ENERGY SYMPOSIUM
The Growing of Sugar Cane For Energy

by Dr. Roger P. Humbert

INTRODUCTION

In April, 1975 Dr. Melvin Calvin, Nobel-prize winning chemist from the University of California, Berkeley and the author were invited to Brazil (PLANAL-SUCAR) to discuss with their technologists the potential of growing sugarcane for energy on a large scale. A green light was given to their programs. President Geisel announced on Oct. 9, 1975 that a National Alcohol Commission would be created permitting the use of alcohol as a fuel, with up to 20% mixtures with gasoline, to reduce costly petroleum imports. Their National Alcohol Commission was established in November, 1975. By July, 1976 they had 14 new distilleries in operation. By August, 1977 they had 51 new distilleries producing at an annual rate of 3.65 billion liters. By September, 1978 they had 74 new distilleries producing at an annual rate of 4.5 billion liters. Brazil has not achieved these annual goals, as many distilleries have not produced continuously at their rated capacities for entire seasons, but their production is climbing dramatically.

The author is a consultant to many Usinas in Brazil, increasing sugarcane production per hectare and thus lowering the cost per liter of alcohol produced. Brazil averages 50 tons cane/ha, while the Usinas in the State of Sao Paulo average 65 tons cane/ha. Usina da Barra, for example now has 70% of their acreage averaging 90 tons cane/ha. They produce 3 million tons of cane per year, with one million tons cane processed directly into alcohol. All of the molasses produced from the two million tons cane for sugar is upgraded into alcohol. Usina da Barra is currently producing over 500,000 liters alcohol per day.

Doubling sugarcane production per hectare through improved cultural practices and varieties selected for their capabilities of “total sugars” production, rather than sucrose alone, result in approximately 30% reduction in costs per liter of alcohol produced. In this period of increasing costs of fossil fuels, sugarcane production for energy is certain to gain prominence in supplying a part of the energy needs of many developing countries of the Tropics that are now forced to import fossil fuels at ever-increasing prices.

Varieties Selected for Total Sugars Production:

Sugar cane varieties are being selected, not for their sucrose production, but for their “total sugars” production. Glucose and other reducing sugars are nearly
equal to sucrose in fermentation into alcohols. In fact, sucrose reverts to glucose prior to its conversion into alcohol, as shown in the following formula:

\[
\begin{align*}
\text{C}_{12}\text{H}_{22}\text{O}_{11} + \text{H}_2\text{O} & \rightarrow 2 \text{C}_6\text{H}_{12}\text{O}_6 \\
\text{Sucrose} & \rightarrow \text{Glucose} \\
\text{C}_6\text{H}_{12}\text{O}_6 & \rightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 \\
\text{Glucose} & \rightarrow \text{Alcohol} \quad \text{Carbon dioxide} \\
180 \text{ grams} & \quad 92 \text{ grams} \\
672 \text{ KCal} & \quad 655 \text{ KCal}
\end{align*}
\]

Varieties in order to be selected for alcohol production must have a high stalk population. High stooling varieties, such as NCo376 that have up to 160,000 stalks per hectare, are desirable. The variety must be fertilizer responsive and be able to use supplementary applications of fertilizer to continue its "boom stage" of growth until near harvest time. Variety L60-14 for example, in replicated variety trials at Hda. San Francisco, Tambo Valley, Peru produced 391 tons cane/ha. for alcohol in 26 months vs other varieties that produced as little as 128 TCH in the same period. Varieties are now available that can produce 200 TCH per year for alcohol! 

The varieties selected for alcohol should be responsive to the chemical ripeners such as POLARIS and ETHREL, so that vegetative growth can be curtailed very quickly, and the sugars stored in the stalks-not used as energy for continued vegetative growth.

Supplementary Applications of Fertilizer:

Multiple supplementary applications of fertilizer, usually nitrogen (urea) and potash (muriate of potash) are applied at 5,7 and 9 months of age to keep the cane growing at optimum rates. With 14 or 15 green leaves in the canopy, less than 5% of the foot candle of energy falling on the upper leaves, ever reach the soil. With stalk populations up to 160,000 stalks/ha. there is no light at the base of the stools to encourage sucker growth unless lodging has occurred.

Application rates range from 50 to 100kg/ha. of urea and 50 to 100kg/ha. of muriate of potash per application. Heavy phosphate fertilization has been applied with the seed at planting time to encourage rapid root and shoot development. Total NPK application rates range from 200 to 300kg N/ha; F\text{2O}_5 ranges from 100 to 200kg/ha; and K\text{2O} ranges from 200 to 400kg/ha.

Continued feeding results in extended periods of “boom stage” of growth,
<table>
<thead>
<tr>
<th>Field Yields</th>
<th>% 8–10 Stalk H₂O</th>
<th>% 8–10 Stalk N</th>
<th>% 8–10 Stalk K</th>
<th>% Reducing Sugars</th>
<th>% Sucrose</th>
<th>Tons Cane/ha.</th>
<th>Tons Cane/TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>17 TS/ha</td>
<td>80.7</td>
<td>0.42</td>
<td>0.68</td>
<td>11.8</td>
<td>37.5</td>
<td>178</td>
<td>10.62</td>
</tr>
<tr>
<td>17–25TSH</td>
<td>77.1</td>
<td>0.25</td>
<td>1.22</td>
<td>6.4</td>
<td>41.7</td>
<td>215</td>
<td>9.64</td>
</tr>
<tr>
<td>25–32TSH</td>
<td>75.3</td>
<td>0.19</td>
<td>1.47</td>
<td>5.7</td>
<td>46.2</td>
<td>197</td>
<td>7.13</td>
</tr>
</tbody>
</table>
in large diameter stalks with long internodes continuing until the chemical ripeners are applied. Balanced feeding is absolutely essential to keep the sugar cane plant growing at or near optimum rates. Table 1 shows data from Hawaii(5) stressing the fact that potassium deficiencies retard the conversion of reducing sugars into sucrose in the cane plant. These data show marked differences in sugar yields because of potassium deficiencies. The same cane produced for alcohol would show smaller differences, but still in favor of balanced nutrition for higher cane yields and higher total sugars production.

**Optimum Moisture Conditions:**

The supplementary fertilizer applications are timed when optimum moisture conditions exist. Supplementary irrigations are applied to prevent moisture from becoming a limiting factor of growth. At Usina Sao Luiz (Didini, Brazil) large block tests with multiple applications of fertilizer by airplane, with a new variety Co775 and supplementary sprinkler irrigation, increased cane yields from 80 tons cane/ha, to 177 tons cane/ha per year with significant reductions in costs per liter of alcohol produced.

The record yields of sugar cane production are now being produced where daily water balance charts are kept, considering the water storage capacities of the soils in the depth of rooting, pan evaporation from a free water surface, and water supplied either as rainfall or in irrigations. Tambankulu Estates in Swaziland, Africa grow up to 235 tons cane/ha. in 13 months of growth, which is 18 tons cane per hectare per month. During the "boom stage" of growth, after full canopy has developed, they apply 27mm of water every 3 days in solid set sprinkler irrigation. Their 1977 blocks treated with extra nitrogen and potash applications by airplane costing R157/ha. produced 27 tons cane/ha, extra, worth R280/ha. for a 78% profit.

**Ripening Prior to Harvest:**

In the growing of sugarcane for sugar, it has been necessary to precede harvest with a ripening period of several weeks to several months in order to dehydrate the reducing sugars to recoverable sucrose. The formula is as follows:

\[
2 \text{C}_6\text{H}_{12}\text{O}_6 - \text{H}_2\text{O} \rightarrow \text{C}_{12}\text{H}_{22}\text{O}_{11}
\]

Glucose \hspace{1cm} Sucrose

In the growing of sugarcane for alcohols and cellulose it is not necessary to ripen the cane and convert most of the sugars to sucrose. The reducing sugars are equally as important as sucrose in the fermentation processes.

Chemical ripeners and plant growth regulators are now being used commercially to convert the cane growing luxuriently to a cycle of sugar storage. In 1977, seventy-
five percent of the acreage of cane harvested in Hawaii used POLARIS to reduce the time required for ripening from as long as 7 months to 8 weeks, with approximately two tons sugar/ha. more "in the bag".

POLARIS is being used commercially in some 15 countries, with consistently good results, now that the varieties have been identified that respond to POLARIS. ETHREL is being used commercially in four countries on sugarcane, largely in Southern Africa. Other chemical ripeners have not given consistently good results in replicated trials with POLARIS and ETHREL in many countries.

Use of Vinaca for Soil Improvement:

The remainder of the fermented juice after alcohols have been distilled off, vinaca, is hauled or pumped back on the fields near the mill. Vinaca is acid and corrosive, so is usually hauled back to nearby fields in stainless steel tank trucks and trailers. Where irrigation is practiced, the vinaca is applied in the mill water to fields below the mill. If necessary, the vinaca and mill water are pumped to higher elevations to spread the large quantities of vinaca over larger areas so as not to build up excessively high levels of potash in the soils. Vinaca is usually applied at rates of 30 to 50m^3/ha. Vinaca is high in organic matter, and high in potash, particularly if molasses from sugar production is upgraded into alcohol along with juice from cane. Typical formulas of vinaca are shown in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2 Chemical composition of &quot;vinaca&quot; (Brazil)</th>
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</thead>
<tbody>
<tr>
<td>From Molasses</td>
</tr>
<tr>
<td>%</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td>Total Solids</td>
</tr>
<tr>
<td>Organic Matter</td>
</tr>
<tr>
<td>Mineral Matter</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>P</td>
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<tr>
<td>K</td>
</tr>
<tr>
<td>Ca</td>
</tr>
<tr>
<td>Mg</td>
</tr>
<tr>
<td>pH</td>
</tr>
</tbody>
</table>

In Hawaii, with continuous applications of irrigation water high in potassium, 1,000kg/ha, K_2O were applied per year, causing KCl to crystallize out in the cane juice. Application rates of 50m^3/ha. of vinaca means up to 350kg/ha. K_2O applied when the vinaca comes from molasses, per application.

As cane yields are increased, potassium removed from the soils will mean
higher potash fertilization requirements on 80 to 90% of the acreage in cane. Two million acres per year are now being planted to cane in Brazil for alcohol and cellulose production. A 100 ton crop of cane removes about 250kg K₂O, which must be replaced in fertilizers if continued high yields are expected. The 10 to 20% of the area that receives vinaca will receive no potash fertilizers. In the 80 to 90% of the acreage producing heavy cane tonnages (120-200 TC/ha/year) fertilizer formulas ranging from 2-1-2 to 2-1-4 are expected to be used in the future.

Energy Output/Energy Input for Sugarcane:

Sugar cane is the world’s most efficient plant, on an annual basis, in the converting of sunlight energy into stored energy. Many plants actually have a negative energy balance of inputs to energy output. Detailed studies by the author have shown up to five times the energy stored as the total of energy inputs in seedbed preparation, fertilization, cultivation and herbicide usage, harvesting and cane transport. A part of the favorable energy balance is due to the long cycle of plant and many ratoon crops where high energy costs of planting occur only once in ten or more years. The ratoon crops have a much higher energy stored/energy inputs ratio than plant cane. They start faster, develop a full canopy of green leaves sooner, and store more total sugars per hectare per annum than plant cane.

Since energy is such an important factor in food, fiber and energy production, it is interesting to compare the energy expended to produce different crops. Table 3 compares the energy produced vs input energy for many crops.

**TABLE 3** Energy content vs energy inputs for food crops

<table>
<thead>
<tr>
<th>Food crop</th>
<th>Calorie Content per Calorie Input</th>
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<tbody>
<tr>
<td>Barley</td>
<td>6.6</td>
</tr>
<tr>
<td>Wheat</td>
<td>5.4</td>
</tr>
<tr>
<td>Sugarcane</td>
<td>5.0</td>
</tr>
<tr>
<td>Sweet sorghum Grain + stems</td>
<td>3.39</td>
</tr>
<tr>
<td>Stems only</td>
<td>2.27</td>
</tr>
<tr>
<td>Corn</td>
<td>3.3</td>
</tr>
<tr>
<td>Rice</td>
<td>2.6</td>
</tr>
<tr>
<td>Potatoes</td>
<td>2.1</td>
</tr>
<tr>
<td>Cassava</td>
<td>1.7</td>
</tr>
<tr>
<td>Apples</td>
<td>1.3</td>
</tr>
<tr>
<td>Dry beans</td>
<td>1.2</td>
</tr>
<tr>
<td>Grapes</td>
<td>1.1</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>0.76</td>
</tr>
<tr>
<td>Peaches</td>
<td>0.73</td>
</tr>
<tr>
<td>Green beans</td>
<td>0.55</td>
</tr>
<tr>
<td>Oranges</td>
<td>0.43</td>
</tr>
<tr>
<td>Lettuce</td>
<td>0.34</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Even though barley and wheat have a higher energy output vs input ratio, the much higher total energy production per hectare per year for sugarcane, places this crop in a class by itself. The harvesting of sugarcane can be completely mechanized at a cost often lower than manual operations.

Value of Sugar Cane Bagasse Climbing:

Sugarcane bagasse, the fibrous material from which the juices and sugars have been extracted, is rapidly becoming as valuable as sugar or alcohol. Thirty-three countries now have cellulose plants using bagasse as the raw material, from which many pulp and paper products are produced. Cellulose from bagasse now has a value of US$270 per metric ton, and is climbing steadily. Brazil, for example, now imports 300,000 tons of pulp and paper products per year. By the mid 1980's they expect to export 2,000,000 tons of cellulose from sugarcane bagasse, eucalyptus and pine fibers to Europe and the United States. In processing sugarcane for alcohol, approximately 40% excess bagasse is not needed for power for processing the cane and for alcohol production, and can be used in cellulose plants.

Future for Alcohol Fuels from Sugar Cane Bright:

All sugarcane growing, petroleum importing countries in the Tropics have a potential of producing a part of their energy needs as alcohols from cane. Equipment costs are relatively cheap, when compared to the costs of sugar mills. Smaller sugar mills, no longer economic for sugar production, can be economic for alcohol production. 100,000 liters/day distilleries require only 60 tons cane per hour, or a relatively low milling capacity.

Since the juices are not converted into sugar, the power and energy requirements of the alcohol plants are far less than that for sugar mills. Consequently, capital investments are far less than those for sugar mills.

The costs of anhydrous alcohol production in a number of consulting mills of the author in Brazil average in a range of US$0.21 to $0.24 per liter. Average cane yields per hectare in Brazil are only 50 tons/ha., with the Sao Paulo mills averaging 65 tons cane/ha. As yields climb, first to 100 TCH and later to 150 and even 200 TCH, costs per liter of alcohol produced will decline. This will be in a period of ever-increasing costs of fossil fuels, so alcohol production for fuel from sugarcane has a bright future!!!

Economic Feasibility Studies:

Economic feasibility studies have been completed by your author for private sectors in Panama, South Africa, Costa Rica and the Philippines in the growing of sugarcane for energy—alcohol, cellulose and animal feeds. Contracts have already been signed for Brazilian distilleries in Costa Rica. Other contracts are certain to be
signed in the immediate future.

SELECTED REFERENCES

1. Anom. 1977. Where Autos Run on Alcohol. BUSINESS WEEK, Nov. 7


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