ENERGY CROPS AND THEIR IMPLICATIONS FOR FORAGES

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ABSTRACT

The US Department of Energy (DOE) reports an annual need for a billion tons of biomass to produce enough biofuel to replace 30% of current USA petroleum consumption. Switchgrass is considered one of the main perennial biomass species for cellulosic ethanol production. Breeding and management research is currently underway at the Samuel Roberts Noble Foundation in partnership with Ceres, Inc. to make switchgrass a higher yielding and more fermentable feedstock. Another target is elite switchgrass varieties with less lignin deposition. Alfalfa, bermudagrass, tall fescue, clovers, and sorghum will be investigated for use in co-cropping or inter-cropping systems with switchgrass. For alfalfa, dividing the harvested product into high value leaf meal and the stems for sale to a biorefinery is an approach. If pharmaceutical co-products are simultaneously extracted from the alfalfa leaf material, the economics improves even more. The Noble Foundation's mission to improve any of these target species crops as biofuels crops should simultaneously translate to improved forage crops for range renovation or a better feed for livestock production.

Key Words: alfalfa, biofuels, biomass, breeding, ethanol, management, switchgrass.

INTRODUCTION

A recent DOE/USDA report predicts by 2030 an annual need for a billion tons of biomass to produce enough biofuel to replace 30% of current USA consumption of petroleum (Perlack et al. 2005). This report is now known as the "billion ton" report. In the report, perennial crops are reported to account for approximately 377 million tons of that annual production. By definition, perennial crops would include all forages and even trees. They are also known as "dedicated energy crops".

BIOMASS TO BIOFUELS

Biofuels include ethanol, biodiesel, and other hydrocarbons achieved either through a fermentation or gasification process using biomass as a "feedstock". However, this current discussion will concentrate mainly on forages for use as cellulosic feedstock to produce ethanol. It is these ethanol cropping systems that are highlighted in the billion ton report as well as many recent newspaper and magazine articles.

Ethanol is "ethyl alcohol," commonly called grain alcohol. The majority of ethanol produced today in the U.S. is made from corn grain with a smaller percentage made from sorghum.

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Cellulosic ethanol is ethanol produced from cellulosic material (e.g. all plant parts especially stems, leaves, seedheads, etc.). Cellulosic feedstocks are generally comprised of three components cellulose (~44%), hemicellulose (~30%) and lignin (~26%). The cellulose and hemicellulose provide a rich supply of carbohydrates that are ultimately used to produce ethanol. Sources of cellulosic material include switchgrass, wood and wood residue, and crop residues such as corn stover and wheat straw. However, ethanol produced from any feedstock, corn grain, switchgrass, wheat straw, etc. is all chemically identical.

Based on current estimates, cellulosic feedstocks are far better than grain in producing ethanol. Cellulosic feedstocks are estimated to produce approximately 5 times more energy that corn grain. Further, cellulosic feedstocks are intended to have a broader range of adaptability to poorer soils, which would allow them to be grown in regions that cannot support large-scale corn production.

The technology to create cellulosic ethanol is becoming closer to reality. Many companies world-wide are in the later stages of development and entering the early stages of commercial scale-up into ethanol plants (also called biorefineries). Though most of the pieces are in place, the key is to continue to make it more cost-effective and economically competitive.

A biorefinery produces fuel-grade ethanol, and that ethanol is then blended in a percentage with gasoline to make a finished motor fuel. Commonly, we hear about E10 (10% ethanol / 90% gasoline) and E85 (85% ethanol / 15% gasoline). It is unlikely U.S. vehicles will run on pure ethanol anytime soon.

At this time, there are not many service stations selling fuel grade ethanol at the pump. This is one of the national issues concerning its use and adoption. There are less than a 1,000 outlets – gas stations and convenience stores – that sell ethanol in the U.S., out of more than 150,000.

SWITCHGRASS AS A BIOENERGY CROP

Switchgrass (*Panicum virgatum* L.) is a perennial grass native to the prairies of North America. Switchgrass was identified by the DOE as a primary target for development as a dedicated energy crop because of its potential for high fuel yields, drought tolerance, and ability to grows well on marginal cropland without heavy fertilizing or intensive management.

The initial DOE program to evaluate and develop switchgrass as a bio-energy crop was recently reviewed and demonstrated its potential as an alternative to corn for ethanol production and as a supplement for coal in electricity generation (McLaughlin and Kszos, 2005). The program identified the best varieties and management practices to optimize productivity, while concurrently developing a research base for long-term improvement through breeding and sustainable production in conventional agro-ecosystems. Gains through plant breeding were found for switchgrass yield to exceed that of corn. Significant carbon sequestration was projected for soils under switchgrass that should improve both soil productivity and nutrient cycling. Co-firing switchgrass with coal will also reduce greenhouse gas production. Finally, collaborative research with industry included fuel production and handling in power production, herbicide testing and licensing, release of new cultivars, and genetic modifications for chemical co-product enhancement.

OTHER FORAGES AS FEEDSTOCK

The main criteria for any biofuels crop are high yields achieved with low input costs in an environmentally friendly manner. This is why switchgrass is a very good crop. By this definition, the traditional, high yielding forages like bermudagrass, tall fescue, red and white clover, and alfalfa are also good candidates. However, the requirement of low cost of the delivered feedstock, possibly as low as $40-50 per ton, is the greatest hurdle for growers of these crops to overcome.

In order for alfalfa to be used, this means dividing the harvested product into components, such as leaves and stems, and using the leaves to produce high value meal and the stems for sale to a biorefinery. If co-products such as pharmaceuticals are simultaneously extracted from the leaf material, this allows the economics of using alfalfa as a biofuel crop to work even better.

It is possible that each specific geographic region will have its own cropping system(s) based on several adaptive crops to supply a local biorefinerary. So, co-cropping alfalfa or tall fescue with switchgrass to achieve an off-season supply of biomass, or inter-cropping switchgrass with alfalfa or clovers to supply nitrogen into the production system are good examples of how this could work.

THE NOBLE FOUNDATION'S BIOFUELS RESEARCH PROGRAM

In June 2006, the Samuel Roberts Noble Foundation (NF) and Ceres, Inc., a California biotechnology company, announced a long-term relationship for the purpose of developing feedstocks for a growing bioenergy industry; especially that part of the industry dedicated to ethanol production. As a consequence of this announcement, breeding and management research is currently underway at the Foundation to make switchgrass a higher yielding and more chemically acceptable feedstock. In addition to producing higher biomass types, variety development is underway for less lignin deposition, better drought tolerance, and improved establishment characteristics. These traits increase the crop's economic value as a bio-energy crop especially in lands marginal for corn production.

As part of the DOE initiative mentioned above (McLaughlin and Kszos, 2006), a breeding program at the University of Georgia (UGA) developed adaptive, high-yielding switchgrass experimental varieties for biomass production in the southern region. These experimental cultivars, NF/GA991, NF/GA992, NF/GA993, and NF/GA001, were in-licensed into the Noble Foundation's Forage Improvement Division. Initial performance results of NF/GA 993 demonstrated a 23% average yield enhancement over the best available variety, Alamo. This type of performance warranted release and commercialization of this variety for the entire southern region. Therefore, seed production was begun on NF/GA 993 in partnership with Ceres with commercial sales projected for 2009.

The population improvement approach used to produce NF/GA 993 is used to develop new experimental synthetic cultivars. However, switchgrass is highly self-incompatible allowing hybridization from simple mutual or isolation crossing. High heterosis is found when single cross hybrids were made from specific, clonally replicated genotypes. Clonal replication using tissue culture is also possible for large scale production of the individual genotypes which should allow their use in a commercially viable seed production program. These three characteristics demonstrate the potential is high for developing high yielding single cross hybrids of switchgrass.

There have always been problems establishing good stands of switchgrass. Even when plants emerge, their productivity during the initial year is very poor. The reason for this is not readily apparent. Recent experiments continue to show a need for using pre-plant and post-plant herbicides, especially when using no-till methods, to give more productive stands. Management research to better establish switchgrass is therefore continuing. Other research problems to be investigated via management research are inter-cropping and co-cropping with other traditional forages as mentioned above.

Although the main trait of interest for the breeding program is biomass yield, specific value added traits such as forage chemical aspects that affect biomass feedstock quality are also being investigated. Due to the difficult nature of these traits, biotechnologies are used to improve them.

Molecular markers are powerful tools for genetic mapping, genotype fingerprinting, population structure and genetic diversity studies. Regular use of molecular markers for breeding and other applied research in a plant species depends on development of a large number of markers for the species of interest. However, a very limited number of molecular markers are currently available for switchgrass. As part of the research project with Ceres, a comprehensive molecular marker system will be generated for switchgrass and then used for selection of important traits such as those that affect drought tolerance, chemical composition, and storage aspects.

Finally, Rick Dixon and his laboratory in the Foundation's Plant Biology Division were very successful in manipulating lignin composition and levels in alfalfa through transgenic technologies to improve its digestibility. The issue – and the bottleneck in supplying cheap ethanol from cellulosic feedstocks – is gaining ready access to the cellulose and hemicellulose. The obstacle is lignin. As lignin is responsible for a plant's structure, strength and rigidity, lignin naturally encompasses the plant's cellulose and hemicellulose. Because lignin is so effective serving its primary role – as the "scaffolding" within each plant – it has increased the cost for efficiently accessing cellulose and hemicellulose for fermentation into ethanol. Lignin manipulation techniques created in the Plant Biology Division should allow development of plants capable of producing ethanol much more efficiently and cost effective.

WHEN WILL FARMERS GET INVOLVED?

Farmers will choose to grow dedicated energy crops such as switchgrass based on simple economics. The on-farm value of these crops is determined by a combination of variables including market demand, input requirements and costs, government support programs, and the alternative use of the land, for example, cattle production. Despite years of research and the development of improved biofuels feedstocks through government research programs, little has been done to definitively establish these economics.

The Noble Foundation's Agricultural Division will take the lead in looking at many of these issues for at least the Agricultural Division's service area. This is a critical project that will ultimately help define the likelihood of this industry coming to southern Oklahoma and North Texas. More importantly, it will lay the foundation for producer education in the service area and beyond.

The mission of the Foundation's Forage Improvement Division remains the same: "To develop improved forage cultivars for the southern Great Plains, and in the process, advance the science of plant improvement." An excellent research team has been assembled that will continue to focus on the development of improved forages – it is this model that has enabled us to advance the science of forage improvement into the bioenergy area.

Therefore, the Foundation's work in bioenergy crops will continue to focus switchgrass, but also on those crops that have a dual purpose for us – forages and bioenergy. In addition to switchgrass, this may include alfalfa, bermudagrass, tall fescue, clovers, and sorghum. At the end of the day, our work to improve switchgrass – or any other of our target crops – for bioenergy will hopefully also translate to an improved crop for range renovation or a better feed for livestock production.

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