Corn showed up best in this trial, but sugarbeet could compete if growing costs were reduced.

Comparison of high-energy crops for alcohol production

F. Jack Hills □ Stanley S. Johnson □ Shu Geng
Akbar Abshahi □ Gary R. Peterson

With petroleum prices increasing at a faster rate than prices for agricultural products, the efficiency of exporting food to import petroleum for fuel has decreased and the use of agricultural products to produce alcohol (ethanol) for fuel has gained national interest. Several economic studies, ranging from optimistic to pessimistic, have been reported on the feasibility of growing crops to furnish carbohydrates for fermentation to alcohol. A problem common to many of these analyses has been the lack of truly comparative crop yield and energy input data. As a start in developing such data, we conducted a field experiment at Davis in 1980 to compare corn, sweet sorghum, fodderbeet, and sugarbeet—known for their productivity and high content of fermentable carbohydrates.

Procedure

Corn (cultivar NC+ 59), sweet sorghum (Keller), fodderbeet (Sharpe's BMCJ/54), and sugarbeet (US H11) were grown on raised planting beds, 30 inches from center to center. Crop plots were 12 rows wide by 400 feet long and were replicated twice. Plant spacing in the rows was 8 inches for corn, fodderbeet, and sugarbeet and 6 inches for sweet sorghum. Each crop plot was split into four-row subplots to provide four replications of six levels of nitrogen fertilization ranging, in 50-pound increments, from zero to 250 pounds N per acre. Seeds were irrigated for germination on April 24. Starting May 6, all crops were irrigated at two-week intervals.

Corn and sweet sorghum were harvested at grain maturity on September 22 and October 27, respectively, and sugarbeet and fodderbeet on November 4. Two interior rows, 20 feet long, were harvested from each fertilizer plot. Fermentable carbohydrates were determined by analyzing appropriate plant parts for starch, sucrose, glucose, and fructose. Potential alcohol production was calculated on the basis of 14 pounds of fermentable carbohydrates per gallon.

Results

All crops responded to nitrogen fertilizer but differed in amount required to maximize alcohol yield (table 1). Corn required the most fertilizer N, fodderbeet 80 percent of the corn requirement, and sweet sorghum and sugarbeet the least, only 32 percent of the amount needed by corn.

Irrigation was quite efficient: only up to about 15 percent more water was applied than was required for maximum crop growth. The main reason for differential water use was the time needed for crop maturity.

Most of the sweet sorghum lodged on about July 30, some 20 days before heading. As the plants continued to grow and head,

Above: Fodderbeet (right) had smaller top but much larger root yields than sugarbeet.

Left: Sweet sorghum grew to 11.5 feet at Davis, 2 feet taller than earlier maturing corn held in Akbar Abshahi's right hand.

Because of its rapid growth and heavy yield, most of the sweet sorghum lodged about 20 days before heading (left) but continued to grow and became semi-upright at maturity (right), with a potential for producing 633 gallons of alcohol per acre.

however, the stalks became erect enough to permit harvesting with a forage crop chopper.

Fodderbeet showed considerable damage from *Erwinia* root rot, but sugarbeet, bred for resistance to this organism, was little affected. The fertilizer plots were large enough so that rotted roots could be avoided in harvesting. No other pest problems affected the yield of any of the crops.

Fodderbeet and sugarbeet, with their capacity for continued growth over a long period of favorable growing weather, produced far more alcohol than the two shorter season crops, corn and sweet sorghum. Fodderbeet appears to have little advantage over sugarbeet, because the small increase in additional fermentable carbohydrates from fodderbeet would not pay for the increased costs of handling the additional root tonnage. In addition, the greater susceptibility of fodderbeet to various pathogens makes its cultivation riskier.

Alcohol yield is but one consideration in selecting a crop. Profitability in growing a crop for alcohol production will be a major determining factor in selection.

Costs and profitability

Although it may be possible to alter cultural practices somewhat in growing a crop for alcohol as opposed to its usual commercial use, standard inputs in commercial crop production are one reasonable basis for determining on-farm costs of producing fermentable carbohydrates. We estimated costs of growing the four crops based on University of California 1980 crop budgets for Yolo County, adapting sweet sorghum and fodderbeet figures from existing Yolo County budgets for grain sorghum and sugarbeet (table 2). We made some changes in the budgets to incorporate certain practices

TABLE 1. Fertilizer and water inputs, crop yields, and potential alcohol production

Comparison	Corn	Sweet sorghum	Fodder beet	Sugarbeet
Fertilizer N requirement (lb/acre)	250	80	200	80
Irrigation: Number	9	11	12	12
Water applied (inches)	28.9	35.5	38.0	38.0
Crop evapotranspiration (inches)	25.2	32.8	35.9	35.9
Crop production: Harvested portion	grain	stems & leaves	roots	roots
Tons/acre*	7.70	43.0	63.6	40.9
Fermentable carbohydrates: Percent	55.4	10.3	9.5	14.1
Pounds per acre	8,532	8,858	12,084	11,534
Alcohol potential (gal/acre)†	609	633	863	824

*Corn grain is at 15.5 percent moisture, others are fresh weight.
†Calculated as 14 pounds of fermentable carbohydrates per gallon of alcohol.

TABLE 2. Costs of producing fermentable material from four California farm crops, 1980

Cost categories	Corn	Sweet sorghum	Fodder beet	Sugarbeet
	$/acre	*$/acre*	*$/acre*	*$/acre*
TOTAL RECEIPTS				
(gal alcohol @ $1/gal)	609	633	863	824
GROWING COSTS				
Preharvest costs				
Nitrogen fertilizer	50.00	16.00	40.00	16.00
Irrigation water cost	34.39	47.39	46.74	46.74
Irrigation labor	64.67	79.04	86.22	86.22
Chemicals + custom application	15.30	7.33	86.82	86.82
Thinning and weeding labor	—	—	121.72	121.72
Interest on operating capital	11.49	4.53	36.00	36.00
Other preharvest costs	126.62	59.98	157.53	160.53
Total preharvest costs	302.47	214.27	575.03	554.03
Harvest cash costs	12.24	150.50	95.40	61.35
Hauling costs (@ $1.50/ton)	11.55	67.05	95.40	61.35
Overhead costs				
Cash rent	150.00	150.00	150.00	150.00
Taxes, insurance, office	65.00	65.00	65.00	65.00
Depreciation, interest	27.50	27.50	27.50	27.50
Total overhead	242.50	242.50	242.50	242.50
TOTAL GROWING COSTS	568.76	674.32	1008.33	919.23
NET RETURN TO FARM OPERATOR	40.24	−41.32	−145.33	−95.23
	$	$	$	$
Total growing costs/lb fermentables	0.067	0.076	0.083	0.080
Total growing costs/gal alcohol	0.93	1.07	1.17	1.12

Note: Costs of fermentation and distillation are not considered in this study.

actually used in the trial and to standardize overhead costs for more accurate comparisons among crops.

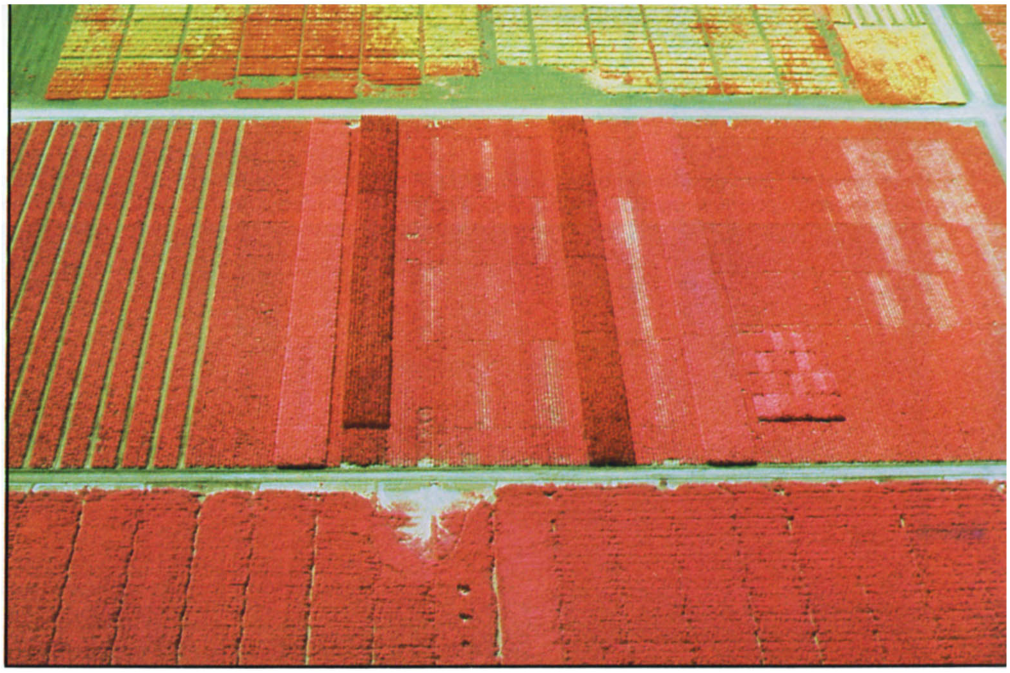
Fertilizer and irrigation practices used in the trial were incorporated into the budgets. A fertilizer level input was chosen at the point where the additional cost of applying another unit of fertilizer just equalled the value of the added yield of alcohol. Nitrogen levels that provided the maximum alcohol for each crop also provided the greatest economic return. Irrigation costs were budgeted on the basis of the actual amounts of water used in the trial and labor prices used in the standard county budgets.

The other components of preharvest costs were taken directly from the standard budgets. These costs were higher for both sugarbeet and fodderbeet, because standard cropping practices specify hand labor for thinning and weeding, and these crops use more chemicals than do corn and sorghum. Preharvest costs for sorghum are low because they are based on a grain sorghum crop following spring-harvested sugarbeet, timed so that little land preparation is necessary.

The harvest cost for sweet sorghum was adapted from a sugarcane custom rate; that for fodderbeet was the same cost per ton as for sugarbeet. Harvest costs for corn and sugarbeet were based on current practices—equipment ownership costs for corn and custom harvesting for sugarbeet. Hauling costs were standardized at $1.50 per ton. With low harvest expenses and only grain to haul, harvesting and hauling cost much less for the corn crop than for the other crops.

The total cost of corn production is the lowest of the four crops at $568.76 per acre, closely followed by sweet sorghum. Fodderbeet and sugarbeet cost 78 and 63 percent more than corn to produce. These costs, however do not reflect the relative profitability of the crops. Since the product sold will eventually be converted to alcohol, a financial return for a crop in terms of gallons of alcohol produced is necessary. One current study estimated a farm price for alcohol based on 7.14 cents per pound of fermentable product, or $1.00 per gallon. At that price, only corn would have a positive return to the farm operator. Based on the comparative costs in our trial, to achieve a net return to the farm operator of $50.00 per acre, the farm price per gallon of alcohol would have to be $1.01 for corn, $1.14 for sweet sorghum, $1.23 for fodderbeet, and $1.17 for sugarbeet.

These costs and returns reflect only those paid and received at the farm for the alcohol feedstock. There are, of course, additional costs in preparation of the feedstock for fermentation, in the fermentation process itself, and in distillation of alcohol. Also, byproducts of each crop may provide a significant amount of gross income—livestock feed from corn grain and root pulp residues, and possibly fuel for alcohol distillation from sweet sorghum stalk residue.



Strips in center of aerial infrared photo are the crop comparison trial.

Yields in this trial were excellent, well above county averages. Since not all farms can be expected to achieve these yields, costs and returns to growers at approximate county yields can be estimated as follows: Yolo County is a large producer of sugarbeet with a long-term average yield of about 7,500 pounds of sucrose per acre. In our trial, corn, sweet sorghum, and fodderbeet alcohol yields were 74, 77, and 104 percent, respectively, of the sugarbeet alcohol yield. Taking these percentages, we made the following estimates of gallons of alcohol per acre, based on the average county sugarbeet crop: corn 397; sweet sorghum, 413; fodderbeet, 557; and sugarbeet, 536. This process maintains the relative yields among the four crops that this trial has demonstrated. Based on the adjusted yields and scaling down harvesting and hauling costs, the price per gallon of alcohol to yield a return of $50.00 per acre to the farm operator would have to be: corn, $1.54; sweet sorghum, $1.57; fodderbeet, $1.78; sugarbeet, $1.73 per gallon.

Even though corn had the lowest potential yield of alcohol per acre, its production cost per unit of alcohol was lowest. Corn also has other advantages—a shorter growing season and the flexibility of selling the product for grain or alcohol.

Alcohol production reported in table 1 for sweet sorghum does not reflect the fermentable carbohydrates in the grain, because the grain probably has to be ground before its starch can be fermented, and no grinding occurs when a standard forage crop harvester is used. Development of a harvester that separates heads from stalks so that the grain could be ground and fermented would increase alcohol production from this crop by 66 gallons per acre, based on the measured dry head yield of 1.13 tons per acre and a carbohydrate content of 40.8 percent. A potential disadvantage of sweet sorghum is that it should be used before winter frosts, which can cause considerable loss of stalk sugars.

Alcohol production from sugarbeet and fodderbeet was substantially higher than from corn and sweet sorghum. If growing costs can be reduced, sugarbeet at least should compete with corn. Major high costs for root crops in the standard budgets relative to corn are the quantities of chemicals used, extensive use of thinning and weeding labor, and high harvest and hauling costs. At least the first two categories are subject to economies, such as planting to a stand or using a synchronous thinner to reduce labor used for thinning and weeding, and relying less heavily on chemicals for pest control. Compared with sweet sorghum, sugarbeet and fodderbeet have an advantage in that they are little damaged by frost and can be harvested the following spring with little additional expense and a possible increase in sugar yield.

F. Jack Hills is Extension Agronomist, Department of Agronomy and Range Science, University of California, Davis; Stanley S. Johnson is Agricultural Economist, Economic Research Service, U.S. Department of Agriculture, stationed with the Department of Agricultural Economics, U.C., Davis; Shu Geng is Associate Professor and Biostatistician, Akbar Abshahi is Graduate Student, and Gary R. Peterson is Extension Staff Research Associate, all with Department of Agronomy and Range Science, U.C., Davis.