Getting More from Forages

Targeted plant modifications:

Introduction

Complementary strategies for improving plants:

Traditional breeding and genetic modification

Neal Martin
This talk will cover...

Forage production – trends
Redesigning alfalfa for dairy diets - CAI
Forage legume breeding - USDFRC
Forage grass breeding - USDFRC
U. S. Forage Production

- **All Hay**
  - 145.7 million tons
  - 60.1 million acres

- **Corn silage**
  - 111.6 million tons
  - 5.96 million acres

- **Alfalfa hay & forage**
  - 80.7 million tons
  - 23.1 million acres
NEW DEVELOPMENTS IN FORAGE VARIEITES

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
Alfalfa Hay Trends . . .

U. S. Alfalfa Hay Production

U. S. Alfalfa Hay Acres

NEW DEVELOPMENTS IN FORAGE VARIETIES
NEW DEVELOPMENTS IN FORAGE VARIETIES

Trends . . . Alfalfa Silage

% of alfalfa harvested as haylage

NY
PA
OH
TX
CA
IA
KS
NM
SD
Forage trends . . .

Least aggressive in yield increases

Yield/acre for all hay

Yield/acre for 4 major crops
Forage trends . . .

Corn silage production in the U.S., 1986-2006

Corn silage production in 5 leading dairy states, 1986-2006

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Forage Trends . . .

<table>
<thead>
<tr>
<th>Category</th>
<th>Acres, Million</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland harvested</td>
<td>406,424,909</td>
<td></td>
</tr>
<tr>
<td>Cropland pastured</td>
<td>35,771,154</td>
<td></td>
</tr>
<tr>
<td>Woodland pastured</td>
<td>370,297</td>
<td></td>
</tr>
<tr>
<td>Permanent pasture &amp; rangeland</td>
<td>408,832,116</td>
<td></td>
</tr>
</tbody>
</table>

Between 2007 & 2002 acreage harvested for hay and haylage declined by 4 %
Acreage grazed declined by 28 %

2007 U.S. Census of Agriculture
Effect of forage quality on 4% fat-corrected milk production at four concentrate levels

Source: Kawas et al., 1989
# Dairy Ration - old and new alfalfa

<table>
<thead>
<tr>
<th>Ration Ingredients¹, % DM</th>
<th>Old²</th>
<th>New²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa silage</td>
<td>22.0</td>
<td>33.5</td>
</tr>
<tr>
<td>Corn silage</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td>High moisture corn</td>
<td>32.0</td>
<td>21.0</td>
</tr>
<tr>
<td>Roasted soybean</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>9.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Vitamin – mineral</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**Ration composition, Dry matter basis**

<table>
<thead>
<tr>
<th></th>
<th>Old</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>16.0</td>
<td>18.2</td>
</tr>
<tr>
<td>NDF</td>
<td>26.1</td>
<td>28.1</td>
</tr>
</tbody>
</table>

Forage:concentrate 52:48 62:36

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¹650 kg cow producing 45kg of 4% Fat corrected milk

²Alfalfa: Old, CP – 18; NDF – 45; New, CP – 22; NDF - 38
Ration change due Alfalfa Quality

Ration with old alfalfa
• crude protein level typical
• NDF level of diet too low – change F:C to 55:45

Ration with new alfalfa (more intensive cutting)
• Increase F:C to 63.5:36.5 to get enough fiber
• Extra protein in diet is excreted in urine
• High AS levels reduce corn in diet which reduces amount of rumen available carbohydrate needed for microbes to use rumen degraded protein
CA Hay Production Per Dairy Cow
(lbs alfalfa/cow/day)

\[ y = 0.0071x^2 - 1.0507x + 52.834 \]

\[ R^2 = 0.9432 \]

Source: Dan Putnam, 2005 Consortium for Alfalfa Improvement

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Alfalfa hay utilization - California

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

Perennial forage crops are good for environment
Good for cow health
Barriers to increasing alfalfa in dairy diets

- Low protein utilization in rumen
  - Low fiber digestibility
  - Low yield per cutting
Redesign Alfalfa for Dairy Cattle

Consortium for Alfalfa Improvement

Noble Foundation

Forage Genetics International

Pioneer Hi-Bred International

Plant Science Research Unit, USDA-ARS

US Dairy Forage Research Center, USDA-ARS
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

Getting More from Forages – July 29-30, 2009
Collaborative efforts of the Consortium for Alfalfa Improvement has resulted in two alfalfa genetic lines with reduced lignin content.
# Lactating Cow Response

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

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

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

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* TMR diets - 50 % alfalfa hay, 10 % corn silage, 40 % concentrate
## Digestibility in Lambs

<table>
<thead>
<tr>
<th>Hay Diet</th>
<th>aNDF</th>
<th>ADL</th>
<th>NDFD</th>
<th>DMD</th>
</tr>
</thead>
<tbody>
<tr>
<td>100% Alfalfa Hay Diet</td>
<td>57.5*</td>
<td>67.5*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMT Inactive</td>
<td>38.2</td>
<td>5.3</td>
<td>57.5*</td>
<td>67.5*</td>
</tr>
<tr>
<td>COMT Active (Control)</td>
<td>39.0</td>
<td>5.8</td>
<td>49.1</td>
<td>64.5</td>
</tr>
<tr>
<td>CCOMT Inactive</td>
<td>39.4</td>
<td>5.2</td>
<td>50.1*</td>
<td>65.3*</td>
</tr>
<tr>
<td>CCOMT (Control)</td>
<td>39.4</td>
<td>5.9</td>
<td>46.4</td>
<td>63.7</td>
</tr>
</tbody>
</table>

*Significant, P < 0.05

**SOURCE:** Mertens *et al.* 2008. *J. Dairy Sci. Supple. 1*
## Need for Updated NIRS Equations

<table>
<thead>
<tr>
<th>Test</th>
<th>Regular</th>
<th>Alfalfa Type ComT Inactive</th>
<th>Alfalfa Type CcomT Inactive</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIRS breeder equation</td>
<td>---------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>ADL (%DM)</td>
<td>12.5b</td>
<td>11.2a</td>
<td>10.9a</td>
</tr>
<tr>
<td>NDFD (%NDF)</td>
<td>31.8a</td>
<td>35.8a</td>
<td>35.3a</td>
</tr>
<tr>
<td>Chemical analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ADL (%DM)</td>
<td>10.2c</td>
<td>9.6b</td>
<td>7.9a</td>
</tr>
<tr>
<td>NDFD (%NDF)</td>
<td>30.6c</td>
<td>41.0a</td>
<td>36.2b</td>
</tr>
</tbody>
</table>

Values within row differ significantly, $P < 0.05$

Plant Material

Birdsfoot Trefoils (~ 2, 4, and 7% Extractable Condensed Tannin by Vanillin-HCl; Miller & Ehlke, 1997)

Alfalfa (No Polyphenols)

Red Clover (Polyphenol Oxidase)
Redesigning Alfalfa

Potential high value alfalfa

Allow us to feed lower protein diets

Allow for digestion of complex carbohydrates – new feeding approach

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.
Conventional Breeding Research

Producing new varieties is a core activity at the USDFRC

Developing Improved Breeding Methodology

- Reducing Field Evaluation Costs
- Integrating Cost Effective Molecular Marker Assisted Selection
- Incorporating Hybrid Breeding into Forages
Field Evaluation Cost Reduction

Moving selection nurseries into pastures and turf

High Maintenance

Low Maintenance
Individual Plant Observation Easy
Conducive to Selection for:
- Grazing Tolerance
- Pasture Grass Competition
- Drought Tolerance
Field Evaluation Cost Reduction

Rapid Evaluation of Plant Traits

- Yield
- Seedling Establishment
- Drought
Integrating Molecular Markers into Conventional Breeding

Goal: Integrated & Cost Effective

- Plant Progeny Rows
- DNA Collection
- Field Evaluation
- DNA Evaluation
- Marker assisted selection (MAS)
- Select Best Families and Plants

Grow New Parents
Increase Forage Yield

Create hybrid alfalfa

- Yellow flowered - falcata
- Male Sterile purple flowered - sativa
Enhanced Population Hybrids

Use red clover's natural self-incompatibility to increase % hybrid seed in population hybrids

<table>
<thead>
<tr>
<th>Cage</th>
<th>% Hybrid Seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Population Hybrid</td>
</tr>
<tr>
<td>Mean</td>
<td>48%</td>
</tr>
<tr>
<td>Self-Incompatibility Manipulated Hybrids</td>
<td>75%*</td>
</tr>
</tbody>
</table>

Seed production study (Riday, 2009); deviation from 50% expectation significant at p < 0.0001
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

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

**The present: 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.
Getting More from Forages – July 29-30, 2009

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.
Team Plant Modification - targeted

Use conventional and molecular breeding where appropriate

Target breeding at dairy cattle intake, nutrient digestion and nutrient metabolism

Use multi-disciplinary approach within unit and with partners

Benefit of high risk research with partners in alfalfa is dependent on acceptance genetic modification by customers