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WINDROWING AND STORAGE OF SUGARCANE IN LOUISIANA FOLLOWING INJURY BY
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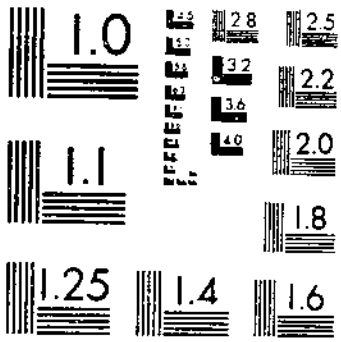

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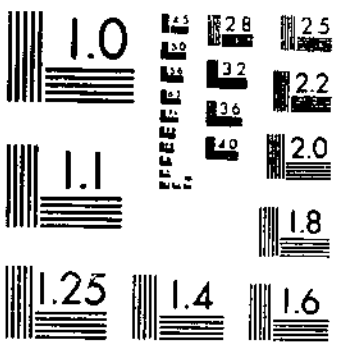

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Windrowing and Storing of Sugarcane in Louisiana Following Injury by Freezing Temperatures [1]

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INTRODUCTION

The purpose of windrowing sugarcane in Louisiana is to protect it against freezing temperatures that often occur during the harvesting period. The safest and best way to insure against freezing damage is to windrow unfrozen cane; i. e., by windrowing early and before a freeze. Unfortunately, to do so would, in many instances, involve some loss of sucrose, because in the absence of freezes cane often continues to grow, mature, and increase in sucrose content. Furthermore, except perhaps under special conditions (*9*),[2] cane in the windrow loses sucrose through physiological inversion produced by the enzyme invertase, a normal constituent of the cane stalk. In earlier publications (*9, 11*), it has been pointed out that, if windrowed cane is kept sufficiently damp to prevent loss of moisture, there is but slight inver-

[1] Submitted for publication, February 12, 1940.
[2] Italic numbers in parentheses refer to Literature Cited, p. 43.

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sion of sucrose, irrespective of the variety of sugarcane, but in the field this condition cannot be readily obtained or maintained. Consequently, in general, it is desirable to windrow only varieties that show the least sucrose inversion under conditions that cause a loss of moisture.

The keeping qualities of seven commercial varieties have been studied and the results reported (*11*). These varieties were divided into three groups according to their resistance or susceptibility to inversion of sucrose, the principal chemical change taking place in harvested unfrozen cane, as follows:

Group 1, resistant to inversion under a wide range of storage and windrowing conditions: Co. 281.

Group 2, showing less resistance than group 1: Co. 290 and C. P. 29/116.

Group 3, usually showing considerable susceptibility to inversion of sucrose in comparison with groups 1 and 2: C. P. 807, C. P. 28/11, C. P. 28/19, and C. P. 29/320.

Co. 281 was the only variety recommended as a windrowing cane. It was considered feasible to windrow varieties belonging to group 2 in an emergency, provided the cane of these varieties was sufficiently mature to justify windrowing.

It is not always practical or possible to windrow unfrozen cane; hence it is necessary to consider the practicability of windrowing cane injured by freezing temperatures. In order for the windrowing of frozen cane to be satisfactory, it must insure against excessive inversion of sucrose and abnormal changes in acidity and pH value, as well as gum formation, or there must be a sufficient delay in these changes to justify the expense of windrowing.

The discovery of a criterion by which it is possible to determine when and when not to windrow sugarcane injured by freezing temperatures would be vitally important in connection with the problem of conserving as well as protecting the crop against further injury by freezing temperatures occurring later in the season. This consideration is particularly true during seasons such as 1937–38 and 1938–39. In the former season, early severe freezing injury was followed by more damaging freezing temperatures, and most of a very large crop was unharvested at the time of occurrence of the first freezing temperature. In 1938 mild freezing temperatures occurred as early as November 9 and 10 and severe freezing temperatures during the period of November 25 to 30, but considerable cane had been windrowed before the latter period. During such seasons the question of the advisability of windrowing cane of varieties other than those normally windrowed presents itself. The answer to this question will depend upon the variety, its maturity, the straightness of the stalk, the degree of injury, the effect of such injury on the normal inversion of sucrose (such as occurs in unfrozen cane), the amount of unharvested cane, the amount of available windrowing cane, and the weather ahead, as well as economic factors, such as labor supply, etc.

In order for nonwindrowing varieties to be as satisfactory for windrowing as Co. 281 they must be equally resistant to moderate freezing injury and such injury must retard their normal susceptibility to inversion to equal resistance. Little is known about either the relative susceptibility of such varieties to freezing injury or to what extent the normal susceptibility to inversion is altered by such injury.

The question in connection with windrowing varieties, such as Co. 281, is simpler than with varieties normally susceptible to considerable loss of sucrose through inversion. The problem is primarily one of determining the extent of injury such varieties will bear and still windrow without serious development of fermentation.

Principal attention will be given in this bulletin to the relation of different degrees of freezing injury to the behavior of cane of the varieties Co. 281 (windrowing variety) and Co. 290 (near windrowing variety—Group 2 (*11*)) when standing, when in the windrow, and when stored at different conditions of temperature and humidity. This work was done during the period 1930–38 at or near (Southdown, Mandelay, Greenwood, Hollywood, Crescent Farm, Ardoyne, and Ellendale plantations) the United States Sugar Plant Field Station, Houma, La.

REVIEW OF LITERATURE

Stubbs (*17*), working with Louisiana Purple and Louisiana Striped varieties of sugarcane, reported less loss of sucrose in cane windrowed immediately before rather than in cane windrowed immediately after a freeze severe enough (29° F.) to kill the bud (terminal buds). Cane windrowed following what he termed a bud-killing freeze (21° F.) kept slightly better than did standing cane, but difficulty was experienced in working with juice from both standing and windrowed cane in the sugar house 21 to 24 days later. Cane subjected to a splitting freeze (19° F.) deteriorated rapidly both when standing and in the windrow, although slightly more rapidly in the former than in the latter case.

On December 7, 1925, Taggart (*18*) windrowed P. O. J. 234 following a bud-killing freeze. On December 21 another lot of this cane was cut for the mill and left in a pile in the field. There was no evidence of inversion in the cane after 11 days in the windrow or after 14 days in the pile.

After the bud-killing freeze of December 8 and 9, 1927 (32° and 26° F., respectively, at Houma, La.) (*20*), Sartoris (*14*) windrowed the varieties P. O. J. 36, 213, and 234 at different locations in Louisiana (Landry Plantation, Lafayette; Crescent Farm near Houma, and the United States Sugar Plant Field Station, Houma). P. O. J. 234 showed considerable inversion during 11 to 23 days in the windrow in two out of four lots. The lot remaining only 11 days in the windrow showed marked inversion. P. O. J. 213 showed little inversion in two different lots, one 11 and one 23 days in the windrow. There was little inversion in one lot of P. O. J. 36 but considerable in another. The standing cane either increased in purity or showed no change (mostly the latter) until more severely damaged on January 1 to 3, 1928. Up to this time there was no evidence of fermentation in the cane. Cane of the varieties P. O. J. 36, 213, and 234 windrowed by Sartoris (*15*) on December 4, 1928, following minimum temperatures November 20, 21, and 23 (35°, 30°, and 31° F., at Houma, La.), showed very rapid inversion.

Cane of these same varieties windrowed following injury by freezing temperature of 25° F. (December 9, 1928), in which the terminal and lateral buds and the leaves were killed, kept better and longer in most instances than the standing cane. The freezing temperatures of December 21, 22, and 23, 1928, and of January 3, 1929 (28°, 27°, 28°,

and 29° F., respectively) (*15*), may have influenced the amount of deterioration in standing cane.

The results of Rands, McKaig, and Bisland (*13*) obtained during the grinding season of 1929–30 (Laurel Grove Plantation, Thibodaux, La.) showed that windrowed cane of varieties P. O. J. 36–M, P. O. J. 213, Co. 281, and C. P. 807, injured by the freezing temperature of December 3 (24° F., temperature in the field at the place of windrowing) that killed all the terminal and lateral buds,[3] kept fairly well, notwithstanding the warm weather that followed windrowing, and after 6 weeks was in as good condition as was the standing cane after 2 or 3 weeks. The effect of the freezing temperatures of December 4 and 5 (Schriever, La., 23° and 25° F., respectively, and Houma, La., 26° and 29° F. (*20*)) and of December 19 to 24, inclusive, ranging from 19° to 31° F. at Schriever, La. (*20*), on standing cane as compared with windrowed cane should be kept in mind when contrasting the results of the two treatments. Undoubtedly the more rapid deterioration in standing cane was due wholly, or in part, to exposure to these temperatures.

SAMPLING OF WINDROWED AND STANDING CANE

In most instances during the years of experimentation (1930–38) the cane used in a given experiment consisted of a block of four to six rows (mostly six), 150 to 250 feet long, back of the first-quarter drain, and exclusive of the buffer rows. Except for some crooked cane used during the season of 1937–38, the cane was straight and of uniform stand and was grown on soil of homogeneous character. One-half of the length of these rows was windrowed (two or three windrows) and the other half left standing. The windrowed and standing cane were divided into two or three equal lengths along the row. Thirty- to forty-stalk samples were taken at the points of division of each windrow and at corresponding pairs of standing rows of cane. Thus, there were from four to nine samples of each windrowed and standing cane at the beginning of the experiment and at successive periods of analyses. The windrowed samples were taken, for the most part, at the top end of each section of the windrows. When taken at the butt end of the windrow, the top cane was removed before selecting the samples. The butt ends of the windrows were covered with leaves after the sampling. This method of sampling yields fairly uniform results, but it is open to the objection that standing cane is subjected to more exposure during later freezes than is cane in commercial blocks. However, this objection can be raised against any method of sampling involving standing cane.

In other experiments dealing with the 7 principal commercial varieties the cane was planted in adjacent 2-row plots. In such cases only 1 windrow of cane and 2 rows of standing cane of each variety were used. Three 30- to 40-stalk samples (selected in the same manner as mentioned above) of windrowed and standing cane were used for each period of analysis. In one experiment only windrowed cane was analyzed.

Samples for Storage

The cane of a block of uniform stand, sufficiently large to yield the desired number of samples, was cut off at the ground and placed, with

[3] The statement relating to the lateral buds is based on information furnished by R. D. Rands rather than on the publication cited.

the tops on, in a long pile. The desired number of samples was then selected by drawing 30 stalks (20 stalks were used during the season of 1938–39) at random from the entire pile for each sample. In the experiments in which both stripped and unstripped samples were stored the cane of the former sample was stripped after the selection had been made. From three to five 30-stalk samples (mostly 5) of each treatment were used for each period of analysis at each condition of storage.

In certain tests the progress of deterioration in different parts of the cane stalk was followed. In such cases the stalks of extra samples from the standing, windrowed, and storage cane were cut into three equal lengths just before analysis, and the juice from these sections was analyzed.

The samples used for studying symptoms and determining the amount of freezing injury were selected by taking stalks at each division point in the windrow and in standing cane, or at random from the pile used in selecting samples for storage.

Method of Analysis

The cane samples were crushed in a 10-inch, three-roller, motor-driven mill, giving roughly 60- to 65-percent juice extraction on the cane basis. The Brix was determined on the juice, after a ½-hour settling, and the direct polarization for apparent sucrose was made on a portion of juice clarified by dry basic lead acetate.[4] Alcohol was used on juice samples that would not clarify properly because of the presence of spoilage products. A double normal weight (56 gm.) of juice and denatured alcohol was made up to a volume of 200 cc. and filtered, and the filtrate was polarized. An approximate correction for the alcohol was applied to the result.

The pH value and acidity of the juice were determined electrometrically by use of a commercial glass electrode. A 50-cc. portion of juice was taken, the pH determined, and then small amounts of 0.1 N sodium hydroxide were added until a pH of 8.3 was obtained. The acidity was expressed as the cubic centimeters of 0.1 N alkali required to neutralize 10 cc. of juice. The end point of pH 8.3 was selected, because it roughly corresponds to the phenolphthalein end point of the usual colorimetric titration. When dealing with juice from deteriorated cane, the difference between the test of the check samples (initial samples) and that of the later samples was termed the excess acidity. During the harvesting seasons of 1937–38 and 1938–39 the excess acidity was, in some instances, determined by the distillation method (*4*).

EARLY WORK (1930–36)

The experimental work on the relation of freezing injury of sugarcane to windrowing conducted during the period 1930–36 was performed incidental to other more pressing work and also was conditioned by the opportunity to do such work; that is, the occurrence and time of occurrence of freezing temperatures. As a result, some of the experiments were of short duration and were not so conclusive as they otherwise might have been. However, experience was gained

[4] The authors are indebted to R. B. Bisland, D. D. Sullivant, and L. F. Harmon for part of the Brix and sucrose analyses referred to in this bulletin.

by which it was possible to judge more accurately the degree of injury sugarcane may suffer and still windrow satisfactorily. By satisfactorily is meant that there is sufficient conservation of recoverable sucrose to justify the expense of windrowing.

Injury to sugarcane by freezing temperatures normally begins at the tip of the leaves and in the spindle. As the freezing condition becomes more severe, the injury tends to become evident farther and farther down the stalk until all the leaves and all the eyes and the stalk are killed. The lower eyes and the lower part of the stalk are the last to be killed. It was found that the number of eyes (lateral buds) killed was a fairly accurate indication of the degree of injury, almost to a point when the cane was completely killed. Other symptoms, such as the killing of the terminal buds, the proportion of leaves killed, external and internal discoloration, etc., and their relation to windrowing, were also studied. These symptoms are of considerable aid in estimating the amount of injury, particularly when it is moderate, but when the damage is more severe they lack a definiteness of injury that is associated with the condition of the lateral buds. When the injury is very severe, the amount of internal discoloration and of splitting of the internodes are aids in estimating the degree of injury.

More than a superficial inspection is required to determine with certainty whether or not eyes are sound, injured, or dead. The eyes should be split open and examined for symptoms of injury, such as softening, water soaking, darkening, and blackening. Only firm eyes that are normal in color and with no signs of discoloration are regarded as sound.

It is believed that the degree of injury is a more satisfactory criterion for determining when and when not to windrow cane than the degree of temperature to which cane has been exposed. The degree of injury that a given freezing temperature may impose will depend upon a number of factors, such as duration of the freezing temperature, the temperature preceding and following freezing, presence or absence of wind, intensity and direction of wind, location, variety, maturity, stand, straightness of cane, etc.

On the basis of the weather records that are now taken there is often some uncertainty as to the exact minimum temperature to which given lots of cane are exposed. The minimum temperatures as recorded by the United States Weather Bureau are believed generally unrepresentative of those that are obtained in the field, because the stations are usually located near the bayous and the Mississippi River where the temperatures are often higher than at locations away from them. The stations are also often sheltered by sugar houses and other buildings. The temperatures at the stations may differ by several degrees from those at locations in the field, as, of course, may also the temperatures at different locations in the field. Although minimum temperature records more representative of field conditions would aid in anticipating possible freezing injury, an accurate prediction of the degree of injury that a particular temperature would cause would not be possible in most instances.

The data presented will be considered as related to the freezing temperatures to which the cane had been exposed but more particularly as related to the degree of injury, especially as measured by the eyes that had been killed, or rather the eyes that remained sound.

During the grinding season of 1930–31, following a freezing temperature of 30° F. (Southdown Plantation, Houma, La. (*20*)) on November 27, P. O. J. 213 (plant cane), grown on black land at Crescent Farm Plantation (a short distance from Southdown), in which the terminal buds had been killed, showed a drop of 2 to 3 points in purity (hand-mill and factory-mill analyses) after 32 days in the windrow, whereas in the standing cane the initial purity was maintained. The temperature in the black lands was probably somewhat lower than at Southdown. The freezing temperature of 30° F. on November 27 was followed by a freezing temperature of 29° F. on December 17 and 26° and 29° F. on December 23 and 24, respectively. These temperatures were recorded at Southdown Plantation. On December 23 the temperature in the standing cane was as low as 23° F. No difficulty was experienced in handling the juice from either the hand mill or the factory mill throughout the duration of the experiment.

In 1932 another lot of P. O. J. 213 (plant cane on Greenwood Plantation near Southdown), in which all the terminal buds were killed, was windrowed on November 13, 2 weeks after exposure to freezing temperatures of 27.5° to 29° F. Two weeks later there was no indication of any abnormal changes and only a slight change in sucrose content and in purity. The standing cane was likewise in excellent condition and showed no change in sucrose content and purity.

On December 17 and 18 (1932) the temperatures went down to 24.5° and 28° F., respectively. Stripped (as for the mill) and unstripped samples of Co. 281 (plant cane) and P. O. J. 36–M (second-year stubble) that showed water soaking more or less throughout the stalks, and in which the terminal buds and most of the lateral buds were killed, were immediately stored at temperatures of 47°, 57°, 65°, and 75° F., and relative humidities of 97, 98, 98, and 93 percent, respectively. Wet bags were placed on the butt and top ends of the stripped samples and sprinkled three times daily, whereas the unstripped samples were left exposed to the humidity of the air. The storage conditions also included a relative humidity of 65 percent at 65° F. All of the samples stored under the latter condition were exposed to the humidity of the air.

During 3 weeks' storage there was an increase in acidity in the juice of samples of both varieties at all conditions of storage, except in the unstripped samples of P. O. J. 36–M at 98-percent relative humidity at 65° F. The increase was slight except in the cases mentioned below. The increase in acidity in samples stored at 65-percent relative humidity at 65° F. was probably no more than may be expected as a result of drying. There was scarcely any change in purity in samples of Co. 281 under any of the storage conditions and only a slightly greater change in P. O. J. 36–M. The greatest drop in purity (2 points in stripped samples and 6 points in unstripped) was in 36–M stored at 65-percent relative humidity at 65° F. Aside from the change in acidity, there were no other signs of abnormal changes in P. O. J. 36–M at any of the conditions of storage.

The results obtained from unstripped samples of Co. 281 at all the conditions of storage and from stripped samples stored at 65 percent relative humidity at 65° F. were similar to those obtained with samples of P. O. J. 36–M except for the difference in the drop in purity.

The juice from wet (stripped) samples of Co. 281 stored at each temperature would not filter (or filtered with great difficulty) after 3 weeks' storage, although no difficulty was experienced during the first 2 weeks of storage. During 3 weeks considerable excess acidity (1.12 cc. at 47°, 3.17 cc. at 65°, and 2.32 cc. at 75° F.) developed in these samples. Although such extreme conditions are rarely, if ever, encountered in the field following windrowing, the results indicate that moisture may become a factor in the deterioration of cane injured by freezing temperatures. The results also indicate that under less severe conditions cane showing such injury would windrow successfully.

Windrowed cane (*1*) grown contiguously to that used in the foregoing storage experiment showed no abnormal changes in 16 days. It is interesting to note that standing cane of P. O. J. 36–M (*1*), in which most of the terminal buds were killed, ceased to increase in sucrose content following the freeze of November 13, whereas Co. 281, with similar injury, continued to mature.

On December 11, 1934, a temperature of 26° F. (Southdown) was recorded and on December 12, 19° F. A quantity of plant cane of varieties Co. 281 and Co. 290 was windrowed on both dates and a corresponding amount of cane was left standing. Co. 281 was from one cut and Co. 290 from another a short distance away, and the cane in each cut was windrowed on both dates. In the Co. 281 cane, windrowed on December 11, 9.4 percent (1.6 eyes per stalk, range 0 to 5 per stalk) of the eyes per stalk were sound, and there was no splitting; in Co. 290 there was 16.5 percent of sound eyes (3.1 eyes per stalk, range 2 to 6 per stalk) and no splitting. In cane windrowed on December 12, all the eyes in both varieties were killed and 6 out of 20 stalks showed splitting in each case. By the end of 2 weeks the juice from samples of standing cane of both lots of each variety was not workable in the laboratory,[5] and considerable acidity had developed. The juice from cane of both varieties windrowed December 11 continued to filter normally, but by the end of 2 weeks the acidity had increased slightly. The drop in purity of Co. 281 was 0.5 point and that of Co. 290, 2.0 points. In Co. 281 cane, windrowed December 12, the juice from 2 out of 4 samples was not workable in the laboratory, and the acidity had increased by 1.1 cc. The juice from none of the samples of Co. 290, windrowed the same date, would filter, and the acidity had increased by 0.8 cc.

On December 3 and 4, 1935, Co. 281 was windrowed at two locations, one on sandy (first-year stubble, United States Sugar Plant Field Station, Houma) and one on black (plant cane, Ellendale Plantation) lands, following the freezing temperatures of December 3. The temperature in sandy land was 29° F. In the black land the temperature was not recorded, but a short distance away it went as low as 22° F. The sandy-land cane showed 4 percent of the eyes sound, 54 percent injured, and 42 percent killed. This injury seems rather severe as the result of a temperature of 29° F. In the black-land cane 24 percent of the eyes were injured and 76 percent killed. After 2 weeks no abnormal changes were evident in either lot of standing or windrowed cane.

[5] By the statement that the juice was not workable is meant that the juice would not filter nor clarify satisfactorily with basic lead acetate. The same condition of the juice is represented when it is stated that it would not filter. It is believed that the nonfiltrability of juice is a rough measure of gum formation. In certain cases, as indicated in the tables and the text, juice that was nonfiltrable, or filtered with difficulty, was treated with alcohol to precipitate the gum in order to obtain a polarization reading.

On November 28, 1936, the minimum temperature at the United States Weather Bureau Station at Southdown Plantation was 29° F.; in the black land at the United States Sugar Plant Field Station it was 26.5° F., and at Crescent Farm Plantation, 25.5° F. Co. 290 (plant cane), in which 50 percent of the eyes were sound, was windrowed on black land at Hollywood Plantation. Unstripped samples were also stored at relative humidities of 97 and 75 percent at 65° F. After 18 days no abnormal changes were evident in standing cane or in cane in the windrow, or at the two conditions of storage after 14 days. The drop in purity (1.2, 1.5, 0.9, and 0.7 points, respectively) was slight in all four lots. Unstripped Co. 281 cane (second-year stubble) that had been subjected to a temperature of 26.5° F., in which 93 percent of the eyes were sound, was stored for 2 weeks at the above conditions of temperature and relative humidity without any deleterious changes being evident by analysis. There was a drop in purity of 1.5 points at 97 percent relative humidity and 1.1 points at 75 percent.

WORK DONE DURING SEASON OF 1937–38

Weather Conditions

The official weather records (*20*) at the stations [6] within that part of Louisiana devoted to growing sugarcane for sugar manufacture show the following ranges in minimum temperatures on different dates on which freezing temperatures occurred during the months of November and December 1937: November 20, 24° to 29° F.; November 21, 22° to 31°; November 22, 27° to 32°; November 29, 25° to 34°; November 30, 28° to 38°; December 6, 22° to 29°; December 7, 18° to 26°; December 9, 24° to 34°; December 10, 22° to 29°; December 11, 25° to 32°; December 19, 30° to 38°; December 20, 30° to 40°; and December 21, 30° to 42° F. The minimum temperatures at the two New Orleans stations were not included, because the temperatures at these stations were higher and less representative of field conditions than those recorded at the other stations. The extreme difference in temperatures on the different dates at the various stations ranged from 5° to 12° F.

Duration of freezing temperatures, which varies considerably, is a factor of importance influencing the amount of injury to cane. On the night of December 6 and the morning of December 7 the temperatures at the United States Sugar Plant Field Station remained below 30° F. for more than 9 hours. This fact may account for the severe damage to standing cane that followed in that locality.

The records given above show that there were four periods of freezing temperatures during November and December: November 20 to November 22, November 29 and 30, December 6 to 11, and December 19 to 21. The minimum temperatures during the second and fourth periods were not sufficiently low in the vicinity of Houma to be responsible for much damage. The data presented relate primarily to injury resulting from freezing temperatures occurring during the first and third periods.

[6] Southern Division: Baton Rouge, Belle Chasse, Cinclare, Donaldsonville, Franklin, Houma, Morgan City, Reserve, and Schriever; Southwestern Division: Abbeville, Chenevville, Crowley, Lafayette, and Melville.

For convenience of discussion, the freezing temperatures of November 20, 21, and 22 will be referred to in this bulletin as the first freeze and that of December 6, 7, 9, 10, and 11 as the second freeze. The weather records at Houma, La., covering the period in which the experiments were conducted, are recorded in table 1.

TABLE 1.—*Weather records*[1] *at Houma, La., during periods in which windrowing experiments were conducted in the harvesting season of 1937–38*

Date	Rainfall	Temperature			Sky	Date	Rainfall	Temperature			Sky
		Maximum	Minimum	Mean				Maximum	Minimum	Mean	
1937	*In.*	*°F.*	*°F.*	*°F.*		*1937*	*In.*	*°F.*	*°F.*	*°F.*	
Nov. 19	0.83	64	41	52.5	Cloudy.	Dec. 16	0.58	75	60	67.5	Cloudy.
Nov. 20	0	45	28	36.5	Clear.	Dec. 17	0	65	55	60.0	Do.
Nov. 21	0	47	28	37.5	Do.	Dec. 18	0	56	42	49.0	Do.
Nov. 22	0	50	30	40.0	Do.	Dec. 19	0	64	33	48.5	Clear.
Nov. 23	0	47	40	43.5	Cloudy.	Dec. 20	0	66	34	50.0	Do.
Nov. 24	.13	58	42	50.0	Do.	Dec. 21	0	66	37	51.5	Do.
Nov. 25	.10	61	46	53.5	Do.	Dec. 22	.92	70	49	59.5	Cloudy.
Nov. 26	.03	64	55	59.5	Do.	Dec. 23	0	66	52	59.0	Do.
Nov. 27	0	71	58	64.5	Do.	Dec. 24	0	71	50	60.5	Partly cloudy.
Nov. 28	0	66	40	53.0	Clear.	Dec. 25	0	74	55	64.5	Cloudy.
Nov. 29	0	63	31	47.0	Do.	Dec. 26	0	75	60	67.5	Partly cloudy.
Nov. 30	0	66	32	49.0	Do.	Dec. 27	0	75	54	64.5	Do.
Dec. 1	0	68	35	51.5	Partly cloudy.	Dec. 28	0	70	55	62.5	Do.
Dec. 2	0	67	38	52.5	Clear.	Dec. 29	0	75	57	66.0	Do.
Dec. 3	0	69	33	51.0	Partly cloudy.	Dec. 30	0	72	57	64.5	Do.
Dec. 4	.05	66	52	59.0	Do.	Dec. 31	0	75	54	64.5	Do.
Dec. 5	.83	60	41	50.5	Cloudy.	*1938*					
Dec. 6	0	42	26	34.0	Clear.	Jan. 1	.40	68	59	63.5	Cloudy.
Dec. 7	0	53	24	38.5	Partly cloudy.	Jan. 2	0	59	45	52.0	Partly cloudy.
Dec. 8	1.25	56	42	49.0	Cloudy.	Jan. 3	0	64	35	49.5	Clear.
Dec. 9	0	50	34	42.0	Do.	Jan. 4	0	61	37	49.0	Partly cloudy.
Dec. 10	0	44	27	35.5	Partly cloudy.	Jan. 5	1.15	61	44	52.5	Cloudy.
Dec. 11	0	44	29	36.5	Do.	Jan. 6	.10	65	47	56.0	Do.
Dec. 12	.02	65	40	52.5	Cloudy.	Jan. 7	0	56	43	49.5	Partly cloudy.
Dec. 13	0	73	57	65.0	Clear.						
Dec. 14	0	77	53	65.0	Partly cloudy.	Total or average.	6.39	63	44	53.5	
Dec. 15	0	76	61	68.5	Do.						

[1] U. S. Department of Agriculture Weather Bureau Climatological Data (*20*).

CONDITION OF CANE AT THE TIME OF FIRST FREEZE

At the time of the first freeze the cane differed greatly in maturity. Because of dry weather in some of the western parishes of the Sugar Belt during the early part of the growing season, the growth of sugarcane was very much retarded. With the return of rainy weather in early October the cane resumed active growth, which resulted in an immature condition of the cane. In other localities, near Houma for example, the cane was relatively mature.

As a result of the torrential rains of October 2 and 3, much of the cane in many of the localities was badly lodged and crooked. Such cane does not form a close mat in the windrow and, therefore, is not as satisfactory for windrowing as straight cane.

INJURY RESULTING FROM FREEZING TEMPERATURES OF FIRST FREEZE

The effect of the freezing temperatures occurring on November 20, 21, and 22 (the first freeze) varied from cane that was slightly injured to cane that was practically killed, with only an occasional eye at the bottom of the stalk remaining sound (*16*). In some instances all the

eyes may have been killed. Variation in the degree of freezing temperatures at different locations throughout the Sugar Belt would account for most of this difference in injury. However, in some instances there were differences in the amount of injury in the same field, depending, it would seem, upon the direction of the wind. In one or two instances the difference was rather striking.

In most localities one of the immediate effects of this freeze was a cessation in the formation of sucrose. This effect was particularly serious in immature cane. In certain cases the sucrose content was so low as to make the manufacture of sugar unprofitable, although the condition of the cane was otherwise satisfactory for grinding. It is expected that with the same exposure immature cane would suffer more actual injury than cane of greater maturity.

It is believed that lodged cane is subject to more injury (and probably more varied injury) by freezing temperatures than straight, erect cane, although this fact has not been clearly demonstrated. It would seem that the lodged cane would permit the cold air to settle more readily into the cane and the heat to radiate from the soil more promptly, whereas the leaves of the erect cane would tend to retard the loss of heat from the soil and most of the cane stalk and to interfere with the settling down of the cold air around the cane stalk. Records taken during the grinding seasons of the last few years show that normally the coldest minimum temperature in the cane field is at or near the growing point of the cane stalk, increasing at lower levels as the ground is approached. King (*8*) has already reported similar observations.

Injury Following Freezing Temperatures of Second Freeze

WINDROWED CANE

In some instances after the second freeze (December 6, 7, 9, 10, and 11) considerable injury was observed in cane windrowed immediately following the first freeze. A large part of this injury was due to the crookedness of the cane when windrowed. The principal damage was to stalks or portion of stalks that were uncovered or incompletely covered by leaves, or to stalks projecting into the air. Although freezing injury sometimes occurs in straight cane in the windrow, it is usually limited to the top joints of the stalk, the upper part of which lies at or near the top of the windrow.

STANDING CANE

Much of the standing cane was killed outright by the low temperatures of December 6 and 7. In many localities this injury was undoubtedly aggravated by the freezing temperatures of December 9, 10, and 11. The windrowed cane (i. e., before windrowing) and the cane used for storage at different temperatures and humidities in the experiments discussed in this bulletin were exposed only to the freezing temperatures of December 6 and 7.

The data relating to killing of the eyes and splitting of the stalk of cane used in these experiments are reported in table 2.

TABLE 2.—*Degrees of freezing injury to sugarcane varieties Co. 281 and Co. 290 used in windrowing and in storage experiments as measured by injury and killing of eyes and splitting of stalk*

Variety and experiment No.	Stalks used	Eyes per stalk (average)	Eyes per stalk killed (average)	Eyes per stalk injured (average)	Eyes per stalk sound (average)		Remarks
Co. 281 (plant cane):	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	
1 [1]	10	15.0	6.9	2.4	5.7	38.0	None out of 30 stalks showed splitting.
2 [2]	18	14.0	9.9	1.3	2.8	20.0	1 internode in each of 2 out of 9 stalks showed splitting.
3 [3]	30	17.3	15.4	1.6	[4] .3	1.7	1 internode in 1, 2 in 1, and 3 in 1 out of 10 stalks showed splitting.
4 [5]	20	15.4	15.4	0	0	0	1 internode in each of 5 stalks and 2 internodes in each of 2 stalks out of 20 stalks showed splitting.
Co. 290 (plant cane):							
1 [1]	10	16.3	7.0	3.3	6.0	36.8	1 internode in 1 stalk out of 30 showed splitting.
2 [2]	18	16.0	12.3	1.8	1.9	11.9	1 internode in each of 5 stalks and 2 internodes in each of 3 out of 18 stalks showed splitting.
4 [5]	20	16.5	16.5	0	0	0	1 to 4 internodes in 12 out of 20 stalks showed splitting.

[1] Windrowing experiment No. 1: Cane of varieties Co. 281 and Co. 290 windrowed November 22, 1937, Hollywood Plantation. Storage experiment No. 1: Cane from same cuts as windrowing experiment No. 1 stored at different temperatures and relative humidities, Nov. 24. Data apply to both windrowing and storage experiments.

[2] Windrowing experiment No. 2 (Co. 281): Cane windrowed Nov. 29 at the U. S. Sugar Plant Field Station, Houma, La. Windrowing experiment No. 2 (Co. 290): Cane windrowed Nov. 26 at Hollywood Plantation.

[3] Windrowing experiment No. 3 (Co. 281): Cane windrowed Dec. 2 at Ardoyne Plantation.

[4] The lower eye only of 9 out of 20 stalks was sound.

[5] Windrowing experiment No. 4: Cane windrowed Dec. 9. Co. 290 was located in the same cut and adjacent to that used in windrowing and storage experiment No. 1. Co. 281 was from a different cut at Hollywood Plantation. Storage experiment No. 4: Cane from the same cuts as that used in 4, stored Dec. 9 at different temperatures and relative humidities. Data apply to windrowed and stored cane of both varieties.

GERMINATION EXPERIMENTS

In order to determine whether it is possible to detect viable eyes by their physical appearance, the eyes (single eye seed pieces) that appeared to be alive in 10 stalks of each of the varieties Co. 281 and Co. 290, taken at random from the windrow in connection with experiment No. 1 [7] (table 2), were incubated for 2 weeks in wet sawdust at a temperature of 80° F. The injured and dead eyes (the upper eyes) were discarded. In Co. 281, 85 percent of the eyes germinated and 100 percent of the seed pieces rooted. In Co. 290, 18 percent of the eyes germinated and 92 percent of the seed pieces showed rooting. The rooting in Co. 290 was not as profuse as in Co. 281. It is possible that the conditions of germination were not as favorable for Co. 290 as for Co. 281; otherwise, it must be concluded that the vitality of the part of the cane from which the eyes came was not normally as great in Co. 290 as in Co. 281, or that it was impaired more by freezing or by conditions in the windrow, or by both. The results in connection with Co. 281 were definite and conclusive. Although the results in connection with Co. 290 are less conclusive, they do show that there was some life in most of the seed pieces selected.

[7] In this experiment a quantity of the cane was windrowed on November 22, part of which was used for storage at different temperatures and humidities and the remainder was left in the windrow, from which samples were taken for the germination test on December 6.

Windrowing Experiments

Three lots of Co. 281 (experiments No. 1, No. 2, and No. 3, table 3) and two lots of Co. 290 (experiments No. 1 and No. 2, table 3) showing different degrees of injury (table 2) were windrowed during the interval between the first and second freezing periods, and one lot of each variety was windrowed on December 9 (experiment No. 4, table 3) following the more severe temperatures of December 6 and 7, in which all the eyes were killed and there was also considerable splitting of the stalk (table 2). The Co. 290 used in experiments No. 1 and No. 4 was from adjacent areas located in the same cut (table 2). It had been expected to obtain Co. 281 for experiments No. 1 and No. 4 from the same cut, but by mistake the standing cane of this cut was harvested just before and the windrowed cane just after initiating experiment No. 4. The Co. 281 and Co. 290 in experiment No. 1 were located on the opposite side of the same road. The other lots of both varieties were somewhat more widely separated.[8]

[8] Location of cane used in various experiments: No. 1, both varieties from Hollywood Plantation; No. 2, Co. 290 from Hollywood Plantation and Co. 281 from the United States Sugar Plant Field Station; No. 3, Co. 281 from Ardoyne Plantation; and No. 4, both varieties from Hollywood Plantation.

TABLE 3.—*Relation of the degree of freezing injury to changes in Brix, apparent sucrose, acidity, and pH value, and to the workability of juice in standing and windrowed sugarcane of varieties Co. 281 and Co. 290*

Variety and experiment No.	Date of analysis	Duration of experiment	Average sound eyes per stalk	Standing cane						Windrowed cane					
				Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
	1937	*Days*	*Percent*	°	*Percent*			*Cubic centimeters*	*Percent*	°	*Percent*			*Cubic centimeters*	*Percent*
Co. 281 (plant cane):															
1	Nov. 24	0	38	16.33	14.04	86.0	5.30	2.62	60	16.41	14.07	85.7	5.30	2.58	60
	Nov. 30	6		15.80	13.40	84.8	5.32	2.53	60	16.06	13.53	84.2	5.30	2.49	60
	Dec. 13	19								16.43	13.61	82.8	5.38	2.61	60
2	Nov. 29	0	20							16.18	13.54	83.7	5.25	2.65	58
	Dec. 14	15								17.04	14.14	83.0	5.33	2.57	57
	Dec. 27	28								16.60	13.35	80.4	5.30	2.70	58
	1938														
	Jan. 4	36								17.04	[1] 13.72	80.5	4.98	3.08	56
	1937														
3	Dec. 3	0	1.7	14.86	11.90	80.1	5.42	2.20	62	14.88	11.81	79.4	5.43	2.21	65
	Dec. 10	7		14.41	11.61	80.6	5.30	2.66	61	14.71	11.85	80.6	5.38	2.43	62
	Dec. 17	14		13.57	(2)		4.20	7.28	94	14.66	11.52	78.6	4.90	3.50	63
	Dec. 23	20		13.36	8.43	[3] 63.1			60	15.14	11.81	78.0			65
	Dec. 31	28								15.42	12.16	[4] 78.9	4.82	3.33	63
4	Dec. 10	0	0	14.89	12.57	84.4	5.30	2.92	64	15.13	12.66	83.7	5.35	2.59	63
	Dec. 19	9		14.27	9.76	[3] 68.4	4.28	6.84	59	14.91	10.43	[3] 70.0	4.37	5.82	60
Co. 290 (plant cane):															
1	Nov. 24	0	37	16.96	14.58	86.0	5.25	2.56	63	16.93	14.47	85.5	5.25	2.78	63
	Nov. 30	6		16.62	14.09	84.8	5.32	2.56	64	16.86	13.95	82.7	5.30	2.57	65
	Dec. 13	19		15.58	12.66	81.3	5.06	3.33	62	17.02	13.68	80.4	5.37	2.73	62
	Dec. 31	37		14.70	(2)		3.97	9.15	58	17.00	13.59	79.9	5.29	2.81	56
	1938														
	Jan. 7	44								16.78	12.76	76.0	5.12	3.65	57

	1937														
	Nov. 27[4]	0		15.63	12.83	82.1	5.25	2.96	62	15.74	12.02	82.1	5.25	2.87	62
	Dec. 2	6		15.64	12.80	81.8	5.35	2.78	63	16.02	13.06	81.5	5.35	2.76	61
2	Dec. 10	14	11.9	15.34	12.56	81.9	5.30	2.86	61	16.15	13.17	81.5	5.30	2.78	58
	Dec. 17	21		14.59	(2)	.....	4.20	7.26	60	16.22	13.06	80.5	5.28	3.01	62
	Dec. 31	34		.....	.....	.....	.....	.....	.....	16.37	13.36	81.7	5.18	3.07	57
	Dec. 10	0		15.52	12.89	83.1	5.32	2.86	64	15.45	12.54	81.2	5.33	2.96	62
4	Dec. 19	9	0	14.98	10.36	[3] 69.2	4.20	6.44	61	15.15	10.71	[3] 70.7	4.46	5.80	60

[1] Juice from 1 out of 3 samples was not workable and was analyzed by adding alcohol.
[2] Juice was not workable and no polarization was made.
[3] All juice samples were analyzed by adding alcohol.
[5] Juice from 2 out of 6 samples was not workable by the usual method and was analyzed by adding alcohol.
[4] Cane windrowed Nov. 26.

Under the conditions of the experiments it is not possible to divorce the full effect of the two freezes on either variety. First, the cane had already been injured at the time of the second freeze. It is very likely that the effect of the second freeze on uninjured cane would not have been so severe as the combined effect of the two freezes. Secondly, although there was no serious deterioration in standing or windrowed cane of either variety before the second freeze as compared with the rapid deterioration that followed this freeze, it is possible that the relative low temperatures prevailing during the interval between the two freezes might have been largely responsible for the conservation of the cane during the first period, whereas the somewhat higher temperatures (fig. 1) that followed the second freeze

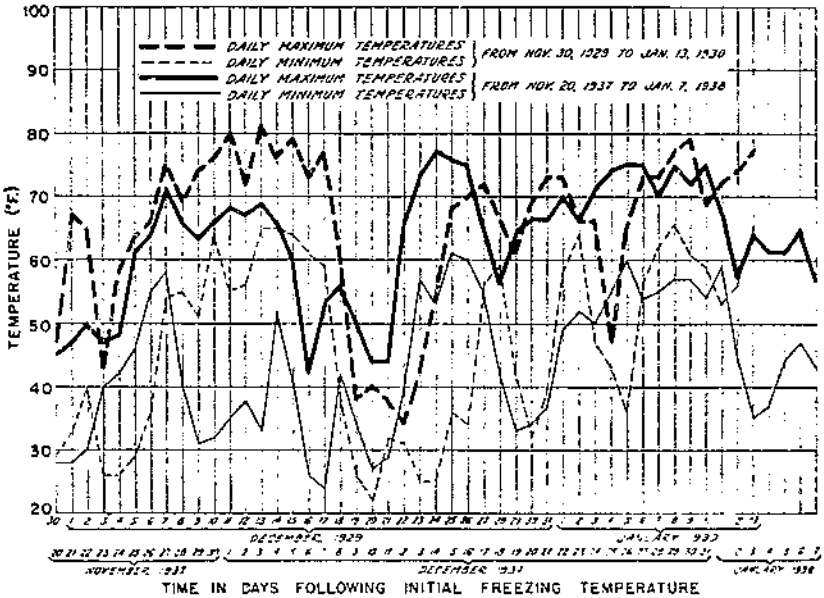

FIGURE 1.—Maximum and minimum temperatures during experiments conducted during the seasons 1929–30 and 1937–38 (20).

may have been largely responsible for the very rapid deterioration that followed. And thirdly, both standing and windrowed cane suffered from the second freeze and, therefore, it is not possible to know exactly what would have happened to the cane had not the second freeze occurred. However, the fact remains that the cane windrowed before the second freeze continued to hold up long after the standing and windrowed cane used in the experiments initiated after the second freeze had reached an advanced state of deterioration. This fact indicates that the conservation during the interval between the two freezes was not due so much to the weather conditions that followed windrowing as it was to the condition of the cane. This observation is particularly valid in connection with Co. 290 in which a lot of cane from the same source and with the same initial injury was used in experiments following both freezes (experiments No. 1 and No. 4, table 3). That the degree of injury was a more important factor than weather influencing the relative conservation of the cane

following the two freezes is further substantiated by storage experiments discussed on p. 21.

The most important observation to be made from the data presented in table 3 is that under weather conditions such as those of the season of 1937–38 serious development of fermentive changes is not to be expected in windrowed cane of the varieties Co. 281 and Co. 290 showing any sound eyes at the time of windrowing. The cane of both varieties used in experiments begun following the second freeze, in which all the eyes were killed, deteriorated very rapidly whether standing or windrowed. The deterioration was slightly more rapid in standing cane, but windrowed and standing cane alike were soon unfit for sugar manufacture. It should be stated in this connection that in many other sections in the Sugar Belt factories continued to grind standing cane for 2 or 3 weeks later, indicating that much of the cane in these sections was not injured so severely as a result of the second freeze as was the cane used in these experiments.

In windrowed cane analyzed at the termination of the experiments there were signs of deterioration in the way of excess acidity and gum formation in the two lots of Co. 281 showing 1.7 and 20 percent of sound eyes. There was some excess acidity in the two lots of Co. 290 windrowed before the second freeze, but no difficulty was experienced in filtering juice of any of the samples.

The cane of both varieties windrowed before the second freeze exhibiting the greater injury showed the lesser drop in purity. Particularly was this true of Co. 290. These results are in harmony with those obtained by Sartoris (*15*) and Rands, McKaig, and Bisland (*13*) in connection with varieties fairly susceptible to inversion of sucrose, as well as with Co. 281 in the latter case, and would seem to indicate that with a certain severity of injury inversion is impaired or that reducing sugars are destroyed. However, it should be kept in mind that cane grown at the same location was not used in any two of the experiments discussed, and that different lots of uninjured cane from different sources sometimes behave somewhat differently (*11*). Before definite conclusions can be drawn regarding the effect of freezing injury on inversion of sucrose, experiments designed to isolate this effect must be conducted.

Analyses given in table 4 were made of samples of the top-, middle-, and bottom-third portion (by length) of the stalks of Co. 281 in experiments No. 3 and No. 4, and of Co. 290 in experiments No. 1, No. 2, and No. 4 (tables 2 and 3). Although the analysis was limited to 1 sample (30 pieces) in each case, and should not be given the same importance as the data in table 3, the results are fairly uniform, and definite trends are indicated in connection with the more marked changes that took place. Because of the difference in the amount of injury, the data, so far as varieties are concerned, are not comparable except in experiment No. 4, where the cane of both varieties was probably entirely killed. The data obtained from experiment No. 4 indicate very rapid deterioration in all sections of both varieties. In the main, the greatest deterioration was found in the top third, the next greatest in the middle third, and the least in the bottom third of the stalk when measured by the excess acidity, the decrease in pH value, and the drop in purity. There was no significant difference in deterioration between standing and windrowed cane.

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TABLE 4.—*Relation of degree of injury to changes in Brix, apparent sucrose, acidity, and pH value, and workability of juice in top, middle, and bottom sections of stalks from standing and windrowed sugarcane of two varieties*

Variety and experiment No.	Date of analysis	Duration of experiment	Part of cane (thirds)	Average sound eyes per stalk	Standing cane						Windrowed cane					
					Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
									Cubic centimeters						*Cubic centimeters*	
Co. 281 (plant cane):	*1937*	*Days*		*Percent*	°	*Percent*				*Percent*	°	*Percent*				*Percent*
	Dec. 3	0			13.29	9.39	70.7	5.32	3.20	62	13.19	9.12	69.1	5.35	2.74	67
	Dec. 11	8			11.47	7.77	67.7	5.18	3.83	60	12.82	8.65	67.5	5.30	3.32	62
3	Dec. 18	15	Top	1.7	11.85	(1)		4.00	10.05	55	11.95	(1)		4.65	5.60	54
	Dec. 23	20			11.50	[2] 5.90	51.3			55	12.39	[2] 8.05	65.0			60
	Dec. 31	28									12.37	[2] 7.40	59.8	4.28	6.15	54
	Dec. 3	0			15.49	12.49	80.6	5.40	2.37	66	15.69	12.71	81.0	5.45	1.86	65
	Dec. 11	8			14.52	11.76	81.0	5.38	2.66	64	15.22	12.25	80.5	5.43	2.35	63
3	Dec. 18	15	Middle	1.7	14.24	(1)		4.05	8.50	64	15.14	11.58	76.5	5.05	3.48	60
	Dec. 23	20			13.09	[2] 8.05	61.5			62	15.09	11.61	76.9			62
	Dec. 31	28									15.47	12.17	78.7	5.00	2.84	57
	Dec. 3	0			16.99	15.00	88.3	5.55	1.52	64	16.89	14.90	88.2	5.60	1.30	66
	Dec. 11	8			15.80	13.63	86.3	5.52	1.82	61	16.02	14.55	87.5	5.55	1.53	62
3	Dec. 18	15	Bottom	1.7	15.34	(1)		4.25	4.84	61	16.44	14.15	86.1	5.30	1.90	61
	Dec. 23	20			13.99	[2] 10.67	76.3			58	16.59	14.51	87.5			61
	Dec. 31	28									16.87	14.84	88.0	5.41	1.62	57
	Dec. 11	0			11.61	7.60	65.5	5.15	4.44	61	12.94	9.12	70.5	5.30	3.50	60
4	Dec. 20	9	Top	0	13.00	[2] 6.04	46.5	4.02	11.04	53	12.74	[2] 6.32	49.6	4.13	10.00	56
	Dec. 11	0			15.62	12.78	81.8	5.40	2.90	63	15.64	13.11	83.8	5.40	2.42	64
4	Dec. 20	9	Middle	0	14.84	[2] 8.68	58.5	4.20	7.42	62	15.64	[2] 10.56	67.5	4.36	6.15	58
	Dec. 11	0			16.52	14.85	89.9	5.50	2.28	61	16.92	15.22	90.0	5.62	1.60	60
4	Dec. 20	9	Bottom	0	15.94	[2] 12.55	78.7	4.78	3.66	60	16.64	[2] 13.49	81.1	4.90	3.53	61
Co. 290 (plant cane):																
	Dec. 11	17									13.14	9.19	69.9	5.30	3.32	61
1	*1938*		Top	37												
	Jan. 7	44									13.86	[2] 8.52	61.5	4.85	4.04	54
	1937															
	Dec. 11	17									16.04	13.30	82.9	5.37	2.70	63
1	*1938*		Middle	37												
	Jan. 7	44									17.16	13.37	77.9	5.15	2.74	56

1	1937 Dec. 11	17	Bottom	37						16.74	15.17	90.6	5.48	1.90	62
	1938 Jan. 7	44								18.26	15.63	85.6	5.25	1.96	55
2	1937 Dec. 3	7	Top	11.0	12.10	8.10	66.9	5.28	3.72	64	12.20	7.93	65.0	5.30	3.60	61
	Dec. 10	14			10.97	7.22	65.8	5.25	3.74	59	12.36	8.21	66.4	5.22	3.66	59
	Dec. 18	21			11.45	(1)		4.00	11.15	55	13.14	8.95	68.1	4.97	4.20	55
	Dec. 31	34									13.47	8.72	64.7	5.05	4.55	51
2	Dec. 3	7	Middle	11.9	16.60	13.61	81.5	5.40	2.88	65	16.60	13.76	82.4	5.35	2.84	65
	Dec. 10	14			16.32	13.74	84.2	5.27	3.07	63	16.76	13.90	82.9	5.32	2.78	63
	Dec 18	21			15.14	(1)		4.02	9.50	60	17.24	14.21	82.4	5.33	2.94	61
	Dec. 31	34									17.07	13.82	81.0	5.42	2.64	57
2	Dec. 3	7	Bottom	11.9	17.88	15.99	89.4	5.45	2.11	62	17.98	16.11	89.6	5.45	2.07	62
	Dec. 10	14			16.82	15.38	91.4	5.37	2.30	59	17.92	16.09	89.8	5.40	2.06	60
	Dec. 18	21			15.74	(1)		4.15	5.88	58	18.22	16.12	88.5	5.45	2.20	57
	Dec. 31	34									17.77	15.69	88.3	5.54	2.12	52
4	Dec. 11	0	Top	0	13.14	9.19	69.9	5.30	3.32	61	12.24	8.10	66.2	5.28	3.66	62
	Dec. 20	9			12.30	[2] 6.60	53.7	4.25	8.86	56	12.30	[2] 6.04	49.1	4.15	10.30	57
4	Dec. 11	0	Middle	0	16.04	13.30	82.9	5.37	2.70	63	16.14	13.49	83.6	5.37	2.76	64
	Dec. 20	9			15.10	[2] 10.55	69.9	4.52	5.50	59	15.90	[2] 10.66	67.0	4.45	5.68	56
4	Dec. 11	0	Bottom	0	16.74	15.17	90.6	5.48	1.90	62	17.08	15.78	92.4	5.48	1.96	63
	Dec. 20	9			15.90	13.30	83.6	4.95	3.36	60	16.80	13.87	82.6	4.88	3.34	58

[1] Sour juice would not filter and no polarizations were made.
[2] Analyzed by adding alcohol.

Co. 290 showed slightly less deterioration than Co. 281 in standing but not in windrowed cane.

The data obtained from the experiments started following the first freeze indicate only a slight deterioration in standing cane of both varieties until after the second freeze, when it was marked and the rate tended to be of the same order in the various sections as indicated in cane windrowed after the second freeze. This same order prevailed in Co. 281 windrowed before the second freeze. There was a slight increase in acidity and decrease in pH value in the middle and bottom sections of windrowed Co. 290 in experiment No. 1 (table 4), (37 percent sound eyes (table 2)). There was no indication of change in acidity and pH in the middle and bottom sections of Co. 290 with 11.9 percent sound eyes in experiment No. 2 (table 4). In both experiments (1 and 2) there was a slight increase in acidity and decrease in pH value in the top section. The drop in purity was 8.4, 5.0, and 5.0, respectively, in the top-, middle-, and bottom-third sections of windrowed Co. 290 in experiment No. 1 (37 percent sound eyes (table 2)) after 44 days in the windrow.

The formation of gum, as indicated by the nonfiltrability of the juice, was more promptly (about 2 weeks earlier) recognized in the top section of the stalk than in whole-stalk samples in the case of Co. 281 windrowed before the second freeze (experiment No. 3, tables 3 and 4). These results also indicate that by topping back it would have been possible to obtain samples containing little or no gum.

Because of the badly lodged condition of the cane in many sections during the season of 1937–38, the question arose as to whether it was practical to windrow crooked cane. In order to obtain information on this subject, 75 feet of two rows of badly lodged and crooked cane of the principal commercial varieties (Co. 281, Co. 290, C. P. 807, C. P. 28/11, C. P. 28/19, C. P. 29/116, and C. P. 320), grown in two-row plots side by side at the United States Sugar Plant Field Station, were windrowed shortly after the first freeze (November 27), and a corresponding amount left standing at the end of each windrow. Three samples of windrowed and three of standing cane were analyzed at the initiation of the experiment and after 6 and 27 to 29 days (only one sample of standing cane of each variety was used in the last analysis. The standing cane was analyzed 2 days later than the windrowed cane). Because of the great variation in sucrose content and purity in the different samples, reliable results of sucrose losses were not obtained. However, the changes in acidity, pH value, and the filtrability of the juice indicate that windrowing afforded considerable protection against the second freeze. The juice was not workable from any of the samples of standing cane of all varieties (analyzed December 29). It was possible to obtain, without difficulty, polarization readings of the juice of all samples of windrowed cane (topped normally). The excess acidity in the standing cane ranged from 1.77–3.70 to 6.70 cc. and in the windrowed cane from 0.20 to 1.35. The greatest excess acidity in windrowed cane occurred in Co. 290 (1.35) and the next in Co. 281 (0.96). Co. 281 was badly exposed because of the small amount of cane that was left in the windrow. C. P. 28/11 exhibited the lowest excess acidity in standing (1.77) and windrowed cane (0.20).

Storage Experiments

One storage experiment (No. 1, table 2) was started November 24, in which unstripped samples of Co. 281, showing 38 percent of the eyes sound, and of Co. 290, showing 37-percent-sound eyes, were stored at five combinations of temperature and relative humidity (tables 2, 5, and 6).

A second storage experiment (No. 4, table 2) was started December 9, in which unstripped samples of the same two varieties, showing no sound eyes and stalks badly damaged, if not killed, were stored at six combinations of temperature and relative humidity (tables 2 and 7).

The Co. 290 used in the storage experiments came from adjacent areas from the same cut as the cane used in windrowing experiments No. 1 and No. 4. The Co. 281 used in the storage experiment No. 1 and windrowing experiment No. 1 came from adjacent areas in the same cut and that used for storage experiment No. 4 and windrowing experiment No. 4 from contiguous areas of another cut. In the case of both varieties, windrowing experiment No. 1 and storage experiment No. 1 were started November 22 (i. e., the cane was cut on that date) and windrowing experiment No. 4 and storage experiment No. 4 December 9.

The conditions of temperature and humidity are given in tables 5, 6, and 7. In experiment No. 1 relative humidities at three temperatures (50°, 71°, and 80° F.) represent approximately equivalent evaporating capacities of the air (saturation deficits) and in experiment No. 4 the same saturation deficits prevailed at these temperatures, as well as at 62° (73 percent relative humidity). At 62° F., experiment No. 1, there were two relative humidities (97 and 58 percent), but they were not equivalent in evaporating power to those obtained at the other temperatures. In experiment No. 4 there were two additional relative humidities (96 and 57 percent) to the one mentioned at 62° F.

TABLE 5.—*Brix, apparent sucrose, apparent purity, acidity, and pH value in unstripped samples of sugarcane varieties Co. 281 and Co 290, showing 62 and 63 percent, respectively, of the eyes killed by the freezing temperatures of November 20, 21, and 22, or 38- and 37-percent sound eyes stored at different temperatures and relative humidities representing about the same saturation deficit,* [1] *1937*

Variety and date of analysis	Duration of storage	Temperature of 50° F. and relative humidity of 66 percent						Temperature of 71° F. and relative humidity of 81 percent						Temperature of 80° F. and relative humidity of 86 percent					
		Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
Co. 281 (plant cane): [2]	*Days*	°	*Percent*			*Cc.*	*Percent*	°	*Percent*			*Cc.*	*Percent*	°	*Percent*			*Cc.*	*Percent*
Nov. 24	0	16.15	13.70	84.8	5.30	2.56	60	16.15	13.70	84.8	5.30	2.56	60	16.15	13.70	84.8	5.30	2.56	60
Dec. 1	7	16.06	12.99	80.9	5.30	2.60	60	16.26	13.42	82.5	5.35	2.56	60	16.00	13.37	83.6	5.35	2.60	60
Dec. 8	14	16.37	13.20	80.6	5.32	2.48	59	16.29	13.35	82.0	5.40	2.48	59	16.25	13.30	81.8	5.35	2.52	60
Co. 290 (plant cane): [2]																			
Nov. 24	0	16.65	13.90	83.5	5.25	2.84	63	16.65	13.90	83.5	5.25	2.84	63	16.65	13.90	83.5	5.25	2.84	63
Dec. 1	7	16.73	12.85	76.8	5.30	2.84	64	16.46	13.33	81.0	5.35	2.80	61	16.36	13.24	80.9	5.35	2.80	60
Dec. 8	14	17.09	12.39	72.5	5.30	2.94	58	16.93	13.57	80.2	5.37	2.70	63	16.74	13.39	80.0	5.32	2.80	64

[1] The saturation deficit is the difference between the vapor pressure of the air at saturation and any vapor pressure of the air at any point below saturation and is a measure of the evaporating power of the air. A given saturation deficit has equal value at all temperatures, whereas relative humidity is a function of a given temperature. The relative humidity at 50° F. is a little high or the saturation deficit a little small as compared with that at 71° and 80°. The saturation deficit aimed at was 0.144 inch of mercury, which would give approximately 60, 80, and 86 percent relative humidities at 50°, 70°, and 80° F., respectively.

[2] Experiment No. 1, table 2.

TABLE 6.—*Brix, apparent sucrose, apparent purity, acidity, and pH value in unstripped samples of sugarcane varieties Co. 281 and Co. 290, showing 62 and 63 percent, respectively, of the eyes killed by the freezing temperatures of November 20, 21, and 22, or 38- and 37-percent sound eyes stored at 2 relative humidities at 62° F., 1937*

Variety and date of analysis	Duration of storage	Temperature of 62° F. and relative humidity of 97 percent						Temperature of 62° F. and relative humidity of 58 percent					
		Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
	Days	°	*Pct.*			*Cc.*	*Pct.*	°	*Pct.*			*Cc.*	*Pct.*
Co. 281 (plant cane)[1]													
Nov. 21	0	16.15	13.70	84.8	5.30	2.56	60	16.15	13.70	84.8	5.30	2.56	60
Dec. 1	7	15.90	13.14	82.6	5.35	2.60	59	16.12	13.18	81.8	5.35	2.55	61
Dec. 8	14	15.99	13.16	82.3	5.42	2.40	61	16.73	13.79	82.4	5.38	2.52	59
Co. 290 (plant cane)[1]													
Nov. 24	3	16.65	13.90	83.5	5.25	2.84	63	16.65	13.90	83.5	5.25	2.84	63
Dec. 1	7	16.48	13.10	79.5	5.35	2.82	64	16.09	13.30	78.6	5.35	2.58	63
Dec. 8	14	16.51	13.31	80.6	5.37	2.74	63	17.55	13.39	76.3	5.33	2.76	63

[1] Experiment No. 1, table 2.

TABLE 7.—*Relation of freezing injury of sugarcane, in which all the eyes and apparently the stalk have been killed, to changes in Brix, apparent sucrose, apparent purity, acidity, and pH value, and to gum formation in unstripped samples of varieties Co. 281 and Co. 290 stored at relative humidities representing approximately the same saturation deficit at temperatures of 50°, 62°, 71°, and 80° F. and at 3 relative humidities at 62° F.*

Date of analysis	Storage conditions			Co. 281 (plant cane)[1]						Co. 290 (plant cane)[1]					
	Duration	Temperature	Relative humidity	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
1937	*Days*	*° F.*	*Pct.*	°	*Pct.*			*Cc.*	*Pct.*	°	*Pct.*			*Cc.*	*Pct.*
Dec. 10	0	...	...	14.96	12.14	81.1	5.40	2.65	62	15.62	12.86	82.3	5.33	2.72	61
Dec. 16	6	50	64	14.60	[2]11.54	79.0	5.92	3.70	60	15.47	12.57	81.3	5.12	3.50	59
1938															
Jan. 4	25	50	64	.....	(3)	.....	4.02	8.20	...	.....	(3)	.....	4.09	7.33	...
1937															
		62	73	14.30	(3)	...	4.42	6.04	61	15.25	(3)	.....	4.47	5.28	62
		71	81	14.52	(3)	...	4.22	6.84	63	14.95	(3)	.....	4.32	5.94	63
Dec. 16	6	80	86	13.73	(3)	...	4.29	7.08	59	14.57	(3)	.....	4.12	7.20	60
		62	90	14.55	(3)	...	4.40	6.18	61	15.09	(3)	.....	4.50	5.66	62
		62	57	15.19	(3)	...	4.38	6.20	63	15.32	(3)	.....	4.45	5.35	65

[1] Experiment No. 4, table 2.
[2] Juice samples from 2 out of 3 samples were not workable
[3] Juices of all samples not workable.

There were no abnormal changes apparent in samples of either variety stored before the second freeze at any of the storage conditions during 2 weeks. These results indicate that the conservation of cane with similar injury in the windrow during the season of 1937–38 was due to the condition of the cane rather than the relatively cool weather following the first freeze. Judging from these results and the results from the windrowing experiments, and the fact that no factory difficulties were encountered until after the second freeze, it is quite possible that all the cane of these varieties might have been windrowed without danger of serious changes in acidity, pH value, and development of gum. So far as can be seen from these data, the behavior during 2 weeks' storage of cane stored before the second freeze was similar to that of sound cane. Although there was an apparent greater consumption of total solids with the rise in temperature, there was a greater drop in purity (marked in Co. 290) at 50° F. than at the higher temperatures. There was a much greater drop in purity in Co. 290 at 58 percent relative humidity than at 97 percent at 62° F.

The effect of storage conditions on changes in cane exposed to the second freeze was very different from that on cane of less injury. The juice from all the samples of both varieties after 6 days' storage showed an increase of acidity and a decrease in pH value at all conditions of storage. These changes were accentuated with the rise in temperature. Gum formation was sufficient at all conditions of storage except at 50° F. to prevent filtering and polarization readings by the usual methods. Even at 50° F. the juice from two out of three samples of Co. 281 was not workable in the laboratory.

Samples of each variety from each condition of storage were sectioned into thirds and pH and acidity readings made after intervals of 6 and 12 days, check readings having been made at the initiation of the experiment. Brix and polarization readings (table 8) were made of initial samples and in connection with storage samples from temperatures of 50° and 80° F. Not only was there a much greater drop in purity in all sections of both varieties at 80° than at 50° F., but there was a greater destruction of total solids, as indicated by the drop in Brix in all instances at 80° F., in spite of the fact that the cane was stored at conditions favoring the loss of moisture. At 50° F. there was an increase in Brix in all sections of Co. 290 and in the bottom section of Co. 281, as might be expected from the loss in moisture. The top and middle sections of Co. 281 also showed a decrease in Brix, which may have been caused by the fact that these sections showed greater evidence of deterioration at the end of 6 days than did Co. 290.

TABLE 8.—*Changes in Brix, apparent sucrose, apparent purity, acidity, and pH value, and the development of gum in top, middle, and bottom third sections of samples of cane stored at relative humidities representing approximately the same saturation deficit at 50° and 80° F., 1937*

Variety and date of analysis	Duration of storage	Part of cane	Temperature of 50° F. and relative humidity of 64 percent						Temperature of 80° F. and relative humidity of 86 percent					
			Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction	Brix	Sucrose	Purity	pH	Total acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
Co. 281 (plant cane):[1]	*Dy.*		°	*Pct.*			*Cc.*	*Pct.*	°	*Pct.*			*Cc.*	*Pct.*
Dec. 10	1	Top	12.54	8.46	67.5	5.28	3.48	61	12.54	8.46	67.5	5.28	3.48	61
Dec. 16	6	do	12.51	(2)		4.45	6.46	59	11.01	(2)		4.03	11.64	58
Dec. 22	12	do	12.05	6.84	[3] 56.8	4.30	8.10	56	10.35	2.99	[3] 28.9	4.02	12.48	54
Dec. 10	0	Middle	15.54	12.98	83.5	5.38	2.54	60	15.54	12.98	83.5	5.38	2.54	60
Dec. 16	6	do	15.72	(2)		4.95	3.94	63	14.02	(2)		4.20	7.16	61
Dec. 22	12	do	14.92	10.70	[3] 71.7	4.60	5.14	61	13.14	7.81	[3] 59.4	4.10	8.56	58
Dec. 10	0	Bottom	16.44	14.85	90.3	5.50	1.82	61	16.44	14.85	90.3	5.50	1.82	61
Dec. 16	6	do	16.92	14.07	88.5	5.20	2.66	61	15.62	(2)		4.55	4.36	55
Dec. 22	12	do	17.14	14.65	[3] 85.5	5.00	3.03	62	14.04	11.37	[3] 77.7	4.30	1.88	59
Co. 290 (plant cane):[1]														
Dec. 10	0	Top	11.94	8.12	68.0	5.30	3.80	57	11.94	8.12	68.0	5.30	3.80	57
Dec. 16	6	do	12.72	(2)		4.55	6.30	61	11.91	(2)		4.00	10.70	58
Dec. 22	12	do	13.54	8.29	[3] 61.2	4.45	6.30	54	11.15	5.01	[3] 44.9	4.00	10.80	58
Dec. 10	0	Middle	16.24	13.54	83.4	5.33	2.90	63	16.24	13.54	83.4	5.33	2.90	63
Dec. 16	6	do	16.42	13.49	[3] 82.2	4.92	3.93	58	14.92	(2)		4.05	8.02	60
Dec. 22	12	do	16.34	12.24	[3] 74.9	4.57	4.28	61	14.64	8.38	[3] 57.2	4.16	8.42	60
Dec. 10	0	Bottom	16.98	15.36	90.5	5.43	2.28	59	16.98	15.36	90.5	5.43	2.28	59
Dec. 16	6	do	17.02	16.11	94.4	5.28	2.48	60	16.12	(2)		4.30	4.62	60
Dec. 22	12	do	17.52	15.71	[3] 88.2	5.00	2.44	58	15.64	10.99	[3] 70.3	3.92	6.76	56

[1] Experiment No. 4, table 2.
[2] Juice samples would not filter and were not analyzed for sucrose.
[3] Analyzed by adding alcohol.
[4] Barely workable.

The juice of the top and middle sections of Co. 281 stored at 50° F. would not filter and there was a greater increase in acidity than in the same sections of Co. 290. However, these differences may not have much significance because the juice from the top section of Co. 290 would not filter and the middle section was barely filtrable. The increase in acidity and decrease in pH value were decidedly greater in all sections of both varieties at 80° than at 50° F. The changes in acidity and pH value as related to the different temperatures are represented in figures 2 and 3, in which increase in acidity and decrease

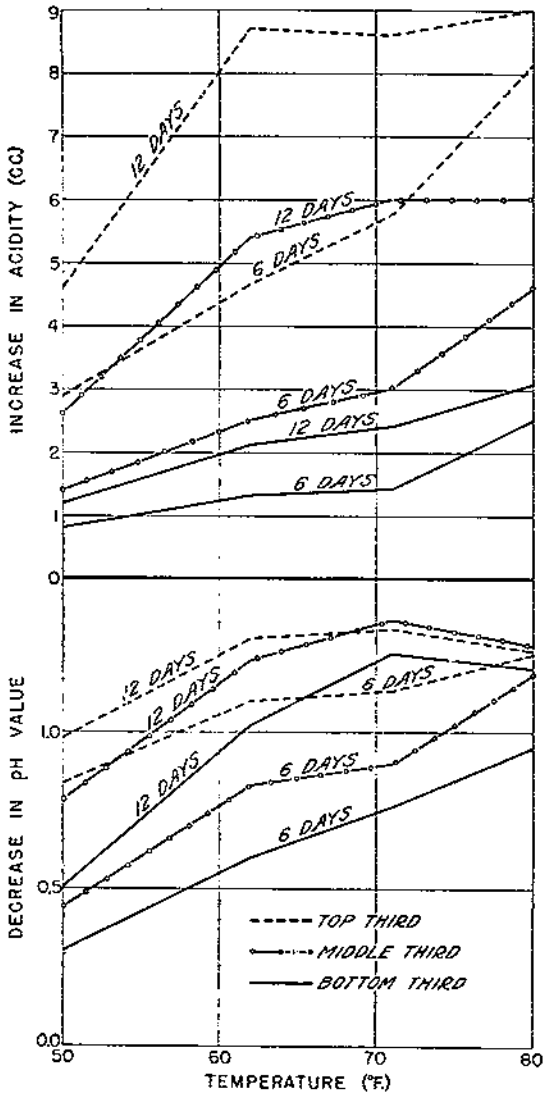

FIGURE 2.—Increase in acidity (excess acidity) and decrease in pH value at storage temperatures of 50°, 62°, 71°, and 80° F. in different parts of the cane stalk (Co. 281 plant cane) apparently killed by the freezing temperatures of 26° and 24° of December 6 and 7, 1937. The samples of injured cane were stored without stripping and stripped and sectioned into three equal lengths after 6 and 12 days' storage, and the acidity and pH value of the sections determined. The initial determinations were made on similar sections at the beginning of storage.

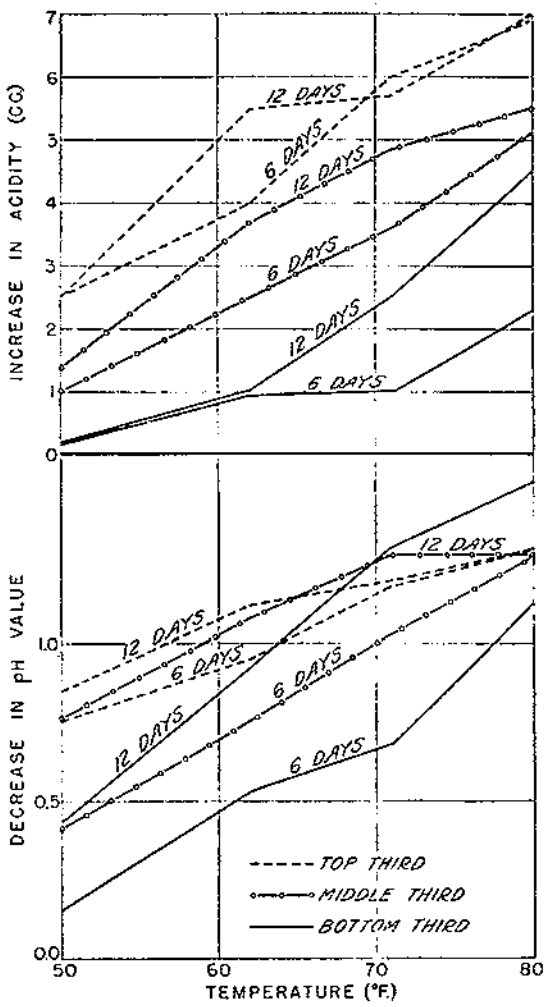

FIGURE 3.—Increase in acidity (excess acidity) and decrease in pH value at storage temperatures of 50°, 62°, 71°, and 80° F. in different parts of the cane stalk (Co. 290 plant cane) apparently killed by the freezing temperatures of 26° and 24° of December 6 and 7, 1937. The samples of injured cane were stored without stripping and stripped and sectioned into three equal lengths after 6 and 12 days' storage, and the acidity and pH value of the sections determined. The initial determinations were made on similar sections at the beginning of storage.

in pH value for the various sections are plotted against temperatures for 6 and 12 days. At the end of 6 days the decrease in pH value and increase in acidity were greater with the rise in temperatures. As the duration of storage increased to 12 days, there was a slowing up of the change at temperatures of 70° and 80° F., except for the acidity in the bottom sections of both varieties. It would seem that with the lapse of time these reactions tend to come to some sort of an equilibrium at the two higher temperatures.

It is possible that there may have been a retardation of acid formation at the higher temperatures because of an inhibition of the activities of the acid forming micro-organism, or micro-organisms, as the concentration of acid increased or there may have been a consumption of acid by respiration as the fermentation advanced. It would be of interest to find out whether the rate of acid formation is retarded at the two lower temperatures with an increase in the period of storage. The difference in the changes between 50° and 60° F. sometimes tends to be exaggerated by the continuation of storage. Even at 50° F. the rate of change in acidity and pH was rather rapid, especially in the upper two-thirds of the stalk.

Judging by the weather records for southern and southwestern sections of Louisiana, the prospects of having average temperatures below 50° F., following a freeze in November and December, except for short periods, is not to be expected. Consequently, a sufficient retardation of deleterious changes in the windrow in cane so badly damaged to justify the expense of windrowing cannot be expected.

WORK DONE DURING SEASON OF 1938–39

Weather Conditions

The ranges of minimum temperatures for the Sugar Belt, as represented by the records of the United States Weather Bureau stations mentioned in footnote 6, p. 9 (Belle Chasse excepted [9]) for the days on which freezing temperatures occurred during November and December 1938 (*20*), were as follows: November 9, 29° to 38°; November 10, 29° to 37°; November 25, 23° to 31°; November 26, 28° to 41°; November 27, 24° to 32°; November 28, 20° to 29°; November 29, 22° to 28°; November 30, 24° to 31°; December 6, 29° to 38°; December 10, 29° to 38°; December 15, 29° to 35°; December 16, 25° to 33°; December 17, 30° to 39°; December 19, 26° to 33°; and December 28, 27° to 34° F.

The records of the maximum and minimum temperatures, condition of the sky as to cloudiness, etc., and precipitation at Houma, La., covering the period during which the windrowing experiments were conducted are recorded in table 9. The temperature trends following windrowing indicate slightly higher temperatures than immediately following windrowing during 1937–38.

The precipitation was low in most places in the Sugar Belt during both November and December.

[9] The minimum temperatures at Belle Chasse, La., although fluctuating considerably, were generally much lower, particularly in December, than at the other stations. On November 9, 10, 25, 26, 27, 28, 29, and 30 the minimum temperatures at Belle Chasse were 36°, 35°, 28°, 37°, 30°, 25°, 16°, and 18° F., respectively, and on December 6, 10, 15, 16, 17, 19, and 28 they were 23°, 23°, 36°, 21°, 25°, 25°, and 22° F. It would seem that to include the ranges would be less representative of the Sugar Belt than to exclude them.

TABLE 9.—*Weather records at Houma, La., during the periods in which experiments were conducted in the harvesting season of 1938–39*

Date	Rainfall	Sky	Temperature			Date	Rainfall	Sky	Temperature		
			Maximum	Minimum	Mean				Maximum	Minimum	Mean
	Inches		°F.	°F.	°F.		*Inches*		°F.	°F.	°F.
Nov. 9	0	Clear	65	32	48.5	Dec. 5	0	Clear	64	47	55.5
Nov. 10	0	do	77	32	54.5	Dec. 6	0	do	67	32	49.5
Nov. 11	0	Partly cloudy	81	41	61.0	Dec. 7	.32	Partly cloudy	73	36	54.5
Nov. 12	0	do	86	59	72.5	Dec. 8	0	do	66	44	55.0
Nov. 13	0	do	88	71	79.5	Dec. 9	0	Clear	59	36	47.5
Nov. 14	0	Cloudy	82	69	75.5	Dec. 10	0	do	72	34	53.0
Nov. 15	0	do	77	63	70.0	Dec. 11	0	Partly cloudy	77	55	66.0
Nov. 16	0	Partly cloudy	84	59	71.5	Dec. 12	0	do	79	48	63.5
Nov. 17	0	do	84	67	75.5	Dec. 13	0	do	68	49	58.5
Nov. 18	1.07	Cloudy	81	69	75.0	Dec. 14	.10	Cloudy	62	42	52.0
Nov. 19	0	Clear	71	47	59.0	Dec. 15	0	Clear	60	33	46.5
Nov. 20	0	do	67	34	50.5	Dec. 16	0	do	67	28	47.5
Nov. 21	0	do	75	36	55.5	Dec. 17	0	Partly cloudy	72	33	52.5
Nov. 22	0	Partly cloudy	78	50	64.0	Dec. 18	0	do	63	52	57.5
Nov. 23	0	do	80	49	64.5	Dec. 19	0	Clear	64	29	46.5
Nov. 24	.18	do	69	39	54.0	Dec. 20	0	Partly cloudy	71	40	55.5
Nov. 25	0	Clear	53	26	39.5	Dec. 21	0	Cloudy	76	55	65.5
Nov. 26	0	Cloudy	53	40	46.5	Dec. 22	0	do	71	52	61.5
Nov. 27	0	Clear	50	30	40.0	Dec. 23	0	Partly cloudy	78	62	70.0
Nov. 28	0	do	53	24	38.5	Dec. 24	1.01	Cloudy	59	55	57.0
Nov. 29	0	do	61	24	42.5	Dec. 25	3.67	do	62	47	54.5
Nov. 30	0	do	68	27	47.5	Dec. 26	0	Partly cloudy	62	49	55.5
Dec. 1	0	Partly cloudy	74	35	54.5	Dec. 27	0	do	51	43	47.0
Dec. 2	0	do	77	47	62.0						
Dec. 3	.02	do	73	57	65.0	Total or average	6.37		70	44	57.0
Dec. 4	0	do	74	38	56.0						

CONDITION OF CANE BEFORE WINDROWING

The cane of all varieties generally attained a higher degree of maturity, as measured by its sucrose content, than during 1937–38. In some localities the process of maturing undoubtedly was interrupted by the freezing temperatures of November 9 and 10.

INJURY TO CANE

Although most, if not all, of the sugarcane produced in the Louisiana Sugar Belt during 1938 was milled, there was considerable loss of sucrose in consequence of the injury resulting from freezing temperatures.

Some loss of sucrose resulted from the freezing temperatures of November 9 and 10, particularly in some localities, and, judging by the amount of leaf injury, it would seem that there could have been no further maturing of the cane. In some instances the terminal buds were killed and growth of lateral buds occurred, and in one instance factory difficulties were reported in connection with relatively immature cane showing such injury. In connection with cane used in experiments discussed in this bulletin only an occasional bud was killed.

As a result of the freezing temperatures of November 25 to 30 and those occurring in December, the damage was sufficiently severe to require lower topping. Considerable losses may have been experienced through loss of sucrose because of fermentation, as will be indicated in connection with data to be discussed, page 32.

The injury to the cane used in the windrowing and storage experiments will be discussed in connection with the consideration of the plan of the experiments and the treatment of the data.

Windrowing Experiments

The windrowing experiments were designed to study the effect of different degrees of freezing injury on inversion of sucrose, changes in acidity and pH, and the development of other fermentative changes affecting the loss or recovery of sucrose in plant cane of the varieties Co. 281 and Co. 290.

The cane of each variety was selected before the experiments began at locations in black land, where severe and moderate freezing might be expected. It would have been desirable to have had the two varieties side by side at the same locations, but such adjacent plots of the size desired were not available. Therefore, four locations, two of each variety, were selected. Unfortunately, there was insufficient Co. 290 at the one location to complete the series of tests conducted at the other locations. Otherwise, the series of experiments at each location were similar.

Minimum thermometers were installed at each location, and daily minimum temperatures were recorded, starting a few days before the time of windrowing, until December 18.

In anticipation of freezing temperatures the morning of November 25, six rows of cane 80 feet long were windrowed at each location during the afternoon of November 24 (lot No. 1). Severe freezing temperatures occurred on the mornings of November 25, 28, 29, and 30. A lot of six rows 80 feet long of each variety was windrowed November 25 at each location (lot No. 2) and a lot of four rows 80 feet long on each of the following dates: November 29 (lot No. 3), November 30 (lot No. 4), and December 1 (lot No. 5), respectively, at the two locations in the case of Co. 281 and at one location in the case of Co. 290. Two rows of Co. 290 at the other location were windrowed December 1 (lot No. 5). To avoid excessive injury to the successive lots that might occur at the edge of the cuts in the standing cane immediately adjacent to the windrowed cane, two rows of cane were left standing on each side of the windrowed cane of each lot and 20 feet of standing cane where the successive lots were along the same rows.

The freezing temperatures at the different locations and the degree of injury to the eyes in the various lots, excepting lot No. 1, are given in table 10. The injury to lot No. 1 was largely limited to slight damage to leaves and an occasional injury or killing of the terminal buds.

The data in table 10 indicate that lots No. 3, No. 4, and No. 5 of each variety at each location were more severely injured than any of the cane windrowed following the first series of freezing temperatures during the season of 1937–38 and less severely than cane windrowed after the second freeze. However, the germination data (table 11) obtained in connection with untopped cane stored for about 2 weeks at 80° F. and a relative humidity of about 87 percent indicate about equal or a slightly higher percentage of viable eyes in Co. 281, lot

No. 3 (about equal), Crescent Farm, and in Co. 281, lot No. 3 (slightly higher) and lot No. 4 (about equal), Southdown Plantation, than in Co. 281 windrowed at Ardoyne Plantation in 1937 (experiment No. 3, table 3).

TABLE 10.—*Injury to two varieties of sugarcane at certain locations as indicated by the amount of damage done to the eyes (lateral buds) by freezing temperatures of November 25 (windrowed, lot 2), November 25 and 28 (windrowed, lot 3), November 25, 28, and 29 (windrowed, lot 4), and November 25–30, inclusive (windrowed, lot 5), and standing cane,[1] 1938*

Treatment and lot No.	Date of freezing temperature	Minimum temperature	Stalks of cane examined	Eyes per stalk (average)	Total eyes				Eyes			
					Sound	Injured	Doubtful[2]	Killed	Sound	Injured	Doubtful[2]	Killed
						CO. 281, CRESCENT FARM PLANTATION						
		°F.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Windrowed cane:												
Lot 2	Nov. 25	21.5	15	15.7	32	39	0	155	14.2	17.3	0	68.6
Lot 3	Nov. 28	20.0	30	13.9	1	2	1	414	.2	.5	.2	99.1
Lot 4	Nov. 29	20.6	30	15.6	0	0	0	469	0	0	0	100.0
Lot 5	Nov. 30	22.3	30	14.5	0	0	2	433	0	0	.5	99.5
Standing cane			10	13.8	0	0	0	138	0	0	0	100.0
						CO. 281, SOUTHDOWN PLANTATION						
Windrowed cane:												
Lot 2	Nov. 25	24.5	10	17.6	79	25	0	76	43.9	13.9	0	42.2
Lot 3	Nov. 28	21.6	30	17.2	2	15	0	498	.4	2.9	0	96.7
Lot 4	Nov. 29	21.1	30	17.5	0	4	4	516	0	.8	.8	98.4
Lot 5	Nov. 30	23.2	30	15.7	3	2	0	465	.6	.4	0	99.0
Standing cane			10	16.0	0	3	0	157	0	1.9	0	98.1
						CO. 290, HOLLYWOOD PLANTATION						
Windrowed cane:												
Lot 2	Nov. 25	24.6	10	17.1	42	18	0	111	24.6	10.5	0	64.9
Lot 3	Nov. 28	21.8	30	15.3	2	9	0	448	.4	2.0	0	97.6
Lot 4	Nov. 29	22.0	30	16.7	1	1	2	497	.2	.2	.4	99.2
Lot 5	Nov. 30	23.1	30	17.1	2	0	0	512	.4	0	0	99.6
Standing cane			10	15.8	1	0	0	157	.6	0	0	99.4
						CO. 290, SOUTHDOWN PLANTATION						
Windrowed cane:												
Lot 2	Nov. 25	24.5	10	16.8	61	26	0	81	36.3	15.5	0	48.2
Lot 5	Nov. 30	23.2	30	16.4	2	1	3	487	.4	.2	.6	98.8
Standing cane			10	14.4	0	0	0	144	0	0	0	100.0

[1] The standing cane was examined Dec. 8 and 9.
[2] Eyes were badly injured, but it was not certain that they were dead.

TABLE 11.—*Germination and rooting in two varieties of sugarcane injured by freezing temperatures occurring from November 25–30, 1938, when stored at 80° F. and at about 87 percent relative humidity*

Lot No.[1]	Stalks examined	Stalks showing germination	Eyes germinating (total)	Stalks showing rooting	Root bands rooting	Remarks
	Number	*Number*	*Number*	*Number*	*Number*	
CO. 281, CRESCENT FARM PLANTATION						
3	20	3	5	3	3	3 of the eyes germinating were on 1 stalk.
4	20	0	0	0	0	1 eye apparently was sound but did not germinate.
5	20	0	0	1	1	Node was cut off at the ground level.
CO. 281, SOUTHDOWN PLANTATION						
3	20	8	13	2	2	
4	20	5	5	6	11	1 additional eye apparently sound but not germinating.
5	20	2	2	1	1	
CO. 290, HOLLYWOOD PLANTATION						
3	20	3	3	7	9	
4	20	1	1	3	3	1 additional eye swollen.
5	20	0	0	4	4	

[1] These lots correspond to those given in table 10. The samples were selected at the same time for examination of injury and for storage.

The severity of freezing injury was greater in Co. 281 located at Crescent Farm (table 10) than in that located at Southdown Plantation and in Co. 290 at Hollywood Plantation than in that at Southdown. The difference was greater at the two locations in the case of Co. 281 than in Co. 290, as might be expected from the minimum temperature records. The behavior of the cane at the different locations in the case of both varieties was similar, except that chemical and fermentive changes attributable to freezing injury were more marked in cane with the greater injury. Only the data relating to Co. 281 at Crescent Farm and Co. 290 at Hollywood Plantation will be reported in full.

The data indicate (table 12) little or no abnormal or fermentive changes in lots No. 1 and No. 2 of either variety. There was a slight drop in purity in Co. 281 and a considerably greater drop in Co. 290. Concomitant with the drop in purity there was the normal increase in Brix as a result of a loss in moisture. In lots No. 3, No. 4, and No. 5 and in standing cane a high level of purity was maintained until during the period before the last analysis when there was a slight drop in all cases except Co. 281, lot No. 3. Although there was an initial increase in Brix (table 12 and fig. 4) in lot No. 3 of both varieties, it tended to decline until the last analysis, when there was a loss in Brix in both varieties. There was a marked decline in Brix in lots No. 4 and No. 5 and in standing cane of both varieties beginning with the first analysis. The decline was greater in lot No. 5 than in lot No. 4 and greater in standing cane than in lot No. 5.

TABLE 12.—*Relation of the degree of freezing injury in cane of varieties Co. 281 and Co. 290 to changes in Brix, sucrose, acidity, and pH value when standing and when in the windrow, 1938*

CO. 281 (PLANT CANE), CRESCENT FARM PLANTATION

Treatment, lot No., and date of windrowing	Windrowed following freezing temperatures: Date	Temperature	Date of analysis	Duration of experiment	Average eyes per stalk: Sound	Average eyes per stalk: Injured	Brix	Sucrose	Purity	pH	Acidity (0.1 N NaOH per 10 cc. of juice)	Juice extraction
		° F.	1938	Days	Pct.	Pct.	°	Pct.			Cc.	Pct.
Standing cane			Nov. 25	0			17.17	14.70	85.6	5.39	2.5	59
			Dec. 2	7			16.48	13.93	84.5	5.36	2.7	60
			Dec. 9	14	0	0	15.82	13.65	86.3	5.42	2.8	59
			Dec. 15	20			15.89	13.87	87.3	5.29	3.0	55
			Dec. 22	27			14.95	12.77	85.4	4.82	3.7	58
Windrowed cane:			Nov. 25	0			17.53	15.14	86.4	5.36	2.5	60
Lot 1, Nov. 24	Nov. 9		Dec. 6	11	(1)	(1)	17.75	14.92	84.1	5.28	2.8	59
			Dec. 15	20			18.00	15.29	84.9	5.29	2.5	53
			Dec. 22	27			17.87	15.20	85.1	5.22		56
Lot 2, Nov. 25	Nov. 25	21.5	Nov. 25	0			16.97	14.48	85.3	5.39	2.5	60
			Dec. 6	11	14.2	17.3	17.30	14.51	83.9	5.32	2.8	58
			Dec. 15	20			17.75	15.11	85.1	5.32	2.6	56
			Dec. 22	27			17.61	14.88	84.4	5.22		58
Lot 3, Nov. 28	Nov. 28	20	Nov. 26	0			16.81	14.50	86.3	5.31	2.7	57
			Dec. 2	4			17.33	14.88	85.9	5.36	2.7	58
			Dec. 9	11	.2	.5	17.06	14.81	86.8	5.42	2.7	59
			Dec. 15	17			16.89	14.77	87.4	5.43	2.6	54
			Dec. 23	25			16.03	13.99	87.3	5.38	2.6	56
Lot 4, Nov. 29	Nov. 29	20.6	Nov. 29	0			16.86	14.41	85.5	5.37	2.5	58
			Dec. 5	6			16.64	14.11	84.8			60
			Dec. 12	13	9	6	16.51	14.30	86.6	5.36	3.0	53
			Dec. 19	20			15.90	13.82	86.9	5.36	3.2	52
			Dec. 27	28			15.74	13.15	83.5	4.92	3.4	54
Lot 5, Dec. 1	Nov. 30	22.5	Dec. 1	0			17.11	14.72	86.0	5.36	2.7	57
			Dec. 5	4			16.74	14.47	86.4			60
			Dec. 12	11	0	0	16.68	14.50	86.9	5.26	3.3	54
			Dec. 19	18			16.18	14.00	86.5	5.15	3.2	52
			Dec. 27	26			15.65	13.24	84.6	4.67	3.8	55

CO. 290 (PLANT CANE), HOLLYWOOD PLANTATION

			Nov. 25	0			15.85	13.16	83.0	5.34	2.5	62
			Dec. 2	7			15.49	12.54	81.0	5.35	2.9	60
Standing cane			Dec. 9	14	0.0	0	15.09	12.45	82.5	5.35	3.3	60
			Dec. 15	20			14.69	11.96	81.4	5.28	3.0	59
			Dec. 22	27			14.22	11.09	78.0	4.86	4.2	60
Windrowed cane:			Nov. 25	0			16.05	13.13	81.8	5.34	2.5	61
Lot 1, Nov. 24	Nov. 9		Dec. 6	11	(1)	(1)	16.72	12.57	75.2	5.29	2.9	61
			Dec. 15	20			17.03	12.97	76.2	5.28	2.8	59
			Dec. 22	27			16.87	12.67	75.1	5.17	2.8	59
Lot 2, Nov. 25	Nov. 25	24.6	Nov. 25	0			15.82	13.13	84.1	5.34	2.5	58
			Dec. 6	11	24.6	10.5	16.57	12.65	76.3	5.29	2.8	60
			Dec. 15	20			16.79	12.87	76.7	5.31	2.7	57
			Dec. 22	27			16.92	13.04	77.1	5.17	2.8	61
Lot 3, Nov. 28	Nov. 28	21.8	Nov. 28	0			15.82	12.87	81.4	5.34	2.6	58
			Dec. 2	4			16.29	13.13	80.6	5.34	2.9	60
			Dec. 9	11	.4	2.4	16.02	12.53	80.1	5.35	2.7	60
			Dec. 15	17			16.37	13.19	80.6	5.31	2.9	57
			Dec. 23	25			15.68	12.52	79.8	5.22	2.9	55
Lot 4, Nov. 29	Nov. 29	22.0	Nov. 29	0			15.83	12.87	81.3			59
			Dec. 5	6			15.77	12.88	81.7	5.32	3.1	58
			Dec. 12	13	.2	.2	15.51	12.78	82.4	5.34	2.9	57
			Dec. 19	20			15.18	11.96	78.8	5.07	3.1	57
			Dec. 27	28			16.04	13.07	81.5	5.34	2.9	57
Lot 5, Dec. 1	Nov. 30	23.1	Dec. 1	0			15.63	12.70	81.3			61
			Dec. 5	4			15.31	12.49	81.6	5.23	3.3	57
			Dec. 11	11	.4	0	14.88	12.08	81.2	5.18	3.3	60
			Dec. 19	18			14.63	11.75	80.3	5.14	2.9	56
			Dec. 27	26								

[1] The injury resulting from the freezing temperatures of Nov. 9 and 10 was limited to slight injury to the tips of the leaves and to the injury or killing of an occasional terminal bud.

In comparing the various curves in figure 4, which were based on data contained in table 12, the time factor, as well as the difference in exposure of the cane to drying, should be considered. There must have been some decrease in Brix in lot No. 5, and probably in lot No. 4, in the interval between November 25, the day standing cane was first analyzed, and the dates of windrowing of lots No. 4 and No. 5, as indicated by the decrease in Brix in standing cane during that interval. To the apparent decrease in Brix in lots No. 3, No. 4, and No. 5 should be added the undetermined effects on Brix of drying in the windrow, which was not a factor in standing cane, at least to the same degree.

The Brix values in standing cane in lots No. 4 and No. 5 and in the later stages of the experiment in lot No. 3 are probably a little low as the result of the presence of a small quantity of ethyl alcohol (*6*) in the juice, which was discovered in connection with some of the later analyses. However, there was considerable loss of solids, as indicated by the loss of sucrose. These data indicate that the decrease in Brix or loss of solids in the badly frozen cane was paralleled by a similar loss of sucrose. The decrease in Brix, however, is normally a more accurate measure of the loss of solids than the loss of sucrose, because the sucrose content is more variable than the Brix. The maintenance of a high level of purity in lots No. 3, No. 4, and No. 5 and in standing cane throughout most of the periods of the experiment would seem to have resulted largely from the consumption of invert sugars by the fermentive processes going on and the effect of the alcohol on the Brix.

The development of excess acidity in lots No. 4 and No. 5 and in standing cane was slow (table 13) until the last interval between analyses, when it became more marked. The excess acidity remained small in lot No. 3 and did not develop in lots No. 1 and No. 2. The acidity values obtained by the usual methods were erratic, due, it was found, to the presence of carbon dioxide in the juices in varying and abnormal proportions. More accurate values were obtained by employing the distillation method; that is, by boiling the distillate and titrating it while hot (*7*).

TABLE 13.—*Development of excess acidity*[1] *in the standing cane and in the different lots of windrowed cane considered in table 12, 1938*

Treatment and lot No.	Date of determination	Co. 281, Crescent Farm				Co. 290, Hollywood Plantation			
		Whole stalk	Top third of stalk	Middle third of stalk	Bottom third of stalk	Whole stalk	Top third of stalk	Middle third of stalk	Bottom third of stalk
		Cc.	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*	*Cc.*
Windrowed:	Dec. 9	0.05	0.15	0.05	0	0	0	0	0
3	Dec. 16	.10	.20	.05	.05	0	0	0	0
	Dec. 23	.05	.30	.00	.00	.15	.25	.05	0
	Dec. 13	.20	.45	.20	.15	.10			
4	Dec. 19	.20	.20	.20	.15	.10	.25	.10	.10
	Dec. 27	.55	.85	.30	.50	.30	.60	.10	
	Dec. 13	.20	.70	.25	.15		.90	.25	.10
5	Dec. 19	.30	1.00	.30	.25	.20	.85	.30	.10
	Dec. 27	.85	3.00	1.10	.60	.30	1.50	.70	.20
	Dec. 9	.10	.25	.15	.05	.10	.15	.10	0
Standing	Dec. 15	.15	.55	.20	.20	.15	.65	.20	0
	Dec. 22	.90	2.30	.25	.20	.70	2.10	.25	.15

[1] Determined by distillation of juices from whole stalk and from the top-, middle-, and bottom-third sections of the stalk of sugarcane.

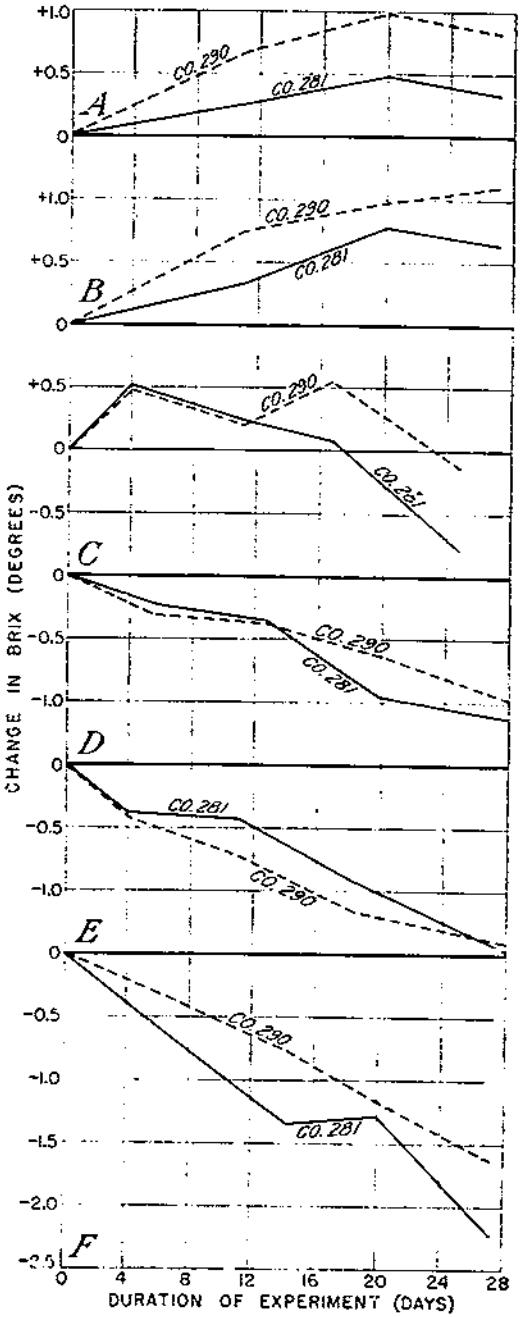

FIGURE 4.—Change in Brix (degrees) in windrowed and standing cane injured by freezing temperatures: *A*, Lot No. 1, windrowed November 24, following slight injury resulting from freezing temperatures of November 9 and 10, 1938; *B* to *E*, lots No. 2 (*B*), No. 3 (*C*), No. 4 (*D*), and No. 5 (*E*) windrowed on successive dates following freezing temperatures of November 25, 28, 29, and 30. The freezing temperatures to which the cane was exposed on these dates were for Co. 281 (Crescent Farm Plantation), 21.5°, 20.0°, 20.6°, and 22.3° F. and for Co. 290 (Hollywood Plantation), 24.6°, 21.8°, 22.0°, and 23.1° F., respectively. Standing cane (*F*) was exposed to all these temperatures and those following these dates until the final analysis was made. (See table 9.) The injuries suffered by the different lots are given in table 10.

Until the last set of analyses of lots No. 3, No. 4, and No. 5 and of standing cane little or no difficulty was experienced in filtering and clarifying the juices for polarization readings. Even then that difficulty was limited to juice of the top third of the stalk.

The presence of alcohol (*6*) and abnormal quantities of carbon dioxide in juices of badly frozen cane during the season of 1938–39 suggests the dominance of a different type of fermentation other than that which prevailed during 1937–38. Concomitant with the formation of these substances there was a destruction of sugars, including sucrose, in windrowed cane that showed little development of excess acidity or formation of gum.

This same type of fermentation may have occurred in the badly damaged cane (varieties Co. 281, P. O. J. 36–M, P. O. J. 213, and C. P. 807) windrowed by Rands, McKaig, and Bisland (*13*) in 1929, for there was a decrease in Brix from the start in all four varieties.

The data confirm previous results (*10*) in showing that cane injured by freezing temperatures, but having some sound eyes, will keep for 3 to 6 or more weeks in the windrow without serious development of excess acidity or of gum. The chances for the occurrence of these changes tended to increase and the time required for their development tended to shorten as the degree of injury increased. Fermentation was not obvious at all in lots No. 1 and No. 2. The development of excess acidity was more rapid in standing cane than in lot No. 5 in the case of Co. 290, but in the case of Co. 281 the difference was less obvious. Standing cane of both varieties showed slightly more marked development of gum than windrowed lot No. 5, due to a greater degree of deterioration in the top third of the standing cane.

The greatest protection against deleterious changes resulting from freezing injury was obtained in connection with windrowed lots No. 1 and No. 2 of both varieties. As it is not possible to govern the amount of injury or to predict with certainty the degree of injury an anticipated freeze may occasion, it is safer to windrow unfrozen cane.

Protection by windrowing became less and less as the degree of injury increased (table 12 and fig. 4, lots No. 3, No. 4, and No. 5). The deleterious effects of freezing appeared to be slightly less in lot No. 5 than in standing cane. Had the series of freezing temperatures of November 25 to 30, inclusive, been followed by severe freezes in December, the protection afforded by windrowing undoubtedly would have been more evident.

There appears to be little difference in the loss of sucrose [10] in lots No. 1 and No. 2 in both varieties. The loss of sucrose tends to increase in lots No. 3, No. 4, and No. 5 and in standing cane. The loss is obviously more in lots No. 3, No. 4, and No. 5 and in standing cane than in lots No. 1 and No. 2 of Co. 281, as well as of Co. 290, with the possible exception of lot No. 3. Although there is a greater drop in purity in lots No. 1 and No. 2 of Co. 290 than in the remaining lots and in standing cane, it is believed that it is more than offset by the loss indicated by the decrease in Brix and sucrose. As shown by the difference in the drop in purity between Co. 281 (lots No. 1 and No. 2) and Co. 290 (lots No. 1 and No. 2) the behavior was quite

[10] It is not possible at present to calculate accurately the loss of sucrose in windrowed cane because of the undeterminable loss of moisture in cane while in the windrow. The changes in Brix, sucrose, and purity are fairly accurate measures of the comparative losses of sucrose.

normal for unfrozen or moderately injured cane of these varieties in the windrow. The losses of solids in the two varieties appear to be similar in lots No. 3, No. 4, and No. 5 but slightly greater in standing cane of Co. 281 than of Co. 290. The greater injury to Co. 281 as compared with Co. 290 may account for these results. The better behavior of these two varieties in the Southdown tests than at Crescent Farm and Hollywood was also apparently due to the smaller degree of damage suffered by that cane (table 10).

The losses experienced in connection with these lots (No. 3, No. 4, and No. 5) of both varieties at all locations were such as commend windrowing if possible before such injury is incurred.

Storage Experiments

The very rapid development of excess acidity and its apparent relation to the formation of gum in cane in which all the eyes were killed in contrast to the absence of excess acidity in cane showing only about 60 percent of the eyes killed when stored at different temperatures during the season of 1937–38 (tables 5, 6, and 7, and figs. 2 and 3) suggested that by storing at high temperatures it might be possible to determine promptly when cane has reached a critical condition of injury and is no longer fit for windrowing. Experiments designed to yield information on this question were, therefore, initiated during 1938–39.

Unstripped samples of Co. 281 from Crescent Farm and Co. 290 from Hollywood Plantation were selected from cane adjacent to lots No. 2, No. 3, No. 4, and No. 5 at the time these lots were windrowed and stored at a temperature of 80° F. Excess acidity determinations by the distillation method were made at frequent intervals. The presence of carbon dioxide in the juices of badly frozen cane prevented accurate determinations in the early trials. In the later determinations the carbon dioxide was driven off by boiling the distillate before titrating (7). Only the latter determinations will be presented. No excess acidity developed in lot No. 2 of either variety in 20 days.

After 17 days the excess acidity for lot No. 3 of Co. 281 was 0.35 cc. and for lot No. 3 of Co. 290, 0.2 cc; after 16 days it was 0.8 cc. for lot No. 4 of Co. 281 and 0.5 cc. for lot No. 4 of Co. 290. There was 0.2 cc. excess acidity in lot No. 5 of Co. 281 and 0.25 cc. of lot No. 5 of Co. 290 after 6 days, and 0.8 cc. and 0.70 cc., respectively, after 14 days.

It will be seen that the rate of development of excess acidity was relatively slow for a temperature of 80° F. It is evident from these results, as well as by the data dealing with eye injury, that none of these lots of cane were damaged as severely as the windrowed cane after the second freeze of the season of 1937–38. Furthermore, the better keeping qualities of the cane of the past season in the field was associated with the lighter degree of injury rather than weather conditions following the freeze.

DISCUSSION AND CONCLUSIONS

The essential characteristics of a good windrowing cane, such as resistance to inversion of sucrose, straightness of stalk, etc., are as important in connection with windrowing cane injured by freezing temperatures as with unfrozen cane. In the absence of such characteristics, aside from those associated with freezing injury, heavy losses of sucrose may be expected in the windrowed cane. In the presence of such characteristics the primary purpose of windrowing sugarcane is to protect it against freezing injury. It is only when cane has become so injured that it no longer resists the attacks by fermenting and gum-forming organisms (*2, 3, 6, 12, 19, 21*) that windrowing ceases to involve the element of protection against future freezes and becomes merely a provision for possibly retarding these reactions. The degree of retardation of fermentation in the windrow is actually too slight to justify windrowing, except as a protection against more severe subsequent freezing. In the absence of freezing temperatures, freezing injury, or injury severe enough to cause fermentation, there is little object to windrowing, although there may be some loss of sucrose resulting from sprouting in standing cane, in which the terminal buds are killed, if such injury is followed by warm weather. Windrowing probably involves losses of sucrose through inversion and certainly involves losses of sugars through respiration. Even when many of the eyes are killed the data indicate that standing cane usually keeps as well as windrowed cane, provided that there are no later freezes. The difficulty arises from the fact that later freezes can be expected, especially following early freezing temperatures, and the severity of such freezes tends to become greater with the advance of the season. Because windrowing is largely a provision of protection against freezing injury, the most effective protection is afforded by the windrowing of unfrozen cane, which also removes the element of uncertainty as to the degree of injury associated with any freeze. To windrow unfrozen cane is not always advantageous or possible (at least when it should be done), consequently the feasibility of windrowing cane that has already been injured becomes a practical consideration. This is especially true during seasons such as those of 1937–38 and 1938–39, particularly the former season when the first damaging low temperatures came early when most of the crop (*16*) was still in the field.

Aside from impairing or destroying the photosynthetic mechanism, thus retarding or stopping sucrose formation, the problems associated with cane injured by freezing temperatures arise from the invasion and activities of micro-organisms (*2, 3, 6, 12, 19, 21*). These activities may result in the loss of sucrose, the development of excess acidity, decrease in pH value, and formation of carbon dioxide, alcohols, gums, etc. Although the loss of sucrose is always of serious consideration, it is the formation of gum that is most dreaded by the planter and factory manager. Gum interferes with, and sometimes prevents, the clarification and recovery of the sucrose that is in the cane.

Because of the serious consequences of the congestion of gum in the factory, it is important to be able to detect its presence in the cane before it is prepared for the mill, in order that the cane may be properly topped or withheld for milling. Results obtained during the

season of 1937–38 (*5*) and 1938–39 (*7*) indicate a relationship between the development of excess acidity and gum formation. If these results are confirmed, the determination of excess acidity could be used as an index to gum formation.

A simple method (*4, 6*) of determining excess acidity has been developed. The method of determining gum formation is more laborious and time consuming. It is believed, however, that filtrability and turbidity of the juice are indications of gum formation and measure, to some degree, the workability of the juice in the laboratory, especially when such signs are used in connection with analysis of the different parts of the cane stalk.

The injury to erect cane in the field by freezing temperatures is at first evident at the tips of the leaves and in the spindle and tends to move down the plant as the degree of cold becomes greater. The lower part of the stalk and the lower eyes are the last to be injured and killed, thus the number of eyes that remain sound becomes an indication of the degree of injury so long as all the eyes are not killed. When all the eyes are killed there are no symptoms, recognizable at present, by which the degree of injury may be accurately measured.

The leaves of a good stand of erect cane form a continuous canopy over the entire field and tend to insulate the lower part of the plant from the cold air. In lodged cane the continuity of this leaf layer is broken, leaving mats of cane and open spaces that give rise to a greater variation in exposure and probable injury.

Windrowed cane may be injured under severe freezing conditions. If the cane is straight, the injury is likely to be limited to the upper internodes, some of which have no commercial value because of their very low sucrose content. When the cane is crooked, greater and more varied damage may be expected, and it may frequently extend to the lower portion of the stalk, which is often exposed.

The data thus far accumulated (*10*) indicate that so long as any of the eyes remain sound, cane of varieties Co. 281 and Co. 290 injured by freezing temperatures will keep in the windrow from 3 to 6 weeks under the usual weather conditions in Louisiana after November 20 without serious development of excess acidity and gum. The chances for the development of these abnormalities becomes less and less as the percentage of sound eyes approaches 100 or, in other words, increases as the killing of the tissue moves down the stalk. The necessity for topping back becomes greater as the zero point of sound eyes is neared. The invasion of the gum-forming organism, *Leuconostoc mesenteroides* (Cienk.) V. Tiegh. (*12*) apparently occurs only in dead tissue. When the stalk is completely dead, invasion and reproduction may be prompt and rapid.

Near or at the zero point of sound eyes, i. e., when none or only the basal or an occasional basal eye remains sound, there may be a destruction of solids at the expense of sucrose. In cane so injured, and windrowed during the season of 1938–39, the Brix decreased in spite of the loss of moisture in the windrow. This condition was found in connection with a fermentation in which carbon dioxide and ethyl alcohol were formed (*6*). The data of Rands, McKaig, and Bisland (*13*) show a similar decrease in Brix in cane of four varieties (Co. 281, C. P. 807, P. O. J. 36–M, and P. O. J. 213) windrowed after all the eyes were killed.

The behavior of cane in which all the eyes were killed has differed. Such cane windrowed by Rands, McKaig, and Bisland (*13*) in 1929 kept fairly well for 6 weeks. This was especially true of Co. 281. In experiments reported here, Co. 281 and especially Co. 290 windrowed in 1934 showed gum formation in 13 days; Co. 281 windrowed in 1935, in which all the eyes were injured or killed, showed no abnormal changes after 16 days in the windrow; Co. 281 and Co. 290 windrowed in 1937 showed gum formation and marked changes in acidity and in pH value in 9 days. The weather following windrowing in these instances does not account for the difference in behavior. There was little difference in the precipitation in the experiment conducted during 1929 and 1937. The temperature was higher and the high temperature more prolonged immediately following windrowing in 1929 (fig. 1) than in 1937, showing that the difference in behavior of the cane in the two seasons was due to the condition of the cane rather than to the temperature following windrowing. It is quite possible that the worse condition of the cane windrowed in 1937 was due to it having been subjected to at least five nights of freezing temperatures, and on the night of December 6 and morning of December 7 the temperature remained below 30° F. for more than 9 hours, whereas in 1929 the cane was subjected to one slight freeze (29° F., November 30) and one night of severe freezing (24° F., December 3). The cane used in 1929 was windrowed before the second night of cold temperature (December 4). It should be kept in mind, however, that the successive freezes that occurred in 1937 did not result in as severe damage to all cane as it did to cane used in the experiments discussed here. In many sections the grinding of standing cane continued until in January.

In Co. 281 and Co. 290 without any sound eyes, or a small percentage of sound eyes, windrowed during the season of 1938–39, the development of excess acidity was very slow.

Cane (Co. 281 and Co. 290, season of 1937–38) with 38 and 37 percent sound eyes when stored at temperatures from 50° to 80° F. showed no abnormal changes during 2 weeks' storage; nor did a high humidity at 62° bring about abnormal changes. What the result would have been had there been more moisture present cannot be said. It does not necessarily follow that if storage were continued beyond 2 weeks at these conditions the effect of temperature and moisture would have remained the same. It does show, however, that such cane exhibits considerable resistance to the invasion of fermenting and gum-forming organisms.

The storing of cane (Co. 281 and Co. 290) after all the eyes were killed during the season of 1937–38 temperature had a marked effect on the development of excess acidity, decrease in pH values, and apparently on gum formation. After 6 days' storage at temperatures of 50°, 62°, 71°, and 80° F., only juice of samples stored at 50° was workable. Even at this temperature juice from two out of three samples of Co. 281 was not workable. All samples of both varieties stored at 50° F. were affected, as shown by the fact that juice from the top two-thirds of the stalks was not workable, or barely workable. There was an increase in acidity and a decrease in pH value with the rise in temperature. This relationship was also exhibited by samples sectioned into thirds, the changes at all temperatures being greatest

in the top, next in the middle, and least in the bottom third of the cane stalk.

The rate of development of excess acidity and of gum formation in cane (Co. 281 and Co. 290) showing from 0 to 0.6 percent sound eyes when stored at a temperature of 80° F. during the season of 1938–39 was relatively slow (7). On the basis of these results and those obtained during the season of 1937–38, it may be possible by storing cane thought to have reached a critical condition of injury at a relatively high temperature and humidity to determine in a relatively short period whether or not it will be profitable to windrow such cane.

In cane of all degrees of injury (table 4) in which deterioration had begun the changes in acidity and in pH value are more marked in the upper third of the cane stalk, and apparently begins there. In cane in which all, or nearly all, the eyes were killed gum formation began in the upper part of the stalk and advanced toward the bottom part of it. In windrowed Co. 290 that showed 11.9 and 20 percent sound eyes there was little change in acidity and in pH value in the bottom two-thirds of the stalk. There has been a growing conviction in the authors' minds that the advance of these changes is very definitely limited by sound tissue, and that advance in such tissues takes place only after further impairment of their vitality, either resulting from long periods in the windrow, in storage, or by further freezing injury. Further proof, however, is required before this conclusion can be fully justified.

The question as to how inversion of sucrose in cane injured by freezing temperatures differs from that in unfrozen cane when in the windrow, is of considerable importance. This question cannot be completely answered at the present time. The behavior of cane showing as many as from about 60 to 85 percent of the eyes killed was similar to that in sound cane, i. e., there apparently was a normal increase in Brix due to loss of moisture and there was the usual difference in the rate of inversion as measured by the drop in purity between Co. 281 and Co. 290.

There is a suggestion in some of the data that a certain degree of injury may inhibit inversion of sucrose. For example, during the season of 1937–38 (table 3) there was a greater drop in purity in one lot of Co. 281 with 80 percent of eyes killed than in one lot with 98.3 percent, and in one lot of Co. 290 with 63 percent of the eyes killed than in one lot with 88.1 percent. However, the cane in these instances came from different locations, and some other factor, such as destruction of reducing sugars by alcoholic fermentation, may have exercised an influence on the net results.

An examination of the data in table 12 relating to Co. 290 will reveal that in windrowed cane with 24.6 percent sound eyes and in cane with nearly all the eyes sound (lots No. 1 and No. 2) there was an increase in Brix and a drop in purity of about 7 points, whereas in windrowed cane with 0.2 to 0.4 percent sound eyes (lots No. 3, No. 4, and No. 5) there was little drop in purity until the last period (corresponding to the beginning of gum formation), when there was a slight drop in purity. Coincident with this maintenance of high purity there was a decline in Brix in spite of the loss of moisture, indicating that the high purity may have been influenced by the consumption of invert sugars. The presence of alcohol in the juice of these lots, as previously indicated, would have had the effect of giving an exaggerated low Brix

reading and a high purity. However, this effect is insufficient to account for the marked decline in Brix. The response of Co. 281 was similar to that of Co. 290, except that lots No. 1 and No. 2 showed little drop in purity. It will be seen that the small drop in purity in lots No. 3, No. 4, and No. 5 of both varieties is not a measure of the loss in sucrose, which was actually considerable as indicated by the drop in Brix and sucrose. This heavy loss of sucrose occurred in spite of the slow development of excess acidity and gum. Judging by the difference in the drop in purity in lots No. 3, No. 4, and No. 5, as compared with lots No. 1 and No. 2 in the two varieties (table 12), it would appear that inversion was altered more in Co. 290 than in Co. 281. However, this greater alteration was partially, if not entirely, compensated by a greater alteration in Brix in Co. 290 (fig. 4).

The consistency of the excellent behavior of Co. 281 in the windrow as compared with Co. 290 when moderately injured or when not injured by freezing temperature, favors Co. 281 as a windrowing cane. The behavior of Co. 290 when sufficiently mature justifies its consideration as an emergency windrowing cane.

SUMMARY

The data presented here deal primarily with windrowing and storage experiments of cane of varieties Co. 281 and Co. 290 injured by freezing temperatures, and the discussion in the summary will be limited to these varieties.

Under the influence of mild freezing conditions the regions of the sugarcane stalk first to be injured are in the spindle and at the tips of the leaves. As the conditions of freezing become more severe the injury extends downward killing the terminal buds, the eyes, and the stalk. The last of the eyes to remain sound are the lower ones.

The behavior of cane exhibiting different degrees of freezing injury when stored at different temperatures and relative humidities and when windrowed was similar in respect to the occurrence or nonoccurrence of fermentive changes. Cane that showed no such changes in the windrow also showed none when stored at the different temperatures and relative humidities, whereas badly damaged cane showed fermentive changes under both sets of conditions.

The first signs of change in acidity, pH value, and gum formation were found in the upper part of the sugarcane stalk. In cane severely injured these changes were greatest in the top third, next in the middle third, and least in the bottom third of the stalk after a period of time in the windrow or in storage.

The data reported indicate that so long as any eyes are sound at the time of windrowing, cane varieties Co. 281 and Co. 290 will windrow from 3 to 6 weeks under the usual weather conditions during the harvesting season in Louisiana without serious increase in acidity, decrease in pH value, and gum formation.

It has been found that in cane in which all the eyes, or all the eyes except an occasional basal eye, have been killed before windrowing, there may be a heavy consumption of solids at the expense of sucrose, although the development of excess acidity and gum is slow. During the season of 1938–39 this heavy consumption of sucrose was associated

with the fermentation involving the production of carbon dioxide and ethyl alcohol.

When all the eyes have been killed, the behavior of cane in the windrow or in storage seems to depend upon a degree of injury at present not measurable by physical symptoms. Cane showing a lesser degree of injury may keep for a period of weeks in the windrow without souring or gum formation, whereas cane showing a greater degree of injury rapidly develops these changes. Weather conditions following windrowing do not appear to be responsible for this difference.

It is possible that the storage of cane so injured at a high temperature (say, 80° F.) may determine promptly whether or not such critical condition of injury has been reached and whether such cane is fit for windrowing. Cane that has been critically injured will deteriorate rapidly whether standing or in the windrow.

The results relating to inversion of sucrose in frozen cane of the varieties Co. 281 and Co. 290 justify the same grouping as employed for unfrozen cane. Although certain lots of Co. 290 show high resistance to inversion, others show considerable susceptibility to it.

The data justify the conclusion that it is safer and wiser, when possible and practical, to windrow cane before it has been injured by freezing temperatures. They also justify the windrowing of cane damaged by freezing temperatures in which sound eyes are found as a protection against further injury.

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