Progress in Developing Sweet Potato (Ipomoea batatas (L.) Lam.) Cultivars for Fuel Alcohol Production

Author: Wanda W. Collins, Associate Professor, Department of Horticultural Science, North Carolina State University, Raleigh, NC 27650, USA.

ABSTRACT

The potential use of sweet potatoes for fuel alcohol production in the United States and the development of cultivars specifically for that purpose are discussed. Field and laboratory studies were conducted in 1981 on yield of dry matter and protein per hectare and on yield of 100% ethanol per hectare after fermentation. Selection for dry matter and protein content in early stages of a breeding program was also evaluated.

'Pelican Processor', one of the older cultivars tested, produced the largest amounts of dry matter and protein per ha. Root yield ranged from 29.3 mt/ha to 54.7 mt/ha. Protein content was highest in the experimental clone WJ2 (6.9% dry weight basis) but because of the high dry matter content (30.7%) and high root yield, 'Pelican Processor' yielded more protein per ha (0.3 mt/ha).

Determination of dry matter content and protein content in seedlings were considered unreliable for estimating these values in mature plants. Correlations between seedlings and mature plants for these characters were significant but low and would not be useful unless severe selection pressure were used.

Production of fuel alcohol from agricultural crops as an alternate source of energy has received much attention in the United States. Although sweet potatoes have the potential to produce more ethanol/hectare than any starch or sugar crops now being used for this purpose (Fike, 1980; Jump et al., 1944), the price per liter of ethanol from sweet potatoes has generally been prohibitive (Fike, 1980). Since this is based on market prices that reflect sales of sweet potatoes as a fresh product to consumers rather than on a crop grown specifically for alcohol production, the cost/liter is perhaps misleading. A goal of breeding programs should be development of cultivars which possess those characteristics most suitable for use as a fuel alcohol source with no emphasis on fresh product consumption.

Several researchers have investigated the potential for using sweet potatoes for fuel alcohol production. Keitt (1909) tested 14 clones and concluded that yield was the most important factor influencing ethanol production/ha since starch

percentage did not vary considerably between clones. When clones with different levels of starch were tested (Boswell, 1944), both plant yield and starch content contributed significantly to the total yield of ethanol. Jump et al. (1944) found that a quantity of dehydrated sweet potatoes yielded 15% to 20% more alcohol than an equal quantity of high-grade corn. However, they questioned the value of the distillage by-product of sweet potatoes as an animal food supplement since it was much lower in protein than the corn distillage.

The objectives of this study were to evaluate sweet potato seedlings and selected cultivars and experimental clones for traits desirable for fuel alcohol production.

Materials and Methods

Evaluation of experimental clones and selected cultivars

Nine sweet potato clones were chosen based on preliminary dry matter and yield data. Uniform-size plants from bedded roots were transplanted to a Norfolk sandy loam soil at the Horticultural Crops Research Station, Clinton, North Carolina. A randomized complete block design with four replications was used. Rows were spaced 1.2 m apart with plants 0.3 m apart within the row. Each plot consisted of 30 plants. Cultural practices recommended by the North Carolina Agricultural Extension Service (1980) were followed.

Roots were harvested 161 days after transplanting and total yield was measured for each plot. Samples were collected from each plot for evaluation of dry matter, protein and alcohol production. Dry matter was measured by drying a composite, preweighed sample of 2 roots for 48 hr in a forced air drying oven and reweighing. Protein was measured on a composite sample of 6 roots by analyzing for nitrogen content using a semi-micro Kjeldahl using 6.25 as a conversion factor for calculation of protein nitrogen. Ethanol was prepared from a 1,200-1,700 g sample of root tissue which was weighed and ground in a food mill for 2 minutes. An equivalent weight of water was mixed with 5 g of α-amylase and then added to the ground sweet potatoes to form a slurry. The slurry was brought to the boiling point with moderate stirring and boiled for 30 minutes. The slurry was cooled naturally to 77°C in the cooker. When the temperature reached the 77°C to 80°C level, another 5 g of α-amylase was added and stirred to assure mixing of the additional enzyme. The slurry was cooled to room temperature. Five g of glucoamylase (Biocon) was added to the slurry along with 5 g of distiller's yeast (Biocon). The yeast-containing mixture was then placed in a constant temperature box at 27° to 32°C for 7 days.

Polyethylene milk bottles prewashed with a sulfite solution were used as fermentation chambers. After 7 days the fermented mash was placed in an air-cooled stripping still and boiled slowly until the mash temperature reached 100°C (about 3 hours). The alcohol was collected in a graduated cylinder, the volume and specific gravity were measured at 15.6°C and the results converted to the volume of 100% ethanol. All results are reported on that basis. The hot mash with the alcohol removed was then filtered on a large Buchner funnel to separate the distillage from the water. The filtration was carried out at 51 mm of HG vacuum long enough to remove the excess liquid. Samples of the distillage were frozen for later analysis of protein (by the method previously described) and total sugar.

Evaluation of seedlings

One hundred seedlings with white root flesh were selected from the 1981 seedling population at North Carolina State University. The seedling root of each of the 100 plants was removed for dry matter and protein analysis as described previously. A terminal cutting approximately 150 mm in length was taken from each of the 100 plants and transplanted to the field in rows 1.2 m apart with plants spaced 0.3 m in the row. After 135 days roots from each of these one hundred plants were harvested. Half the roots on each of the 100 hills were removed for protein and dry matter analysis; the other half were placed in paper bags, cured (95% RH, 30°C) for 1 week and stored (16°C) for future use.

Results and Discussion

Experimental clones and selected cultivars

The 9 sweet potato clones differed significantly in yield, dry matter, and protein content. Yields ranged from 31.4 mt/ha to 58.6 mt/ha. 'Jewel' yielded 50.2 mt/ha, not significantly different from 'Pelican Processor' which yielded 58.6 mt/ha. Therefore, none of the lines used in this study surpassed 'Jewel' in total yield. 'Jewel' is the cultivar which is now most widely grown in the United States as a fresh market product. However, 'Pelican Processor' had one of the highest dry matter contents (31.4%) and consequently the highest dry matter yield (18.3 mt/ha) of all lines tested in this study. 'Whitestar' was comparable to 'Pelican Processor' in dry matter content (29.4%) but had lower total dry matter production (14.3 mt/ha) due to lower total yield. Protein content ranged from 4.3% to 6.8% (dry weight basis) with the highest dry matter types ('Pelican Processor' and 'Whitestar') having the lowest percent protein. However, actual protein production (ranging from 0.43 to 0.80 mt/ha) was high in these two lines because of high total yield.

These results indicate that although percentage dry matter is an important genotype characteristic in selecting lines with high potential for fuel alcohol production, total yield is more important and should be used as the primary characteristic for selection. Clones with high dry matter content ('Potojam', 'Vogel White') may have low actual yields (mt/ha) of dry matter due to this low yield characteristic. The same was true of percentage protein as a selection characteristic.

Alcohol yield differed significantly among the 9 clones tested. 'Pelican Processor' yielded 0.1467 l/kg of ethanol compared to only 0.0684 l/kg by NC 835. Residue analysis indicated that protein content in the fermentation products of these 9 clones was considerably lower than optimal for extraction as a human food supplement (corn distillers' grains average 30% protein). The residue contained from 0.70% to 2.17% total sugar which indicated that the fermentation procedure was relatively efficient for all clones.

Correlation coefficients were determined for all traits measured (Table 1). Protein content (%) was inversely correlated with dry matter content. However, this will have little significance in selecting for types that yield high amounts of dry matter and high amounts of protein since protein yield (mt/ha) was more dependent on total yield than on actual percent protein; 'Pelican Processor' had low percent protein but high total yield and therefore it had a higher actual yield of protein.

Table 1. Correlation coefficient of screening characters in mature sweet potato clones and cultivars.

	Protein (%)	Dry matter (%)	Yield	Alcohol yield	Residue protein	Residue sugar
Protein (%)	-	-0.66*	0.21	-0.57	0.47	0.73*
Dry matter (%)		-	0.08	0.96**	0.31	0.63
Yield			-	-0.23	-0.56	0.46
Alcohol yield				-	0.30	0.52
Residue protein					-	-0.37
Residue sugar						-

*,** Significant at the 1% and 5% levels, respectively, (seven degrees of freedom).

Alcohol yield was significantly and positively correlated with percent dry matter. Although the dry matter in sweet potatoes contains materials other than fermentable carbohydrates, this correlation indicated that percent dry matter can be confidently used as the selection criterion for alcohol yield.

Residue sugar was negatively and significantly correlated with percent protein. This correlation probably is a reflection of the high negative correlation between percent protein and percent dry matter (the correlation coefficient between residue sugar and percent dry matter was very high although not significant). Residue protein was not significantly correlated with any other screening character. Therefore, residue protein itself must be evaluated in all lines unless it can be shown that no genetic factor is responsible for the level of residue protein (i.e., all lines tested may be similar in residue protein even though they differ in other characters). It is possible that the method of alcohol production may greatly influence the level of protein in the residue in all clones.

Seedling evaluations

In general, dry matter content changed minimally between seedling roots and clone samples. The correlation coefficient between the two types of samples was significant although fairly low. Protein content (dry weight basis and fresh weight basis) was generally higher when measured after one growing season (clone sample) than when measured in the seedling root. The mean, when measured on DWB or FWB, doubled from seedling evaluation to clonal evaluation. The correlation between seedling root samples and clonal samples, although low, was significant, indicating that rankings might still be accurate in the seedling population but that actual protein content must be determined after one growing season.

The correlation between percent dry matter and percent protein (DWB) was negative and significant in the seedlings as it was in the experimental selections and cultivars.

These results indicate that determination of dry matter and protein content in seedlings will be unreliable for estimating these values in mature plants. The efficiency of selecting for total yield in seedlings is questionable since seed-

ling yield and clonal yield have not been shown to be well correlated (Kamalam et al., 1976). In addition, high yield and high starch content have been shown to be negatively correlated in some sweet potato populations although highly productive, high starch types were obtained using suitable crosses (Zhang, et al., 1981).

Literature Cited

Boswell, V.R. 1944. Place and season effects on yield and starch content of 38 kinds of sweet potatoes. USDA Circ. 714, U.S. Dept. Agri., Washington, DC.

Fike, W.T. 1980. Alcohol production from agricultural crops grown in North Carolina. North Carolina State University Crop Science Department New Crops Memo 10. Raleigh, NC. 5p.

Jump, J.A., A.I. Zarow, and W.H. Stark. 1944. Dehydrated sweet potatoes for ethanol production. Ind. and Eng. Chem. 36:1138-1140.

Kamalan, P., N. Hrishi, P.G. Rajendra and M.T. Srelkumari. 1976. Variability and the scope for selection in the open-pollinated progenies of sweet potato. Proceedings, IV International Symposium on Tropical Root Crops, Cali, Colombia.

Keitt, T.E. 1909. Sweet potato work in 1908. North Carolina Agr. Exp. Sta. Bull. 146, North Carolina State University, Raleigh, NC.

N.C. Agricultural Extension Service. 1980. Growing and marketing quality sweet potatoes. North Carolina Ag. Ext. Serv. Bulletin AG-09. 50 p.

Zhang, Bi Tai, Xue Pin Lean, and Qu Rea Lean. 1981. Breeding for high yield and high starch content in sweet potatoes. Jiangsu Province Agricultural Scientific Academy, Peoples' Republic of China. 7 p.