Challenges and Opportunities of Perennial Biomass Cropping Systems

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Water quality
Tile drainage and hypoxia
What about Miscanthus?

2 to 5 years to reach maturity, **but** 12 to 25 years before replanting

Very low N requirement, excellent retention
- only 25 lb N/acre harvested in IL trials

<table>
<thead>
<tr>
<th>County</th>
<th>dry tons/acre/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>2 – 7</td>
</tr>
<tr>
<td>Britain</td>
<td>4 – 7</td>
</tr>
<tr>
<td>Switzerland</td>
<td>6 – 8</td>
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<tr>
<td>Germany</td>
<td>2 – 13</td>
</tr>
<tr>
<td>Spain</td>
<td>6 – 15</td>
</tr>
<tr>
<td>Italy</td>
<td>13 – 14</td>
</tr>
<tr>
<td>Greece</td>
<td>12 – 20</td>
</tr>
</tbody>
</table>

Lewandowski et al., Biomass & Bioenergy 19:209

150-bushel corn crop = 3.5 t/acre stover
(not all harvestable)
Potential benefits

Excellent reductions in soil erosion
Excellent soil carbon improvement
Fair to excellent wildlife habitat
Low inputs required after fully established
Implications for water quality and flow

Compared to corn:

• Perennials will reduce nitrate losses through tile drainage

• Switchgrass may reduce total flow, but may not

• Miscanthus likely to cause large decreases in flow
  – Low stream flow in late summer and fall
  – Less dilution of riverine nitrate
Potential problems

- Long rotation – reduced flexibility
- Yield loss (>30%) if harvest delayed until spring (Adler et al., Agron. J. 98:1518)
- Weed control during establishment of mixtures
- Low yields in first few years
  Multi-site SG study: 0.4, 2.5, 3.2, 4.2 t/a in years 1 to 4 (Perrin et al., 2006)
- Lower winterhardiness with harvest stress?
- Increasing disease incidence?
An Alfalfa Biomass System

- CO₂
- Leaves
- N₂
- Manure
- Stems
- Soil
- Ash
- Monitoring station (fuel pump)
An Alfalfa Biomass System

CO₂

Manure

Leaves

N₂

Water quality

Soil

Stems

Ash

Several value-added products
An Alfalfa Biomass System

- CO₂
- Manure
- Leaves
- Stems
- Soil
- Ash
- N₂
- Sunlight
- Fuel (E85)
Alfalfa is not a new crop

Established infrastructure

– Private and public plant improvement
– Private seed production and marketing
– Variety testing
– Extension Service / crop consultants
– Machinery manufacturers
– Transportation
Alfalfa is widely adapted in the USA
2002 Agricultural Census

21 million acres  72 million tons  $7.5 billion as forage

United States: Alfalfa Hay

Yellow numbers indicate the percent each state contributed to the total national production. States not numbered contributed less than 1% to the national total.

Note: Counties shaded in gray contain data that are not published by NASS, and hence were not used in delineating the major and minor agricultural areas. Additional information on these agricultural areas can be found at: http://www.nass.usda.gov/census/.

- Major areas combined account for 75% of the total national production.
- Major and minor areas combined account for 99% of the total national production.
- Major and minor areas and state production percentages are derived from NASS 2002 Census of Agriculture data.
Declining alfalfa acreage

Consolidation of livestock industry

Changing feed practices

(increased corn silage & soybean meal)

In the past 50 years alfalfa declined by 136,000 acres annually

USDA-NASS
Input cost trends

Midwestern USA

Relative price

- Diesel
- Alfalfa seed
- Corn seed
- Soybean seed
- Urea fertilizer

USDA-NASS
Compatibility with corn

- Nitrogen credit
- Residue cover
- Erosion control
- Aesthetics
- Wildlife habitat
Symbiotic $N_2$ fixation

- *Sinorhizobium*
  - Dazzo & Wopereis, 2000
  - Root hair curling around rhizobia

- Bacteroids filling a single cell
  - Vance et al., 1980

- Bacteria reproduce in infection threads
  - Gage and Margolin, 2000

- Alfalfa root nodule
  - M. Barnett
Fixation rates:

Alfalfa  40 to 400 lb N/acre  mean=135 lb N/acre

Soybean  0 to 165 lb N/acre  mean=75 lb N/acre
Fertilizer N replacement value and other rotation effects

Yield benefit
$30 to 60/acre
Lower fertilizer N required (2 yr)
$75 to 150/acre
No insecticide required (1 yr)
$15/acre
Total
$120 to 225/acre

Mallarino et al., 2005
Fertilizer N cost was 22% of total cost of corn production in 2005

Average farm price for fertilizer N in the North Central Region
Alfalfa and livestock manure

- Large nutrient removal
- Limits nitrate leaching
- Limits runoff
- Opportunity for summer applications
Alfalfa builds soil C and N

Maximum N benefit after 1 to 3 yrs of alfalfa

100 to 190 lb N/ acre fertilizer N replacement value
Alfalfa:
- Deeply rooted
- High yield potential
- High nitrate uptake
- Long growing season

Improved water quality from tile drained soils

Nitrate loss from tile drains

Randall et al., 1997
Ground water vulnerability

Nitrate in the Ogallala aquifer

Protected ground water quality

Nolan et al., 1996

Public drinking water limit

Taylor and Bigbee, 1973
Removal of excess nitrate
Salinity control in arid regions
Alfalfa enhances wildlife habitat

Example: Alfalfa in California

> 27% (182 species) of all resident and migratory terrestrial wildlife (mammals, birds, amphibians, and reptiles) use alfalfa for **cover, feed, or reproduction**

> ~1000 species of insects, mites, spiders, and their relatives live in alfalfa fields

D.H. Putnam et al., 2001
One-pass separation of leaves and stems is feasible.

90% leaves
27% protein
20% fiber

90% stems
13% protein
50% fiber

K. Shinners, U WI
Alfalfa for biomass – ARS & U of MN research

• Early 1990s
  – Integrated gasification combined cycle process
  – Stems for energy, leaves for feed
• Early 2000s
  – Reduced harvest frequency
  – Thick stems
    (plant breeding, management)
  – Disease and insect resistance

➢ *Doubled stem yield, equal leaf yield*

• Currently
  – from genes to plants to fields
Alfalfa – a crucial crop for the biomass feedstock portfolio

- Multiple benefits
- Multiple products
- Knowledge base
- Infrastructure

Needs

- Variety development
  - Yield of stems and leaves
  - Carbohydrate components
- New management systems
  - Shorter rotations
  - More rapid establishment
- Measurement of impacts
  - Economics
  - C and greenhouse gas balance
  - Water quality
  - Fertilizer N credit