Switchgrass as a Dedicated Bioenergy Crop

Joe Bouton
The Samuel Roberts Noble Foundation
Ardmore, Oklahoma

Noble Foundation Overview

Type: Non-Profit Foundation

Location: Ardmore, Oklahoma

Employees: >300 (80 PhDs)

Annual Budget (Science & Consulting Operations): $35.0 million

Annual Budget (Granting-Public Charity): $8.0-12.0 million

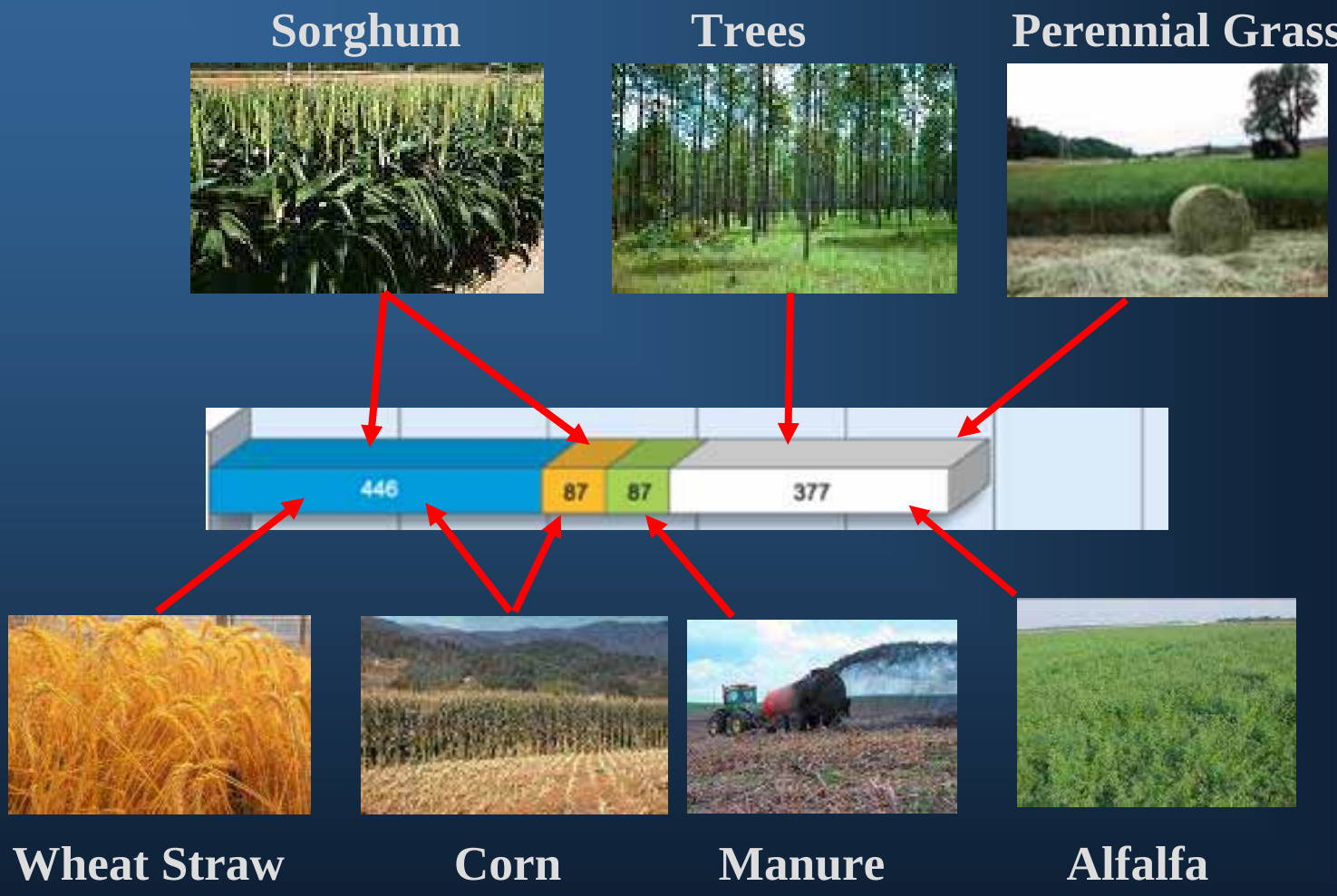
Resources: 12,000 acres; 500,000 sq. ft. building & lab space

Endowment: $1.2 billion

Mission: Influencing agriculture by exploring and improving production agriculture techniques and advancing plant science through research and discovery

www.noble.org

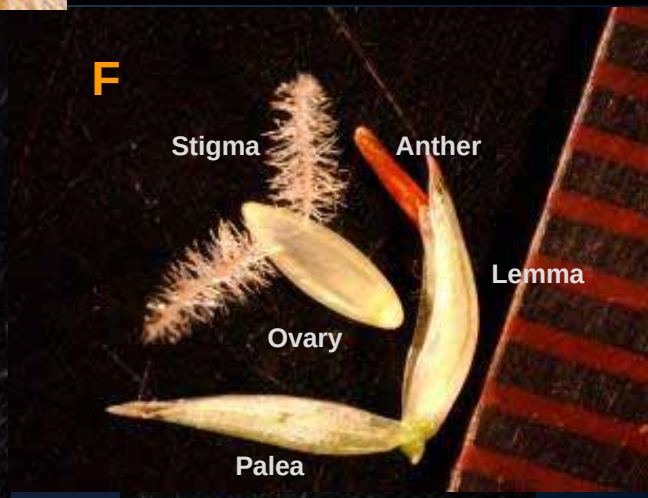
Which Feedstock(s)?



“All Biofuel Industries Will Be Local”
(Southern Great Plains has a history of grass based agriculture and a strong oil and gas industry)

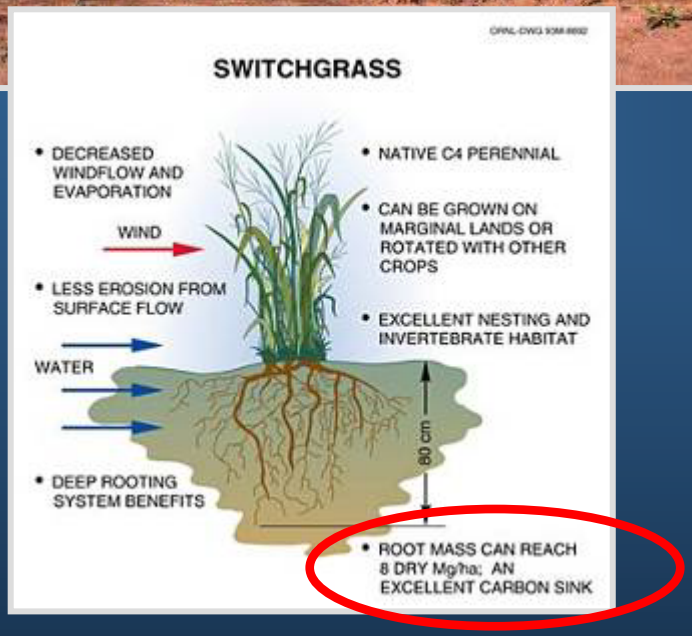
If State, 10th largest cattle herd

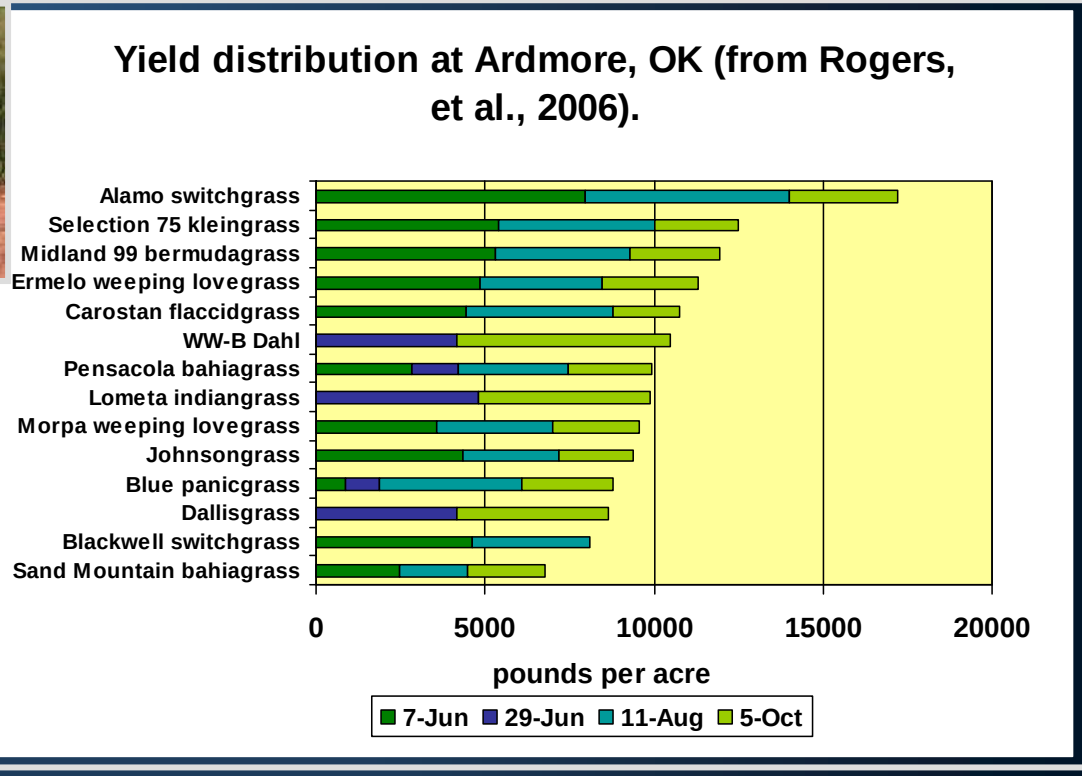
Switchgrass and All Its Parts



Forage Improvement Division

Why switchgrass as a main biofuel crop?





- Native, perennial grass with high root and shoot yield.
- Good for use as pasture, wildlife habitat, and as conservation crop to reduce erosion.
- High yielding lowland types can be grown in the southern region.
- Shows higher yield over other perennial grasses especially with low fertilizer inputs.

Net energy of cellulosic ethanol from switchgrass

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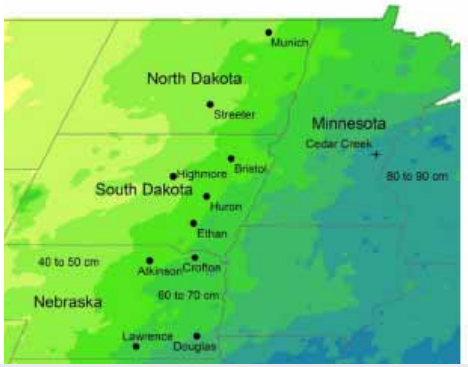
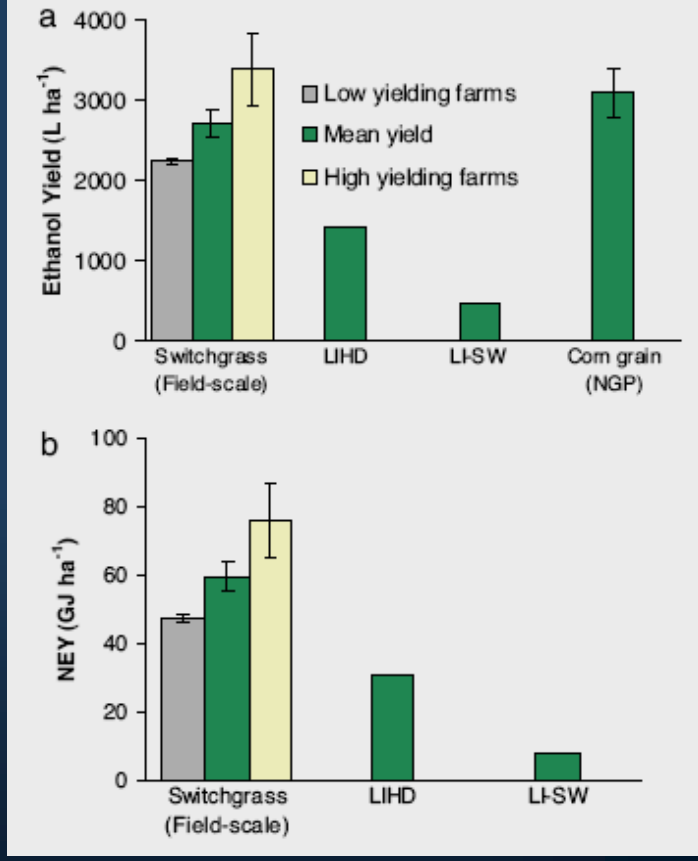
Edited by Pamela A. Matson, Stanford University, Stanford, CA, and approved November 21, 2007 (received for review May 21, 2007)

Perennial herbaceous plants such as switchgrass (*Panicum virgatum* L.) are being evaluated as cellulosic bioenergy crops. Two major concerns have been the net energy efficiency and economic feasibility of switchgrass and similar crops. All previous energy analyses have been based on data from research plots (<5 m²) and estimated to be slightly positive (8) for ethanol derived from switchgrass.

Lignocellulosic feedstocks such as switchgrass, woody plants, and mixtures of prairie grasses and forbs have been proposed to offer energy and environmental and economic advantages over

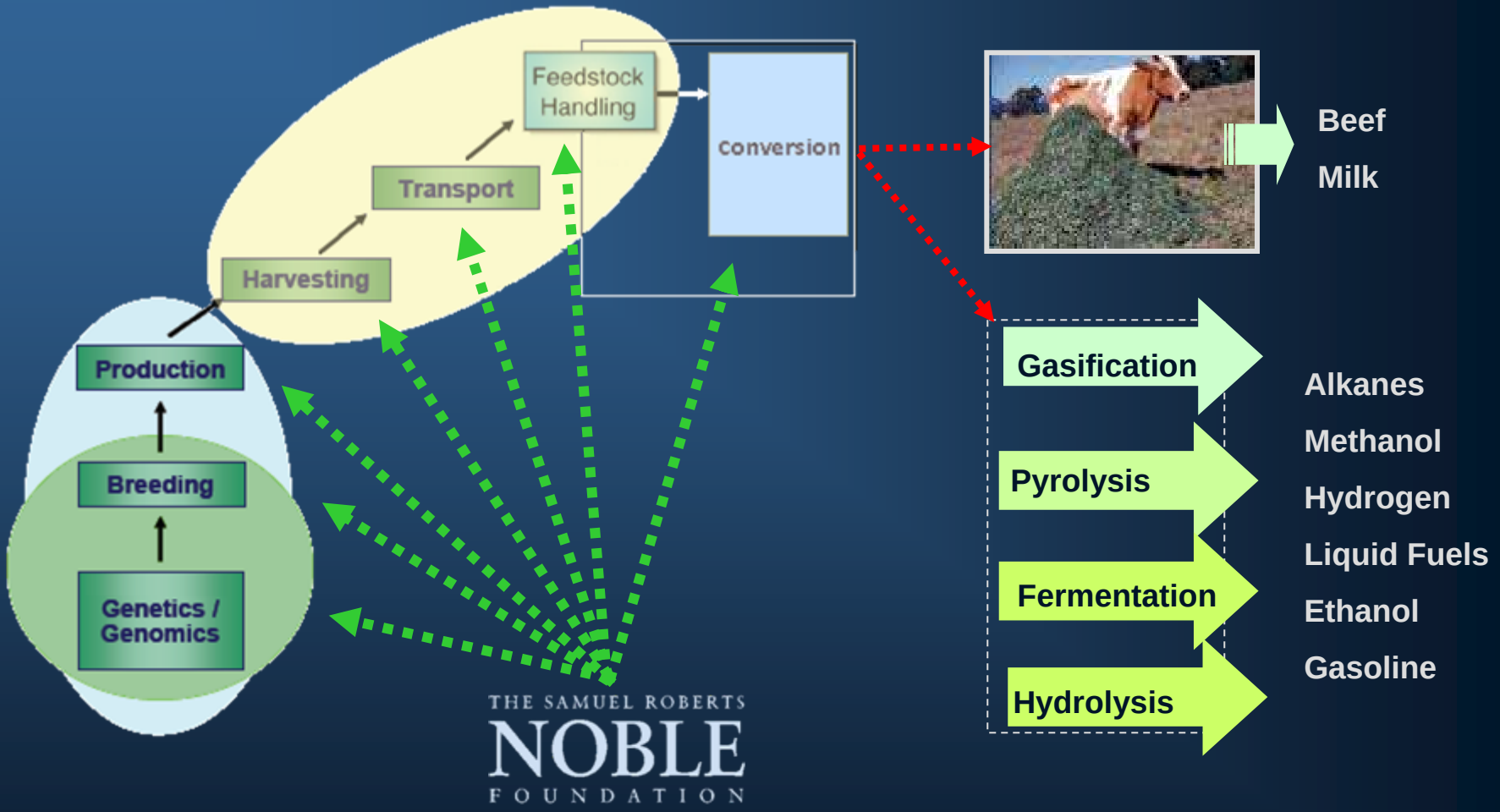


- Published in Proceedings of the National Academy of Sciences
- Done on-farm (10 sites in Northern Great Plains
- Marginal crop land (e.g. non-corn)
- High yield sites (5.5 tons/acre) produced ethanol yields comparable to irrigated corn
- Switchgrass produced 540% more energy produced than used
- Improved varieties and management practices should improve performance even further since this study was first established in 2000.



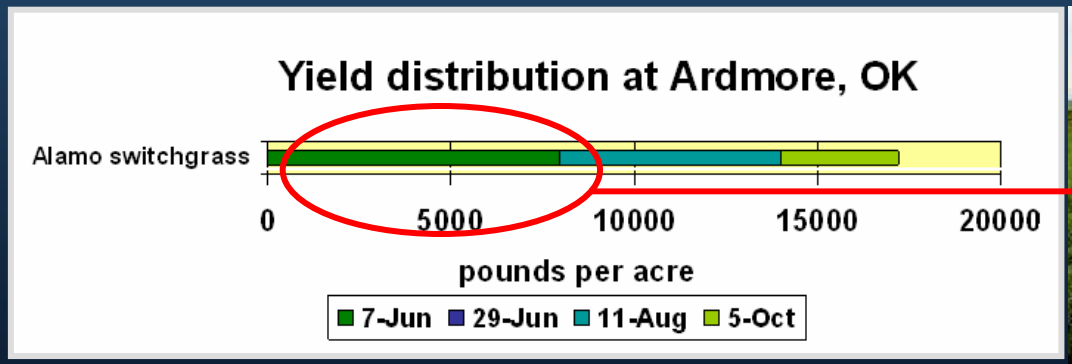
Feedstock is feedstock!

How can we integrate biofuels and forage/livestock research?



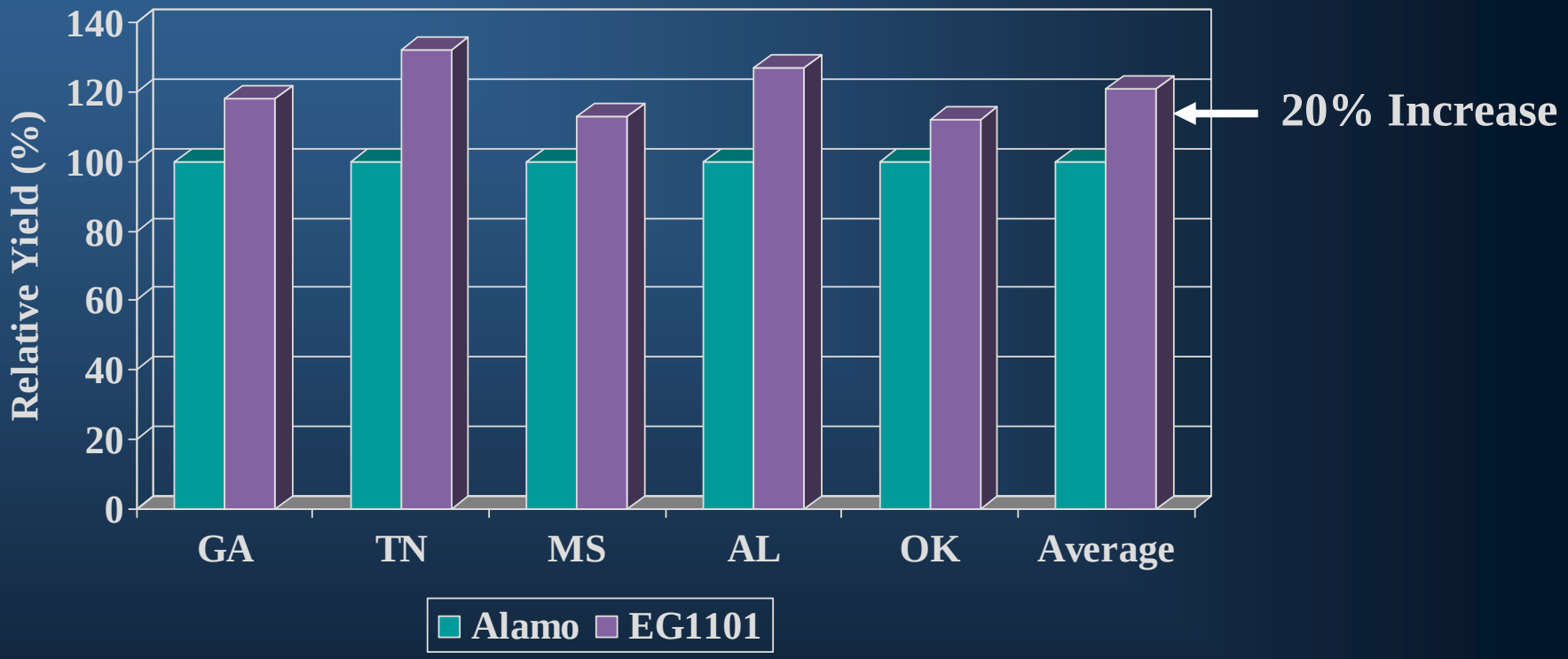
Initially, NF will also assess the crop's ability to serve as a hay and grazing crop. This will promote early adoption and help producers learn to grow the crop in the context of their current livestock operations. It is then an easy transition to a biofuels operation.

Why? Because switchgrass has a long growing season with high yield and palatability; especially in the spring of the year. These are important traits for any hay and grazing crop.



Developing new varieties of switchgrass. Measured actual yield on individual plants and used the best ones a parents for the new, high yielding varieties

Example of Conventional Breeding Progress: Dry Matter Yield Performance of EG1101 (tested as NF/GA993) Switchgrass Variety Relative to the 'Alamo'



Commercial seed should be available in 2009-10 through Ceres

The University of Georgia

ceres

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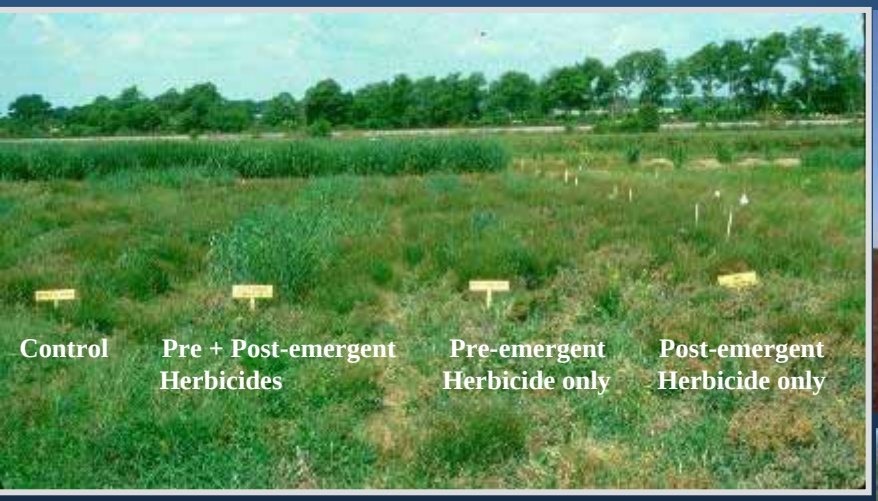
NF Switchgrass Research Projects

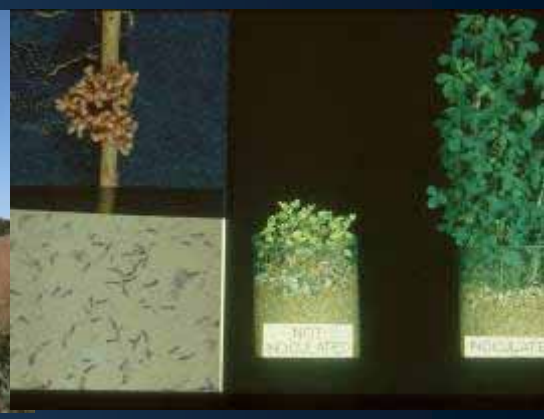
- **Commercialization and testing of EG1101 switchgrass**
- **Establish better management protocols for growers**
- **Development of new varieties including F1 hybrids**
- **Develop biotech tools for breeding new varieties**

Managed testing trials

Establish the Best Management Practices for Switchgrass in a Biomass Cropping System

- Emergence and stand development (weeds & fertility mgt)
- Improve seed production practices
- Co-cropping with legumes for off-season yield & N_2 fixation.
- Address harvest, transport, storage, and economics issues.





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Continued Development of New Varieties with Performance Better Than EG1101

Family Selection

Most of the families selected based on early vigor were also among the ones produced by plants that were superior in initial nursery (phenotypic selection based on GRID approach)

1

3

5

7

9

Switchgrass Hybrid Varieties

Heterosis is found in switchgrass with the F1 hybrid out-yielding its parents. Still need to develop a system for commercial seed production of these hybrids.

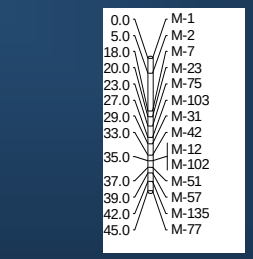
Parent 1 **Hybrid** **Parent 2**

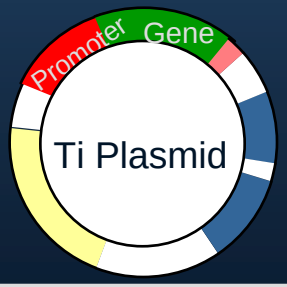
Why use biotechnologies?

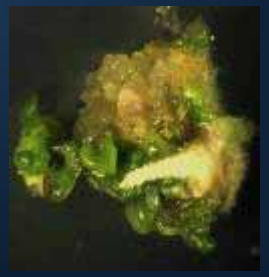
- An **ability** to **easily manipulate and control G** (genes) is most important to breeders.
- **Molecular tools** now available through **gene mapping** and **genetic engineering** offer this ability.
- **Combining** traditional **plant breeding** with these **molecular tools** should assist with making progress in **cultivar development.**

P=G+E+GE

Phenotype (How it looks) = Genes + Environment + GenesxEnvironment



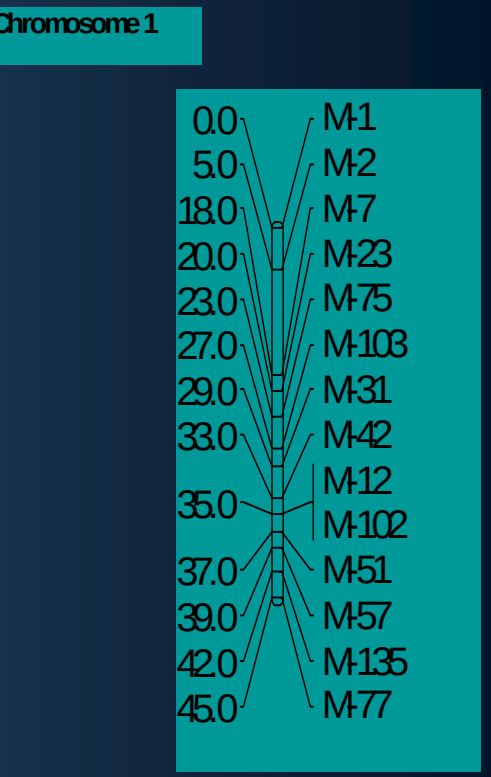




Why molecular markers and gene mapping?

Analagous to Road Maps

- Chromosomes are like the highways.
- The molecular markers on the chromosome are like the mile markers on a road map.
- Easier to find a stalled car on the road if you report the mile marker it is near.
- It is the same for a gene. It is easier to find the gene if it is associated with a marker that you can find and easily manipulate.

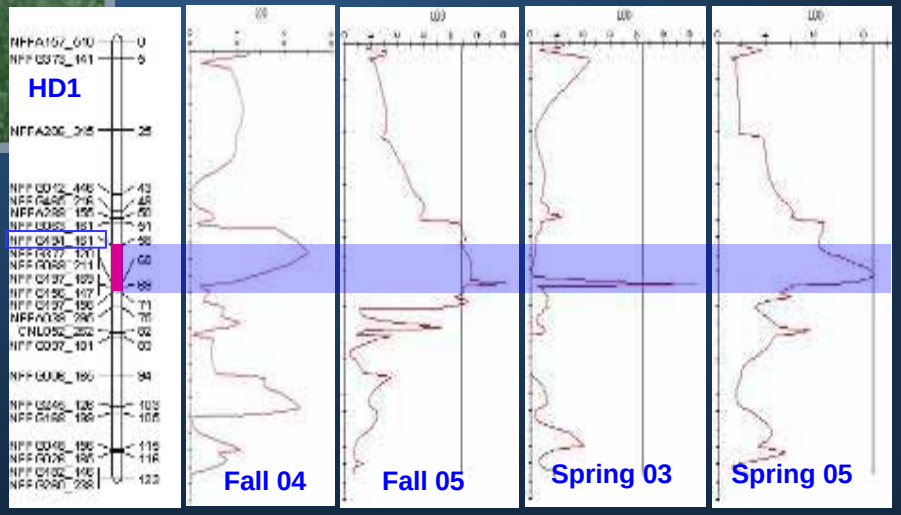


Example: Improving Forage Digestibility in Fescue

Objectives

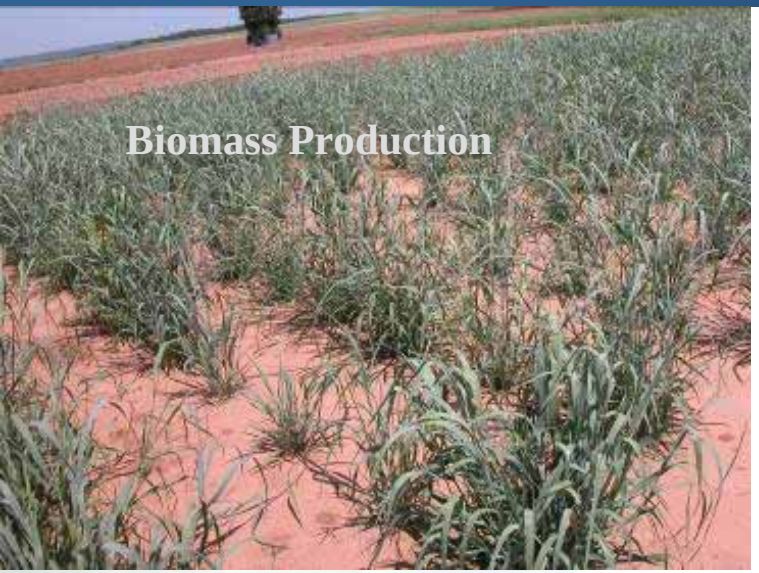
To detect digestibility genes and markers associated with them for routine marker-assisted selection (MAS)

- A 1% increase in digestibility leads to a 3.2% increase in average daily live-weight gains in cattle
- This would also have a similar effect for ethanol fermentation



Forage digestibility genes identified on chromosome 1 (HD1) at marker NFF131_151. We can now select for this trait based on the marker.

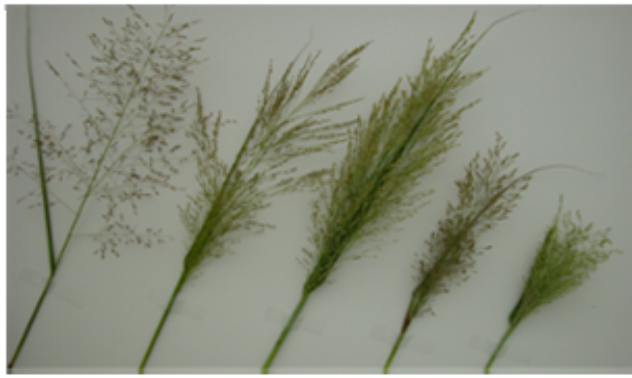
Traits to be Mapped in Switchgrass

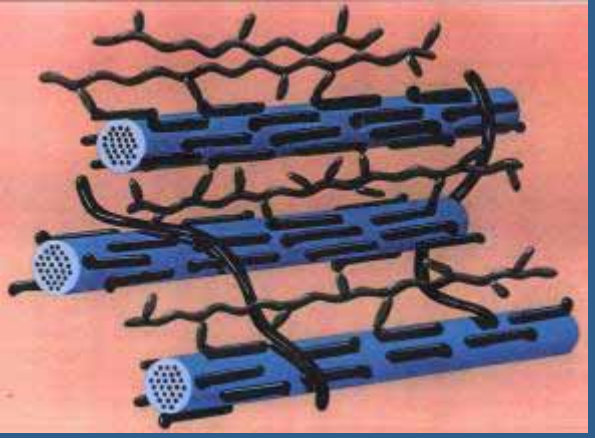



Profuse flowering


Bluish stem and leaf


Early vs late senescence

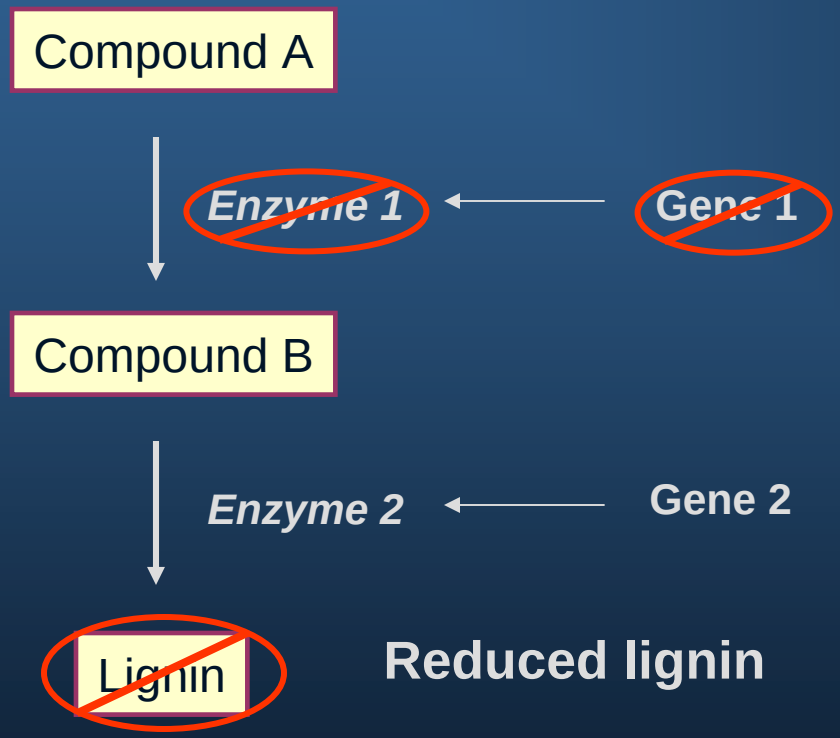

Variability in inflorescence



Reducing Lignin Content via Biotechnology

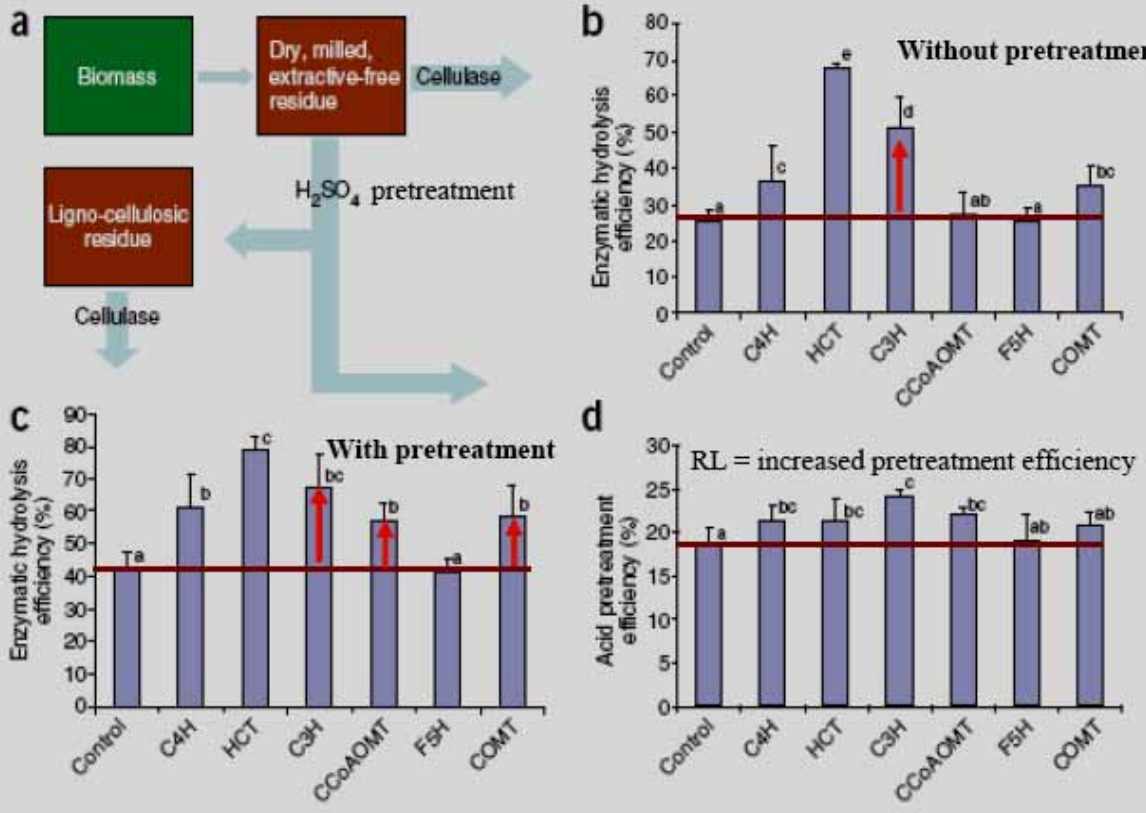
- Lignin content increases with advanced maturity in grasses.
- Lignin is indigestible, and binds with cellulose – reducing fiber digestibility.
- Reducing lignin content should increase fiber digestibility and fermentation.
- Genetic engineering can be used to reduce lignin content in plants

Gene knockout to modify lignin pathway



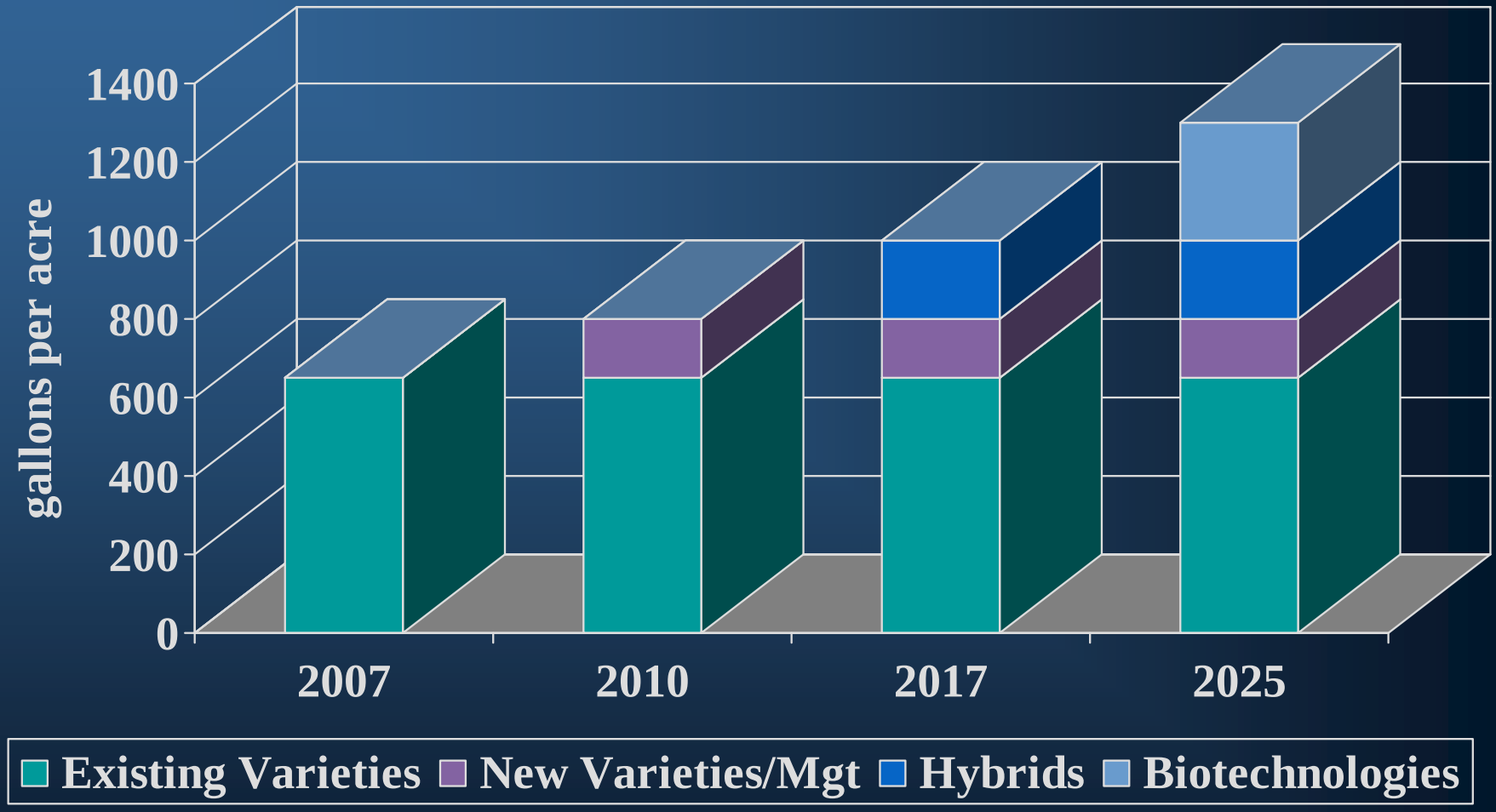
Use genetic engineering, genes controlling lignin production were “knocked out”

Lignin modification improves fermentable sugar yields for biofuel production



Chen and Dixon, 2007

Summary: Achieving the Ethanol Yield Goals for Switchgrass



Assumption: 1 ton of biomass = 100 gallons of ethanol

African Proverb

- When the gazelle wakes up, he knows he must run faster than the fastest lion.
- When the lion wakes up, he knows he must run faster than the slowest gazelle.
- So, whether you are a lion or a gazelle,
- When the sun comes up, you better be Running!

From “The World is Flat” by Thomas L. Freidman