STALK COLD TOLERANCE OF COMMERCIAL AND CANDIDATE VARIETIES DURING THE 2010-2011 HARVEST

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INTRODUCTION

The exposure of sugarcane to damaging frosts occurs in over 20 of the 79 sugarcane producing countries, but is most frequent on the mainland of the United States. The frequent winter freezes in the sugarcane area of Louisiana forced the industry to adapt to a short growing season (7-9 months) and a short milling season (about 3 months). In order to measure the post-freeze deterioration of stalks of commercial and candidate varieties, a collaborative study was conducted between the LSU AgCenter, Audubon Sugar Institute, St. Gabriel, LA and the USDA-ARS, Sugarcane Research Unit at Houma and New Orleans, LA, at the USDA-ARS Ardoyne Farm on Bull Run Road at Chacahoula, LA.

METHOD

Variety trials for estimating stalk cold tolerance by measuring post-freeze deterioration of stalks of commercial and candidate varieties in the field are routinely planted at the Ardoyne Farm, Houma, LA. Commercial varieties of known cold tolerance are grown as controls. They include, but are not limited to, the following varieties: LCP 85-384 for "good" stalk cold tolerance and TucCP 77-42 for "poor" cold tolerance. Good stalk cold tolerance generally means that it will be possible to crystallize sugar from the juice of a variety at four weeks following a freeze event where the temperature drops to 24-26°F. Poor stalk cold tolerance generally means that it will not be possible to crystallize sugar from the juice of a variety after at four weeks following a freeze event where the temperature drops to 24-26°F. From 8 to 10 commercial and candidate varieties, including the control varieties, are planted in the late summer or early fall of each year. Planting is done on raised ridges 1.8 m apart. Variety plots are 12-15 m long and 3 rows wide. The experimental design is a randomized complete block with 3 or 4 replications. Plots are cultivated and fertilized according to recommended plantation practices; insecticides are applied as required according to the economic threshold. The cane is allowed to remain in the field until the first freeze of the harvest season of the year following planting (plant-cane crop). Just prior to or immediately following a freeze, samples are removed serially along the center row of each plot. Normally, from 1 to 5 post-freeze samples are taken depending upon the severity of the freeze and post-freeze weather conditions. Each sample consists of 10 stalks cut at the ground by hand but not stripped or topped. All samples are weighed and passed through a pre-breaker. A sub-sample of 2.2 lb (1000 g) of the prepared cane is pressed in a hydraulic press at 2,500 psi for 1 minute, 15 seconds that separates the cane sample into juice and residue (bagasse), both of which are analyzed, the former for Brix by refractometer and sucrose by polarimetry and the latter only for moisture (by drying). The Brix, sucrose, purity and fiber content of the cane are then calculated from these analyses. From these data, the estimated yield of theoretical recoverable sugar per ton of cane (TRS/TC) is calculated.

Mean stalk weight is calculated by dividing the sample weight by the number of stalks per sample. Juice samples are also analyzed for pH, titratable acidity, mannitol and dextran by the ASI II Method and total soluble polysacharide. When possible, visual ratings are made for both leaf and stalk cold tolerance in the field.

In the current experiment, 10 commercial and 1 candidate varieties were planted at the Ardoyne Farm during the late summer 2009. The commercial varieties included in the study were: LCP 85-384, HoCP 96-540, L 97-128, L 99-226, L 99-233, HoCP 00-950, L 01-283, L 01-299, L 03-371 and TucCP 77-42 (Argentina). The candidate variety included in the study was: HoCP 04-838.

RESULTS AND DISCUSSION

Freezing temperatures that impacted the Louisiana sugar industry during the 2010-2011 harvest season occurred the nights of December 13 and 26, 2010, when the temperatures in the field site at the Ardoyne Farm dipped to 23.7°F and 22.9°F, respectively. Subfreezing temperatures occurred for 11.5 hours on December 13 and 13.5 hours on December 26. Subfreezing conditions actually occurred on the nights of December 6, 8 and 9 leading up to the damaging freeze the night of December 13; however, field inspections revealed that these freezes only affected the growing point (terminal bud) of the stalks and no sampling was indicated. An inspection of the stalks on the morning of December 14 revealed that all internal stalk tissue had been damaged by the previous night's freeze. The subfreezing conditions of December 26 exacerbated the damage seen following the initial freeze event of December 13; it was noted that some stalks had evidence of longitudinal (freeze) cracks appearing on the stalks. Freezing conditions again occurred during the week following the December 26 freeze but not to the not to the same magnitude of the previous two freeze events that damaged the stalks. However, many stalks were frozen solid on the morning of December 27 and, after thawing, all internal tissue appeared ruptured with a brownish and watery appearance. Day-time high temperatures remained relatively cool between December 13 and 26 with the low temperature for the month December averaging only 36.6°F, a departure from normal of -5.5°F (Louisiana Office of State Climatology). Further, for the month of January the average low temperature was 36.3°F, a departure from normal of -3.9°F. Undoubtedly, the low temperatures that followed the hard freezes of December 13 and 26 helped to reduce the deterioration that did occur. With warmer temperatures the signs of deterioration would have been seen sooner following the freeze events and the extent of the deterioration would have been greater for all varieties in the test.

Samples were taken the mornings of December 14, 20 and 28, 2010, and January 4 and 11, 2011. Results for sucrose % cane, purity % cane, yield of theoretical recoverable sugar per ton cane (TRS/TC), pH and titratable acidity (ml 0.1 N NaOH/10 ml juice to raise pH to 8.3) are shown in Tables 1-5. Data for Brix % cane and fiber % cane are not shown. Analyses for total soluble polysaccharides, mannitol and dextran are incomplete and will be reported later.

There was a significant reduction in sucrose % cane for L 99-233 at two, three and four weeks after the initial sampling date on December 14 following the initial freeze on December 13 (Table 1). No other variety showed such a reduction in sucrose % cane until four weeks after the initial sampling date and, then only L 99-226, L 01-283, L 03-371 and TucCP 77-42 showed

a significant reduction when compared to the initial sampling date. The varieties, LCP 85-384, HoCP 96-540, L 97-128, HoCP 00-950, L 01-299 and HoCP 04-838, showed no significant differences throughout the sampling period when compared to the initial sampling date and would be considered as having stalk cold tolerance. Using the drop in sucrose % cane following the freeze events of 2010, L 99-233 would be considered very susceptible to freeze damage. The other varieties that showed a significant drop in sucrose % cane at four weeks after the initial freeze event would be considered susceptible to freeze damage. Those that showed no drop in sucrose % cane during the sampling period would be considered as resistant.

Both L 99-226 and L 99-233 had a significant drop in purity % cane at three and four weeks after the initial freeze event while HoCP 00-950, L 01-283, L 01-299, L 03-371 and TucCP 77-42 showed a significant drop in purity % cane at only four weeks after the initial freeze event (Table 2). The remaining four varieties, LCP 85-384, HoCP 96-540, L 97-128 and HoCP 04-838, showed no drop in purity % cane during the sampling period and would be considered as having stalk cold tolerance. Again, L 99-233 as well as L 99-226 would be considered very susceptible to the freezing temperatures of 2010 using purity % cane as the criteria. HoCP 00-950, L 01-283 and L 01-299 would be considered susceptible. The remaining varieties would be rated as resistant.

Only L 99-233 showed a significant reduction in the yield of theoretical recoverable sugar per ton of cane (TRS/TC) at three and four weeks following the initial freeze event (Table 3). There was a significant reduction in TRS/TC for L 01-283 at one week following the initial freeze event, however, this was considered an anomaly since by week three there was an increase in TRS/TC over week two. By week four, besides L 99-233, four other varieties, L 99-226, L 01-283, L 03-371 and TucCP 77-42, showed a significant reduction in TRS/TC from the initial sampling date. Using the drop in TRS/TC as a criteria for stalk cold tolerance, L 99-233 would be rated as very susceptible while L 99-226, L 01-283, L 03-371 and TucCP 77-42 would be rated as susceptible. The remaining varieties would be rated as resistant.

L 99-233 showed a significant reduction in the pH of the juice at two, three and four weeks following the initial sampling date while L 99-226, HoCP 00-950, L 01-299 and TucCP 77-42 showed a significant reduction in pH at three and four weeks (Table 4). Two varieties, L 01-299 and HoCP 04-838, showed significant reductions at one week but again this was considered an anomaly since the pH of the juice for these two varieties increased the next week before dropping again. All varieties in the test with the exception of two, HoCP 96-540 and L 97-128, showed a significant drop in pH of the juice by week four. Using this criteria for stalk cold tolerance, L 99-233 would be classified as very susceptible as would be L 99-226, HoCP 00-950, L 01-299 and TucCP 77-42. The remaining varieties, with the exception of HoCP 96-540 and L 97-128 would be considered susceptible. HoCP 96-540 and L 97-128 would be considered resistant using the reduction in pH of the juice as the sole criteria.

Both L 99-233 and TucCP 77-42 showed a significant increase in titratable acidity at three and four weeks after the initial sampling date (Table 5). There was an apparent anomaly for L 97-128 at two weeks after the initial sampling date. At four weeks after the initial sampling date, LCP 85-384, L 97-128, L 99-226, HoCP 00-950 and L 03-371 along with L 99-233 and TucCP 77-42 showed significant increases in titratable acidity when compared to the

initial sampling date. The remaining varieties, HoCP 96-540, L 01-283, L 09-299 and HoCP 04-838, showed no changes in titratable acidity during the sampling period. Using titratable acidity as the sole criteria, L 99-233 and TucCP 77-42, would be rated as very susceptible and LCP 85-384, L 97-128, L 99-226, HoCP 00-950 and L 03-371 would be rated as susceptible. The remaining varieties, HoCP 96-540, L 01-283, L 01-299 and HoCP 04-838, would be rated as resistant.

Considering all the data collected and reported thus far for sucrose % cane, purity % cane, TRS/TC, pH and titratable acidity, the reaction (ratings) for our current commercial varieties and one candidate varieties to stalk cold tolerance can be found in Table 6. The ratings are based on the weighted average of the five parameters mentioned above with sucrose % cane and TRS/TC given a weight of two and the other parameters given a weight of one. From the data, it appears that HoCP 04-838 has significantly better stalk cold tolerance than any of the other varieties in the test and was rated as **"Resistant or Very Good"**. LCP 85-384, HoCP 96-540, L 97-128, HoCP 00-950, L 01-283 and L 01-299 were rated as **"Intermediate or Good"** while L 99-226, L 99-233, L 03-371 and TucCP 77-42 were rated as **"Susceptible or Poor"**. These ratings are mostly comparable to the ones given the varieties last year following a freeze event of similar magnitude and duration. However, the rating of one variety, HoCP 00-950, was switched from Resistant to Intermediate with additional data. The ratings for the 2010-2011 harvest season are subject to change with data on total soluble polysaccharide, mannitol and dextran which are considered more sensitive criteria for determining stalk cold tolerance.

It is not known just how much the second significant freeze event on December 26 contributed to the overall results of this test; however, it did serve to enhance the damage seen in the stalks after the first significant freeze event on December 13 and, undoubtedly, contributed to the rate and extent of deterioration. The five criteria used to describe freeze reaction described above are considered not as sensitive as total soluble polysaccharide, mannitol and dextran in determining how a variety might react following the freezes of the magnitude and duration that occurred during the 2010-2011 harvest season.

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Table 1. Post-freeze changes in sucrose % cane of 10 commercial varieties and 1 candidate variety in the plant-cane crop following sub-freezing temperatures on December 13 (23.7°F) and 26 (22.9°F), 2010 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm at Schriever, Louisiana.

	Sucrose (%)					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	12/14	12/20	12/28	1/04	1/11	Change[2]	(%)
LCP 85-384	14.19	14.10	14.31	14.00	12.47	-1.72	-12.1
HoCP 96-540	13.40	13.40	13.08	13.30	13.14	-0.26	-1.9
L 97-128	13.80	13.51	13.48	13.52	12.96	-0.83	-6.1
L 99-226	14.59	13.83	14.04	13.94	13.06 -	-1.54	-10.5
L 99-233	13.17	12.73	12.64 -	13.01 -	12.37 -	-0.80	-6.1
HoCP 00-950	13.36	13.67	13.57	13.07	11.78	-1.58	-11.8
L 01-283	14.32	13.78	13.89	13.60	13.46 -	-0.86	-6.0
L 01-299	14.09	13.92	13.78	12.80	11.14	-2.94	-20.9
L 03-371	14.19	13.59	13.11	12.04	10.45 -	-3.75	-26.4
HoCP 04-838	12.96	13.38	12.83	13.37	12.94	-0.02	-0.2
TucCP 77-42	11.53	10.41	11.03	10.62	9.17 -	-2.36	-20.4
Averages by date	13.60	13.30	13.25	13.02 -	12.09 -	-1.51	-11.1

[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).

Table 2. Post-freeze changes in purity % cane of 10 commercial varieties and 1 candidate variety in the plant-cane crop following sub-freezing temperatures on December 13 (23.7°F) and 26 (22.9°F), 2010 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm at Schriever, Louisiana.

	Purity (%)					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	12/14	12/20	12/28	1/04	1/11	Change[2]	(%)
LCP 85-384	87.63	88.03	87.42	88.51	<u>85.62</u>	-2.01	-2.3
HoCP 96-540	88.51	87.85	88.43	88.25	<u>85.67</u>	-2.84	-3.2
L 97-128	89.50	88.99	89.19	88.48	<u>86.69</u>	-2.80	-3.1
L 99-226	89.18	88.65	88.79	84.16 -	<u>75.89</u> -	-13.29	-14.9
L 99-233	88.63	87.28	85.32	79.02 -	<u>70.58</u> -	-18.05	-20.4
HoCP 00-950	88.83	88.79	89.26	87.80	<u>82.22</u> -	-6.60	-7.4
L 01-283	89.18	87.88	89.31	88.76	<u>84.91</u> -	-4.27	-4.8
L 01-299	87.98	86.97	87.22	87.55	<u>84.23</u> -	-3.76	-4.3
L 03-371	87.77	88.22	87.84	85.58	<u>79.81</u> -	-7.96	-9.1
HoCP 04-838	88.66	88.59	88.27	89.46	<u>87.63</u>	-1.03	-1.2
TucCP 77-42	82.93	79.75	81.30	78.50	<u>70.61</u> -	-12.32	-14.9
Averages by date	88.07	87.36	87.49	86.01 -	<u>81.26</u> -	-6.81	-7.7

[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).

Table 3. Post-freeze changes in yield of theoretical recoverable sugar per ton of cane (TRS/TC) of 10 commercial varieties and 1 candidate variety in the plant-cane crop following sub-freezing temperatures on December 13 (23.7°F) and 26 (22.9°F) at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm at Schriever, Louisiana.

	TRS (lbs/ton)					Actual and percent change during harvest	
Cultivar	12/14	12/20	12/28	1/04	1/11	Change[2]	(%)
LCP 85-384	200	207	195	208	199	-5	-2.5
HoCP 96-540	216	210	212	212	202	-14	-6.4
L 97-128	229	211	217	215	209	-20	-8.7
L 99-226	225	221	221	198	165 -	-60	-26.7
L 99-233	222	209	203	176 -	142 -	-80	-36.0
HoCP 00-950	224	219	226	218	185	-39	-17.4
L 01-283	238	216 -	223	223	203 -	-35	-14.7
L 01-299	212	201	200	206	194	-18	-8.5
L 03-371	213	219	220	206	179 -	-34	-16.0
HoCP 04-838	210	208	204	208	210	-6	-2.9
TucCP77-42	176	154	169	160	129 -	-47	-26.7
Averages by date	215	207	208	203 -	183 -	-32	-14.9

[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 juice pH of 10 commercial varieties and 1 candidate variety in the plant-cane crop following sub-freezing temperatures on December 13 (23.7°F) and 26 (22.9°F), 2010 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm at Schriever, Louisiana.

	pH					Actual and percent change during harvest	
	Harvest Dates[1]						
Cultivar	12/14	12/20	12/28	1/04	1/11	Change[2]	(%)
LCP 85-384	5.41	5.33	5.46	5.44	4.94 -	-0.47	-8.7
HoCP 96-540	5.42	5.33	5.51	5.34	5.14	-0.28	-5.2
L 97-128	5.48	5.38	5.53	5.45	5.36	-0.13	-2.3
L 99-226	5.53	5.47	5.50	4.79 -	4.62 -	-0.91	-16.4
L 99-233	5.44	5.24	5.14 -	4.34 -	4.27 -	-1.17	-21.4
HoCP 00-950	5.43	5.32	5.46	5.22 -	4.98 -	-0.45	-8.2
L 01-283	5.46	5.39	5.49	5.47	5.26 -	-0.19	-3.6
L 01-299	5.44	5.33 -	5.44	5.34 -	5.12 -	-0.32	-5.8
L 03-371	5.59	5.53	5.44	5.07	4.61 -	-0.97	-17.4
HoCP 04-838	5.50	5.35 -	5.47	5.57	5.28 -	-0.22	-4.0
TucCP 77-42	5.33	5.14	5.21	4.79 -	4.56 -	-0.77	-14.4
Averages by date	5.46	5.34	5.42	5.16 -	4.92 -	-0.53	-9.8

[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 5. Post-freeze changes in the titratable acidity of 10 commercial varieties and 1candidate variety in the plant-cane crop following sub-freezing temperatures on December 13 (23.7°F) and 26 (22.9°F), 2010 at the USDA-ARS, Sugarcane Research Unit's Ardoyne Farm at Schriever, Louisiana.

	Titratable acidity (ml 0.1 N NaOH/10 ml juice)						Actual and percent change during harvest	
	Harvest Dates[1]							
Cultivar	12/14	12/20	12/28	1/04	1/11		Change[2]	(%)
LCP 85-384	1.62	1.61	1.52	1.47	2.10	+	0.49	30.0
HoCP 96-540	1.79	1.88	1.65	1.81	2.18		0.40	22.1
L 97-128	1.87	2.17 +	1.84	1.97	2.09	+	0.22	11.8
L 99-226	1.55	1.45	1.36	2.29	2.95	+	1.41	90.9
L 99-233	2.16	2.29	2.57	4.98 +	6.05	+	3.89	180.1
HoCP 00-950	1.87	1.91	1.83	2.11	2.68	+	0.81	43.0
L 01-283	1.73	1.91	1.73	1.71	2.11		0.39	22.3
L 01-299	1.74	1.87	1.76	1.72	1.96		0.22	12.7
L 03-371	1.47	1.34	1.45	2.13	3.56	+	2.10	143.0
HoCP 04-838	1.94	1.82	1.87	1.53	1.86		-0.08	-3.9
TucCP 77-42	3.06	3.25	3.23	4.29 +	5.95	+	2.89	94.6
Averages by date	1.89	1.95	1.89	2.36 +	3.04	+	1.16	61.2

[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 and candidate sugarcane varieties to subfreezing temperatures during the 2010-2011 harvest season [1].

Resistant	Intermediate	Susceptible
HoCP 04-838* (9)	LCP 85-384 (29)	L 99-226 (59)
	HoCP 96-540 (24)	L 99-233 (70)
	L 97-128 (23)	L 03-371 (61)
	HoCP 00-950 (50)	TucCP 77-42 ** (64)
	L 01-283 (34)	
	L 01-299 (36)	

[1] Number in parenthesis is the weighted average of the five criteria, sucrose % cane (X2), purity % cane (X1), yield of theoretical recoverable sugar per ton of cane (TRS/TC)(X2), pH (X1) and titratable acidity (X1). Lower the number, the better the cold tolerance.

* Candidate variety; ** Argentine commercial variety