Perennial Warm Season Grasses for Bio-fuels

REAP-Canada is undertaking a second major bio-energy research project, the evaluation and development of warm season grasses as bio-fuel feedstocks.

What is the difference between cool and warm season grasses?

The major advantages that warm season grasses have over cool season grasses (e.g. timothy or reed canarygrass) are higher carbon fixation rates and higher N and water use efficiency. Further, warm season grasses (as bio-energy feedstocks) have advantages over trees in the following ways:

1. Greater moisture use efficiency, which makes a much larger land base available for their production (i.e. the Canadian prairies). In many parts of Canada, adequate soil moisture is the most important factor for biomass production.

2. Lower cost of production: currently, native grass hay is being sold for less than $30/tonne on the Canadian prairies, while studies estimating the lowest costs from wood energy plantations are approximately 50% higher.

3. A more efficient carbon sink, as trees lose approximately one third of their annual dry matter accumulation when the leaves drop, with most of this carbon material being oxidized. Warm season grasses, through their enormous root systems, are more efficient than trees in accumulating carbon in soil. Carbon accumulation in soil organic matter is more important than carbon accumulation in standing biomass (i.e. above and below-ground living plant material). The richest soils in North America are those which originated from the root system of the tallgrass prairie, which can reach ten feet in depth. From a CO2 standpoint, warm season grasses have the potential of being not only a more efficient means to off-set the greenhouse effect, but cheaper than trees as well.

Native vegetation

One way of assessing which species hold the most potential for various areas is to classify species by how they fit into various prairie plant communities by soil moisture gradients. Ecologists have been working for the past century to classify prairie plants within prairie communities as they were found at the time of settlement.

A basic breakdown of prairie communities includes 5 groups. Promising biomass species which are typically associated with these communities in native stands are listed below within these communities.

In these prairie communities, these plants evolved over a period of 30,000 years to be exceptionally well adapted. In many instances, the species are also found in the other types of prairies but not to the same extent and mainly with neighbouring communities.

In studies of prairie communities, biomass productivity is highest in the wettest prairie areas with species reaching 6-10 feet in height while species in dry prairie areas reach only half that height in favourable years. If biomass productivity is the goal, planting the higher biomass producing species outside of their traditional range may provide optimal biomass productivity over a shorter time period (e.g. 30 years).

Just because a species has not been the dominant climax species in a particular prairie region does not mean that it will not be very successful over a 5-50 year lifespan in a seeded field. For example, switchgrass has been so successful in prairie plantings on mesic prairies in the mid-west U.S. that it is no longer being recommended by some ecologists for inclusion in prairie plantings.

Even though a mixed tallgrass prairie is seeded, the resulting stand becomes a switchgrass monoculture because of the species' strong competitive ability compared to most prairie plants. Switchgrass is also proving to be the early winner in biomass production trials through much of the U.S. corn belt and in regions receiving less than 14" of rainfall in the Northern Great Plains.

For some conservationists, a monoculture switchgrass stand is too dense and lacks the diversity and openness required for optimal wildlife habitat provided through the diversity of forbs (???)

and a mixed tallgrass prairie. Compared to conventional annual grain cropping and summerfallow, however, perennial biomass crops with a late harvest date will be a wildlife haven and will be appealing to farmers looking for diversification away from annual grain production through the most efficient soil building crop.

Ultimately, a number of species need to be developed to maximize biomass production in the various types of prairie environments. Mixtures will undoubtedly have to be used in many instances, particularly on marginal lands where variable field drainage exists. Mixtures will also provide greater stability against disease and pest problems, as well as the previously mentioned improved wildlife habitat.

Developing a number of feedstock varieties will prove to be not only more ecologically stable but will probably provide a more continuous supply of feedstock to the energy conversion plants. Therefore, introduced species should identified for their biomass potential as well as native ones. Europe's most promising biofuel crop is Elephantgrass, which is an introduced species from Northern China and

Japan, which has shown tremendous biomass productivity and is being evaluated for both energy and fiber markets.

The two main potential energy markets for the warm season grasses are:

1. Ethanol production: where the grass is exploded using steam, then through enzymatic hydrolysis and fermentation converted into ethanol. Lignin is a by-product of the ethanol conversion process, which can be mechanically de-watered and burned to generate the steam and electricity for the entire conversion process.

2. Electricity and steam generation: where grasses replace straw as a feedstock for direct combustion in batch and continuous burn systems (potentially providing a cheap energy source for industries and heating in rural communities).

Species will have to be evaluated to determine their suitability for the various conversion processes. For combustion purposes, it would be most desirable to find species which have a high ash melting point (in straw conversion, melting of ash is a major constraint to efficient operation of conversion plants).

Summary of Canadian Candidate Biomass Species

Big Bluestem (Andropogon Gerardii)

Advantages: native range is farther north than most native warm season grasses, was once the dominant of the tallgrass prairie.

Disadvantages: slow establishment, difficult to seed, high seed costs.

Little Bluestem (Andropogon scoparious)

Advantages: better adapted to dryer regions than tallgrasses.

Disadvantages: slow establishment, difficult to seed, high seed cost.

Elephantgrass: (Miscanthis sinensis)

Advantages: extremely high productivity.

Disadvantages: establishment by rhizomes creates high establishment costs, potentially weedy. (???)

Indiangrass: (Sorgahastum nutans)

Advantages: may be most N efficient biomass candidate species.

Disadvantages: native range is more southern than the other warm season grasses, which results in some winterhardiness and establishment problems (but not as problematic as the bluestems).

Prairie Cordgrass: (Spartina pectinata)

Advantages: very high productivity on wetter sites.

Disadvantages: some seed quality problems.

Prairie Sandreed (Calamovilfa longifilia)

Advantages: probably the highest biomass producing species for dry sandy sites.

Disadvantages: persistence may be a problem on heavier soils, may have a high ash content.

Switchgrass: (Panicum virgatum)

Advantages: probably the best warm season grass for establishment, well documented productivity, best agronomically researched warm season grass and wide number of commercial releases available; significant amount of U.S. Department of Energy research work already carried out on species.

Disadvantages: does not perform well in low rainfall areas.

Major questions which need to be addressed?

1. What species are best suited for what regions and types of soil? How can they be best utilized for energy?

2. How to best maintain year-round feedstock supply - bale material in the fall or use stiff stalked species which will over-winter and enable spring harvest?

3. Will perennial polyculture systems out-yield perennial monoculture systems on high producing land? On marginal soils?

4. Which strategies will minimize nitrogen extraction and optimize the energy balance (late fall harvest, spring harvest or through use of most N efficient species)?

5. What species, mixtures and harvest management will most benefit wildlife?

6. Since soil moisture and humidity are critical to biomass accumulation, which strategies will be most efficient at optimizing biomass accumulation - spring harvesting prior to the next season's growth in dryland areas to enable reduced surface transpiration and optimal snow trapping? Or, use of field shelterbelts to reduce drying effects of wind?

7. How much more efficient are warm season grasses than trees as bio-fuels in CO2 sinking and reduction?

8. Can field shelterbelts and spring residue burning increase soil temperatures and subsequent warm season grass growth? Will this enable warm season grass production to be moved northward?