Recurrent Selection for Sucrose has Altered Assimilate Partitioning Between Growth and Storage in Sugarcane Internodes

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Introduction:

Sugarcane is a tropical crop adapted to long, warm growing season. In Louisiana the growing season for sugarcane is short compared to other sugarcane growing areas. This short growing season reduces the cane yield that can be achieved. Therefore, sugarcane breeders in Louisiana have concentrated on increasing sucrose content of the cane in order to increase sucrose yield.

The modified recurrent selection for sucrose method used in Louisiana was described by Breaux (1984): "(a) select the highest sucrose phenotypes available; (b) intercross these varieties; (c) grow large seedling populations (60-80,000 annually); (d) select rigidly for sucrose; and (e) intercross the selections to produce still another improvement cycle."

There have been six cycles of selection for sucrose content. We conducted this study to examine the changes in patterns of growth and sugar storage in sugarcane internodes that have resulted from selection for sucrose.

Methods:

- 5 cultivars from each of Generation 1 and Generation 7 (Table 1) planted in single-row plots near Schriever, LA in November 2004 and November 2006.
- 4 reps in randomized complete block design
- Sampled in 2006 (first stubble crop of 2004 planting) and 2007 (plant cane crop of 2006 planting)
- 20 stalks flagged per plot in July. Leaf with the topmost visible collar marked with a whole punch.
- At 1- to 2-week intervals for 12 weeks, one flagged stalk removed from each plot.
- Internode subtended by the marked leaf was cut, measured, and weighed.
- Internode chopped, freeze dried.
- Dried material was ground in Wiley mill with a 20-mesh (0.8 mm) screen.
- Sugars extracted with 80% aqueous ethanol
- Sugars in the extract separated by ion chromatography, detected with an integrated pulsed amperometric detector and quantified by comparison with external standards.
- The ratio of sucrose to total sugar was calculated after converting each concentration to molar amounts.
- The data were analyzed by fitting several logistic curves and segmented trends to the data by year and generation using the NLIN procedure of SAS.
- Equations that resulted in the lowest error mean square for each parameter were used.
- Internode length was fitted to a segmented equation consisting of a linear and a quadratic function
- Internode fresh weight (FW) and dry weight (DW) were fitted to logistic equations of the form
  - $y = Y_{max}/(1 + \exp\text{-}k(t\text{-}t_m))$
    where Y_{max} is the maximum fresh or dry weight, t is heat units, t_m is the inflection point of the curve, and k is a rate parameter.
- Water content data were fitted to a linear function segmented with a linear function.
- Total sugar and sucrose were fitted to logistic curves of the form
  - $y = Y_{max}(\exp(-\exp(-k(t\text{-}t_m))))$
    where k is a unit-less constant that allows the curve to be asymmetrical.
- Analysis of covariance used to determine the significance of differences between cultivars within a generation, between generations within years, and between years.

Results:

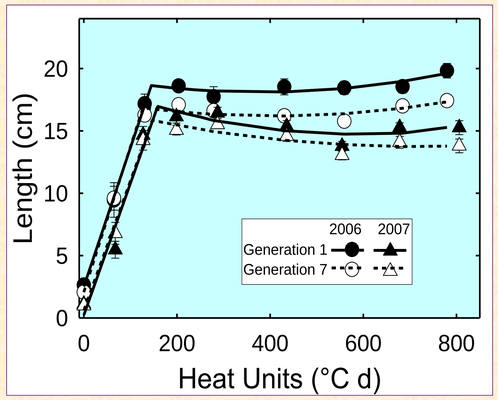
Table 1. Cultivars used in the study.

Generation	Cultivar	Year of Release	Sucrose % Cane
1	Co 281	1930	10.8
1	Co 290	1933	9.9
1	CP 807	1930	9.4
1	POJ 234	1924	12.8
1	POJ 2878	1928	13.0
7	HoCP 00-950	2007	13.9
7	HoCP 01-534	NR[1]	13.6
7	HoCP 96-540	2003	12.8
7	L 97-128	2004	12.9
7	L 99-226	2006	13.7

[1]Not released

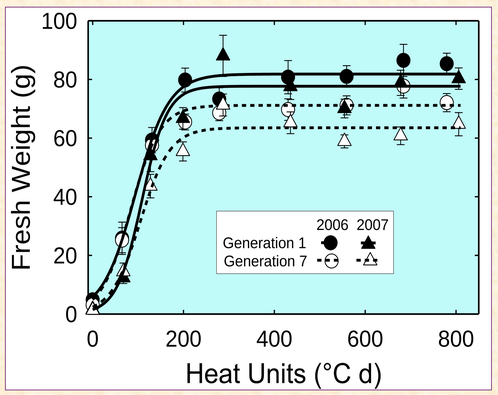
Cultivars from Generation 1 were foundation cultivars bred and selected in India (Co 281, Co 290) , Java (POJ 234, POJ 2878) or Florida (CP 807), and introduced to Louisiana in the year indicated. The Generation 7 cultivars were developed in Louisiana at the USDA Sugarcane Research Laboratory (HoCP 00-950, HoCP 01-534, HoCP 96-540) or LSU Sugarcane Research Station (L 97-128, L 99-226). HoCP 01-534 was not released but was included in the study because it is being used as a parent in the next round of recurrent selection.

Figure 1. Length of marked internode



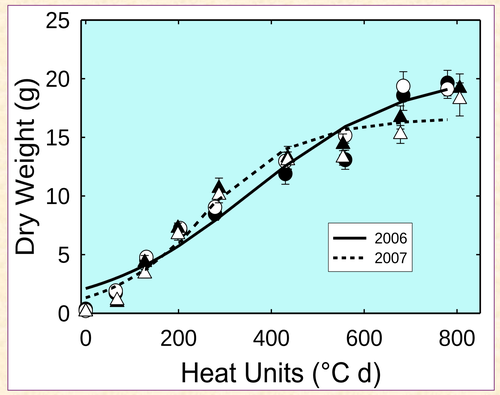
Internodes from both generations elongated at the same rate in both years, but elongation stopped a little earlier in internodes from Generation 7 cultivars.

Figure 2. Fresh weight of marked internode



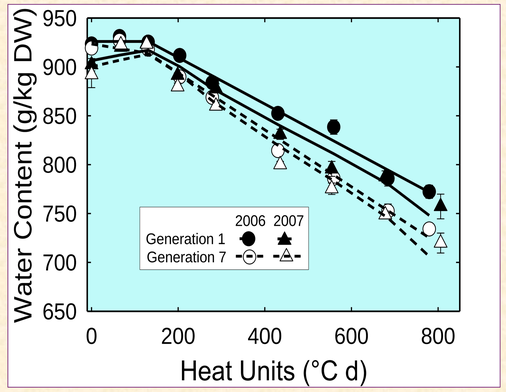
FW increased rapidly as elongation proceeded. The internode from Generation 7 cultivars reached a lower final fresh weight, and reached it earlier, than the internode from Generation 1 cultivars.

Figure 3. Dry Weight of marked internode



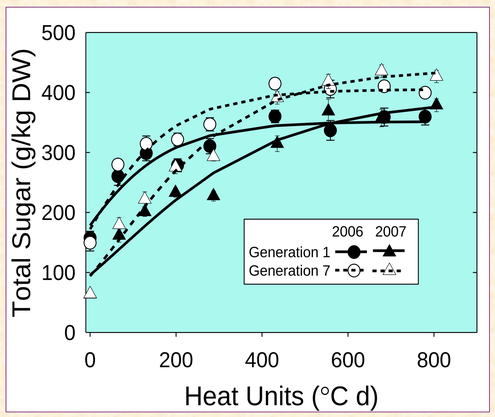
Internode DW did not vary between generations, but did vary between years.

Figure 4. Water content of marked internode



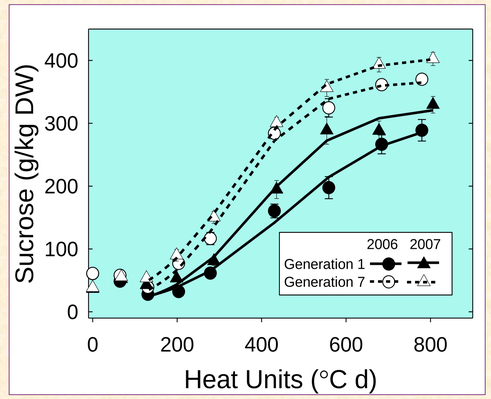
Water content started decreasing after elongation ceased in internodes of both generations, but decreased faster in internodes from Generation 7 cultivars.

Figure 5. Total sugar content of marked internode



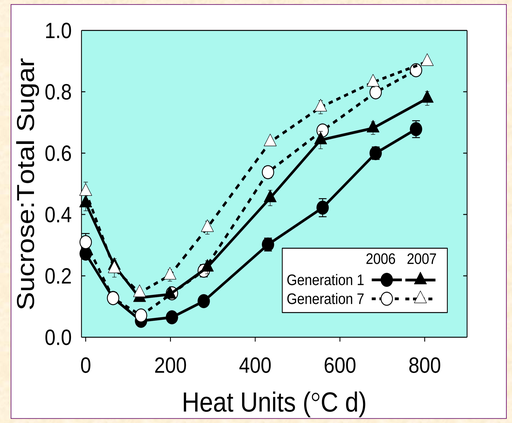
Initial total sugar content was similar in both types of cultivars, but total sugar content increased faster in Generation 7 cultivars. The final total sugar content was also higher in Generation 7 than Generation 1 cultivars.

Figure 6. Sucrose content of marked internode



Sucrose did not start accumulating until elongation had ceased. It increased more rapidly, and to a higher content, in Generation 7 cultivars than in Generation 1 cultivars.

Figure 7. Sucrose to total sugar ratio of marked internode



The ratio of sucrose to total sugar declined during elongation, then began to increase. It increased faster in internodes from Generation 7 cultivars than in Generation 1 cultivars. The ratio at the final sampling was higher in Generation 7 cultivars.

Discussion:

Elongation ceased 1 to 2 days earlier in Generation 7 internodes than in Generation 1 internodes. As a result of this, internodes of Generation 7 weren't as long as those of Generation 1 (Fig. 1), and they had a lower final fresh weight (Fig. 2). However, dry weight accumulation was the same in both (Fig. 3). Water content decreased after elongation ceased in both Generation 7 and Generation 1 internodes, but it decreased faster in Generation 7 internodes (Fig. 4). Total sugar accumulated faster and to a higher content in Generation 7 internodes (Fig. 5), and more of this sugar was sucrose (Figs. 6 and 7). Therefore, we conclude that recurrent selection for sucrose has modified the metabolism of the internode so that more of the assimilate is stored rather than being used to support growth. This may be due to changes in the regulation of soluble acid invertase, which is related to elongation in sugarcane internodes.