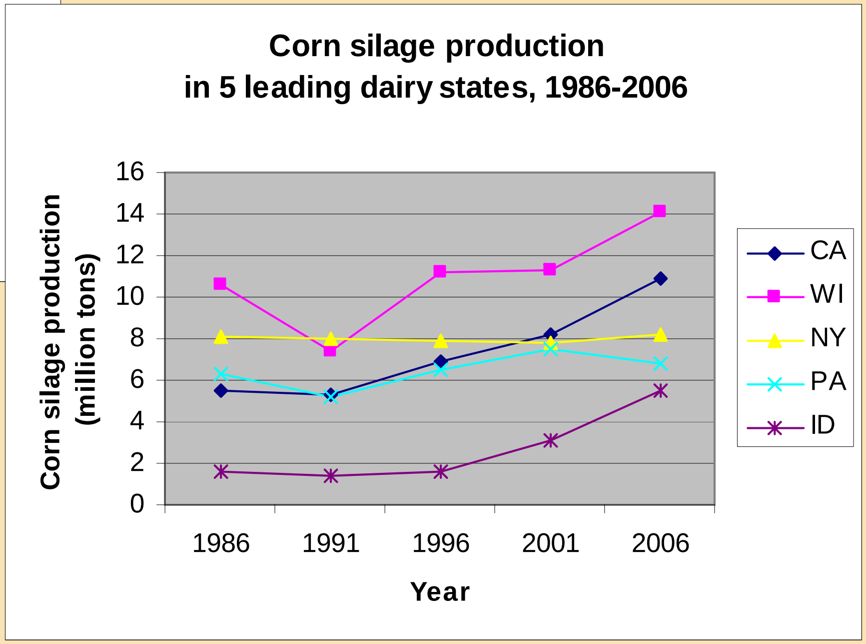


Trends . . . Alfalfa Silage Production



Forage trends . . .



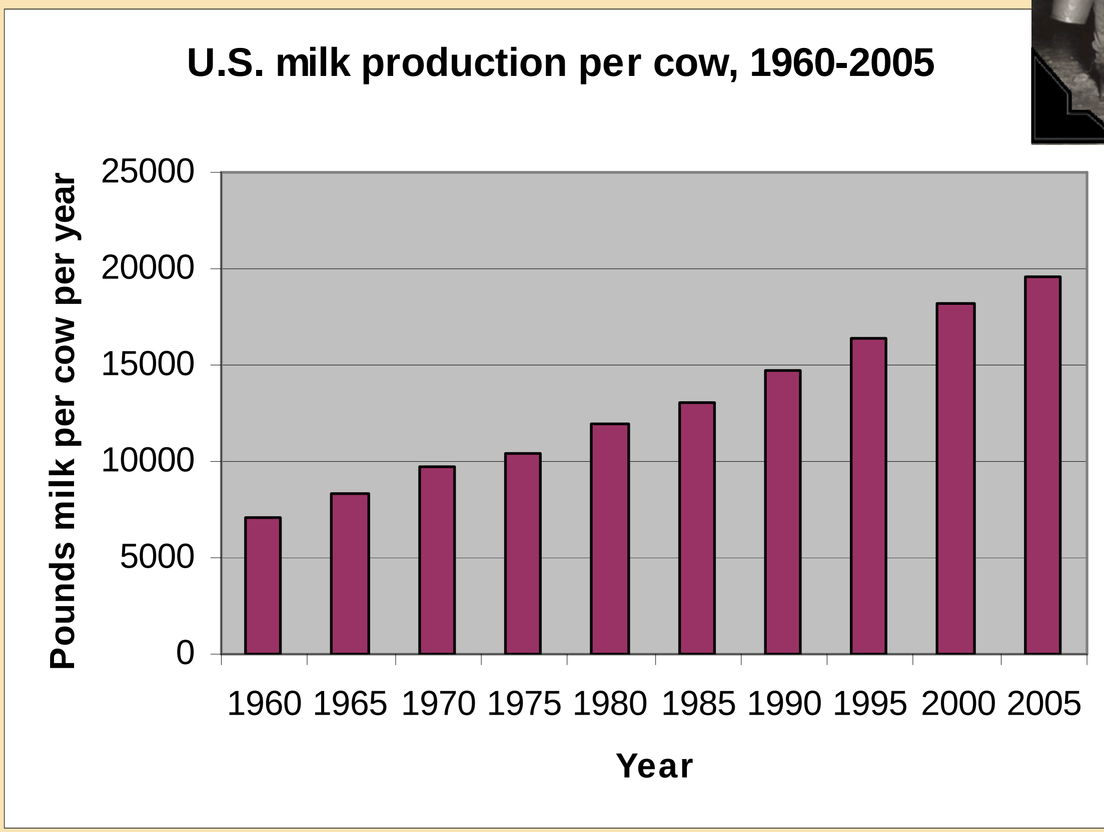


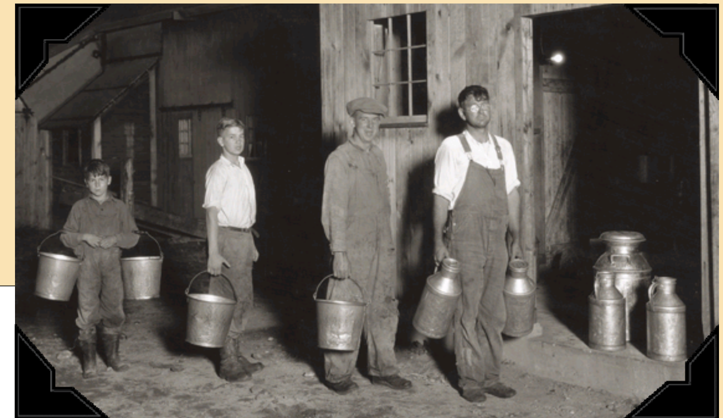
Barriers to increasing forage usage . . .

These aren't your father's dairy or beef cattle.

Barriers to increasing forage usage . . .

They've been fed and bred to produce ever increasing amounts of milk.



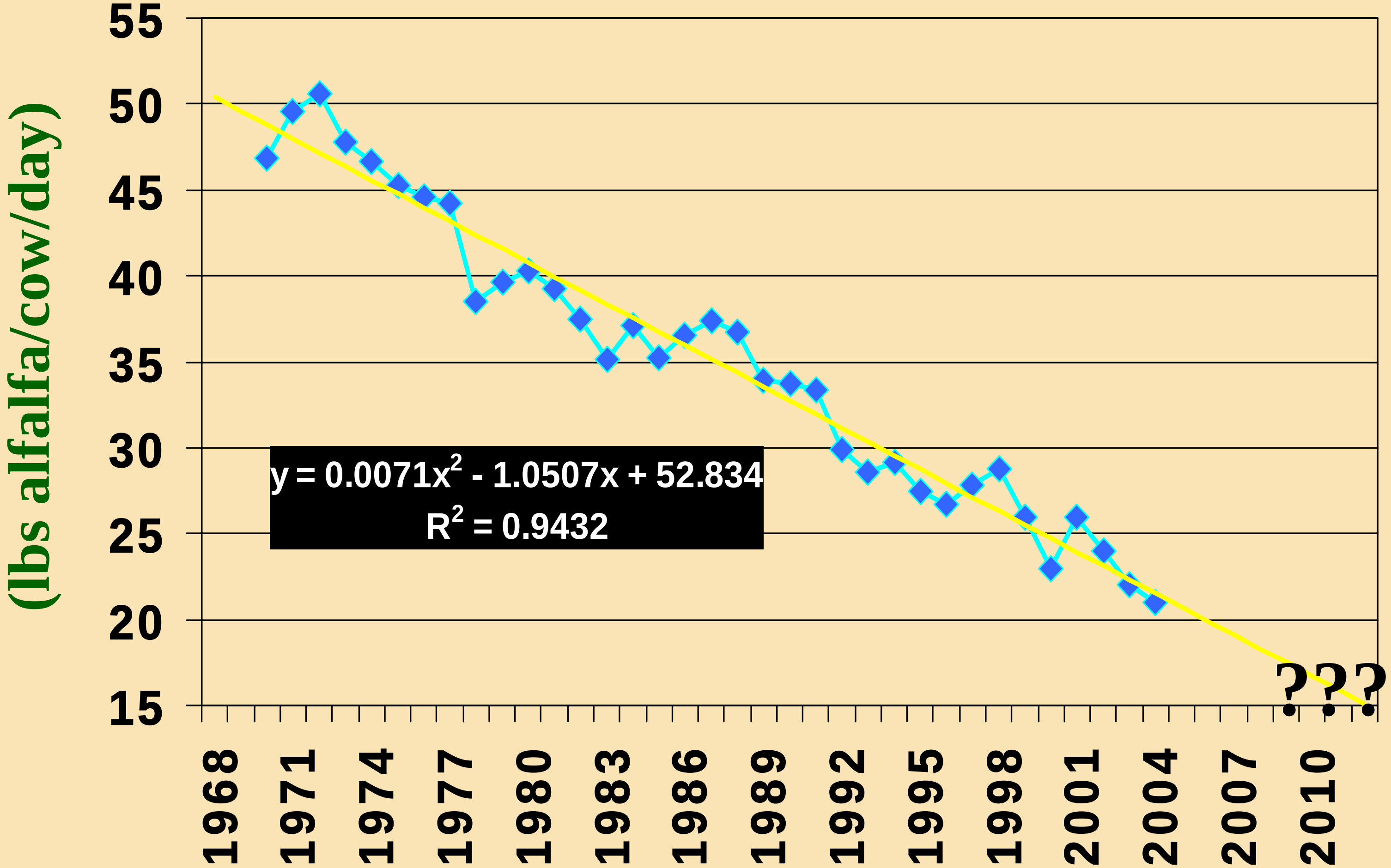


Barriers to increasing forage usage . . .

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

Dairy Ration Overview

% OF DM

40 — **FORAGES**

- **FIBER**
  - Physical & Chemical
- Protein, minerals, CHO

20 — FORAGE, GRAIN OR BYPRODUCTS

- **Nutrient needs and $**

40 — CONCENTRATES

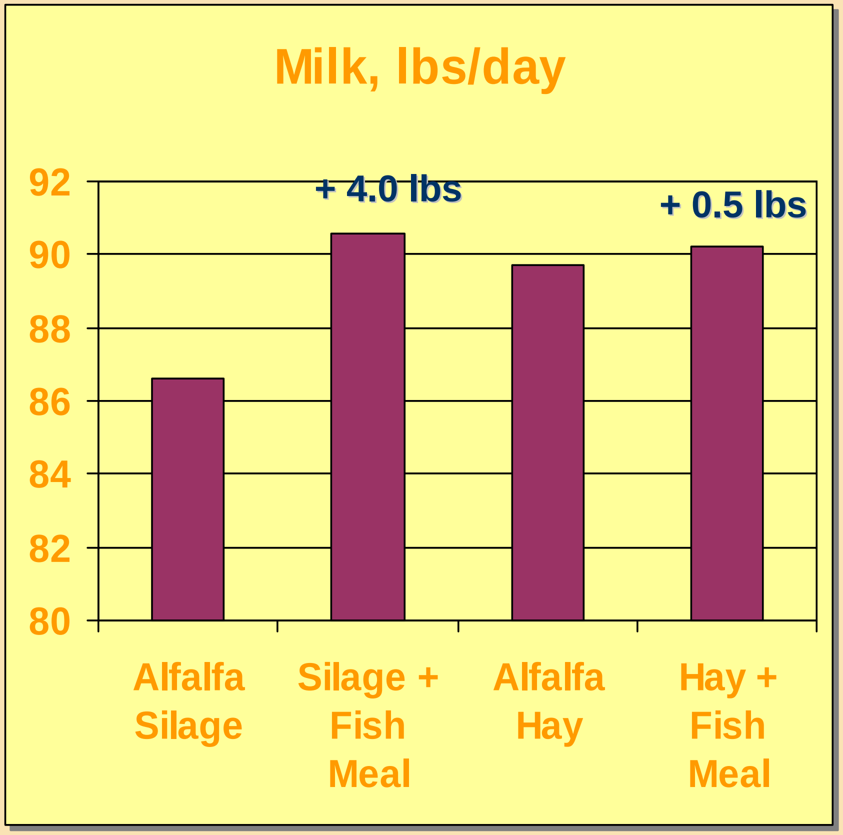
- CORN
- PROTEIN
- MINERALS/ADDITIVES

Non-Fiber CHO
- Starch

Protein
- RDP & RUP

Minerals

Milk Yield from Alfalfa Silage and Hay Diets

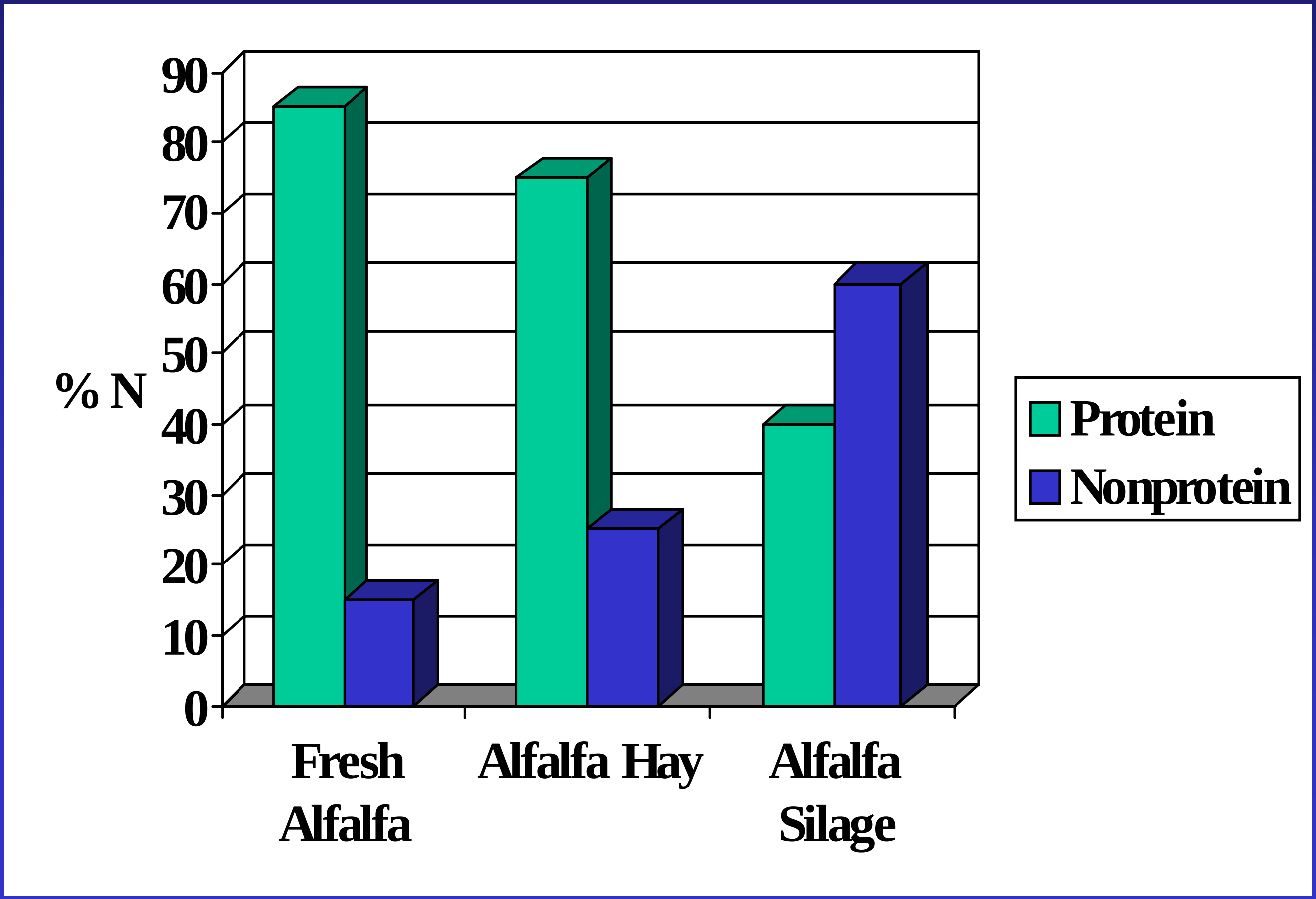


- **Fish meal is beneficial in alfalfa silage diets, but not alfalfa hay diets.**
- **Bottom line: alfalfa silage nitrogen is not efficiently used by the cow**

Source: Vagnoni and Broderick, 1997

Feed Storage Problems

- However in alfalfa, our primary forage:



Trends . . .

- **Hay acreage remains unchanged**

- **Dairy cattle feeding – declining amounts**

Barriers to increasing forage 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

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

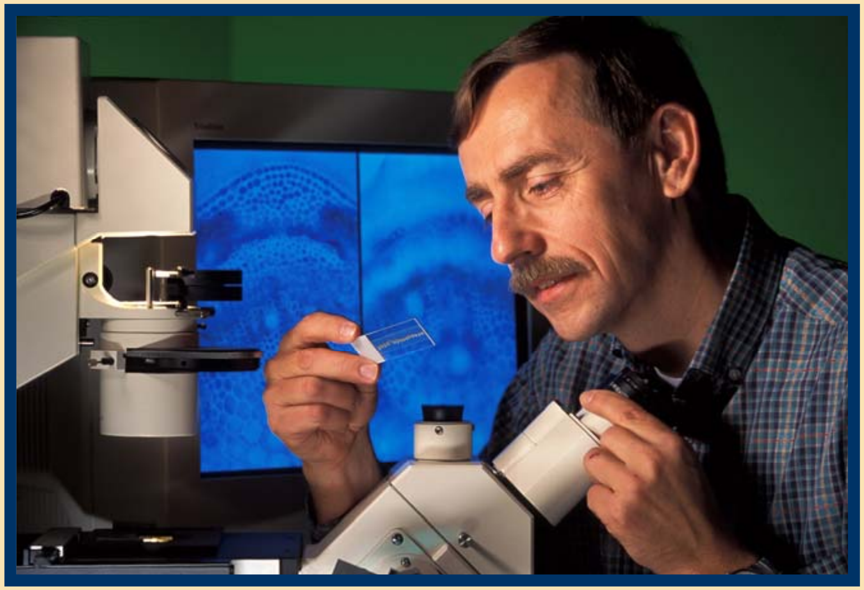
- **Perennial forage crops are good for environment**
- **Good for cow health**

Challenges . . .

. . . of the dairy forage industry

Research strategies and opportunities . . .

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



Redesigning forages: The DFRC Team

Geoff Brink
Agronomist

John Grabber
Agronomist

Ron Hatfield
plant physiologist

John Ralph
chemist

Heathcliffe Riday
geneticist

Mike Sullivan
molecular geneticist

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

Barriers to increasing alfalfa in dairy diets

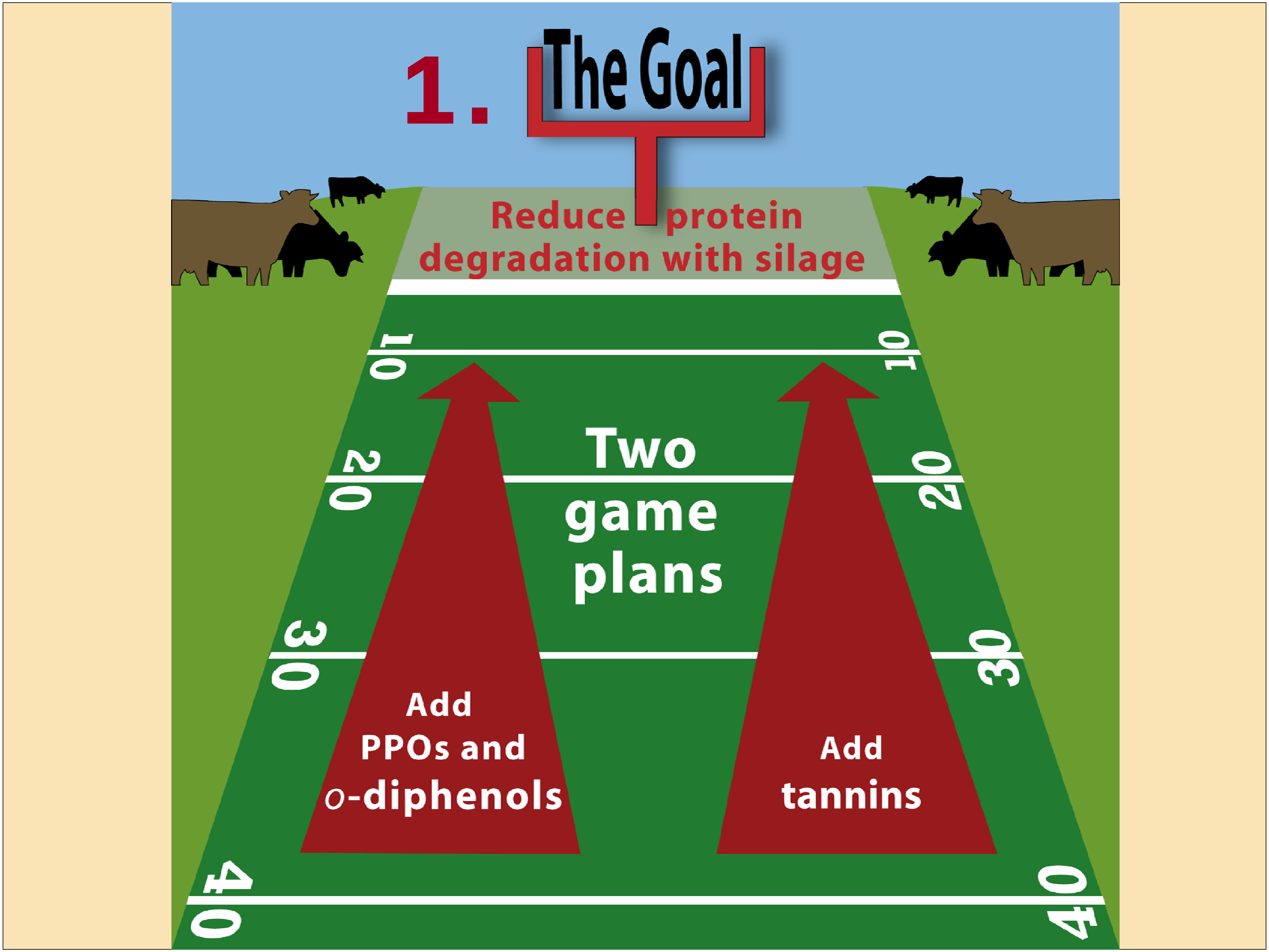
Redesigning alfalfa for dairy cows

- Improve protein utilization
- Increase fiber digestion
- Increase yield

Redesigning forages: 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.


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

Barriers to increasing forage usage . . .

- Increasing use of corn silage
- Forage quality of alfalfa haylage, alfalfa hay and corn silage
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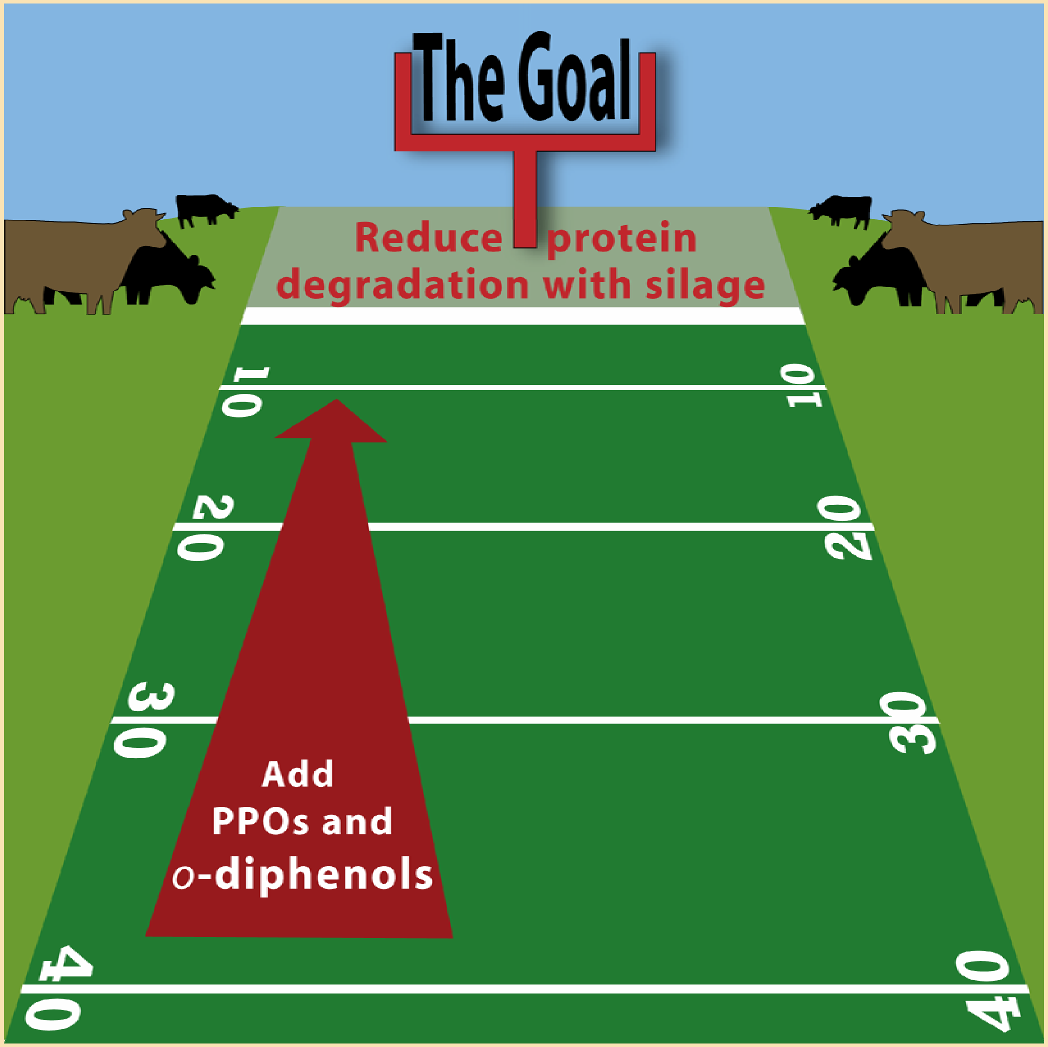


(PPO is an enzyme, found in many plants, that causes browning and loss of quality.)

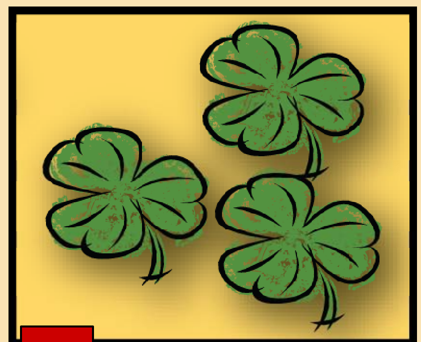
Consortium *for* Alfalfa Improvement

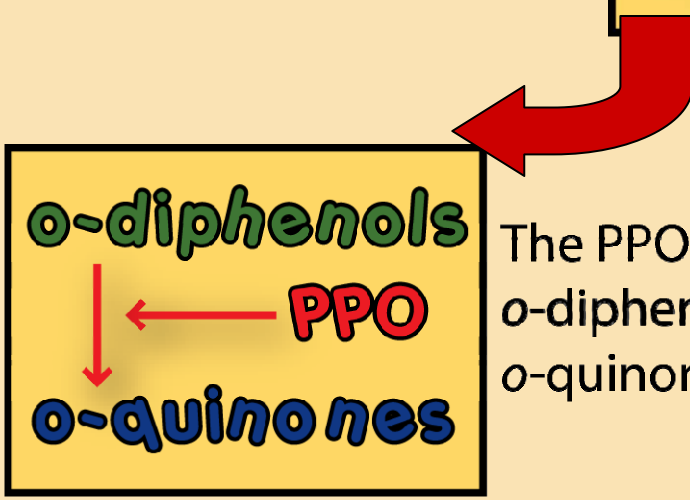
Redesigning forages: Alfalfa

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 forages: Alfalfa

Goal #1: Reduce protein degradation

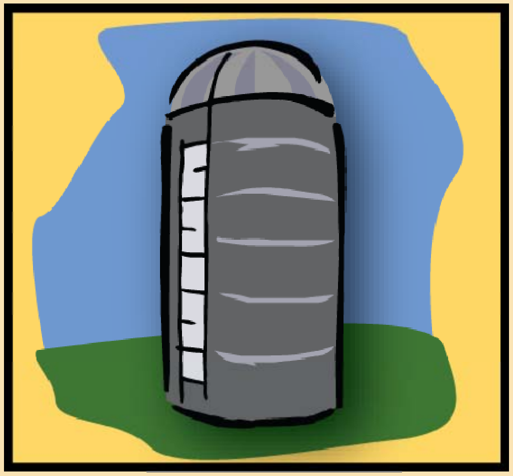
The highly reactive *o*-quinones bind with protein.

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

Redesigning forages: Alfalfa

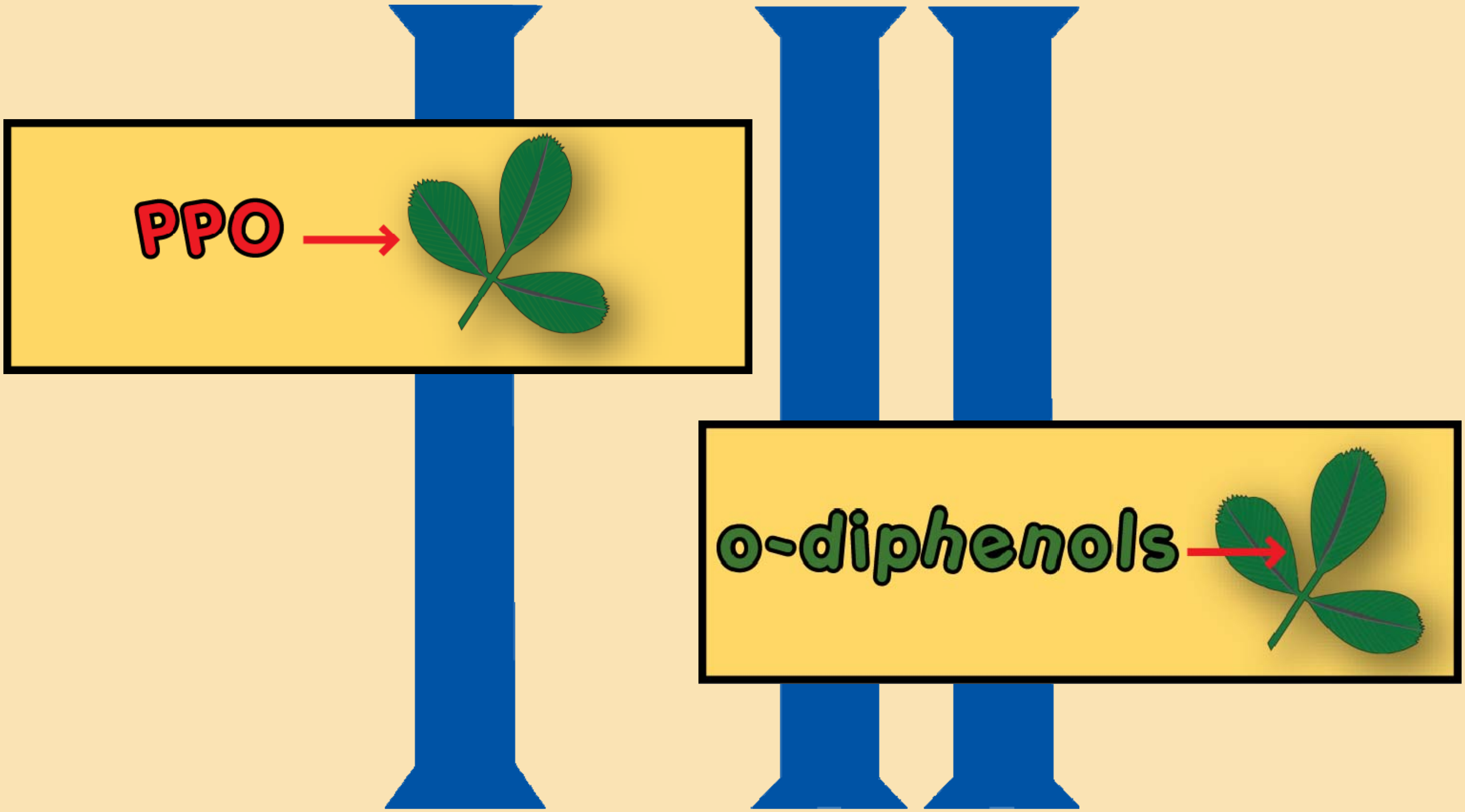
Goal #1: Reduce protein degradation

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



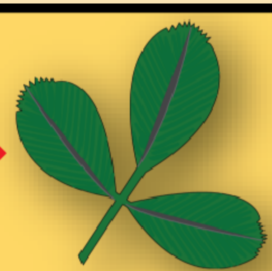
Can we take what works in red clover and transfer it to alfalfa?

Redesigning forages: Alfalfa



Redesigning forages: Alfalfa

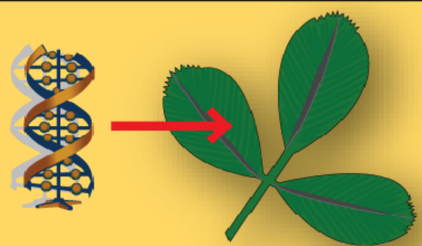
PPO →



PPO genes occur naturally in some variety of alfalfa?

NO.

Insert red clover gene into alfalfa?

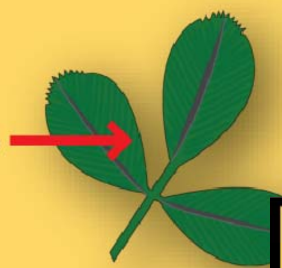


YES.

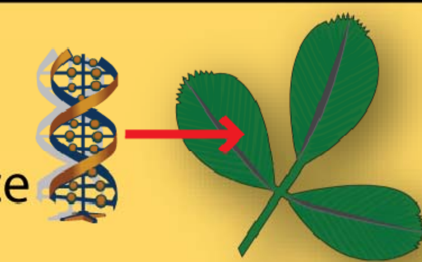
DFRC has successfully done this.

Redesigning forages: Alfalfa

o-diphenols



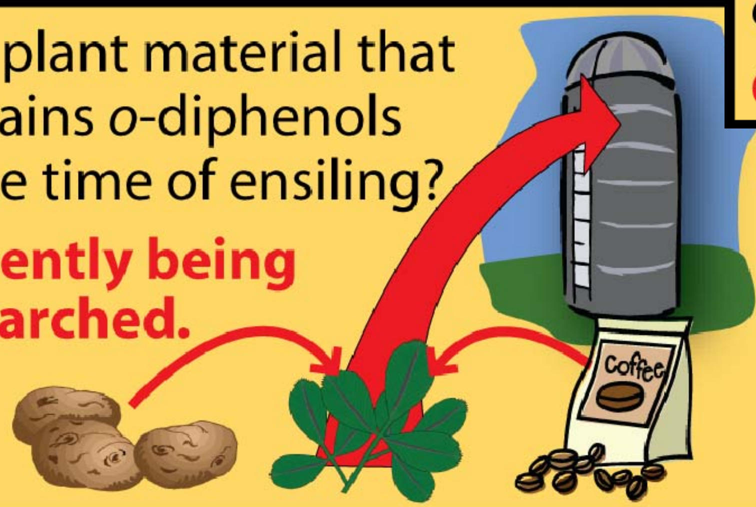
Introduce genes for the enzymes needed to produce *o*-diphenol?



Currently being researched.

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

Currently being researched.



Redesigning forages: Alfalfa

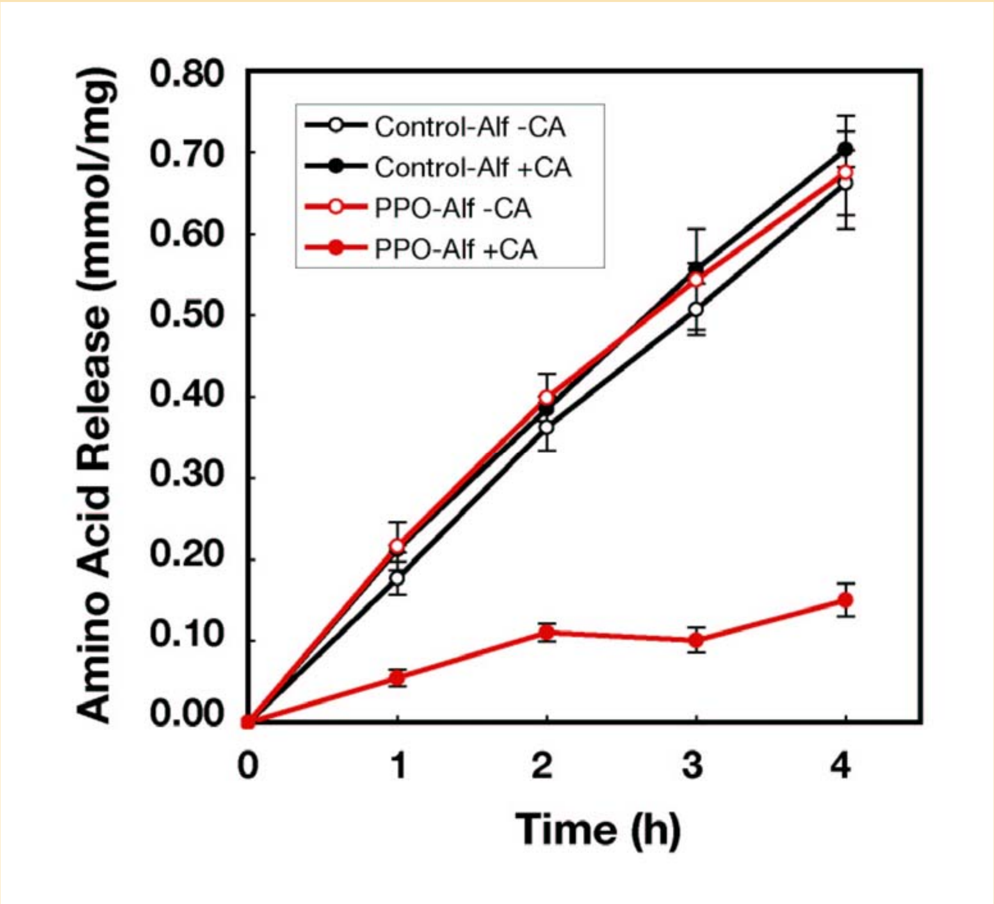
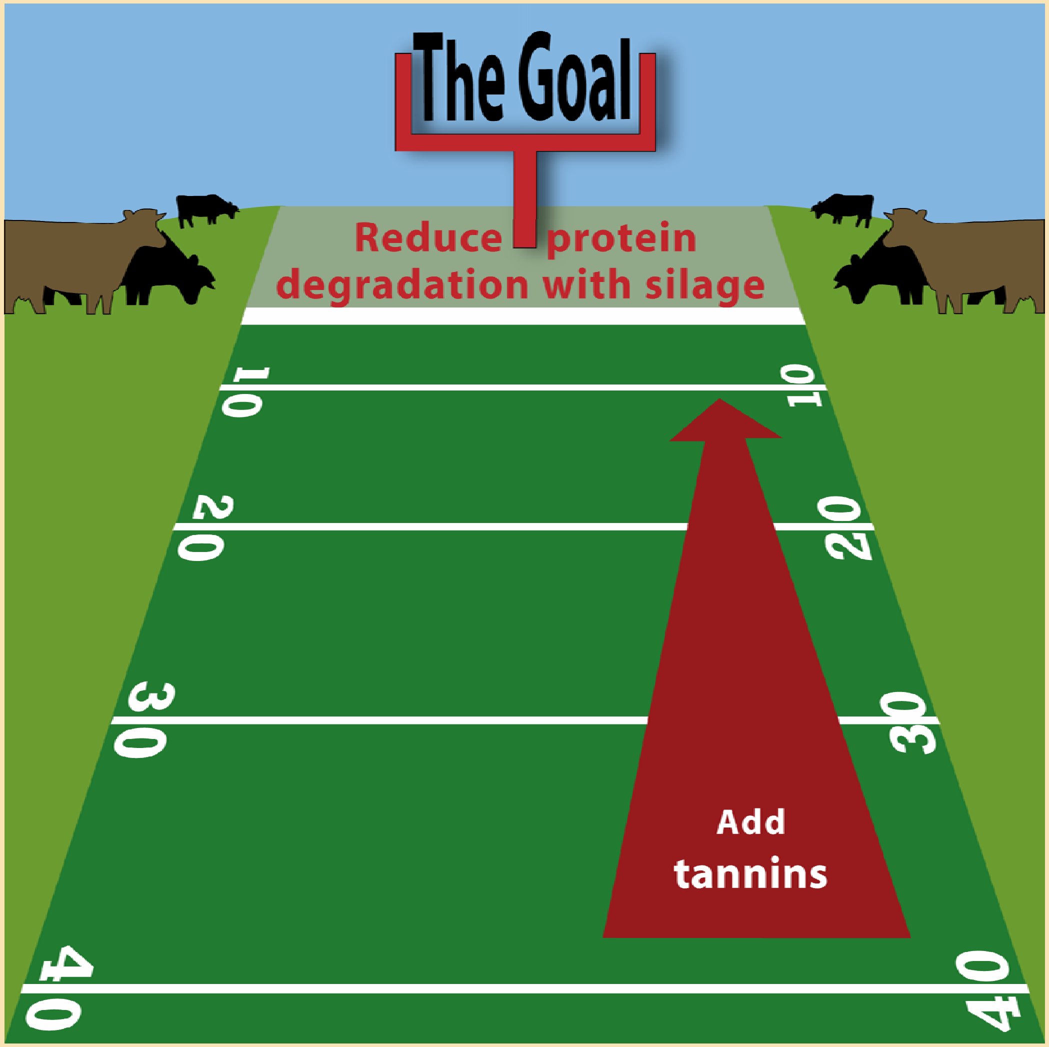


Chart shows how much less protein is degraded in alfalfa silage when alfalfa has PPO gene and *o*-diphenol* is added at time of ensiling.

***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.



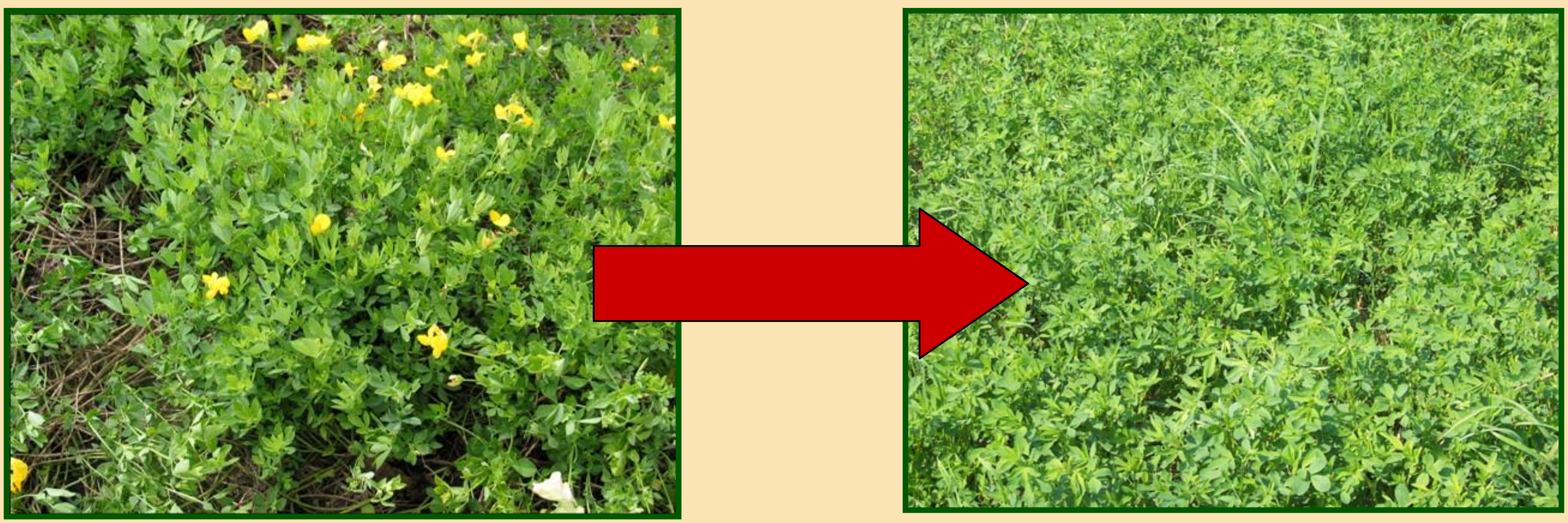
THE SAMUEL ROBERTS NOBLE FOUNDATION

Consortium *for* Alfalfa Improvement

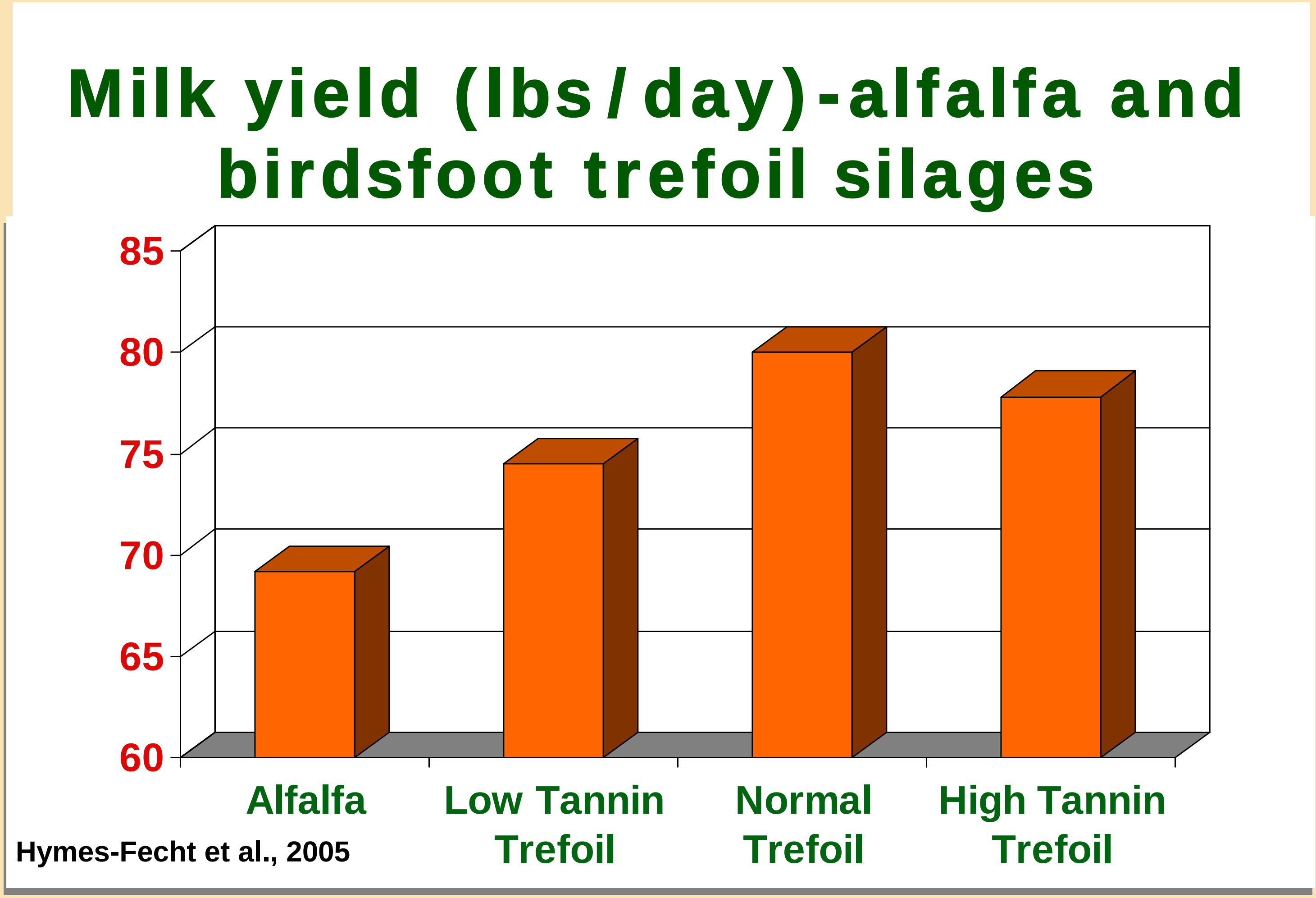
Redesigning forages: Alfalfa

Research efforts:

- Can we insert a tannin gene into alfalfa?
- Can we grow and ensile birdsfoot trefoil with alfalfa and have an effect?

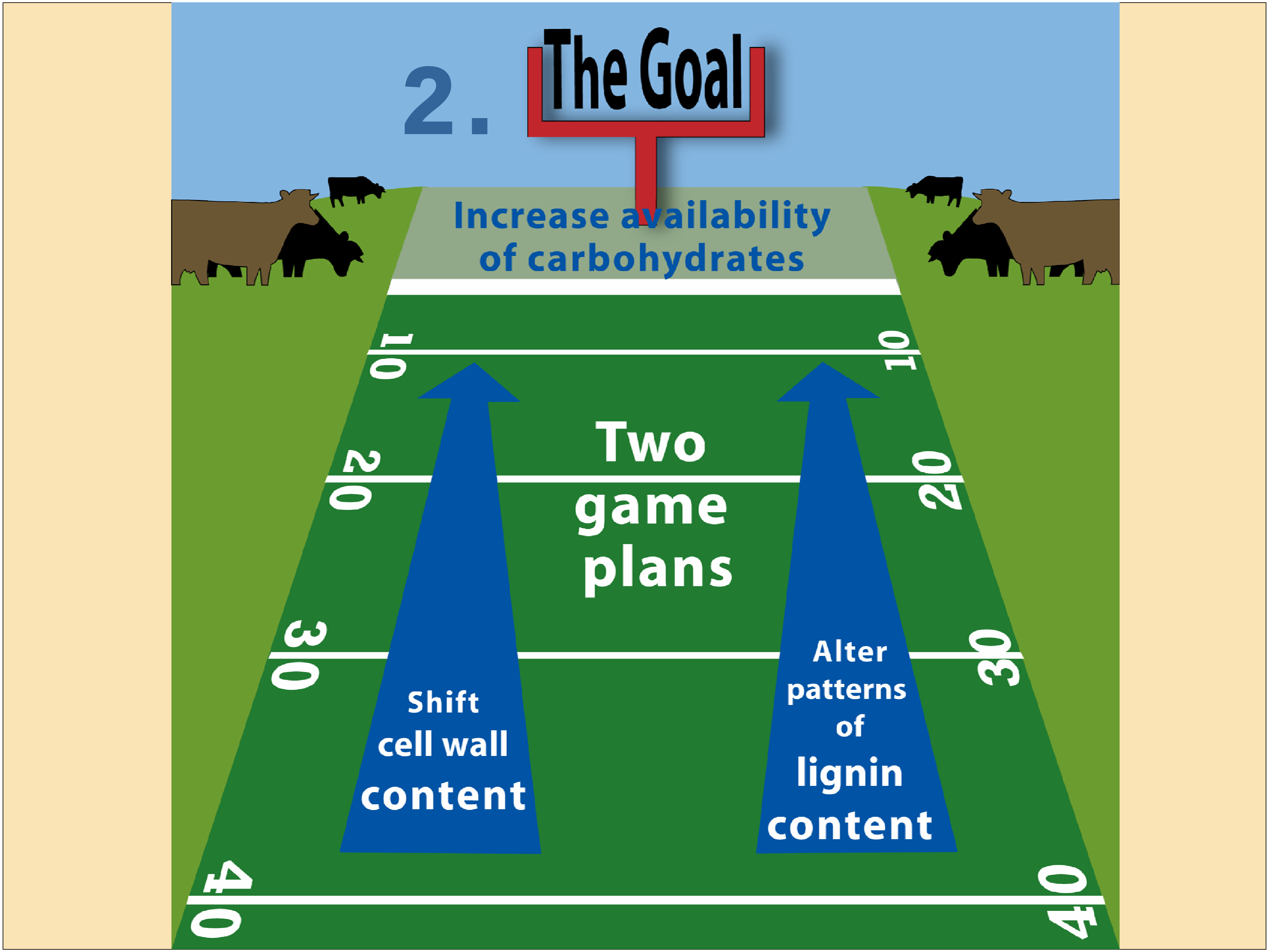


Redesigning forages: Alfalfa



Research Challenge / Opportunity . . .

. . . fiber digestion

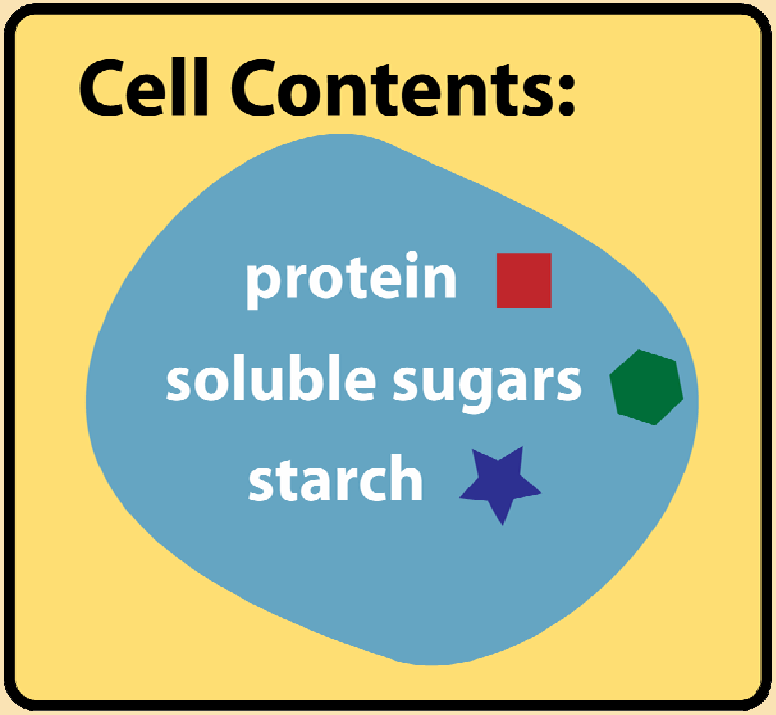

2.
The Goal
Increase availability of carbohydrates
Two game plans
Shift cell wall content
Alter patterns of lignin content
10
20
30
40

Redesigning forages . . .

First: A lesson on cell walls

Cell contents are completely digestible.

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



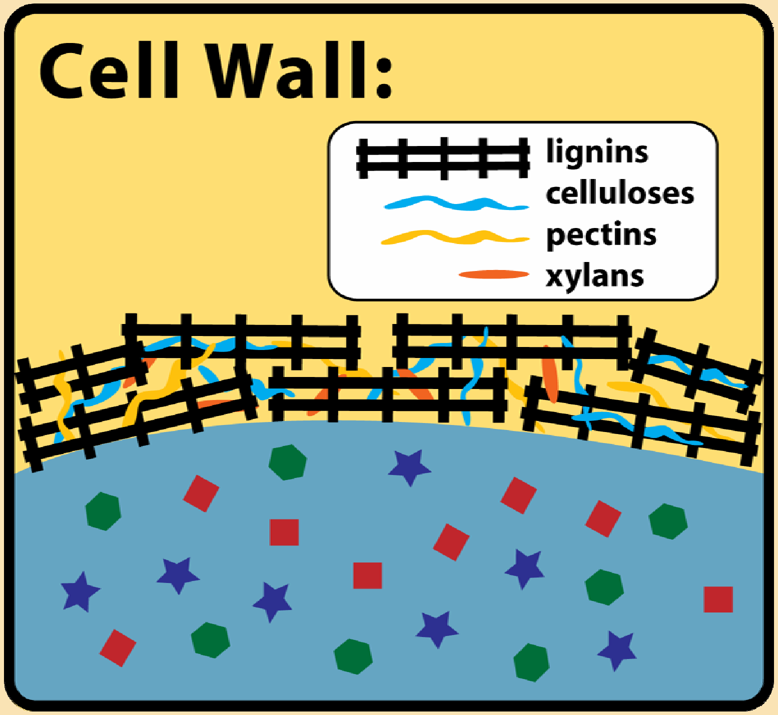
Redesigning forages: Alfalfa

Cell walls contain carbohydrates such as:

- celluloses
- pectins
- xylans

that are partially available to the cow.

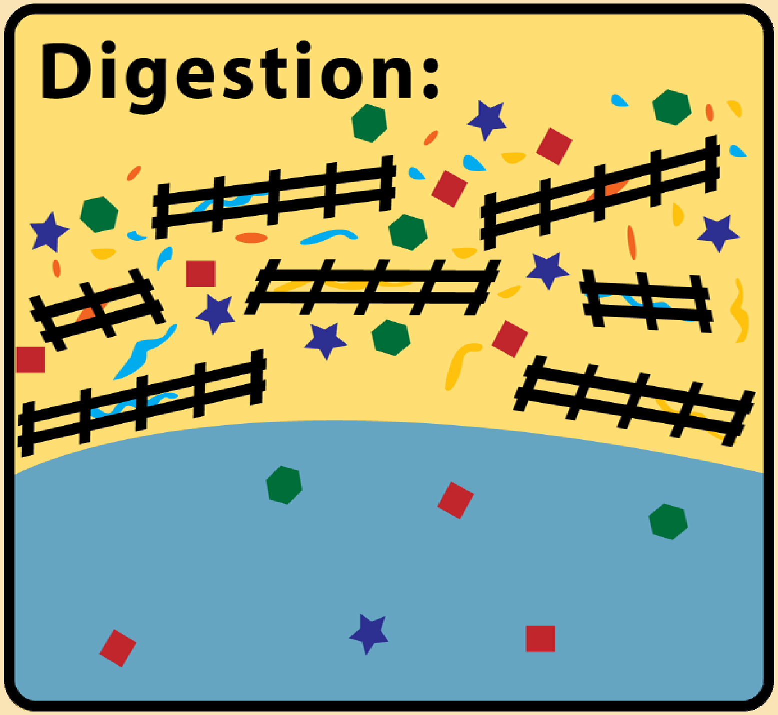
Cows cannot digest lignin.

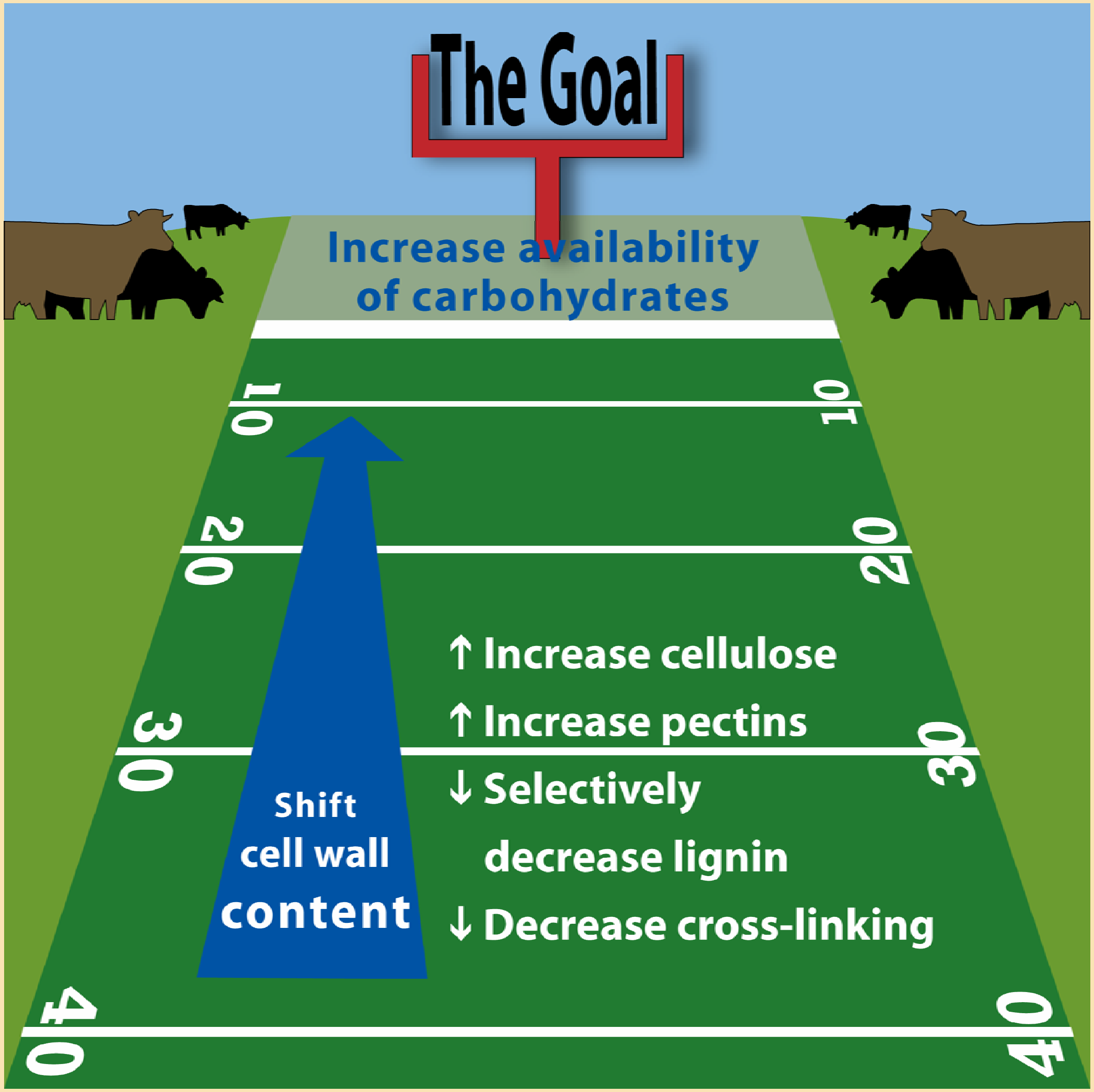


Redesigning forages: Alfalfa

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.

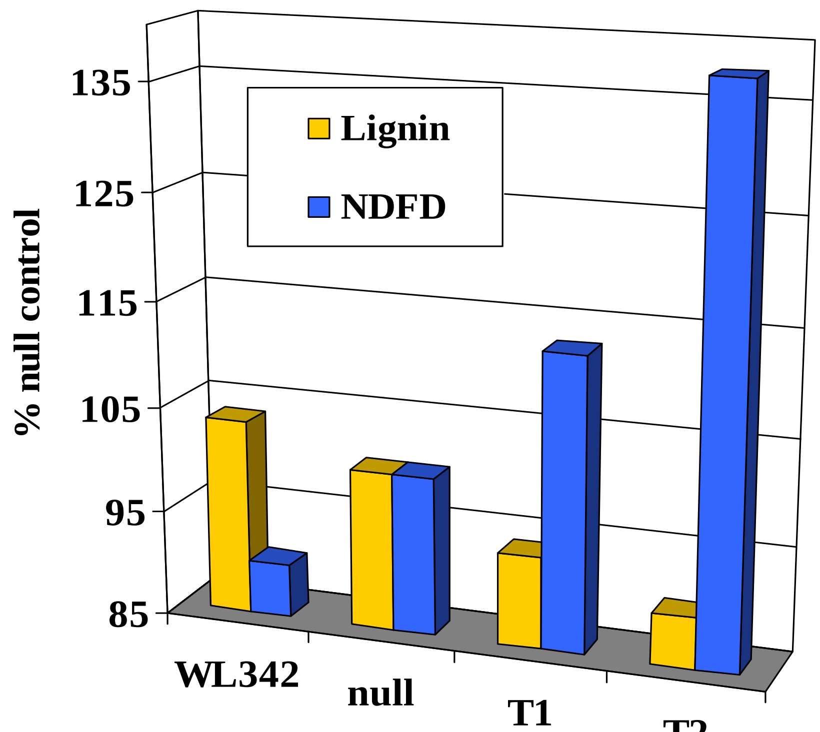




Can’t get rid of lignin . . . So research goal is to decrease the percentage of it in the cell wall by increasing celluloses and pectins.

Redesigning forages: Alfalfa

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



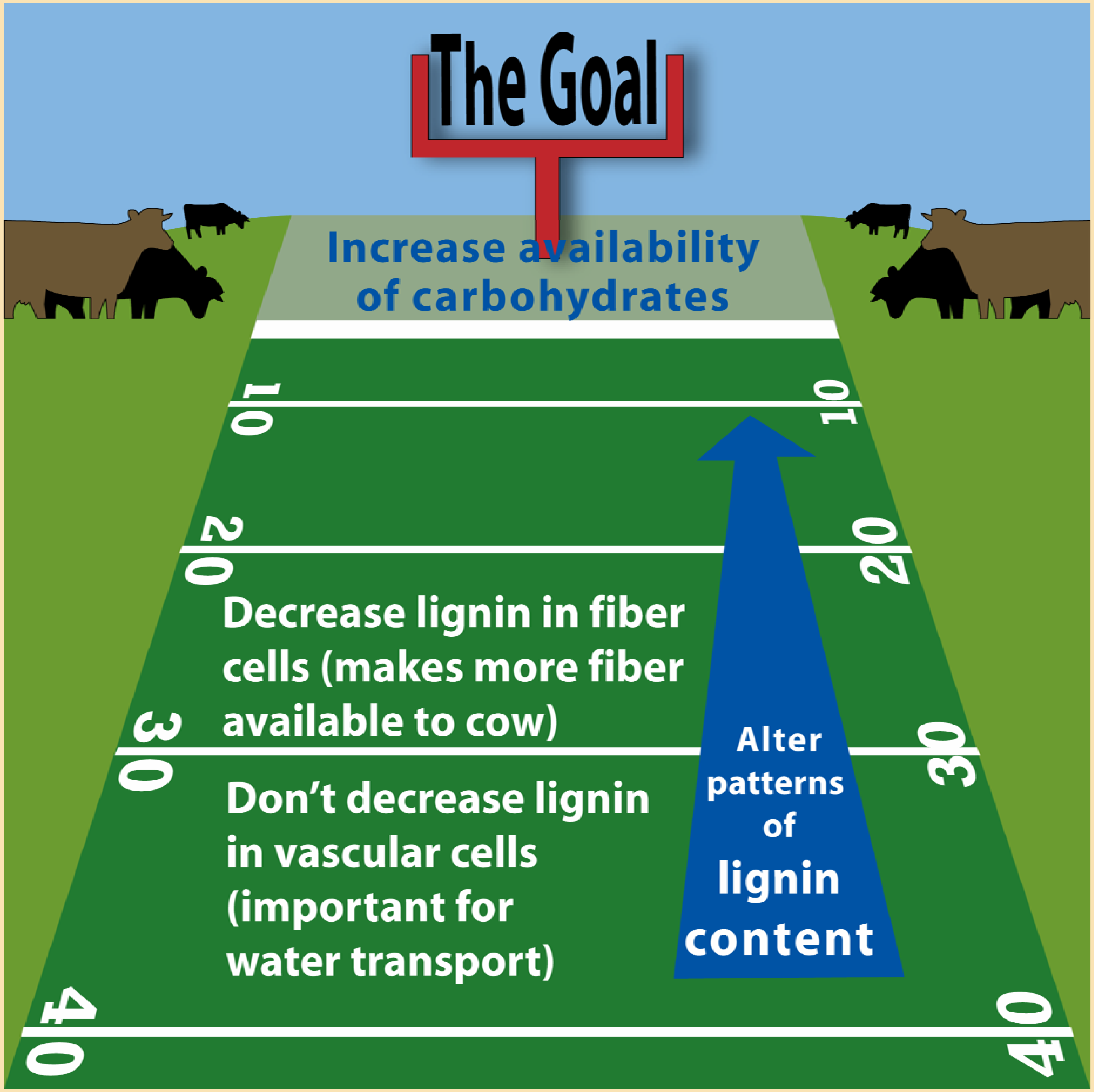
Source: McCaslin et. al., 2002

- Transgenic plants have been generated that show decreased lignin content and increased fiber digestibility.
- The USDFRC estimates that a 10% increase in cell wall digestibility (NDFD) would increase milk and beef production by $350 million/yr and decrease manure production by 2.8MM tons/yr.

Forage Genetics International

Consortium for Alfalfa Improvement

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.



Redesigning forages: 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

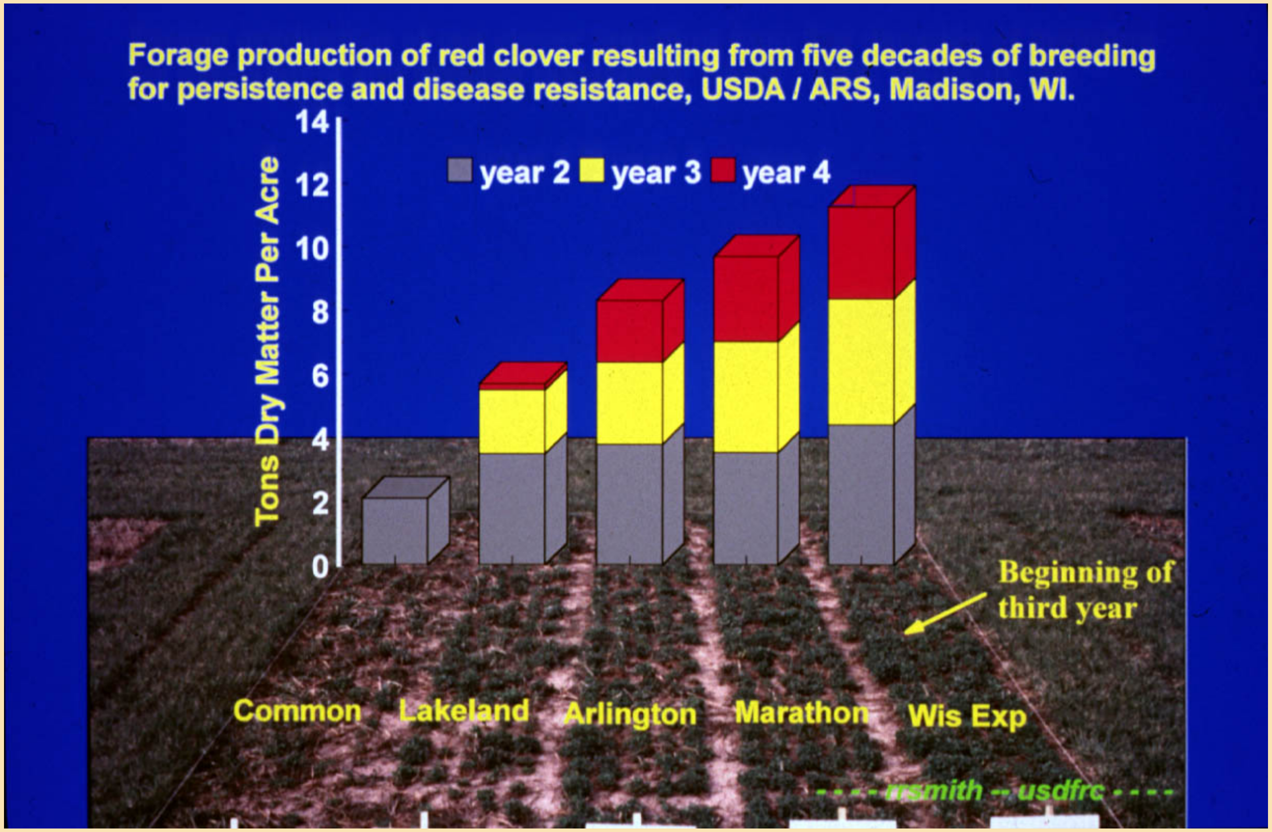
Redesigning forages: Grasses

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: 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.

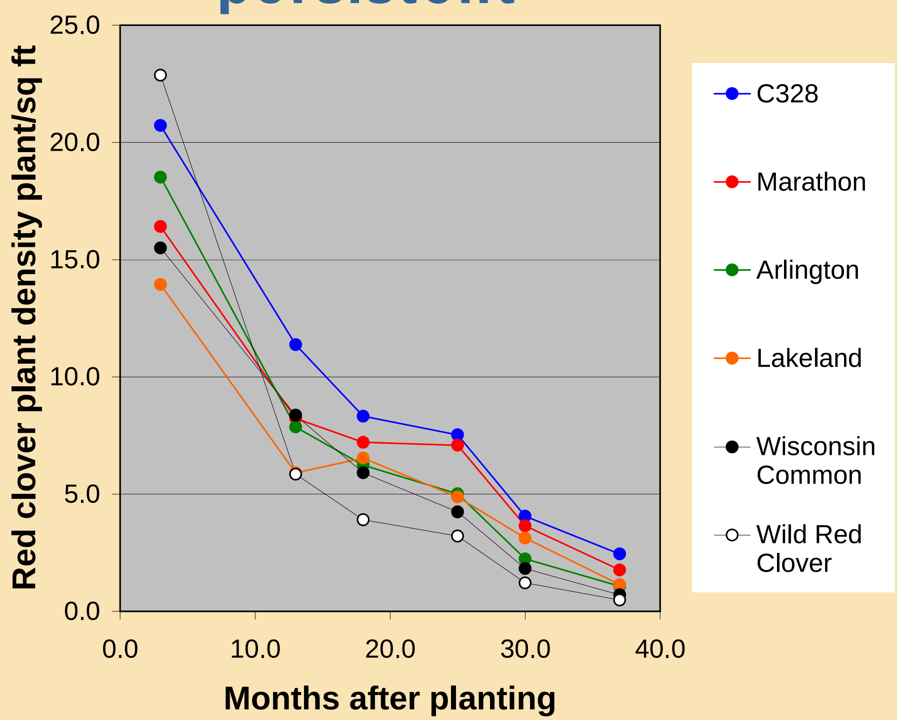


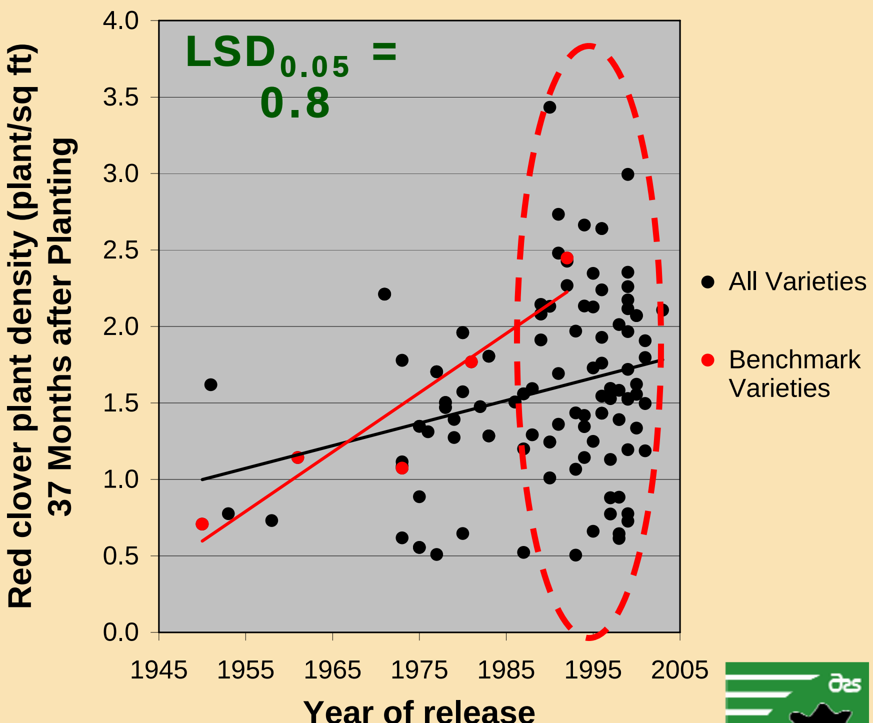
Grazing Red Clover

- Improved Persistence under Grazing?
- 224 - Varieties (1950s-Present), Experimentals, and Plant Introductions tested at Lancaster, WI (planted 2004 in mixture with tall fescue)
  - 2004-2006 Variety results available: Riday et al., 2007 (Grass Clippings 2(1):3-8. U. Wisc. Ext.) http://www.cias.wisc.edu/pdf/pasturenews207.pdf

Grazing Red Clover

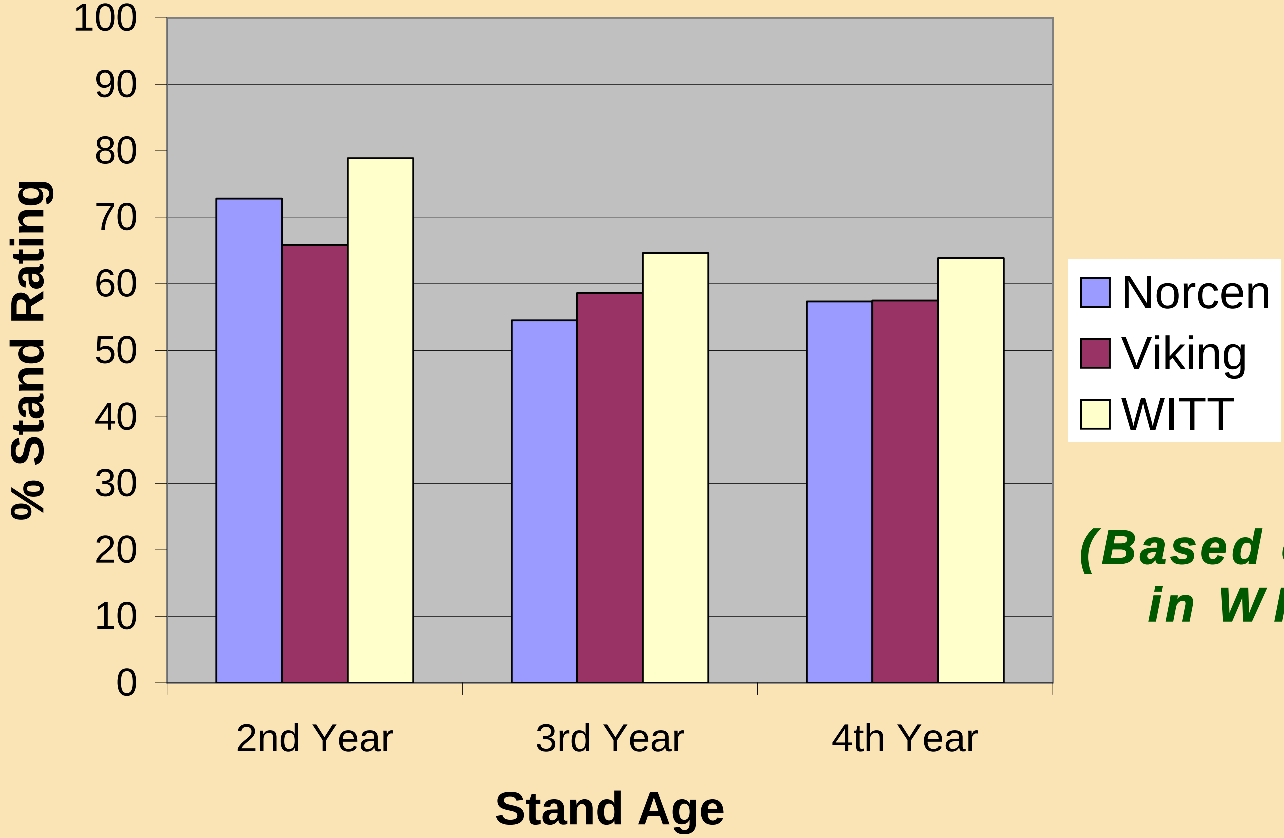
- **Newer red clover more persistent**
  - 100% red clover ground cover at 9 or more plants per sq. ft
  - Not all new red clover varieties are equally persistent





Birdsfoot Trefoil

- **'WITT' trefoil variety with increased persistence released in 2007**



(Based on 16 trials in WI & MN)

Redesigning forages: Grasses

Targets for Grass Breeding

- **The past:** 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 pasture / grazing research

Geoff Brink, DFRC Agronomist

Evaluating the potential of meadow fescue for grazing lands.

What grasses were evaluated?

Bronc orchardgrass

Barolex soft-leaf tall fescue

Bartura, WMF1, and Hidden Valley meadow fescue.

Redesigning forages: Grasses

Summary of results:

- Meadow fescues produced greater spring and early summer yield than orchardgrass and tall fescue when grazed.
- Meadow fescues exhibited a greater increase in yield as N rate increased than orchardgrass or tall fescue.

Redesigning forages: Grasses

Ongoing grazing research:

Study comparing intake, grazing behavior, and digestibility of bred dairy heifers grazing orchardgrass, meadow fescue, reed canarygrass, and quackgrass – 4 grasses that different in sward structure and quality.

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

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

- **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

- ‘Spring Green’ Festulolium
  - Meadow fescue x perennial ryegrass hybrid

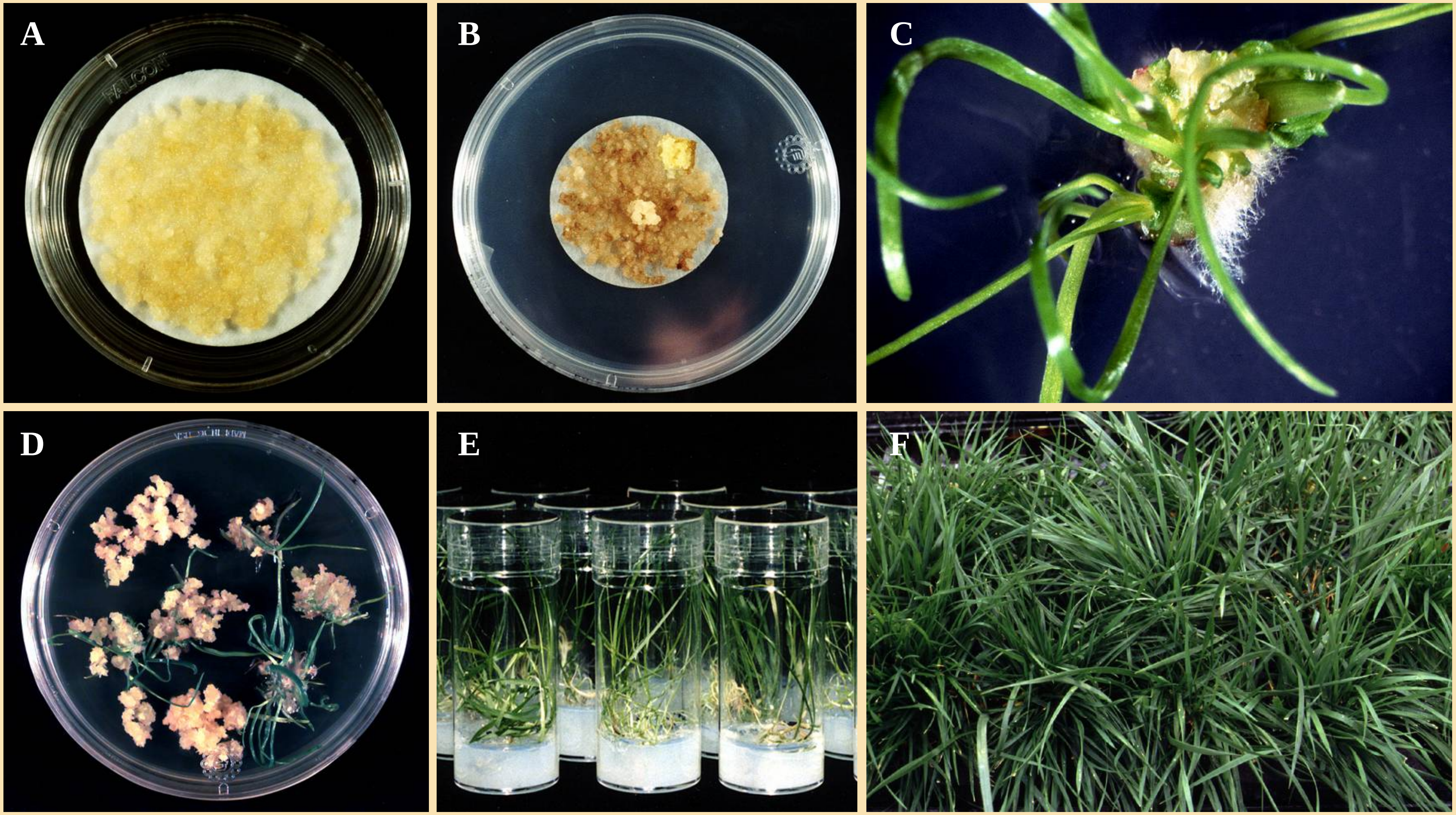
X

  - 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



SOURCE: Bouton and Wang, 2006. The Samuel Roberts Noble Foundation

Redesigning forages: Grasses

Grass breeding summary:

- We have changed the focus of our grass 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.

Growing forages for renewable energy . . .

Switchgrass:

- Currently only 4 labs in the U.S. are breeding switchgrass.
- Will be 10-15 labs doing this within a year or so.
- Only one plant of switchgrass has been made into a GMO plant to date.

USDA-ARS researchers
Mike Casler (left), Madison WI
and Ken Vogel, and Lincoln, NE.

Growing forages for renewable energy . . .

Switchgrass:

- **Pollen-transfer issue:**
  - Switchgrass is a native plant that is wind pollinated.
  - Must develop a way to pollinate without the modified pollen being allowed to function outside the seed production field.

Growing forages for renewable energy . . .

Switchgrass:

- Research is looking at:
  - Harvest management and timing
  - Nitrogen fertilization rates
  - Cultivar evaluations, classification, and geographic adaptation
  - Genetic improvements and new cultivar development
  - Production economics

Growing forages for renewable energy . . .

Switchgrass:

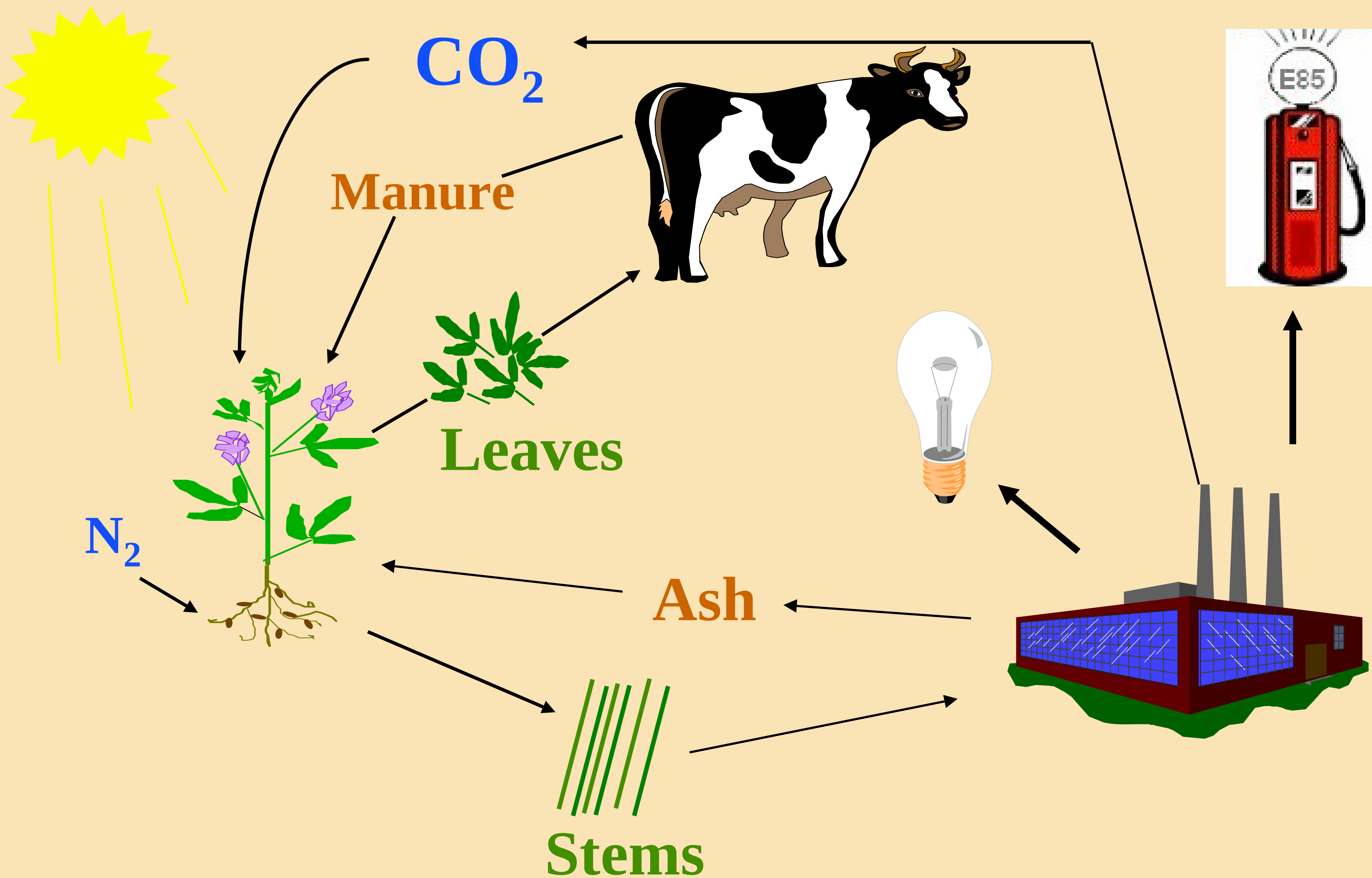
- **Lessons learned, future research needs:**
  - Economic production efficiency can be improved via agronomic research and producer training.
  - Improved high yielding cultivars/hybrids with improved conversion efficiency are needed.
  - Additional region-specific agronomic research is needed to optimize fertility, establishment, seed quality, & other factors.

Growing forages for renewable energy . . .

Switchgrass:

- Feedstock harvesting and storage research is needed, including effect of agronomics and genetics on pretreatment and conversion efficiency.
- Low input systems are not competitive, either economically or on an energy yield per land unit basis.

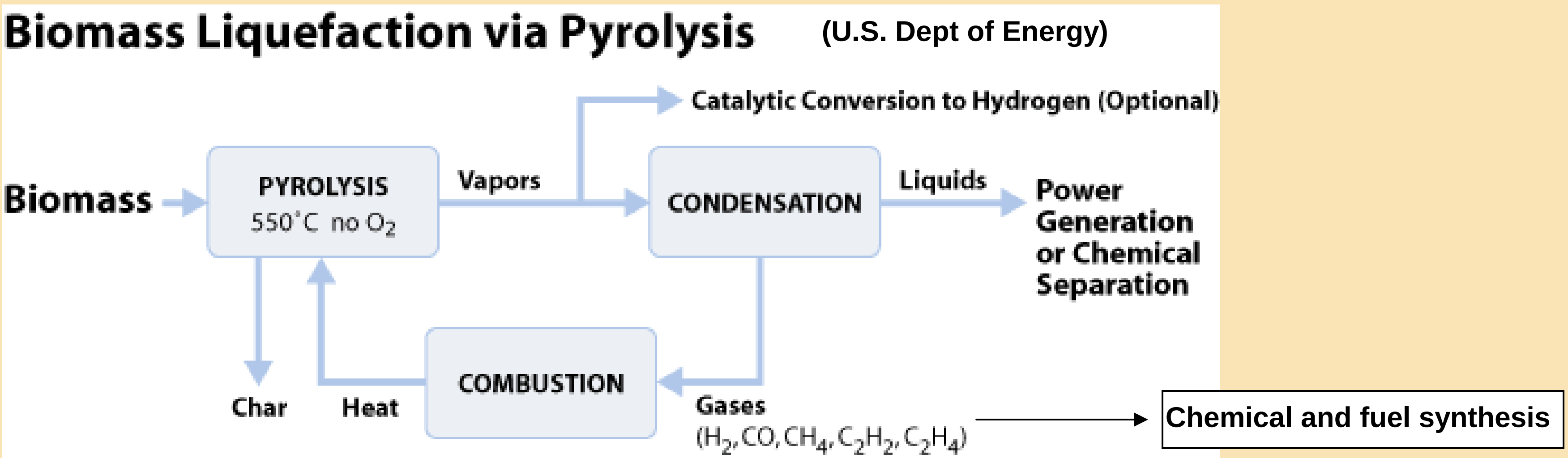
An Alfalfa Biomass System



SOURCE: Hans Joachim G. Jung

Thermochemical conversion

Pyrolysis – Application - Gasification



-High lignin content should make alfalfa a good feedstock for pyrolysis

-Yields of different fractions can be controlled by pyrolysis temperature (500 to 1100 °C)

(Collaboration with A.A. Boateng, USDA-ARS-ERRC)

Bio-based products from alfalfa

Products from dry fractionation

- Leaves (high-protein and digestible fiber for ruminant feeds)
- Stems (high fiber and lignin for combustion and gasification, or for fermentation)

Bio-based products from alfalfa

Products from wet fractionation

- Juice fraction
  - High-protein juice
  - Lutein

- Fiber fraction
  - Human dietary fiber supplements
  - Absorbent mats for binding heavy metals and other toxins
  - Substrate for fermentation to other bio-based products

Bio-based products from alfalfa

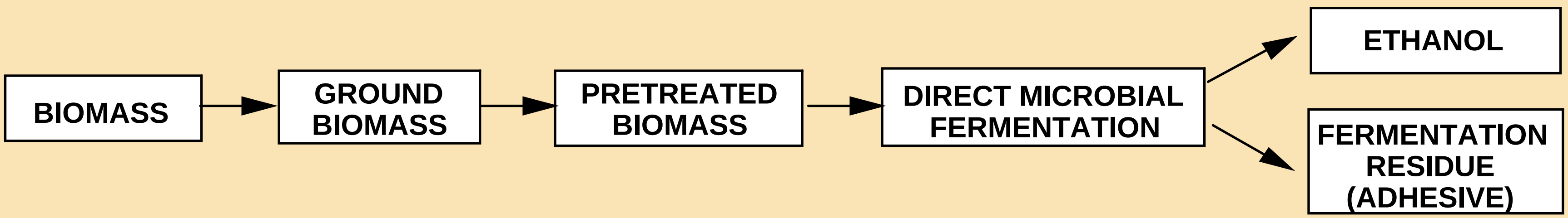
Products from fermentation of fiber from wet fractionation, or of stems from dry fractionation

- Ethanol
- Butanol
- Adhesives
- Methane from anaerobic digestion

Products from transgenic alfalfa

- Enzymes (phytase, a-amylase)
- Plastics (poly-b-hydroxybutryate)

Consolidated Bioprocessing of Biomass - Ethanol and Bio-based Adhesive



- Uses anaerobic bacteria that produce their own fiber-degrading enzymes, and convert the resulting enzymatic products to ethanol, acetic acid, H_2 and CO_2 (no yeast or additional enzymes added)
- Fermentation residue contains a novel material with wood adhesive properties, and which may add value to the process

Production costs and energy balances for likely biofuel crop rotations.

Rotation*	Cost	Net Energy**		
		Produced	Cost	Ethanol
	$/A	GJ	cents/GJ	MJ/gal
3A-1C	177	14,986	2.2	118
Switch	66	13,078	1.9	73
Corn	260	31,605	1.3	96

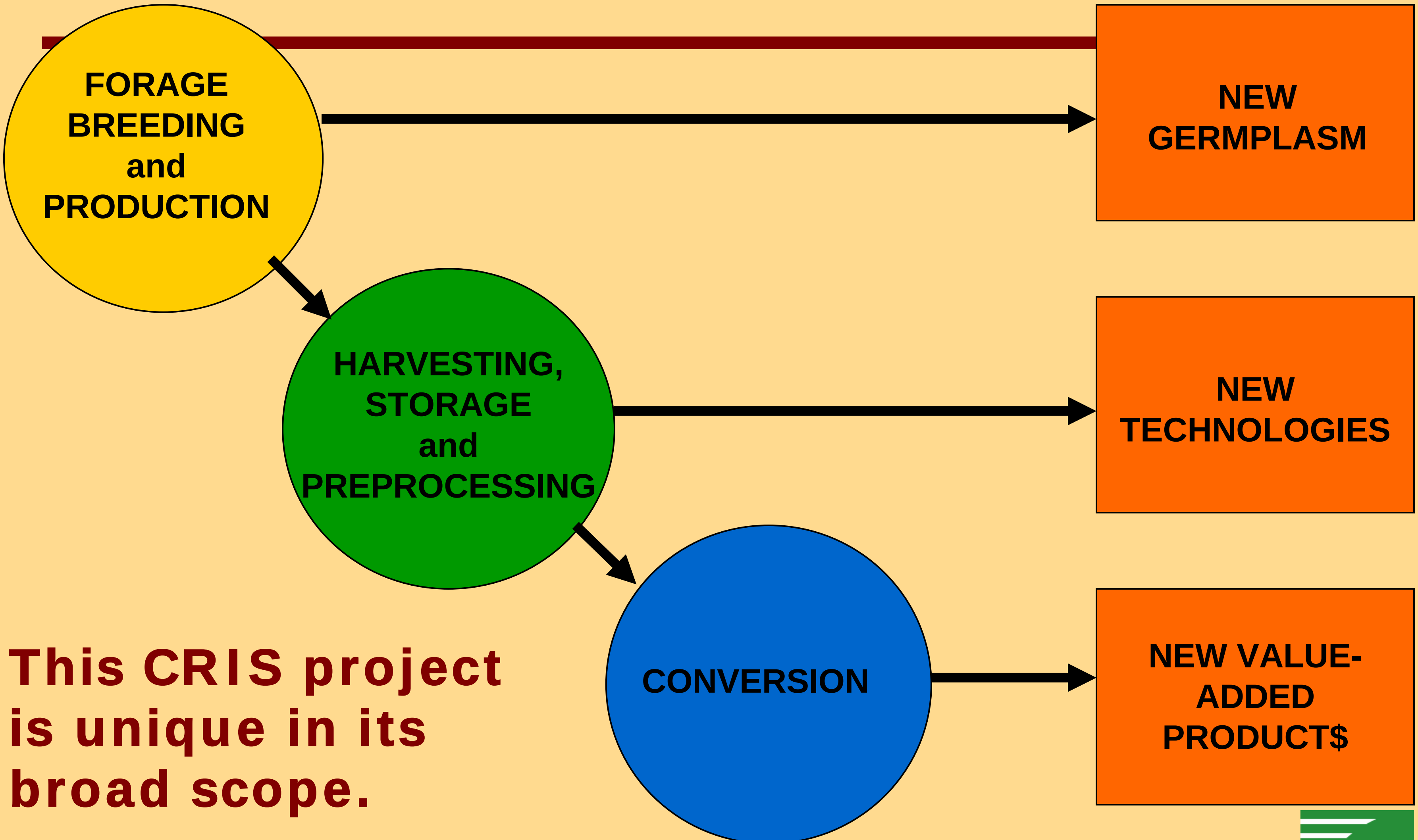
**3A: 3 & 6 T/A, seed & production; corn: 158 bu/A & 4.4 T/A*

Switchgrass: 5 T/A

Corn: 189 bu/A & 3.1 T/A, grain & stover

***GJ=giga joules; MJ= mega joules*

USDFRC Biomass Research



This CRIS project is unique in its broad scope.

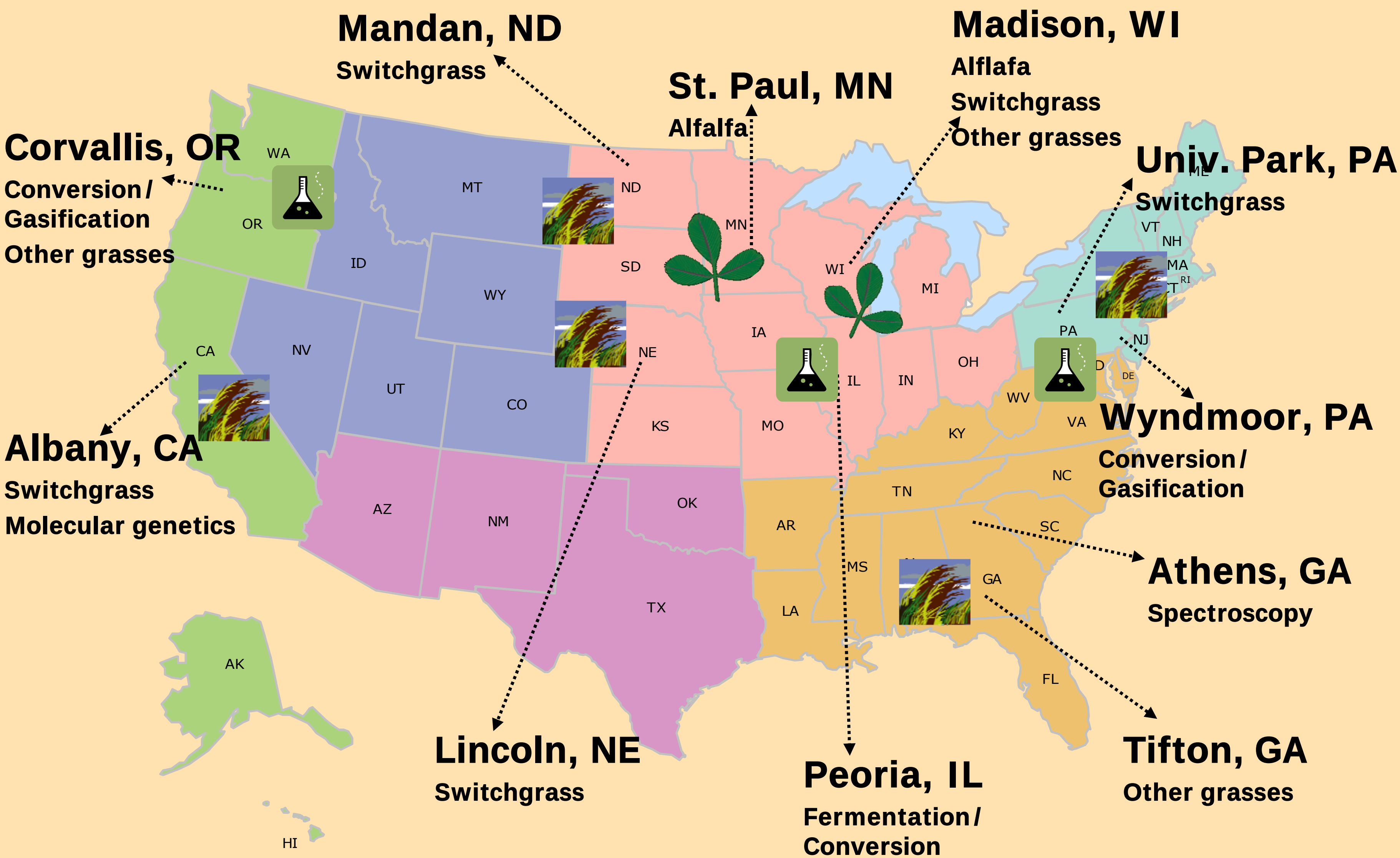
Single-Pass, Split-Stream Harvesting of Corn Grain and Stover

Addressing Challenges to Biomass Production and Processing

***Objective*: On-farm pretreatment of biomass materials:**

- **To produce a product that is more susceptible to enzymatic or chemical hydrolysis**
- **Add on-farm value to product**


Herbaceous Bioenergy Crop Research at the ARS



Questions ?

Presentation to be posted on DFRC web site:

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

Or 'google' Dairy Forage Research