Alfalfa: A Companion Crop with Corn

Hans Jung
USDA-Agricultural Research Service
St. Paul, MN
Why Alfalfa/Corn Short Rotations?

• National bioenergy goals require massive amounts of biomass.
• The Midwestern Corn Belt cannot be excluded if required biomass supply is to be achieved.
• Bioenergy must be an additional product of agriculture – cannot reduce food and feed supply.
• Alfalfa/Corn Short Rotations offer the potential to maintain food and feed production while providing a sustainable cellulosic biomass supply … without plowing more acres.
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U.S. Midwest Corn Belt
2009 Crop Harvest (millions of acres)

Corn – 71 million acres; Soybean – 61 million acres; Alfalfa – 12 million acres
Economic Advantages of an Alfalfa/Corn System

- Alfalfa is an established crop (21 million acres, $8 billion in 2009) with excellent infrastructure (seed, equipment, experience).
- Alfalfa can provide protein feed for livestock (leaves) and cellulosic biomass (stems).
- Alfalfa supplies own N fertilizer and could provide about 75% of N needed by following 2 yrs of corn.
- Corn grain yields are 5 to 15% higher following alfalfa than after soybean.
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• Reduced greenhouse gas emissions because of N fixation in place of fertilizer.
• Reduced soil erosion because of early spring and fall ground cover and less frequent tillage.
• Reduced nutrient run-off into surface water and leaching into groundwater because of less N fertilizer and soil erosion reduction.
• Greater carbon sequestration by deep rooted alfalfa.
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• Greater **carbon sequestration** by deep rooted alfalfa.
History of Alfalfa for Bioenergy

• From 1993 to 2000 Univ. of Minnesota and USDA-ARS partnered with Minnesota Valley Alfalfa Producers, Northern States Power, and DOE.

• Project to produce 75 MW of electricity from alfalfa stems and leaf meal protein feed.

• Favored crop rotation was 2 yrs corn, 1 yr soybean, 4 yrs alfalfa.

• Project signed Power Purchase Agreement prior to collapse.
History of Alfalfa for Bioenergy
(continued)

• Important lessons learned:
  – Corn/soybean farmers willing to add alfalfa to crop rotation.
  – Alfalfa hay can be easily separated into leaf and stem fractions.
  – Leaf meal can substitute for soybean meal as protein feed for dairy and beef cattle.

• Rotation must be shortened and simplified:
  – Yield differential between corn and other crops is too large.
  – Alfalfa must replace or exceed soybean protein and bioenergy yields.
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How Would Alfalfa/Corn Rotation System Function?

• Alfalfa grown for 2 yrs (seeding yr and one full production yr).
• Alfalfa harvested two to four times annually from June to September.
• Two yrs of corn would follow alfalfa with reduced N fertilizer application.
• A portion of corn stover would be harvested for bioenergy - C sequestration by deep-rooted alfalfa may allow for more corn stover removal.
• Alfalfa would be fractionated into leaf protein product for livestock feed and stems for bioenergy.
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How Does Corn/Alfalfa Compare for Ethanol and Protein Yield?

**Minnesota Example**

- Corn yield (2005 to 2009 average) was 164 bu of grain/acre (stover yield approximately equal).
- Soybean yield was 42 bu/acre.
- Alfalfa hay yield was 3.2 ton/acre (leaf fraction 40 to 60%).
Assumptions for Ethanol Yields

• 2.8 gal ethanol and 17 lb DDGS per bu corn.
• 1.4 gal biodiesel and 47.5 lb SBM per bu soybean.
• 1 gal biodiesel is energy equivalent to 1.621 gal ethanol.
• 15% of total corn stover is cob and 50% of alfalfa is stem.
• Used maximum hexose and pentose for cellulosic feedstocks and NREL theoretical ethanol calculator.
• 75% conversion efficiency of theoretical ethanol yields.
## Per Acre Yields

**Minnesota Example**

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<tr>
<th>Species</th>
<th>Ethanol Gal/Acre</th>
<th>Protein Tons/Acre</th>
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<tbody>
<tr>
<td>Corn (grain)</td>
<td>459</td>
<td>0.42</td>
</tr>
<tr>
<td>Corn (½ stover)</td>
<td>192</td>
<td>0</td>
</tr>
<tr>
<td>Soybeans</td>
<td>96*</td>
<td>0.50</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>115</td>
<td>0.44</td>
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* Ethanol energy equivalent of biodiesel.
## Cropping System Yields
### Minnesota Example

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<th>Ethanol Gal/Acre</th>
<th>Protein Tons/Acre</th>
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<tbody>
<tr>
<td>Corn/Soybean</td>
<td>373</td>
<td>0.46</td>
</tr>
<tr>
<td>Corn/Corn</td>
<td>618</td>
<td>0.40</td>
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<tr>
<td>Corn/Alfalfa</td>
<td>399</td>
<td>0.44</td>
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*a* All systems assume 50% corn stover removal.

*b* Assumes 5% corn yield reduction vs. corn/soybean.

*c* Assumes 5% corn yield increase over corn/soybean.
Biomass-Type Alfalfa + Biomass Management Doubles Ethanol Yield

Production System

- Hay: +40%
- Biomass: +99%

Impact of Improvements to Corn/Alfalfa System

C/S  C/C  C/A  C/A+  C+/A+

Cropping System

Ethanol Yield (gal/acre)

+ 15%  + 24%

Biomass Alalfa  75% Stover Removal
<table>
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<th>System</th>
<th>Gal/Acre</th>
<th>Acres</th>
<th>Land Area*</th>
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<tr>
<td>Corn/Soybean</td>
<td>192</td>
<td>260381</td>
<td>26 (52)</td>
</tr>
<tr>
<td>Corn/Corn</td>
<td>182</td>
<td>274084</td>
<td>27</td>
</tr>
<tr>
<td>Corn/Alfalfa</td>
<td>159</td>
<td>315410</td>
<td>31</td>
</tr>
<tr>
<td>Corn/Alfalfa+</td>
<td>216</td>
<td>231232</td>
<td>23</td>
</tr>
<tr>
<td>Corn+/Alfalfa+</td>
<td>267</td>
<td>187519</td>
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* 25 mile radius (1.257 million acres), assumes 80% of land available for cropping.
Annual Distribution of Biomass Harvest

• In a corn stover-only system, all biomass harvesting is in October/November – requires 10 month storage capacity.

• Alfalfa is harvested during the summer– approximately 40, 30, and 30% of total yield in June, July, and August harvests.

• An Alfalfa/Corn system could reduce storage capacity requirements by 30%.
Bioenergy Yields Need to be Adjusted to Net Energy Yields

- Corn bioenergy yield will be reduced in C/S and C/C rotations by energy used to make N fertilizer compared with C/A.
- Energy costs of cellulosic ethanol are greater than starch ethanol or biodiesel conversion – impact will vary among rotations.
- Energy costs for cellulosic biomass storage will be greater for C/S and C/C than C/A rotation.
- Energy needed for tillage every year for C/S and C/C rotations compared with 25% less for C/A – but benefit off-set by more frequent alfalfa harvests.
Livestock Response to Feeding Alfalfa Leaf Meal

• Successfully replaced SBM as a protein source for calves, lactating dairy cows, and feedlot steers.

• Successfully replaced up to half the alfalfa hay in lactating dairy cow diets.

• Better feed intake and weight gain of feedlot steers.

• May reduce incidence of liver abscess in feedlot steers at slaughter.

Nutrient Composition of Alfalfa Leaf Meal and Other Major Ingredients

<table>
<thead>
<tr>
<th>Feed</th>
<th>Protein</th>
<th>Fiber</th>
<th>Fat</th>
<th>Calcium</th>
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Summary

• Alfalfa/Corn short rotations could provide cellulosic biomass for bioenergy while maintaining food and feed production, improving the profitability and sustainability of corn production, and reducing greenhouse gas emissions.

• Converting only 10% of Minnesota’s corn/soybean rotation acreage to corn/alfalfa could supply enough cellulosic biomass to produce 300 million gal of ethanol/yr.

*How do we move this concept forward?*