STALK COLD TOLERANCE OF COMMERCIAL SUGARCANE VARIETIES DURING THE 2016-2017 HARVEST SEASON

M. J. Duet[1], B. L. Legendre[2], E.O. Dufrene[1], H. Birkett[2], J. Stein[2], J. R. Todd[1]
[1]USDA-ARS, Sugarcane Research Unit, Houma, LA
[2]Audubon Sugar Institute, St. Gabriel, LA

INTRODUCTION

Sugarcane is produced in 79 countries, with exposure to damaging frosts occurring in over 20 of them. The mainland of the United States is most frequently affected, specifically the Louisiana sugarcane growing region. The potential for winter freezes has forced Louisiana to adapt to a short growing season (7-9 months) and short milling season (about 3 months). To measure post-freeze deterioration of stalks of commercial and experimental varieties, a collaborative study was conducted at the USDA-ARS Ardoyne Farm in Schriever, LA between USDA-ARS, Sugarcane Research Unit at Houma, LA and the LSU Agcenter, Audubon Sugar Institute, St. Gabriel, LA.

MATERIALS AND METHODS

Each year variety trials designed to estimate stalk cold tolerance are established on a Sharkey clay soil at the USDA-ARS Ardoyne Farm. Commercial varieties of known cold tolerance are grown as controls. They include HoCP 04-838 for good cold tolerance and the Argentine variety TucCP 77-42 for poor cold tolerance. In general, a variety is considered to have "good" cold tolerance if sugar will crystallize from the juice of the variety four weeks after a freeze event with temperatures between 24-26ºF. Crystallization would be hindered in a variety with "poor" stalk tolerance at the same temperature range. Between 8 to 12 commercial and experimental varieties, including the control varieties, are planted in a randomized complete block design with 4 replications; each plot is 3 rows wide (18 feet), and 32 feet long, with a 5 foot alley between plots. Plots are cultivated and fertilized according to recommended practices; insecticides are applied as required. When a hard freeze occurs (26ºF or lower for over four hours), a field inspection is done to verify the severity of the freeze and determine if testing should be initiated. Samples are cut from the second row of each plot prior to or immediately following a damaging freeze to provide a baseline for comparison. Depending on the severity of the freeze and post-freeze weather conditions, the test is sampled weekly for 1 to 5 weeks post-freeze. Each sample consists of 10 stalks cut at the base by hand but not stripped of leaves or tops. Harvested samples are weighed to estimate stalk weight (lb/stalk) and processed at the USDA's Juice and Milling Quality Laboratory using the pre-breaker-press method. Juice samples were analyzed for Brix by refractometer and sucrose by polarization. The pressed sample residue (bagasse) was weighed, dried, and weighed again to determine moisture content. The Brix, sucrose, purity and fiber content of the cane was estimated from these values. This data were used to estimate sucrose contest (lbs/ton of cane). Mean stalk weight was calculated

from sample weight divided by the number of stalks. To evaluate the effect of freezing temperatures on cane quality, the following analyses were done. Juice samples are analyzed to determine pH, titratable acidity, total soluble polysaccharides, and dextran. Dextran analysis was performed on a subsample of juice using the ASI (Audubon Sugar Institute) Method II. Data were analyzed using the PROC MIXED procedure (SAS 9.4) to determine statistical differences among varieties at each sampling date and across sampling dates.

This experiment included eight commercial varieties (TucCP 77-42, HoCP 96-540, HoCP 00-950, L 01-283, L 01-299, HoCP 04-838, Ho 07-613 and HoCP 09-804) planted at the Ardoyne Farm on October 15, 2015. There were no experimental varieties included in the study.

RESULTS AND DISCUSSION

The first freeze of the 2016-2017 harvest season occurred on the nights of January 7 and 8, 2017. The minimum temperature at the test site was 24.2ºF on both nights. On January 7 subfreezing temperatures occurred for 10 hours, with temperatures dipping below 26ºF for 3 hours, 30 minutes. Temperatures dropped below 32ºF for 14 hours on January 8 and below 26ºF for 6 hours, 30 minutes. A field inspection on the morning of January 8 showed evidence of internal stalk damage on some varieties along with damage to the terminal buds of all varieties. There were no visible freeze cracks; however, weeping eyes were observed on many of the varieties. Daytime temperatures following the freeze event were above average, with a high of 81ºF on January 10 and 12. Typically, warmer temperatures following a freeze event increase the rate of deterioration and cause a greater degree of deterioration within the varieties.

Samples were hand-harvested on the mornings of January 10, 17, 24, 31 and February 6, 2017. Results for purity (%), sucrose content (lbs/ton), pH, titratable acidity (ml 0.1 N NaOH/10 ml juice to pH to 8.3), and total soluble polysaccharides are shown in Tables 1-5.

HoCP 04-838 and L 01-283 showed no significant reduction in purity for the duration of the sampling period (Table 1). One week following the freeze, TucCP 77-42 and L 01-299 each showed a significant drop in purity. The remaining varieties had significant decreases at one week and 4 weeks post-freeze, with HoCP 96-540 also showing a significant decrease at three weeks, and HoCP 09-804 showing a significant decrease at two weeks. Numerically, TucCP 77-42 had the largest decrease in purity followed by Ho 07-613; the smallest purity decrease was observed in HoCP 04-838.

Three varieties, L 01-283, HoCP 04-838 and HoCP 09-804 had no significant reduction in sucrose content after the initial sampling date (Table 2). At one week and four weeks post-freeze, HoCP 00-950 showed a significant decrease in sucrose content. The remaining varieties, TucCP 77-42, HoCP 96-540, L 01-299 and Ho 07-613 showed a significant decrease in sucrose content one week after the initial sampling. Both TucCP 77-42 and Ho 07-613 exhibited the greatest decrease in sucrose content, while HoCP 04-838 and HoCP 09-804 showed the smallest decrease.

Only one variety, TucCP 77-42, showed no significant decrease in pH of juice across all sample dates (Table 3). A significant decrease in juice pH at four weeks post-freeze was recorded in L 01-299, HoCP 04-838 and HoCP 09-804. At three weeks post-freeze, HoCP 96-540, HoCP 00-950, L 01-283 and Ho 07-613 showed significant decreases in juice pH. Although TucCP 77-42 showed no significant decrease in juice pH across sample dates, it had the largest overall decrease in pH followed by Ho 07-613. Similar to other criteria, L 01-283, HoCP 04-838 and HoCP 09-804 showed the smallest decrease in juice pH.

Five varieties, HoCP 00-950, L 01-283, L 01-299, HoCP 04-838 and HoCP 09-804 exhibited no increase in titratable acidity compared to the initial sample date (Table 4). Three weeks post-freeze, both TucCP 77-42 and Ho 07-613 showed significant increases in titratable acidity, while HoCP 96-540 didn't show a significant increase until four weeks post-freeze. The largest increase in titratable acidity occurred in TucCP 77-42, nearly doubling three weeks after the initial sample date. The smallest increase occurred in HoCP 09-804 which showed no significant increase.

HoCP 04-838 was the only variety which did not have a significant increase in total soluble polysaccharides across harvest dates (Table 5). The remaining varieties showed an initial significant increase at one week post-freeze, but only TucCP 77-42 and Ho 07-613 showed a continued increase at two weeks post-freeze followed by a decrease at three weeks. By four weeks post-freeze, all varieties showed a reduction in total soluble polysaccharides when compared to the initial sample date. At four weeks post-freeze, HoCP 96-540 and HoCP 09-804 showed a significant decrease in total soluble polysaccharides from the initial sample date.

Using the five criteria to measure stalk cold tolerance, varieties were ranked based on the % change over the sampling period. Rankings were summed to provide an overall ranking for each variety (Table 6). Based upon this data it appears HoCP 09-804 and L 01-283 performed similar to the cold tolerant check variety HoCP 04-838. These varieties are classified as "Resistant or Very Good". HoCP 96-540, HoCP 00-950 and L 01-299 are classified as "Intermediate or Good". The remaining varieties; TucCP 77-42 and Ho 07-613 are classified as "Susceptible or Poor". These rankings are similar to those from previous test with the exception of L 01-283, which is usually listed in the Intermediate or Good category. Also this is the first time cold tolerance data was collected for HoCP 09-804, although a comparable test conducted in 2013 at the LSU AgCenter Sugar Research Station provided a similar ranking.

This was the first freeze event of the year; therefore, the growing point and canopy were still intact for all varieties sampled. These factors provide some level of protection from sub-freezing temperatures. The erectness of the cane also affects stalk cold tolerance because cold air settles lower to the ground; therefore, lodged cane would be in closer proximity with colder temperatures for a longer duration than standing cane. The varieties in this test were mostly erect at the time of the freeze event. It is likely these factors affected the rate and extent of deterioration over the sampling period.

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Table 1. Post-freeze changes in purity (%) of 8 commercial varieties in the plant-cane crop following sub-freezing temperatures on January 7 (24.2ºF) and 8 (24.2ºF), 2017 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm in Schriever, Louisiana.

	Purity (%)					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	1/10	1/17	1/24	1/31	2/6	change[2]	(%)
TucCP 77-42	86.86	77.94 -	73.18 -	70.35 -	<u>69.76</u> -	-17.10	-19.7
HoCP 96-540	89.74	85.65 -	85.75	84.24 -	<u>81.84</u> -	-7.91	-8.8
HoCP 00-950	90.81	85.56 -	87.02	86.36	<u>81.82</u> -	-8.99	-9.9
L 01-283	90.07	87.76	87.97	<u>84.75</u>	85.76	-5.32	-5.9
L 01-299	91.00	85.79 -	86.92 -	86.22 -	<u>84.46</u> -	-6.53	-7.2
HoCP 04-838	89.93	<u>87.35</u>	89.65	89.52	87.73	-2.58	-2.9
Ho 07-613	91.22	86.99	83.73 -	82.59 -	<u>80.02</u> -	-11.19	-12.3
HoCP 09-804	90.17	86.77 -	87.38 -	87.42	<u>85.16</u> -	-5.01	-5.6
Averages by date	89.97	85.48	85.20	83.56 -	<u>82.07</u> -	-11.51	-12.8

[1]Statistically significant ($P = 0.05$) differences from first harvest date are denoted with a plus (+) or minus (-) sign.

[2]Represents the difference between initial sampling date and date with the lowest or highest value underlined in the following tables.

Table 2. Post-freeze changes in sucrose content of 8 commercial varieties in the plant-cane crop following sub-freezing temperatures on January 7 (24.2ºF) and 8 (24.2ºF), 2017 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm in Schriever, Louisiana.

	Sucrose content (lbs/ton)					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	1/10	1/17	1/24	1/31	2/6	change[2]	(%)
TucCP 77-42	230	178 -	160 -	152 -	146 -	-84.52	-36.7
HoCP 96-540	261	231 -	239 -	235 -	222 -	-39.41	-15.1
HoCP 00-950	277	232 -	257	255	232 -	-45.16	-16.3
L 01-283	264	242	255	237	239	-27.32	-10.3
L 01-299	276	230 -	248 -	240 -	238 -	-45.81	-16.6
HoCP 04-838	248	228	252	253	238	-19.47	-7.9
Ho 07-613	279	249 -	227 -	224 -	208 -	-70.77	-25.4
HoCP 09-804	252	235	243	249	229	-22.72	-9.0
Averages by date	261	228 -	235 -	229 -	219 -	-41.90	-16.1

[1]Statistically significant ($P = 0.05$) differences from first harvest date are denoted with a plus (+) or minus (-) sign.
[2]Represents the difference between initial sampling date and date with the lowest or highest value underlined in the following tables.

Table 3. Post-freeze changes in juice pH of 8 commercial varieties in the plant-cane crop following sub-freezing temperatures on January 7 (24.2ºF) and 8 (24.2ºF), 2017 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm in Schriever, Louisiana.

	pH					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	1/10	1/17	1/24	1/31	2/6	change[2]	(%)
TucCP 77-42	5.40	5.27	4.90	5.48	4.57	-0.82	-15.3
HoCP 96-540	5.53	5.67	5.30 -	5.09 -	4.99 -	-0.55	-9.9
HoCP 00-950	5.55	5.65	5.28 -	5.06 -	4.99 -	-0.56	-10.0
L 01-283	5.54	5.74	5.35 -	5.22 -	5.24 -	-0.33	-5.9
L 01-299	5.54	5.54	5.35	5.13 -	4.97 -	-0.58	-10.4
HoCP 04-838	5.57	5.75	5.68	5.18 -	5.36 -	-0.39	-6.9
Ho 07-613	5.58	5.56	5.33 -	5.02 -	4.91 -	-0.67	-12.0
HoCP 09-804	5.54	5.64	5.49	5.24 -	5.19 -	-0.36	-6.4
Averages by date	5.53	5.60	5.33 -	5.18 -	5.03 -	-0.50	-9.1

[1]Statistically significant ($P = 0.05$) differences from first harvest date are denoted with a plus (+) or minus (-) sign.
[2]Represents the difference between initial sampling date and date with the lowest or highest value underlined in the following tables.

Table 4. Post-freeze changes in titratable acidity of 8 commercial varieties in the plant-cane crop following sub-freezing temperatures on January 7 (24.2ºF) and 8 (24.2ºF), 2017 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm in Schriever, Louisiana.

	Titratable acidity (ml 0.1 N NaOH/10 ml juice)					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	1/10	1/17	1/24	1/31	2/6	change[2]	(%)
TucCP 77-42	3.17	3.52	4.40	5.48 +	<u>6.24</u> +	3.07	96.7
HoCP 96-540	2.17	2.04	2.36	2.57	<u>3.00</u> +	0.83	38.2
HoCP 00-950	2.11	2.16	2.14	2.50	<u>2.61</u>	0.50	23.5
L 01-283	2.23	1.80	1.93	<u>2.57</u>	2.22	0.34	15.3
L 01-299	2.01	2.23	2.14	2.41	<u>2.76</u>	0.75	37.3
HoCP 04-838	2.29	1.82	1.74	<u>2.71</u>	1.74	0.42	18.2
Ho 07-613	1.64	1.57	1.85	2.30 +	<u>2.30</u> +	0.66	40.2
HoCP 09-804	2.20	1.94	2.04	2.20	<u>2.20</u>	0.00	0.0
Averages by date	2.22	2.13	2.32	2.84 +	<u>2.88</u> +	0.67	30.1

[1]Statistically significant ($P = 0.05$) differences from first harvest date are denoted with a plus (+) or minus (-) sign.

[2]Represents the difference between initial sampling date and date with the lowest or highest value underlined in the following tables.

Table 5. Post-freeze changes in total soluble polysaccharides of 8 commercial varieties in the plant-cane crop following sub-freezing temperatures on January 7 (24.2ºF) and 8 (24.2ºF), 2017 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm in Schriever, Louisiana.

	Total Soluble Polysaccharides (ppm/brix)					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	1/10	1/17	1/24	1/31	2/6	change[2]	(%)
TucCP 77-42	9693.1	17275.0 +	19586.0 +	12827.0	8678.9	9892.9	102.1
HoCP 96-540	7448.0	10724.0 +	9472.9	8002.5	6827.9	3276.0	44.0
HoCP 00-950	6465.3	10301.0 +	7894.9 +	6584.6	5291.6 -	3835.7	59.3
L 01-283	6603.1	9579.5 +	8335.0	8664.3	5087.7	2976.4	45.1
L 01-299	5882.6	10376.0 +	9189.6 +	7345.1	6747.5	4493.4	76.4
HoCP 04-838	6247.1	9898.6	7390.3	9568.4	5180.9	3651.5	58.5
Ho 07-613	4294.5	6954.7 +	7178.2 +	5789.9 +	3728.6	2883.7	67.1
HoCP 09-804	7427.8	9834.3 +	8706.7	6718.1	5186.5 -	2406.6	32.4
Averages by date	6757.7	10618.0 +	9719.2 +	8187.5	5841.2	3860.3	57.1

[1]Statistically significant ($P = 0.05$) differences from first harvest date are denoted with a plus (+) or minus (-) sign.

[2]Represents the difference between initial sampling date and date with the lowest or highest value underlined in the following tables.

Table 6. Reaction of commercial sugarcane varieties to sub-freezing temperatures during the 2016-2017 harvest season[1].

Resistant	Intermediate	Susceptible
HoCP 04-838 (9)	HoCP 96-540 (23)	Ho 07-613 (35)
HoCP 09-804(9)	HoCP 00-950 (25)	TucCP 77-42 (40)
L 01-283 (12)	L 01-299 (27)	

[1] Varieties were ranked for performance within each of the five parameters used; the number in parenthesis is the sum of these rankings. The lower the number, the better the stalk cold tolerance.