

The Potential of Alfalfa, Switchgrass and Miscanthus As Biofuel Crops in Washington

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ABSTRACT

The need for a billion tons of biomass to produce enough biofuel to replace 30 percent of USA petroleum consumption has been reported by the United States Department of Energy (DOE). The high biomass yield of alfalfa in the state of Washington along with its perennial nature and ability to produce its own nitrogen provides considerable potential for the crop as a feedstock for the production of ethanol.

Switchgrass has been identified by the DOE as a primary crop for development because of its potential for high fuel yields and its ability to grow on marginal cropland without intensive management. Breeding efforts for biomass production in the western part of the US for both switchgrass and alfalfa have been non-existent. Better adapted varieties are needed to meet the need of Washington's growers for economically producing products for cellulosic ethanol production.

Giant Miscanthus (*Miscanthus x giganteus*) is a tall perennial grass that is being grown experimentally in numerous European countries. It can be burned directly or with coal for the generation of electricity and used as a fuel for direct heating of homes and businesses. ZeaChem is in the planning stages of building a 50 million dollar cellulosic ethanol plant near the Port of Morrow in Oregon. Miscanthus could be the primary feedstock for that industry.

Columbia Basin College (CBC) is developing a program to conduct multi-year research for the development of high biomass alfalfa and switchgrass varieties for cellulosic ethanol production. In addition, CBC plans to work in the development and testing of Miscanthus as a biofuel.

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Introduction

With Washington State's renewable fuel standard designed to increase biofuel use with standards that start at 2% and ramp up to 5% for biodiesel and 10% for ethanol, investments in the design of the agricultural plant in addition to the bio-diesel plant (refinery) need to be considered. Since Washington State has suggested that the ramp up will come from feedstock produced from Washington's growers, then research is needed on crops that can be grown for biofuel at a profit. Ethanol from cellulose should be a primary consideration. Domestic ethanol as an alternative fuel can decrease dependence on foreign oil, create jobs, and reduce air pollution, trade deficits, and carbon dioxide buildup.

About one third of the harvested irrigated acres in the Columbia Basin are made up of forage crops with the majority in alfalfa. There are about 500,000 acres of alfalfa in Washington of which over 75% of the production is in the Columbia Basin (1). In the state of Washington, there are about 1.5 million acres of land in the Conservation Reserve Program (CRP) (2), almost 5 million acres in pasture or rangeland and another 2.5 million in summer fallow or idled. Much of that land could be used for the production of switchgrass or another suitable grass for biomass production.

If all the corn and soybean grown in the U.S. were dedicated to producing biofuels, they would meet just 12 percent of the nation's demand for gasoline according to Kate VanderBosch, professor of plant biology at the University of Minnesota. However, a report from the U. S. Department of Agriculture and U. S. Department of Energy indicated the production of cellulosic ethanol could displace at least 30 percent of the nation's petroleum consumption by 2030 (4).

Brazil has made ethanol from switchgrass which is more efficient than corn and Iogen Corp., in Ottawa, Canada is the first business to commercially sell cellulosic ethanol. ZeaChem is in the planning stages of building a 50 million dollar cellulosic ethanol plant at the Port of Morrow in Oregon.

ENERGY FROM ALFALFA

Because of its high biomass production, perennial nature, its symbiotic relationship with specific bacteria for producing its own nitrogen, and valuable co-products, alfalfa (*Medicago sativa L.*) has the potential of being a leading crop in the production of cellulosic ethanol. Due to the increase in the refining of corn and soybeans for biofuels, an increase in continuous row cropping with little rotation to perennial crops could increase.

The result would likely be an increased risk of soil erosion, contamination of surface and groundwater by nitrate and pesticides, and loss of valuable organic matter. More alfalfa acres for biofuel production would reduce greenhouse gas emissions, protect water quality, and improve our soils as a resource. Most importantly, it would contribute to making the United States more energy independent.

In the Columbia Basin, it is not uncommon to obtain yields of alfalfa above 10 tons per acre which are the highest yields in Northern Latitudes in the United States. When alfalfa is grown strictly for biomass with two to three cuts rather than four to five as compared to standard practices for producing dairy hay, total yield of alfalfa can increase as much as 42% and potential ethanol yield from stems doubles (7).

To maximize energy yield by reducing transportation costs, cellulosic biomass production and processing from alfalfa will need to be local. The fit is natural for the Columbia Basin when considering the high yield production by local growers. When located within 15 miles from a processing facility, the efficiency of energy production by alfalfa is 2 to 3 times that of corn grain or soybeans (Table 2).

Table 2: Comparison of Soybean, Corn Grain, Corn Stover and Alfalfa for Energy

Crop (yield)	Energy input	Delivered energy	Ratio of output:input
	Million BTU/acre		
Soybean (40 bu/a)	2.3	18.3	7.1
Corn grain (180 bu/a)	6.0	59.0	8.8
Corn stover (3.6 tons/a)	2.6	51.1	19.7
Alfalfa (6 tons/a)	3.0	78.2	25.0

Hans Jung – University of Minnesota

Although the USDA/ARS at the University of Minnesota is breeding alfalfa for ethanol production, the Midwest environment is much different from that of the Pacific Northwest (PNW). Yield potential is half of what it is in the Columbia Basin and it is grown under non-irrigated conditions. An alfalfa designed to fit a two or three cut system in the Columbia Basin will need to have large strong stems to avoid lodging under sprinkler irrigation and will need to have resistance to a number of pests that are not a problem in the mid-west.

ENERGY FROM SWITCHGRASS

Switchgrass (*Panicum virgatum L.*) is a perennial native grass adapted to the prairies of North America. The Department of Energy identified switchgrass as a primary species for development as an energy crop. It has the ability to grow well on marginal cropland without heavy fertilization or intensive management and has a potential for high fuel yields.

A recent review of the initial DOE program to evaluate and develop switchgrass as a bio-energy crop has shown its potential as an alternative to corn for ethanol production (5). The program developed a research base for improvement of switchgrass through breeding. Yield gains for switchgrass were found to exceed that of corn. In addition, the energy ratio is more favorable for switchgrass than for corn (Table 1). Although switchgrass has been grown for seed in the Pacific Northwest, breeding efforts for biomass production have been limited to the central and eastern parts of the United States. Yield gains through breeding in Washington could be even more significant.

Table 1: Comparison of Corn and Switchgrass for Energy

Component	Corn	Switchgrass
Ethanol Production	2.6 gal/bushel	80 gal/ton
Energy ratio	1.21	4.43
Net energy gain	21%	343%

McLaughlin and Kazos

In response to research needs on switchgrass in Washington, studies on switchgrass adaptability and biomass production were initiated by Washington State University in Prosser (6). Switchgrass was shown to yield over 8 tons of dry matter in young stands. Higher yields can be expected as the stands get older.

ENERGY FROM MISCANTHUS

Giant Miscanthus (*Miscanthus x giganteus*) is a tall perennial grass that reproduces by underground rhizomes and has been evaluated in Europe during the past 10 years as a bioenergy crop. Miscanthus stems may be used as fuel for production of heat and electric power and as a feedstock for the

production of cellulosic ethanol. Since the plant can get taller than 14 feet, it is speculated that 10 to 15 tons of dry matter could be harvested in one harvest in the fall, winter or early spring after dry down.

In the United States, the University of Illinois has been researching Miscanthus for about five years. The reasons for their interest are:

- Greater yields than switchgrass
- Sterile and propagated by rhizomes
- Low maintenance, perennial grass
- Long-life expectancy
- Hardy
- Nitrogen and other nutrients are moved into the rhizomes during the growing season for next year's growth
- 80 to 120 gallons of ethanol per ton of dry matter
- Energy ratio of input to output is expected to be less than 0.2
- Heat and power generation in Europe for over two decades
- Yields obtained in the U of I trials indicate that growing Miscanthus in 10% of Illinois farmland would provide sufficient fuel to produce 50% of the states electricity needs and significantly reduce carbon and sulfur dioxide emissions into the air. (8)

Research and Discussion

Alfalfa

Columbia Basin College has begun an alfalfa breeding program for both standard varieties for dairy forage and germplasm for biomass types. One advanced variety was harvested for foundation seed production in 2007 while breeder seed was produced on eight more experimental varieties. Selections for non-lodging and biomass yield were made in the field and crossed in the greenhouse. Seven thousand progeny from this cross were planted in a spaced plant nursery. Selections for tall, upright growth habit suitable for infrequent cutting management were made from the nursery and are being crossed this winter for potential new varieties targeted as feedstock for cellulosic ethanol production. Alfalfa varieties for the Columbia Basin, regardless of their use, will be selected for resistance to blue aphid, clover root curculio, Verticillium wilt, stem nematode, and root knot nematode to enhance persistence.

Switchgrass

Breeding research is currently underway at CBC to develop adapted, high-yielding switchgrass experimental cultivars for the Columbia Basin. Five thousand switchgrass plants from four high yielding germplasm were started in the greenhouse and transplanted to the field in 2007.

Because the genetics of switchgrass are such that the phenotype of the parent plant is not a good indicator of the genotype, a progeny row experiment is planned for the selection of high biomass parents for the development of a suitable high yielding adapted variety. Upland and lowland types were observed in the field in 2007. Results showed that the lowland types were variable but higher yielding. Therefore, we will focus on breeding lowland types for Washington's environment.

Establishing a good stand of switchgrass has always been a problem. The productivity in the first year is poor. Management research is needed to better establish switchgrass on non-irrigated lands. Investigation of the establishment through the use of rhizomes or tillers might prove useful for higher yields in the first year and the establishment of non-irrigated lands.

Because of its dry conditions during seed maturation, eastern Washington is known for its excellent production of vegetable, legume and grass seeds. If switchgrass becomes the grass of choice for cellulosic ethanol production, the Columbia Basin would be perfect area for producing seed. Research in methods of seed production for switchgrass is needed to capture that potential.

Miscanthus

In 2007 a single plant of Giant Miscanthus was obtained from Minnesota. The rhizomes were split to produce over 100 plants in the greenhouse and planted in the field. CBC will harvest the plants this winter and produce enough rhizomes to establish a nursery field in the spring of 2008.

CBC plans to establish a large field test to evaluate the potential of Miscanthus to utilize potato waste water. The experiment would require the cooperation of the Port of Pasco, Lamb Weston and CBC. A possible future collaboration would be with a cellulosic ethanol producer such as the planned cellulosic plant slated to be built at the Port of Morrow by ZeaChem. CBC sent samples of selected alfalfa, Miscanthus and switchgrass to ZeaChem in November of 2007 for evaluation as a cellulosic ethanol feedstock under their system of production. Their plan to build the \$50 million facility is based on the production system which utilizes an

enzyme that has been isolated from termites. Their goal is to produce 150 gallons of ethanol from each ton of dry matter.

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