CHAIRS' SUMMARY PAPER: Alternative Uses of Forages

E. Coxworth[1] and D. I. Bransby[2]
[1] Consultant, 1332 10th St. E., Saskatoon, Saskatchewan, Canada. S7H 0J3
[2] Dept. of Agronomy and Soils, 202 Funchess Hall, Auburn University, Auburn, AL 36849, U.S.A.

There were two invited keynote papers:

1. Forage Crops as Bioenergy Fuels: Evaluating the Status and Potential. S.B. McLaughlin of the Oak Ridge National Laboratory discussed energy and industrial feedstock research on forages and other biomass feedstocks in the U.S.A. Development of the ability to utilize forages for these applications could provide new sources of income for farmers, reduce degradation of soils, lower U.S. dependence on foreign oil supplies, reduce emissions of greenhouse gases and toxic pollutants to the atmosphere. This potential could only be realized if there were simultaneous development of high yielding, low cost biomass production systems and bioconversion technologies that efficiently converted biomass raw materials into forms usable by industry.

McLaughlin's paper reviewed the many routes being evaluated to convert biomass (including forages) into liquid fuels, gaseous fuels, electricity and a variety of chemical products. One promising new route involves thermal conversion of forages into a mixture of hydrogen and carbon monoxide, followed by use of microorganisms in reactor cells to convert these gases into liquid fuels and chemical products such as solvents.

One of the most promising forage crops for these applications is switchgrass (*Panicum virgatum L.*), a tall C_4 grass native to the tall grass prairie ecosystem of North America. Considerable land is expected to be available in the U.S.A., surplus to the land anticipated to be needed for future food and feed markets, to grow enough switchgrass, and other biomass crops, such as fast-growing willow and poplar, to make a significant contribution to U.S. needs for fuels to generate electricity and feedstocks to produce liquid fuels (e.g., ethanol). One of the appeals of forages and fast growing trees is that they can be grown on poorer quality land not suited for annual crops grown for food and livestock feed.

A major program in the U.S.A. determined costs of production and identified the best locations for switchgrass production for energy purposes. The southeastern United States was identified as one of the more promising regions, with the lowest costs of production (U.S.$31-35 Mg^{-1}). Yields in test plots have averaged 16 Mg ha^{-1}. An active breeding program is underway to improve yields and select for forage properties better suited for bioenergy applications. Economic studies have indicated that there are a number of sites where switchgrass production could be competitively profitable to farmers while obtaining a price per tonne low enough to appear attractive to processors for energy applications.

The United States has low energy prices compared to western Europe. A modest subsidy, to reflect the environmental advantages of bioenergy, might be helpful to encourage bioenergy developments. Another approach is to allow the harvesting of perennial grasses, such as switchgrass, from Conservation Reserve Program (CRP) lands (set aside from current annual crop production).

2. Grass Species as Raw Material for Pulp and Paper. K.A.Pahkala, of the Agricultural Research Centre of Finland, reviewed pulp and paper applications of forage grasses. China is by far the largest user of non-wood species at the present time. Reed canary grass (*Phalaris arundinacea L.*) was identified as the most promising species for applications in Finland and Sweden.

The best time of harvest was determined to be early spring. The mature crop was left standing uncut in the field over winter and harvested the next spring in April and May. Although there were yield losses in next spring harvest, compared to fall harvest, there were a number of advantages: reduced drying costs, reduced content of ash (due to leaching losses overwinter) and reduced content of pulp short fibres (due to leaf loss overwinter). Spring harvested material with less ash and less short fibres had superior pulping characteristics to fall harvested material.

High ash content of forage grasses, compared to wood, was one of the main problems associated with the use of grasses for pulp and paper. The main problem with the ash content was silica, since this interfered with recovery of pulping chemicals in modern pulp mills. At the pulp mill, leaves, dust and dirt were removed from the grass hay by air fractionation, with the remaining stems being used for pulping. This mechanical pretreatment removed 40% of the silica, decreased the amount of fines and improved bleachability. Several methods have been developed for removing the remaining silica from the pulping liquors.

The specifications for forage grasses for pulp and paper applications are almost the reverse of those for traditional livestock feed markets: pulp and paper markets require low protein content, low mineral (ash) content, and high content of fiber (cellulose and hemicellulose).

Pilot plant pulping trials with reed canary grass were promising, especially if reed canary grass pulp was combined (at up to 70% of the total) with pulp from wood in the final blend for the production of paper. The blended pulp made fine quality paper comparable to regular paper made only from wood pulp.

In the introduction to this talk it was noted that pulp and paper could become a major new market for forage grasses: Finnish studies estimated that to supply 15-20% of the raw material for one large commercial pulp mill would create a demand for 100,000 tonnes of reed canary grass per year.

POSTER PRESENTATIONS

Swedish studies on pulp and paper and energy applications of forage grasses (Andersson and Lindval) have come to many of the same conclusions as Finnish studies described by Pahkala (see previous paper). While about 30% of the forage dry matter was lost by spring harvest, compared to fall harvest, much of this loss was in the form of minerals and leaf material, which cut fertilizer costs for the following year considerably.

The remaining standing grass biomass was a better material for pulp and paper applications. It was also a better material for direct energy applications. Removal of some of the potassium and chlorine by leaching (standing forage overwinter) reduced the tendency of the ash from combustion of the grass to melt at low temperatures (potassium) and for combustion to cause corrosion (chlorine).

Harvesting at as late a stage of maturity as possible also reduced ash content and increased fibre content (desirable for pulp and paper uses).

Reed canary grass varieties and populations from many locations were screened in Sweden for variations in yield, ash, silica, potassium and chlorine (Lindval, session on conservation, evaluation and utilization of plant resources). The ideal grass for industrial applications would have high yields of fibre, and low ash, silica, potassium and chlorine contents. In these Swedish screening trials there were significant differences between populations and locations in yield, ash, silica and potassium content, but no significant differences in chlorine content. It was concluded that soil type has a great influence on ash and mineral content. The differences between populations were sufficient to conclude that it should be possible to breed for low ash and mineral content. There were local populations which outyielded available commercial varieties; there are thus good possibilities to develop higher yielding varieties suited to local growing conditions.

The humid lower south of the U.S.A., located in the subtropics, has a long growing season and high rainfall; yields of energy or industrial forages can be very high (Prine et al.). Elephantgrass (*Pennisetum purpureum* Schum.) gave the highest yields at five sites in Florida and Alabama, with one variety yielding 32.1 to 46.7 Mg (d.m.)$ha^{-1}yr^{-1}$ at different locations. Also high yielding were varieties of energy cane and sugarcane (*Saccharum* spp.). Leucaena (*Leucaena leucocephala* (Lam.) de Wit) could be grown as an annual, woody biomass crop or, without freezes, 2 or more years as a short rotation woody crop (19.7 Mg woody stems $ha^{-1}yr^{-1}$). Winter temperatures set the northern limits for these high-yielding crops. It was important to plant varieties adapted to the area in which the crop was to be grown.

A study in northern Italy evaluated the energy inputs (fertilizer, fuel, etc.) and energy outputs (net energy for milk cows) of five intensive forage and grain (grain maize) production systems (Onifrii et al.). The most efficient (high output/input ratio) systems involved short rotations, included maize (corn, a C4 species) (usually as silage) and, included catch crops (e.g. two crops in one year). The most efficient systems used limiting factors to crop productivity (water, light and nitrogen fertilizer) more effectively. Systems using lower intensification of inputs were more efficient (higher output/input ratios).

A study in southern Italy measured the radiation use efficiency (RUE) and the extinction coefficient (k) of sainfoin (*Onobrychis vicaefolia* Scop.) to determine its suitability as a forage crop for the region (Rana et al.). Also measured was the global solar radiation (kg and RUEg). Values were measured over four cutting cycles. The mean values were 2.61 and 1.20 for RUE and RUEg and 0.86 and 0.71 for k and kg. These values confirmed the good adaptation of this forage crop to Mediterranian conditions.

A study from New Zealand described a new model for predicting grassland soil temperature, designed to be useful for assessing the impacts of climate change (Buchan et al.). The new model was a two-layer model partitioning the grassland into a soil surface layer and an equivalent canopy layer, effectively a porous sheet through which the soil exchanges radiation, heat and vapour with the atmosphere. The model converts to a resistance network, with a node for each energy source or sink. The model was tested at two contrasting grassland sites. The two-layer models could predict canopy and soil surface temperatures in good agreement with measurements. Thus these climatic models can be used to characterize grassland microclimate and have potential utility in assessing the impacts of climate change.

GENERAL DISCUSSION

There was considerable discussion on the potential for conflict between rising demands for food and feed (and hence forages) described elsewhere in the congress, and new demands for forages for industrial uses such as energy and pulp and paper. The conclusions of the discussions were that the situation appears to be dependent on local conditions. For example, the U.S.A. expects to have considerable land available surplus to predicted land requirements for future food and feed demand (domestic and export). Since perennial forages can be grown on land too prone to erosion for production of annual food crops, the conflicts between food and industrial uses could be lessened by growing forages on these more marginal lands. Industrial applications of forages could also create rural jobs.

Some industrial applications of forages may also leave a fraction suitable for use as animal feed. Studies in the U.S.A. are examining leaf-stem separation of alfalfa (lucerne). The stem fraction would be gasified to provide a fuel for electric power generation; the leaf fraction would be used as protein-enriched feed for livestock.

The economics of industrial applications of forages in Finland were discussed in a paper cited by Pahkala et al. (Paavilainen and Tulpalla, 1996). The conclusion of that paper was that pulp mills could afford to pay \$88 (U.S.) Mg^{-1} (dry basis) for reed canary grass at the mill gate, and be competitive with the price of birch wood of \$93-104 (U.S.) Mg^{-1}. This price for hay delivered would allow Finnish farmers to produce reed canary grass with similar returns to the production of barley, assuming an average yield of hay of 6 Mg ha^{-1} and a hauling distance of 50 km.

These yields are considerably lower than yields of switchgrass in the U.S.A., but the price paid by pulp mills for forages for fiber applications is considerably higher than the price likely obtainable for energy applications, given cheap fossil fuel energy prices. Thus northern countries (for example) may be able to find industrial applications for forages, even though yields are lower than in the tropics and sub-tropics, provided that the industrial use has a relatively high value, e.g., fibre.