<u>Alfalfa Traits that will Impact Bioenergy Production</u>

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Interest in production of energy from renewable resources such as biomass has increased tremendously with the recent price spike for oil and growing recognition of the threat posed by global warming. Alfalfa is an attractive alternative for biomass production because of its perennial nature, ability to fix nitrogen, and the possibility of fractionating the crop into stems for energy production and leaves for use as a supplemental protein feedstuff for livestock. Other frequently suggested biomass crops such as corn stover and switchgrass do not posses all of these positive attributes of alfalfa. However, there is as yet no commercial energy production from alfalfa. This presentation examines what alfalfa traits are most important for different forms of energy production. Electricity production through direct combustion or gasification is dependent on the gross energy content of the feedstock. Coal has a gross energy of approximately 16,800 kcal/kg whereas all forms of herbaceous biomass contain only 4300 to 4500 kcal/kg. Lipids have the highest gross energy concentration of any biomass component (9000 kcal/kg), but alfalfa contains little of this class of compounds. Lignin is the second most energy dense compound in alfalfa and other biomass (7000 kcal/kg); therefore, increasing lignin concentration of alfalfa stems would increase the value of this crop for electricity production. Protein and carbohydrate have substantially less gross energy (5700 and 4000 kcal/kg, respectively). Production of ethanol from fermentation of carbohydrates presents a different set of requirements. The cell wall polysaccharides represent the vast bulk of carbohydrates present in biomass. Commercial yeast strains ferment glucose and other hexose sugars to ethanol, but cannot effectively utilize the other major cell wall sugars (pentoses and uronic acids); however, progress is being made in developing microbial strains that can utilize a wider diversity of cell wall sugars. Therefore, high concentrations of cell wall polysaccharides in alfalfa stems is advantageous. Unfortunately, high cell wall polysaccharide concentrations are typically found in more mature alfalfa and increased lignin content is associated with stem maturity. Lignin impedes enzymatic hydrolysis of the cell wall polysaccharides and must be removed by harsh chemical and physical pretreatments. Removal of lignin is a major cost factor in ethanol production from biomass. Genetic reductions in lignin concentration without decreased cell wall polysaccharide content would be of great value. Alfalfa appears to require harsher pretreatment conditions to achieve similar polysaccharide hydrolysis efficiencies as observed for grass biomass. Whether this is because of the higher lignin content of alfalfa cell walls, compared to grasses, or some other structural characteristic is unknown. Separation of alfalfa into leaf and stem fractions is an important factor because this provides a valuable, high-protein leaf co-product to supplement the economic returns from energy production. Also, alfalfa's ability to fix nitrogen and accumulate large amounts of leaf protein provides an opportunity to produce industrial enzymes and other protein products through recombinant technology. Because both electricity and liquid transportation fuels are still relatively low value commodities, production of high yields of both leaf and stem material at minimal cost will probably be the ultimate determinant whether a viable alfalfa-based biomass energy system becomes a reality.