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? EFFECT OF FREEZING TEMPERATURES ON DIFFERENT VARIETIES OF SUGARCANE

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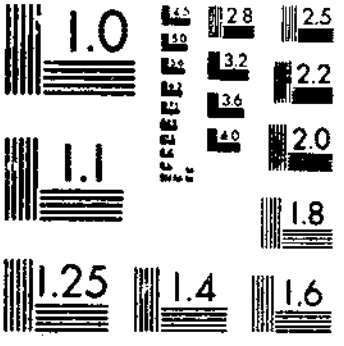

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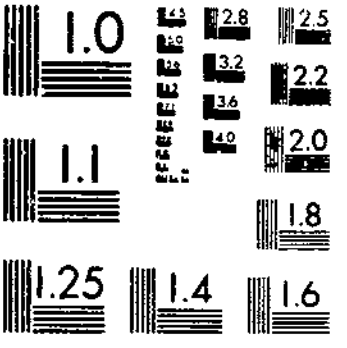

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Effect of Freezing Temperatures on Different Varieties of Sugarcane and the Millability of Damaged Sugarcane in Louisiana [1]

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CONTENTS

In a previous publication (*9*),[2] covering a period from 1930 to 1938, attention was given to the relation of the degree of freezing injury of sugarcane to normal, deleterious, physiological, and chemical changes in standing and windrowed cane and cane stored at different temperatures. The investigation was limited primarily to two varieties, Co. 281 and Co. 290, but it revealed some of the difficulties involved in a varietal study.

Studies reported in this bulletin, covering the period 1939–45, are limited to the freezing injury of leaves, terminal buds, lateral buds (eyes), and stalks of mill cane; and to the effect on sugar manufacture of some of the chemical and physiological changes that occur in injured and killed stalks. However, the investigations were primarily a comparative study of varieties. Since it was not possible in most instances to arrange the studies according to the part of the plant affected, these data will be reported by the year in which the experiments were con-

[1] Submitted for publication March 21, 1949.
[2] Italic numbers in parentheses refer to Literature Cited, p. 34.

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ducted. The study was carried on at the United States Sugar Plant Field Station and adjacent areas, Houma, La.

PROBLEMS IN EXPERIMENTAL PROCEDURE

An accurate evaluation of the relative susceptibility of varieties of sugarcane (mill cane) to freezing injury is difficult, if not impossible, to attain. This difficulty arises from the small difference in susceptibility among varieties to freezing injury, the variation in susceptibility within a variety because of differences in maturity at the time of freezing, and the many environmental variables involved. Among the variables are the presence or absence of wind; wind direction and velocity; intensity, duration, and frequency of freezing temperatures; quantity of moisture in cane, air, and soil; differences in radiation; nearness of canefield to streams, bodies of water, and wooded areas; relative position of bodies of water and wooded areas to canefield; and air drainage. Added to these variables is the problem of sampling the cane and the variation in environmental conditions resulting from the taking of samples from the experimental plots.

The character of the foliage—whether abundant, sparse, spreading, erect, or adhering to stalk—and other factors affect the intensity of freezing injury under the same environmental conditions. These factors are largely varietal and should be so considered in making a comparison between varieties.

The erectness of stalks, density of stand, and the height of cane relative to the surrounding cane within a field also influence the degree of injury under identical environmental conditions. These aspects are normal characteristics of a variety, but they may be modified by storm damage and factors affecting the growth and development of the plant.

In lodged cane of the same variety freezing injury is more variable and severe in spots than in erect cane. Lodging is rarely, if ever, uniform throughout a field; hence, there will be areas in which the cane is down and others in which it is relatively upright and massed together. The cold air settles down into the low areas where it causes more damage than in the cane massed together. All varieties may lodge under the influence of heavy rain and high winds, but some varieties have a propensity to lodge under normal weather conditions. A uniform canopy of leaves interferes with the settling of cold air in the canefield and with the escape of radiated heat from the soil, thus affording considerable protection to the lower part of the cane stalk. An open stand of cane, which is characteristic of certain varieties, is subject to more injury than is a dense stand in which the foliage forms a continuous, thick layer. A thin stand of any variety of cane will be injured more quickly and severely than a thick stand. Cane in the interior of a field is usually injured less than that along the roadways and adjacent to open fields.

In the absence of wind the minimum temperature varies greatly with the location. Normally the minimum temperatures along the bayou fronts in the Delta area are not so low as those farther back toward the lowlands and swamps. This difference arises largely from the variation in the character of the soil and hence the amount of radiation, although air drainage from the higher bayou and river fronts to the lower swamplands may play a part. The soil is lighter

in color and sandier along the Mississippi River and bayou fronts and becomes heavier and darker toward the lowlands and swamps. A difference in minimum temperature of more than 4° F. has been observed (about 4 feet above the ground) between a station near Bayou Black and one about 200 or 300 yards away in black land. The minimum temperature became gradually lower in passing from the first station toward the second, as indicated by the degree of damage to the cane. Wooded areas or high vegetation apparently tend to lower the temperature in the adjacent cane area (*10*). Freezing injury to cane is greater near the swamps.

During still nights there is often striking stratification of temperature. In an open field (*9, 10*) the lowest temperature is observed near the ground. In a stand of unfrozen cane the coldest temperature is observed near the top of the cane and becomes warmer in passing within the cane toward the soil (*7, 9, 10*). A strange effect of this stratification was observed when a large number of varieties were planted in small plots in a field. In such a planting the tops of some varieties will stand several inches above the common level of the field during the fall months. Under the influence of a mild freezing temperature (28° to 32° F.) such foliage was observed to be green while the foliage at the common foliage level was damaged. A more striking effect was observed when cane was planted on a small mound, 4 or 5 feet high, and also at the side of it in the field. The cane on the mound escaped freezing injury, whereas that in the field showed considerable injury. A difference in natural elevation in Louisiana may be responsible, in some instances, for a difference in temperature. A difference in the degree of injury was observed between cane on opposite sides of a bayou. The reason for such difference is not clear.

Because of the obstruction of woods, buildings (*8*), and other obstacles, a certain degree of channeling of freezing temperatures will occur, giving rise to differences in temperature at different locations. With the presence of wind and as the velocity of wind increases, the difference in temperature in local areas tends to disappear, although among large areas major differences may exist. The direction of the wind sometimes gives rise to differences in freezing injury. Under the influence of mild freezing temperatures one side of a field of cane—as few as eight rows from which the cane on both sides had been harvested—showed injury while the other side remained normal. Greater injury often has been observed in cane on the windward side of the field than in that on the leeward side.

If and when freezing temperatures occur singly and are followed by a period of nonfreezing temperature, the problem of studying physical symptoms is relatively simple. Under such circumstances sufficient time is available for the symptoms to develop and for one to examine them leisurely and include in his study larger samples and a greater number of samples. Usually such occurrences are rare. Commonly, freezing temperatures occur during two or more successive nights. Prolonged periods of more than four or five successive nights are rare. The interception of the various stages of successive freezes can be accomplished in part by windrowing cane each morning and examining the cane later. The examination will be limited to injury to the terminal bud, the eyes, and the stalk because the leaves will be further damaged and will dry out in the windrow. The drying effect cannot always be distinguished from the freezing injury. In case there

are severe freezing conditions, the terminal buds, upper eyes, and upper part of the stalk and any exposed lower part of it may be injured in the windrow (*9*).

Considering the accumulated degrees of injury that take place within a short time and the enormous quantity of work required in examining the necessary samples of cane and the recording of detailed data, the scope of the investigation must of necessity be limited, especially if the necessary samples to be chemically analyzed for physiological and fermentative changes that take place are to be included in the investigation.

An initial freezing period may be followed by one or more periods of freezing temperatures of varying intensity. As a result of successive freezing periods, the injurious effect is cumulative in standing cane. Thus, keeping abreast of physical and chemical symptoms is a rather laborious task. Repeated sampling for examination of physical symptoms and chemical changes is required. Such sampling alters a stand of cane, and the exposure becomes greater with each successive freezing temperature and periods of freezing temperature. The nonfreezing environment is also modified by successive sampling. It cannot be assumed that each and all varieties are similarly affected by the removal of samples, although the samples have the same number of stalks. The stalks vary in size and number per unit area. If the investigation is limited to two or three varieties, extreme thinning can be avoided by taking in new plots that are buffered by standing cane, but an error due to location enters into the problem.

Replication for a given degree of freezing does not reduce the thinning out. As the number of varieties is increased, the difficulties of location and thinning are increased. If freezing temperatures were limited to one night or one period, the problem would be greatly simplified. Then succeeding sampling would not be as much of a factor. Such ideal conditions are seldom realized. To synchronize the necessary planting and proper plot technique with the occurrence of such conditions would be accidental, unless large plantings were continuously maintained for no other purpose. The constant shift of varieties in commercial culture and the increasing number of promising unreleased varieties would aggravate this planting problem. It is more practical to take advantage of existing plantings made for other purposes.

Because of the uncertainty and the infrequency of the occurrence of freezing temperatures, it is not feasible to maintain the necessary staff for freezing work alone. Only the available time from other required research work can be devoted to freezing problems; hence, the scope of the investigation must be limited to and conditioned by the extent to which the staff can be shifted to perform the necessary work.

Freezing injury or the killing of sugarcane tissue by freezing temperatures and the resistance or susceptibility of cane to these conditions may be considered under five categories, depending upon the part of the plant affected: (1) Foliage, (2) terminal buds, (3) lateral buds, (4) stalks, and (5) the underground part of the plant. The importance of injury and death or absence of injury and death of these parts depends upon their function.

Injury to and death of leaves result in impairment or destruction of the photosynthetic mechanism and, hence, the growth and the syn-

thesis of carbohydrates, including sucrose. Injury to or death of the terminal buds impairs terminal growth and forces the upper uninjured lateral buds to germinate. Injury to or death of mature lateral buds impairs or destroys their reproductive capacity. Injury to or death of part or all of the sugarcane stalk impairs or destroys its use as seed cane as well as its use for the manufacture of sugar, at least if the injury or death extends to the millable part of the stalk. Injury to or death of the underground parts impairs or destroys the developmental and reproductive capacity of the plant. Such injury and death affect the immediate and succeeding crops.

EXPERIMENTAL DATA

Terminal Bud Injury During the Harvesting Season of 1939–40

During 1939 minimum temperatures of 31°, 29°, 32°, and 31° F. occurred on November 5, 6, 28, and 29, at the United States Sugar Plant Field Station. These temperatures were severe enough to injure the leaves and terminal buds of the cane growing in light land at the station (B–5–F).[3] Data were taken on terminal bud injury in plant cane in 112 8-foot single-row plots (2 plots left blank) in 16 rows (7 plots in each row). There were 15 control plots of Co. 281 and 14 of C. P. 28/19, 1 plot each of 6 other commercial, or formerly commercial, varieties, and 1 plot each of 75 unreleased varieties. Ten tops, cut off at the upper millable joints, were taken at random from each plot and examined for injury and killing of the terminal bud (table 1). The extent of injury was estimated, and the values given are subject to

Table 1.—*Injury to terminal buds of 8 commercial and 75 unreleased varieties of sugarcane following freezing temperatures of 31°, 29°, 32°, and 31° F. on November 5, 6, 28, and 29, 1939, respectively, at the United States Sugar Plant Field Station, Houma, La.*

Variety	Tops used [1]	Terminal buds injured				Terminal buds killed
		Slightly	Moderately	Severely	Total	
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Co. 281 [2]	145	30.3	27.6	23.4	99.3	9.7
C. P. 28/19 [2]	136	43.4	13.9	23.5	59.9	16.1
C. P. 807 [2]	10	20.0	10.0	30.0	60.0	40.0
C. P. 28/11 [2]	10	40.0	50.0	10.0	100.0	0
C. P. 29/99	10	20.0	40.0	10.0	70.0	30.0
C. P. 29/116 [2]	10	10.0	0	10.0	20.0	80.0
C. P. 29/120 [2]	10	0	30.0	40.0	70.0	30.0
C. P. 29/137	10	0	10.0	10.0	20.0	80.0
C. P. 29/320 [2]	10	0	10.0	20.0	30.0	70.0
C. P. 31/101	10	10.0	30.0	40.0	80.0	20.0
C. P. 31/509	10	0	0	70.0	70.0	30.0
C. P. 32/07	10	30.0	40.0	30.0	100.0	0
C. P. 32/118	10	0	20.0	20.0	40.0	60.0
C. P. 32/120	10	0	30.0	40.0	70.0	30.0
C. P. 32/121	10	0	0	20.0	20.0	80.0
C. P. 32/126	10	0	10.0	50.0	60.0	40.0
C. P. 32/134	10	10.0	30.0	30.0	70.0	30.0
C. P. 32/146	10	0	10.0	30.0	30.0	70.0
C. P. 32/202	10	0	20.0	40.0	60.0	40.0

See footnotes at end of table.

[3] Station will hereafter be used in this bulletin instead of United States Sugar Plant Field Station. The symbol B–5–F indicates the exact location of the cane used for observations. Other symbols of location at the station will be used in this bulletin.

TABLE 1.—*Injury to terminal buds of 8 commercial and 75 unreleased varieties of sugarcane following freezing temperatures of 31°, 29°, 32°, and 31° F. on November 5, 6, 28, and 29, 1939, respectively, at the United States Sugar Plant Field Station, Houma, La.*—Continued

Variety	Tops used [1]	Terminal buds injured				Terminal buds killed
		Slightly	Moderately	Severely	Total	
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
C. P. 32/206	10	30.0	20.0	10.0	60.0	40.0
C. P. 32/310	10	20.0	10.0	0	30.0	70.0
C. P. 32/321	10	0	0	30.0	30.0	70.0
C. P. 32/324	10	10.0	20.0	0	30.0	70.0
C. P. 32/332	10	20.0	20.0	30.0	70.0	30.0
C. P. 32/334	10	0	10.0	20.0	30.0	70.0
C. P. 32/336	10	10.0	10.0	20.0	40.0	60.0
C. P. 33/121	9	22.2	77.7	0	100.0	0
C. P. 33/142	10	40.0	40.0	20.0	100.0	0
C. P. 33/165	9	0	55.5	44.4	100.0	0
C. P. 33/173	10	10.0	30.0	20.0	60.0	40.0
C. P. 33/185	8	0	0	50.0	50.0	50.0
C. P. 33/216	10	30.0	30.0	20.0	80.0	20.0
C. P. 33/224	10	0	40.0	10.0	50.0	50.0
C. P. 33/228	10	10.0	0	30.0	40.0	60.0
C. P. 33/229	8	25.0	0	37.5	62.5	37.5
C. P. 33/232	8	0	37.5	12.5	50.0	50.0
C. P. 33/233	9	22.2	0	55.5	77.7	22.2
C. P. 33/243 [2]	10	70.0	20.0	10.0	100.0	0
C. P. 33/253	10	10.0	40.0	40.0	90.0	10.0
C. P. 33/255	10	60.0	30.0	0	90.0	10.0
C. P. 33/257	10	20.0	30.0	50.0	100.0	0
C. P. 33/307	10	30.0	20.0	30.0	80.0	20.0
C. P. 33/320	10	40.0	0	20.0	60.0	40.0
C. P. 33/342	10	20.0	60.0	10.0	90.0	10.0
C. P. 33/343	10	20.0	10.0	20.0	50.0	50.0
C. P. 33/365	10	10.0	10.0	20.0	40.0	60.0
C. P. 33/366	10	20.0	40.0	20.0	80.0	20.0
C. P. 33/370	10	30.0	10.0	30.0	70.0	30.0
C. P. 33/372	9	33.3	33.3	33.3	100.0	0
C. P. 33/389	10	0	60.0	20.0	80.0	20.0
C. P. 33/394	10	60.0	20.0	20.0	100.0	0
C. P. 33/397	10	80.0	20.0	0	100.0	0
C. P. 33/398	10	70.0	30.0	0	100.0	0
C. P. 33/400	10	20.0	20.0	40.0	80.0	20.0
C. P. 33/406	10	0	50.0	20.0	70.0	30.0
C. P. 33/409	10	40.0	30.0	20.0	90.0	10.0
C. P. 33/414	10	50.0	40.0	10.0	100.0	0
C. P. 33/415	9	22.2	55.5	11.1	88.8	11.1
C. P. 33/445	10	0	40.0	60.0	100.0	0
C. P. 33/450	10	0	0	40.0	40.0	60.0
C. P. 33/459	10	10.0	20.0	40.0	70.0	30.0
C. P. 33/471	10	10.0	40.0	50.0	100.0	0
C. P. 33/472	10	30.0	20.0	40.0	90.0	10.0
C. P. 33/485	10	20.0	50.0	30.0	100.0	0
C. P. 33/494	10	30.0	10.0	50.0	80.0	20.0
C. P. 33/500	10	10.0	60.0	20.0	90.0	10.0
C. P. 33/509	10	40.0	30.0	20.0	90.0	10.0
C. P. 34/1	10	60.0	20.0	20.0	100.0	0
C. P. 34/9	10	20.0	40.0	30.0	90.0	10.0
C. P. 34/10	10	50.0	30.0	20.0	100.0	0
C. P. 34/16	10	40.0	10.0	50.0	100.0	0
C. P. 34/21	9	22.2	66.6	11.1	100.0	0
C. P. 34/25	10	50.0	20.0	30.0	100.0	0
C. P. 34/27	10	10.0	10.0	20.0	40.0	60.0
C. P. 34/52	10	30.0	30.0	40.0	100.0	0
C. P. 34/53	9	100.0	0	0	100.0	0
C. P. 34/57	10	70.0	20.0	10.0	100.0	0
C. P. 34/59	10	50.0	10.0	30.0	90.0	10.0
C. P. 34/73	10	10.0	60.0	20.0	90.0	10.0
C. P. 34/77	10	30.0	70.0	0	100.0	0
C. P. 34/79	10	50.0	40.0	10.0	100.0	0
C. P. 34/80	10	40.0	30.0	20.0	90.0	10.0
C. P. 34/81	10	20.0	0	30.0	50.0	50.0

[1] When less than 10 tops are shown, the buds remaining were injured or killed by the sugarcane borer (*Diatraea saccharalis (F.)*).
[2] Commercial varieties.

error of judgment, except when the terminal bud was killed, which generally is definitely indicated. No sound buds were found in any lot or variety, and in no case were all the buds killed. There was some

indication that the injury became slightly greater as the distance from the bayou (Little Bayou Black) was increased.

Studies Made During the Harvesting Season of 1940–41

On November 15 and 16, 1940, the minimum temperatures at the United States Weather Bureau Station at Southdown Plantation were 23° and 22° F. (*11*). The minimum temperatures at the United States Sugar Plant Field Station were 22° and 22°. The cane at the station had not been previously frozen. The freezing temperatures were followed by rather high temperatures (table 2).

Table 2.—*Maximum, minimum, and mean temperatures and rainfall*[1] *during a windrowing experiment with Co. 281 and Co. 290 (table 3), 1940*

Date	Temperatures			Date	Temperatures		
	Maximum	Minimum	Mean		Maximum	Minimum	Mean
	° F.	° F.	° F.		° F.	° F.	° F.
Nov. 14	54	34	44.0	Nov. 25	74	66	70.0
15	47	23	35.0	26	68	49	59.0
16	62	22	42.0	27	58	46	52.0
17	74	36	55.0	28	59	43	51.0
18	75	41	58.0	29	69	46	57.5
19	78	45	61.5	30	75	56	65.5
20	76	56	66.0	Dec. 1	77	64	70.5
21	80	63	71.5	2	68	44	56.0
22	82	64	73.0				
23	81	67	74.0	Average	70.5	49.2	59.8
24	82	69	76.5				

[1] Precipitation November 25, 1.11 inches, and December 1, 0.17.

In anticipation of the predicted freezing temperatures on the night of November 14 and the morning of November 15, adjacent cuts (the cane between two drainage ditches) of Co. 281 and Co. 290 in light land at Southdown Plantation were selected for the purpose of studying the effects of freezing temperatures on injury to the stalk and deterioration of sucrose. On November 14 a block of each variety of cane, consisting of 6 rows (3 windrows), 100 feet long, at the back of the first quarter drain and 2 rows from the drainage ditch, was windrowed (lot 1). Minimum thermometers were installed in a shelter, 4 feet above the ground, in the windrowed cane area of each variety. A second block of the same size of each variety (lot 2) was windrowed November 15, and a third lot, November 16. Each lot was insulated by standing cane. Samples (30 stalks) of each variety and lot were taken from the top end and middle points (along the rows) of each windrow of each lot and from standing cane at the time of windrowing and at the end of each successive period (table 3) for chemical analysis. Likewise, 15-stalk samples were selected along the windrows of lots 2 and 3 for detailed examination of injury (table 4) at the time of windrowing.

Fifteen additional stalks of lots 2 and 3 of both varieties were stored at a temperature of 65° F. and a relative humidity of 95 percent for 11 days (until Nov. 27) and then examined for the presence of sound, injured, and dead eyes. Only the sound and injured eyes, however, were counted. One sound eye and two injured eyes were found in lot 2 of Co. 281; no sound or injured eyes were found in lot 3. Co. 290

showed two sound eyes (lot 2) and one that may or may not have been alive (lot 3). The sound and injured eyes were found only at or near the ground level (basal eyes).

TABLE 3.—*Effect of freezing temperatures of November 15 and 16, 1940, on Brix, apparent sucrose, apparent purity, acidity, and pH value in windrowed and standing cane of the varieties Co. 281 and Co. 290 plant cane*

CO. 281

Treatment, lot No., and date of windrowing	Date of freezing temperature	Minimum freezing temperature	Date of analysis	Duration of experiment	Brix	Sucrose	Purity	Purity change (gain (+) or loss (−))	pH	Excess acidity	Juice extraction
Windrowed cane:		° F.	1940	Days	Degrees	Percent				Cc.	Percent
Lot 1, Nov. 14			Nov. 16	0	16.36	14.07	86.0		5.25	0	62
			Nov. 20	10	16.48	13.63	82.7	−3.3	5.30	0	61
			Dec. 2	16	16.32	13.60	83.3	−2.7	5.25	(1)	63
Lot 2, Nov. 15	Nov. 15	19.6	Nov. 16	0	15.77	13.41	85.0		5.25	0	62
			Nov. 20	4	15.72	13.31	84.7	−.3	5.30	0	62
			Nov. 26	10	15.60	13.16	84.3	−.7	5.20	.05	61
			Dec. 2	16	15.72	13.27	84.4	−.6	5.20	.05	63
Lot 3, Nov. 16	Nov. 16	19.3	Nov. 16	0	15.81	13.51	85.6		5.25	0	62
			Nov. 20	4	15.70	13.53	85.9	+.3	5.30	0	63
			Nov. 26	10	15.28	13.15	86.1	+.5	5.30	.10	62
			Dec. 2	16	15.27	13.18	86.2	+.6	5.25	.10	62
Standing cane			Nov. 16	0	16.09	13.79	85.7		5.25	0	62
			Nov. 20	4	15.24	13.14	86.2	+.5	5.30	0	63
			Nov. 26	10	13.73	11.55	84.1	−1.6	5.20	.15	60
			Dec. 2	16	13.39	11.19	83.6	−2.1	4.85	.35	62

CO. 290

Windrowed cane:											
Lot 1, Nov. 14			Nov. 16	0	16.52	13.80	83.6		5.30	0	64
			Nov. 20	10	16.65	13.35	80.2	−3.4	5.30	0	62
			Dec. 2	16	16.01	13.35	80.4	−3.2	5.20	(1)	64
Lot 2, Nov. 15	Nov. 15	20.4	Nov. 16	0	16.00	13.22	82.3		5.30	0	66
			Nov. 20	4	15.68	12.66	80.6	−1.7	5.30	0	64
			Nov. 26	10	15.53	12.29	79.1	−3.2	5.20	.05	62
			Dec. 2	16	15.36	12.20	79.4	−2.9	5.00	.10	65
Lot 3, Nov. 16	Nov. 16	20.0	Nov. 16	0	15.56	12.68	81.5		5.30	0	66
			Nov. 20	4	15.46	12.40	80.2	−1.3	5.30	0	66
			Nov. 26	10	14.94	11.72	78.4	−3.1	5.15	.15	62
			Dec. 2	16	14.39	11.11	77.2	−4.3	4.85	.45	65
Standing cane			Nov. 16	0	16.12	13.39	83.1		5.30	0	65
			Nov. 20	4	14.93	12.30	82.4	−.7	5.30	0	63
			Nov. 26	10	13.38	10.35	77.4	−5.7	5.00	.30	62
			Dec. 2	16	12.78	9.82	76.8	−6.3	4.85	.60	64

(1) Trace.

TABLE 4.—*Injury to two varieties of plant cane used in windrowing experiments as indicated by the extent of damage done to leaves, stalks, terminal buds, and eyes (lateral buds) by freezing temperatures of November 15 and 16, 1940*

Variety and lot No.	Date of minimum temperature	Minimum temperature	Stalks of cane examined	Eyes per stalk (average)	Total eyes			Eyes			Internodes split
					Sound	Injured	Killed	Sound	Injured	Killed	
		° F.	Number	Number	Number	Number	Number	Percent	Percent	Percent	Number
Co. 281:											
Lot 2	Nov. 15	19.6	15	12.3	0	0	184	0	0	100	0
Lot 3	Nov. 16	19.3	15	13.4	0	0	201	0	0	100	7
Co. 290:											
Lot 2	Nov. 15	20.4	15	15.3	0	[1]1	230	0	0	100	1
Lot 3	Nov. 16	20.0	15	14.9	0	0	223	0	0	100	2

[1] Eye was injured, but there is some question as to whether it was alive.

Aside from the difference in eye injury in lots 2 and 3 of both varieties, the eyes were softer and darker and there was more marked water soaking and more exuded juice on stalks of lot 3 than on lot 2. Co. 281 appeared to be more severely injured than Co. 290. In one or two cases (lot 2) the lower internode of each variety was almost normal; otherwise, the interior of the stalks of both lots and varieties was water-soaked throughout. All the terminal buds and leaves were killed by the freezing temperatures of November 15 and 16.

Concomitantly with the windrowing of lots 2 and 3 enough cane (about 350 stalks) was cut off at the base for selection of 25 (lot 2) to 27 (lot 3) untopped 10-stalk samples of each lot and variety. The samples were selected by drawing stalks at random from a pile of cane. These samples were stored at high humidity at temperatures of 65°, 75°, and 90° F. Only one sample of each lot and variety was stored at 65°, and it was examined for freezing injury after 11 days' storage (table 5). The other samples were divided equally between storage at 75° and at 90°. Two of these samples of each variety and lot were analyzed for changes in Brix, sucrose, pH, and excess acidity at the beginning of storage and at frequent intervals (table 6).

On November 15 the minimum temperatures within the cuts of Co. 281 and Co. 290 were 19.6° and 20.4° F., and on November 16, 19.3° and 20° (tables 4 and 5). The temperature at the station on the night of November 14 had reached 27° by 10:30, and in the cuts of Co. 281 and Co. 290, 23° by 11:00. A thermograph record, taken in a shelter (4 feet above the ground) situated in sandy soil some distance away from the windrowed cane, showed that the temperature had been 32° and lower for 13 hours and 30° and lower for 12 hours during the night of November 15 and the morning of November 16.

TABLE 5.—*Injury to two varieties of plant cane used in storage experiments, as indicated by extent of damage done to eyes (lateral buds) by freezing temperatures of November 15 and 16, 1940*

Variety and lot No.	Date of freezing temperature	Minimum freezing temperature	Storage conditions		Duration of storage	Stalks of cane examined	Total eyes [1]	
			Temperature	Relative humidity			Sound	Injured
		° F.	° F.	*Percent*	*Days*	*Number*	*Number*	*Number*
Co. 281, Lot 2	Nov. 15	19.6	65	95	11	10	0	2
Lot 3	Nov. 16	19.3	65	95	11	10	0	0
Co. 290, Lot 2	Nov. 15	20.4	65	95	11	10	0	1
Lot 3	Nov. 16	20.0	65	95	11	10	0	0
Co. 281, Lot 2	Nov. 15	19.6	75	82	16	20	1	1
	Nov. 15	19.6	90	86	16	20	1	3
Lot 3	Nov. 16	19.3	75	82	16	20	1	0
	Nov. 16	19.3	90	86	16	20	0	[2] 1
Co. 290, Lot 2	Nov. 15	20.4	75	82	16	20	2	0
	Nov. 15	20.4	90	86	16	20	3	3
Lot 3	Nov. 16	20.0	75	82	16	20	0	[2] 1
	Nov. 16	20.0	90	86	16	20	0	2

[1] Only the sound and injured eyes were counted.
[2] Eye severely injured, and there is doubt as to whether it had any life.

All the leaves and terminal buds and most of the eyes (tables 4 and 5) and stalk were killed in both varieties and lots (Nos. 2 and 3).

TABLE 6.—*Changes in Brix, apparent sucrose, apparent purity, acidity, and pH value during storage at 2 temperatures and relative humidities in plant cane injured by freezing temperatures of Nov. 15 and Nov. 16, 1940*

CO. 281

Lot No.	Date of freezing temperature	Minimum freezing temperature	Storage conditions		Date of analysis	Duration of storage	Brix	Sucrose	Purity	Purity change, (gain (+) or loss (−))	pH	Excess acidity	Juice extraction
			Temperature	Relative humidity									
		°F.	°F.	Percent		Days	Degrees	Percent				Cc.	Percent
					Nov. 16	0	16.44	14.25	86.7		5.25	0	59
					Nov. 18	2	14.79	13.03	88.1	+1.4	5.25	(1)	54
2	Nov. 15	19.6	75	82	Nov. 20	4	15.15	12.97	85.6	−1.1	5.25	(1)	59
					Nov. 22	6	15.12	13.07	86.4	−.3	5.25	.05	59
					Nov. 25	9	15.07	12.79	84.9	−1.8	5.15	.15	60
					Nov. 27	11	15.24	12.71	83.4	−3.3	5.20	.05	55
					Nov. 16	0	16.44	14.25	86.7		5.25	0	59
					Nov. 18	2	14.84	12.46	84.0	−2.7	5.25	.05	52
2	do	19.6	90	86	Nov. 20	4	15.45	13.57	87.8	+1.1	5.25	.05	58
					Nov. 22	6	14.72	12.67	86.1	−.6	5.25	.15	60
					Nov. 25	9	14.57	11.93	81.9	−4.8	5.10	.25	55
					Nov. 27	11	14.66	12.17	83.0	−3.7	5.00	.40	55
					Nov. 16	0	16.44	14.25	86.7		5.25	0	59
					Nov. 18	2	14.84	12.43	83.6	−3.1	5.25	.05	55
3	Nov. 16	19.3	75	82	Nov. 20	4	14.76	12.66	85.8	−.9	5.25	.10	55
					Nov. 22	6	14.37	12.29	85.5	−1.2	5.25	.15	59
					Nov. 25	9	14.07	11.99	85.2	−1.5	5.10	.35	56
					Nov. 27	11	13.69	10.96	80.1	−6.6	4.80	1.10	54
					Nov. 16	0	16.44	14.25	86.7		5.25	0	59
					Nov. 18	2	14.89	12.80	86.0	−.7	5.25	(1)	57
3	do	19.3	90	86	Nov. 20	4	14.66	12.66	86.4	−.3	5.25	.20	57
					Nov. 22	6	13.47	11.46	85.1	−1.6	5.20	.55	56
					Nov. 25	9	13.12	10.12	77.1	−9.6	4.70	1.00	62
					Nov. 27	11	13.24	8.98	67.8	[2] −18.9	4.45	3.40	54

2	Nov. 15	20.4	75	82	Nov. 16	0	16.09	13.49	83.8	----------	5.30	0	----------
					Nov. 18	2	15.24	12.46	81.8	−2.0	5.25	0	61
					Nov. 20	4	14.96	12.26	82.0	−1.8	5.30	(1)	63
					Nov. 22	6	14.77	11.87	80.4	−3.4	5.25	.10	59
					Nov. 25	9	14.37	11.08	77.1	−6.7	4.95	.25	63
					Nov. 27	11	14.39	11.02	76.6	−7.2	5.15	.20	60
2	do	20.4	90	86	Nov. 16	0	16.09	13.49	83.8	----------	5.30	0	----------
					Nov. 18	2	15.54	12.89	82.9	−.9	5.25	0	59
					Nov. 20	4	14.91	12.01	80.5	−3.3	5.20	.15	61
					Nov. 22	6	14.77	11.55	78.2	−5.6	5.20	.20	60
					Nov. 25	9	14.27	10.56	74.0	−9.8	4.90	.45	58
					Nov. 27	11	14.51	10.66	73.5	−10.3	5.00	.40	59
3	Nov. 16	20.0	75	82	Nov. 16	0	16.09	13.49	83.8	----------	5.30	0	----------
					Nov. 18	2	15.24	12.48	81.9	−1.9	5.25	(1)	62
					Nov. 20	4	15.10	12.25	81.1	−2.7	5.25	(1)	61
					Nov. 22	6	14.52	11.45	78.9	−4.9	5.15	.25	58
					Nov. 25	9	15.07	10.88	72.2	−11.6	4.60	1.50	62
					Nov. 27	11	14.49	10.64	73.4	[3]−10.4	4.45	1.80	61
3	do	20.0	90	86	Nov. 16	0	16.09	13.49	83.8	----------	5.30	0	----------
					Nov. 18	2	14.89	11.96	80.3	−3.5	5.25	0	62
					Nov. 20	4	14.36	11.41	79.5	−4.3	5.10	.25	63
					Nov. 22	6	13.62	10.74	78.9	−4.9	5.10	.55	64
					Nov. 25	9	13.42	9.27	69.1	−14.7	4.50	2.10	61
					Nov. 27	11	13.71	9.32	68.0	−15.8	5.00	2.40	62

[1] Trace.
[2] Difficulty was experienced in filtering and in obtaining polarization readings in juice of 3 out of 4 samples of cane after 11 days' storage at a temperature of 90° F. and a relative humidity of 86 percent.
[3] Difficulty was experienced in filtering and in obtaining polarization readings in 1 of 4 samples of cane after 11 days' storage at 75° F. and 82 percent relative humidity.

On the basis of the sound and injured eyes remaining, the water soaking of the interior of the stalk, and the presence or absence of a slight amount of sound tissue in the lower internode in both varieties (tables 4 and 5), lot 3 showed severer injury than in lot 2. Co. 281 appeared to be more severely injured than Co. 290.

There was no significant change in Brix in windrowed cane of either variety (table 3) in lot 1 (windrowed before the occurrence of freezing temperatures). The drop in purity was greater, as usual, in Co. 290 than in Co. 281. In Co. 281 it was greater in lot 1 than in lots 2 and 3 and also greater than in standing cane. In Co. 290 it was greater in lot 1 than in lot 2 but less than in lot 3 and in standing cane. The change in Brix and sucrose in lot 2 of Co. 281 was slight. The change in Brix in lot 3, and particularly in standing cane, was considerably greater than in lot 2. The slight increase in apparent purity in lot 3 of Co. 281 and the relatively small drop in purity in standing cane, considered by themselves, would indicate no loss or relatively small loss of sucrose. The rather heavy loss in Brix, however, particularly in standing cane, indicated rather heavy loss of sucrose. This behavior is characteristic of an alcoholic type of fermentation in badly frozen cane (*5, 9*). The invert sugars are destroyed as fast, or almost as fast, as they are formed, thus tending to leave a high purity. The drop in purity in windrowed cane in lot 1 of Co. 290 was greater than in lot 2, but less than in windrowed cane in lot 3 and in standing cane. It was greater in lot 3 than in lot 2 and greater in standing cane than in lot 3.

Taking into consideration the drop in purity and the loss in Brix in lots 2 and 3 and in standing cane, the loss of sucrose was much greater in Co. 290 than in Co. 281. The results clearly indicate that standing cane showed much heavier losses of sucrose than frozen windrowed cane of both varieties. This difference is believed to be due to a lower temperature in the windrow than in standing cane. A trace of excess acidity[4] was indicated in lot 1 of both varieties by the end of the windrowing experiment (December 2). This trace may have developed as a result of injury to cane while in the windrow. Cane has been known to be injured in the windrow by severe freezing conditions (*9*). In the present case the freezing conditions, including the minimum temperatures and the duration of these temperatures, were rather severe. It is also possible that the trace may have been due to carbon dioxide that may not have been driven off before the titration was made.

There was a development of excess acidity in lots 2 and 3 and in standing cane of both varieties. This development was rather slow, but was greater in lot 3 than in lot 2 and in standing cane than in lot 3. This slow development of excess acidity is characteristic of alcoholic fermentation. The change in pH coincided fairly well with the change in acidity.

It is quite obvious on the basis of loss in Brix and drop in purity in lots 2 and 3 of Co. 281 that an increase in temperature from 75° to 90° F. increases the rate of inversion and loss of sugars (table 6). The

[4] Excess acidity was determined by the distillation method (*3*).

loss in Brix in Co. 290 (table 6) was no greater in lot 2 stored at 90° than in that stored at 75°, but the drop in purity indicates that there was a greater loss of sucrose through inversion at 90° than at 75°. In lot 3 the loss in Brix and drop in purity were greater at 90° than at 75°. It also will be noted that the loss of sucrose was greater in lot 3 of both varieties than in lot 2, especially in cane stored at 90°.

The changes in acidity and pH clearly show that lot 3 of both varieties was injured more than lot 2 and that deterioration was more rapid at 90° than at 75° F. They also indicate that deterioration in both lots and varieties was more rapid at 90° and at 75° in case of Co. 290 than in the windrow. This is further emphasized by the fact that the duration of storage at 75° and 90° was several days shorter than storage in the windrow (tables 3 and 6). The average maximum air temperature for the period of windrowing was 70.5° (table 2) and that in the windrow must have been somewhat less (2). It will be seen from these results that the temperature following severe freezing injury may be an important factor in influencing the rate of deterioration.

Judging by the loss in Brix in the two varieties stored at 75° and 90° F., lot 3 of Co. 281 was damaged more than lot 3 of Co. 290. The reverse was true in windrowed cane. Standing Co. 290 lost considerably more Brix than Co. 281. It is doubtful whether, on the basis of these results alone, a definite conclusion can be drawn as to which variety is more resistant to freezing temperatures. The data indicate that windrowed cane of both varieties kept better than standing cane.

Studies Made During the Harvesting Season of 1943–44

FREEZING TEMPERATURES

During November 1943 there were two periods of freezing temperatures (table 7). The minimum temperatures from November 9 to 13 ranged from 30° to 32° F. and from November 17 to 20, 28° to 32°. In December the minimum temperature on the 12th was 32°; it ranged from 23° to 31° from December 16 to 20; and was 30° on December 31. On December 16 the temperature was below 30° for about 8 hours, and on December 17 and 18, for 11 to 12 hours. In January 1944 the minimum temperature fell to 31° on the 9th, 25° on the 10th, and 29° on the 16th.

PLAN OF EXPERIMENTATION

As a result of the freezing temperatures of November, parts of the leaves, most of the terminal buds, and a few of the upper eyes were injured or killed. Late in November some of the upper eyes began to germinate. It was decided to study the effect of such germination and of growth of sprouts on sucrose content of such cane while standing unharvested in the field.

The cane used for observing the degree of injury and for chemical analysis was planted for the purpose of studying the rate of maturation (formation of sucrose) but was not used for that purpose. The planting was arranged in replicated three-row plots, 80 feet long, in

TABLE 7.—*Maximum and minimum temperatures and rainfall for period November 1, 1943, to January 17, 1944, at the United States Sugar Plant Field Station, Houma, La.*

Date	Temperatures		Rainfall	Date	Temperatures		Rainfall
	Maximum	Minimum			Maximum	Minimum	
1943	° *F.*	° *F.*	*Inches*	*1943*	° *F.*	° *F.*	*Inches*
Nov. 1	87	60		Dec. 11	65	53	
2	85	64	0.02	12	72	32	
3	71	59		13	72	47	0.93
4	76	45		14	64	[1] 46	1.46
5	85	47		15	40	30	.10
6	80	64		16	44	24	
7	70	68	.85	17	49	23	
8	69	39		18	56	23	
9	67	31		19	63	26	
10	65	32		20	68	31	
11	69	30		21	68	42	
12	73	31		22	75	49	
13	73	32		23	55	49	.03
14	74	40		24	56	40	.92
15	77	51		25	47	41	
16	70	48		26	58	41	
17	63	32		27	70	42	.03
18	67	28		28	59	48	
19	74	29		29	43	37	
20	78	30		30	58	39	
21	78	33		31	67	30	
22	78	38		*1944*			
23	73	42		Jan. 1	66	41	.02
24	68	42		2	68	52	1.02
25	54	36		3	64	45	
26	71	34		4	63	34	
27	70	44		5	70	41	
28	73	52	.11	6	57	39	
29	59	55		7	57	42	1.82
30	67	49		8	48	46	
Dec. 1	76	34		9	51	31	
2	78	50		10	60	25	
3	75	61		11	64	43	
4	72	62		12	60	53	3.18
5	70	56		13	51	50	.81
6	77	62	.03	14	45	42	.09
7	80	63		15	52	36	
8	81	61		16	65	29	
9	82	63		17	69	36	
10	82	60					

[1] Readings on December 14 were obtained from records at the Southdown plantation, which is adjacent to United States Sugar Plant Field Station.

five tiers with a plot of each variety in each tier (fig. 1). Two tiers of plots 1 and 2 were selected on which to make observations on extent of injury to cane and to obtain samples for chemical analysis. The plots were divided into four sections of equal length along the row (fig. 2).

In order to obtain a detailed picture of the degree of injury, three sets of samples were selected for examination: (1) On November 27, 10 stalks were selected at random from each of plots *A*, Co. 281; *B*, Co. 290; *C*, C. P. 28/19; and *D*, C. P. 34/120 (fig. 1); (2) on December 6, 4 stalks were taken at random from each of the sections of rows labeled No. 1 in tier 1 (fig. 2); and (3) on December 9 this same procedure was followed for tier 2.

Initially the plan called for chemical analysis of 3 25-stalk samples taken from each plot in tiers 1 and 2 at the beginning of the experiment (December 1) and at 3 successive periods of time. The first set of samples (6 samples of each variety) was to be taken from section 1, and the second, third, and fourth sets from sections 2, 3, and 4 (fig. 2). This plan was followed for the first 3 analyses, the last of which was made December 22.

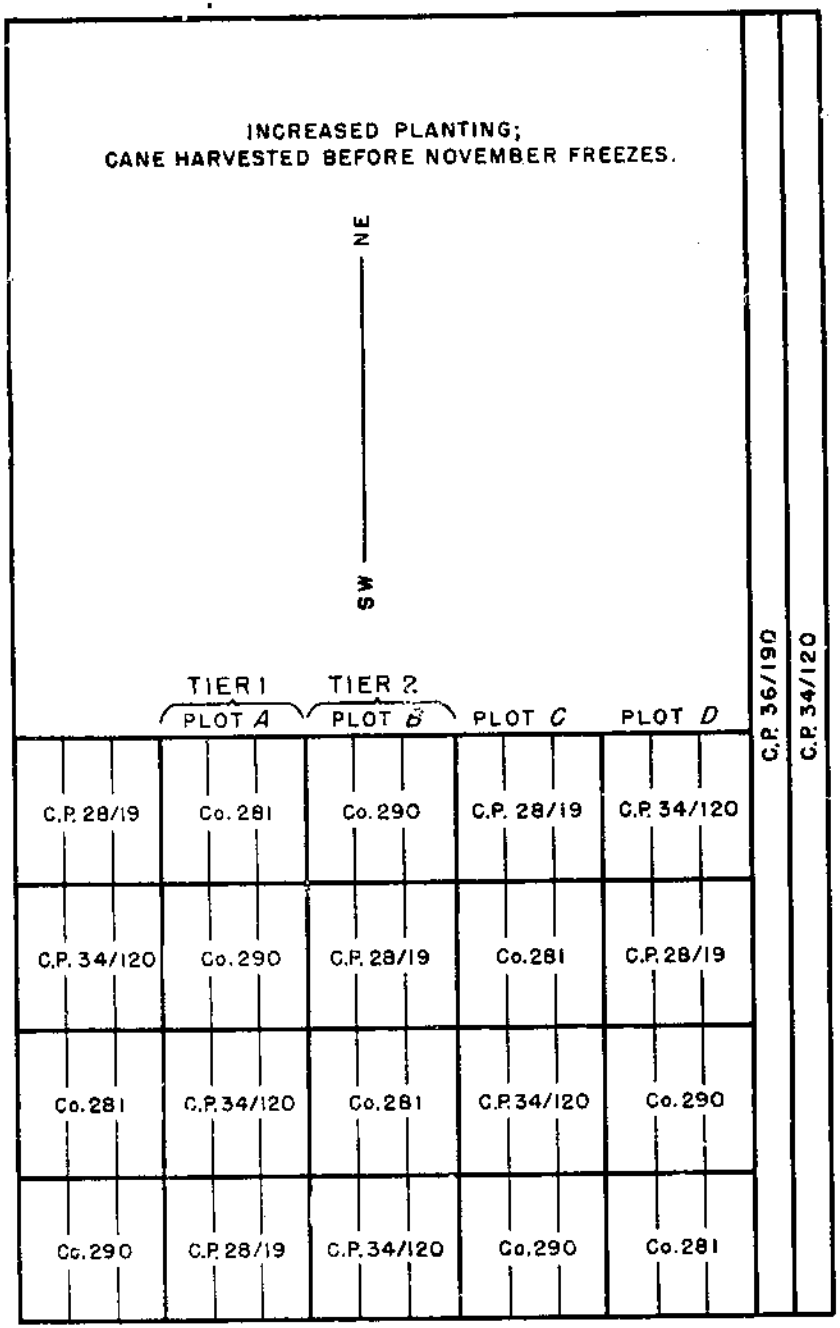

FIGURE 1.—Diagram of plots planted October 1942 from which the cane used for observing injury and making chemical analyses was taken. Each plot consisted of 3 rows 80 feet long; 4-foot pathways between plots. *A*, *B*, *C*, and *D*: Plots from which cane was taken for initial examination of degree of injury. Tiers 1 and 2 include the plots of cane used for studying injury and making chemical analyses.

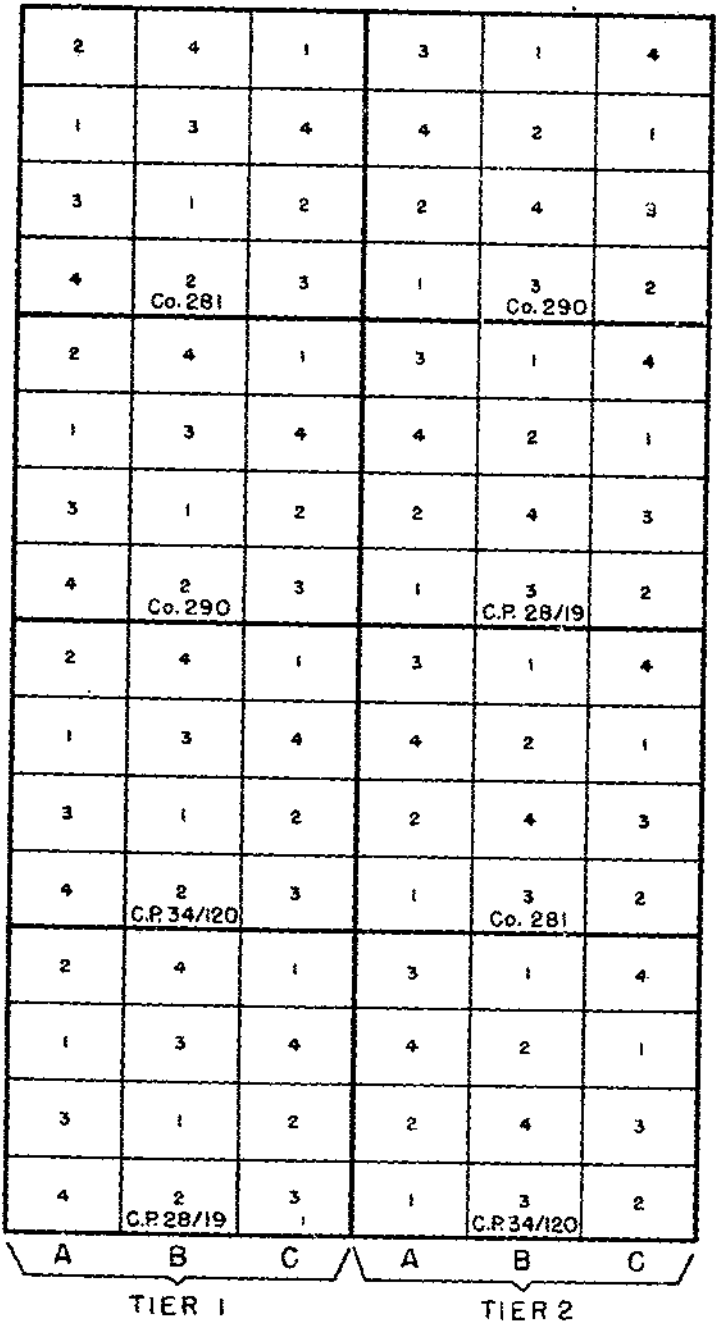

FIGURE 2.—Diagram showing the division of three-row plots of each variety into sections to obtain comparable successive samples for chemical analyses. The samples for first, second, and third analyses came from sections 1, 2, and 3, respectively, of each plot. The samples for the fourth, fifth, and sixth analyses came from section 4 of each plot.

Because of the severe freezing temperatures of December 16 to 20 (table 7), which practically killed the above-ground part of the cane, the plan was modified so as to follow the course of deterioration in badly frozen cane. Section 4 of each tier and variety was divided into 3 subsections. The size of the sample was reduced from 25 to 15 stalks for the fourth analysis (December 30), and to 10 stalks for the fifth analysis (January 10). These samples were obtained from subsections 1 and 2. Only 1 20-stalk sample (composited from cane in subsection 3) of each variety was used for the sixth and last analysis (January 17). An extra 18-stalk sample of each variety was selected by taking stalks at random from the various sections and subsections on each of the 4 dates on which analyses were made following the severe temperatures of December 16 to 20 (December 22 and 30, January 10 and 17). The stalks of these samples were sectioned into 3 equal lengths, and the top, middle, and bottom thirds (tops, middles, and bottoms) analyzed separately.

EXPERIMENTATAL DATA

The degree of injury that resulted from the freezing temperatures that occurred during November is shown in table 8. The leaf injury was estimated; therefore, the values given involve considerable error.

TABLE 8.—*Injury to standing cane of four varieties of sugarcane exposed to freezing temperatures ranging from 30° to 32° F. (November 9 to 15, inclusive) and 28° to 32° F. (November 17 to 20, inclusive), 1948*

Variety	Date examined	Leaf injury	Stalks examined	Terminal bud[1]						Eyes			
				Sound	Injured				Dead	Total	Sound	Injured	Dead
					Slightly	Moderately	Severely	Badly					
		Percent	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number	Number
Co. 281	Nov. 27	30	10	0	1	1	2	5	1	149	116	18	15
	Dec. 6	.	12	0	0	3	0	9	0	175	129	37	9
	Dec. 9	40	12	3	1	3	0	4	1	184	153	20	11
Total			34	3	2	7	2	18	2	508	398	75	35
Co. 290	Nov. 27	70	10	0	0	2	0	7	1	171	140	20	11
	Dec. 6		12	0	2	3	0	7	0	206	160	46	0
	Dec. 9	50	12	0	0	3	0	3	6	102	150	30	12
Total			34	0	8	8	0	17	1	569	450	96	23
C. P. 28 19	Nov. 27	50	10	0	0	0	1	1	8	159	99	28	32
	Dec. 6		12	0	2	2	0	6	2	181	141	20	30
	Dec. 9	40	12	1	2	1	0	2	6	170	122	16	32
Total			34	1	4	3	1	9	16	510	362	64	84
C. P. 34,120	Nov. 27	70	10	1	1	0	0	2	6	180	141	19	20
	Dec. 6		12	1	4	3	0	3	1	224	189	34	1
	Dec. 9	50	12	1	0	4	0	4	3	218	183	22	13
Total			34	3	5	7	0	9	10	622	513	75	34

[1] Other than where the terminal buds were sound or dead, the degree of injury is only a rough estimate between these two extremes. Judgment regarding the degree of injury may shift from time to time, especially from one date to another. Where the difference in the degree of injury is large, however, a satisfactory distinction can be drawn.

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To reduce such error to a minimum, however, the degree of leaf injury of each variety was compared directly with each other on each of the dates on which the cane was examined (November 27 and December 9). The estimated injury of all varieties was greater on November 27 than on December 9. The greater exposure of plots (*A*, *B*, *C*, and *D*, fig. 1) from which the cane was examined November 27 probably accounts for this difference. Leaf injury on both dates was greater in Co. 290 and C. P. 34/120 than in Co. 281 and C. P. 28/19. Data on leaf injury and death are not so definite or so accurate as those on terminal bud injury and death. As noted before (*9*), leaf injury is not necessarily an accurate index to the degree of terminal bud and eye injury.

If one were to judge by the number of terminal buds that escaped injury, Co. 290 was more severely injured than the other varieties. On the basis of the number of terminal buds badly injured and killed, however, Co. 290 ranks closely with Co. 281 and C. P. 34/120. The C. P. 34/120 variety showed more terminal buds killed than Co. 281 and Co. 290, and C. P. 28/19 showed the greatest number of terminal buds killed.

C. P. 28/19 showed a greater number of badly injured and dead eyes and a far greater number of killed eyes than the other varieties. Co. 290 showed the smallest number of eyes killed, but a greater sum of eyes injured and killed than varieties Co. 281 and C. P. 34/120.

The data relative to terminal buds and eyes indicate that C. P. 28/19 was injured more than the other varieties. The cane of C. P. 28/19 was not so tall as that of the other varieties. It is possible that this fact may account for the greater damage to this variety, because the location of the coldest air in a canefield seems to be governed by the height of the cane.

Although at the outset of the experiment one or two eyes were observed to show the beginning of germination, sprouting was not observed in any of the samples examined for injury.

During the period from December 1 to 15, all varieties showed an increase[5] in Brix, sucrose, and purity (table 9 and fig. 3).

The greatest increase in Brix, sucrose, and purity occurred in Co. 281. The increase in Brix was slightly greater in Co. 281 than in C. P. 34/120. If these values are significantly different, they indicate that sucrose was formed more rapidly in Co. 281 than in C. P. 34/120. The increase in Brix was about the same in C. P. 28/19 and in Co. 290, but the increase in sucrose was slightly greater in Co. 290, resulting in a somewhat higher increase in purity in Co. 290 than in C. P. 28/19. These differences are not correlated with the degree of injury as measured by the various symptoms. On the basis of the extent of leaf injury, Co. 281 and C. P. 28/19 should have shown the greatest manufacture of sugars, which probably are responsible for the increase in Brix. Among the varieties, Co. 281 showed the greatest

[5] A similar increase in Brix and sucrose was observed between December 3 and 17 in cane of seven varieties (Co. 281, Co. 290, C. P. 32/206, C. P. 34/115, C. P. 34/139, C. P. 36/1, and C. P. 37/9) growing in sandy land (B-5-R, fig. 5) at the station. There was an increase in purity in all these varieties except C. P. 34/139. Sufficient time had not elapsed between December 15 and 17 for the initiation of deleterious changes as a result of the freezing temperatures of December 16 and 17. (Unpublished data.)

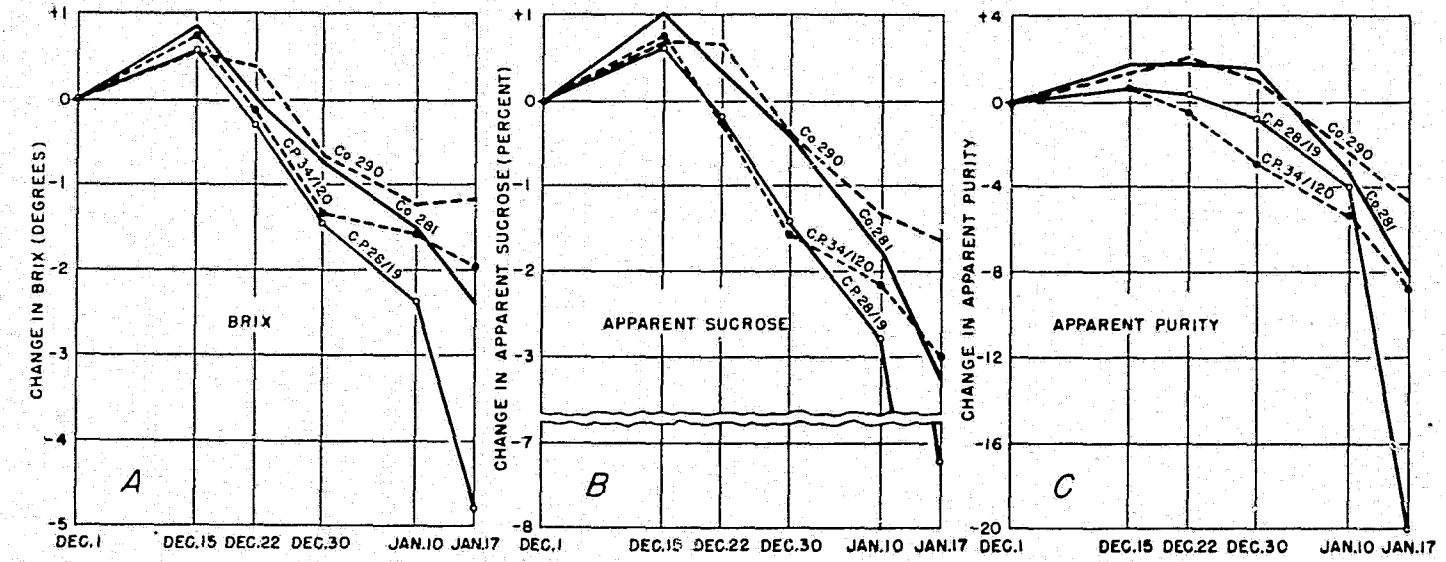

FIGURE 3.—Changes in Brix (*A*), apparent sucrose (*B*), and apparent purity (*C*) during the period from December 1, 1943, to January 17, 1944, in standing cane of four varieties injured by freezing temperatures.

TABLE 9.—*Changes in Brix, apparent sucrose, apparent purity, and acidity in standing cane of four varieties exposed to freezing temperatures of November and December 1943, and January 1944*

Variety and date of analysis	Duration of experiment	Brix	Sucrose	Purity	Gain (+) or loss (−) in—			Total acidity (0.1 N NaOH per 10 cc. juice)	Juice extraction
					Brix	Sucrose	Purity		
Co. 281:	*Days*	*Degrees*	*Percent*		*Degrees*	*Percent*		*Cc.*	*Percent*
Dec. 1, 1943	0	17.43	14.77	84.7					63
Dec. 15, 1943	14	18.28	15.80	86.4	+0.85	+1.03	+1.7	2.30	62
Dec. 22, 1943	21	17.46	15.12	86.6	+.03	+.35	+1.9	2.88	57
Dec. 30, 1943	29	16.68	14.37	86.3	−.77	−.40	+1.6	2.87	54
Jan. 10, 1944	40	15.92	12.95	81.3	−1.51	−1.82	−3.4	3.91	55
Jan. 17, 1944	47	15.04	11.52	76.6	−2.39	−3.25	−8.1	4.90	50
Co. 290:									
Dec. 1, 1943	0	16.60	13.32	80.2					65
Dec. 15, 1943	14	17.15	14.00	81.6	+.55	+.68	+1.4	2.60	62
Dec. 22, 1943	21	16.98	13.98	82.3	+.38	+.66	+2.1	2.97	61
Dec. 30, 1943	29	15.91	12.93	81.3	−.69	−.39	+1.1	3.06	63
Jan. 10, 1944	40	15.38	11.97	77.8	−1.22	−1.35	−2.4	4.83	60
Jan. 17, 1944	47	15.44	11.68	75.6	−1.16	−1.64	−4.6	4.30	57
C. P. 28/19:									
Dec. 1, 1943	0	19.77	17.26	87.3					60
Dec. 15, 1943	14	20.33	17.88	87.9	+.56	+.62	+.6	2.60	57
Dec. 22, 1943	21	19.46	17.07	87.7	−.31	−.19	+.4	3.12	48
Dec. 30, 1943	29	18.30	15.85	86.6	−1.47	−1.41	−.7	3.34	53
Jan. 10, 1944	40	17.40	14.47	83.2	−2.37	−2.79	−4.1	4.27	46
Jan. 17, 1944	47	14.99	10.10	67.4	−4.78	−7.16	−19.9	7.30	39
C. P. 34/120:									
Dec. 1, 1943	0	17.49	14.68	83.9					59
Dec. 15, 1943	14	18.24	15.43	84.6	+.75	+.75	+.7	2.50	55
Dec. 22, 1943	21	17.35	14.47	83.4	−.14	−.21	−.5	3.18	54
Dec. 30, 1943	29	16.16	13.11	81.1	−1.33	−1.57	−2.8	3.14	55
Jan. 10, 1944	40	15.92	12.52	78.6	−1.57	−2.16	−5.3	4.13	51
Jan. 17, 1944	47	15.54	11.68	75.2	−1.95	−3.00	−8.7	4.45	52

amount of sucrose formation and C. P. 28/19 the least. It is true that C. P. 28/19 showed more terminal bud and eye injury than Co. 281. It is believed that if these differences are significant, they result from varietal differences rather than from differences in freezing injury.

These data (along with those cited in footnote 5, p. 18) show that cane subjected to a rather high percentage of injury and killing of leaves and terminal buds and limited eye injury and killing by freezing temperatures may, under favorable conditions, manufacture sucrose. It would be interesting to know if there was an increase in the quantity of sucrose in cane during the 2 weeks preceding December 1. There is some evidence (*1*) that temperatures at or slightly above or below 32° F. may cause a temporary cessation of sucrose formation, but this may be resumed later under favorable conditions.

Following the period of freezing temperatures of December 16 to 20, which killed most of the above-ground part of the stalk, a decline in Brix and sucrose occurred in all varieties. In Co. 290 the loss of sucrose between December 15 and 22 was not significant and the loss of Brix was small (table 9; fig. 3). The loss of Brix and sucrose in Co. 281 and C. P. 28/19 continued at about the initial rate between December 22 and January 10, when there was a marked increase in rate, particularly in C. P. 28/19. A loss in Brix and sucrose was noticeable in Co. 290 after December 22 and continued at about the same rate until January 10, when the rate was slightly retarded. The loss of Brix and sucrose in C. P. 34/120 was rapid, beginning Decem-

ber 15, although there was a slight retardation in rate following December 30. Beginning December 15 and continuing until December 30 the rate of loss of Brix and even the loss of sucrose was greater in C. P. 34/120 and C. P. 28/19 than in the two other varieties.

Between December 15 and 22 the purity of the juice increased slightly in Co. 290, remained practically constant in Co. 281, and declined slightly in C. P. 28/19 and to a greater degree in C. P. 34/120. The purity remained practically constant between December 15 and 30 in Co. 281 and showed a slight decrease in Co. 290, but the drop in purity became progressively greater in C. P. 28/19 and C. P. 34/120. Following December 30 the rate in drop in purity became greater in all varieties except C. P. 34/120. Between January 10 and 17 the rate in drop in purity increased in all varieties. It was very pronounced in C. P. 28/19 and much greater in Co. 281 than Co. 290.

Up until January 10 the behavior relative to change in Brix, sucrose, and purity was similar in Co. 281 and Co. 290 and similar in C. P. 28/19 and C. P. 34/120. The rate of increase in acidity was gradual from December 15 until January 17 in Co. 281, Co. 290, and C. P. 34/120, and in C. P. 28/19 between December 15 and January 10, when it increased rapidly. No difficulty was experienced in filtering the juice until January 10.

The rapid loss of Brix and sucrose, the maintenance of a relatively high purity, the slow increase in acidity, and the absence of filtering difficulties of juice are characteristics of alcoholic fermentation (*5, 9*), a condition associated with cane that closely approaches 100-percent killing of the tissues of the stalks. This type of fermentation appeared to be dominant until December 30, following the damaging temperatures of December 16 to 20. Following December 30, fermentation caused by *Leuconostoc mesenteroides* (Cienk.) V. Tiegh., or gum formation (*4, 6, 9*), was evident by January 10 by the more rapid deterioration and the difficulty experienced with filtering of the juice.

On the basis of the deleterious changes that occurred up until January 10 as a result of the freezing temperatures of December 16 to 20, C. P. 28/19 and C. P. 34/120 were injured more than Co. 281 and Co. 290. The behavior of the members of each pair of varieties was very similar (fig. 3). Between January 10 and 17 the differences in behavior of the various varieties easily may have arisen from unequal exposure to the freezing temperature (25° F.) of January 10. Sampling also may have been a factor, because only one sample of each variety was used January 17. In any case these changes in rate were much larger in Co. 281 and C. P. 28/19 than in the other two varieties.

The course of deterioration in the top, middle, and bottom third of the stalk was similar to that in the whole stalk during the period between December 22 and 30. The Brix and sucrose declined, but the drop in purity was slight (table 10). The top part of the stalk of all four varieties showed an increase in acidity. The middle section of Co. 281, Co. 290, and C. P. 34/120 showed an increase, but Co. 290 and C. P. 34/120 less than Co. 281; the middle part of C. P. 28/19 showed no increase. The bottom part of all varieties showed no increase until after December 30. All these changes tend to become more pronounced in the succeeding periods. Previous results have also shown that these changes were greatest in the tops, less in

TABLE 10.—*Changes in Brix, apparent sucrose, apparent purity, and acidity in the different parts of sugarcane stalk of 4 varieties while standing in the field exposed to freezing temperatures of November and December 1943 and January 1944*

Variety	Date of analysis	Top part of sugarcane stalk					Middle part of sugarcane stalk					Bottom part of sugarcane stalk				
		Brix	Sucrose	Purity	Total acidity (0.1 N NaOH per 10 cc. juice)	Juice extraction	Brix	Sucrose	Purity	Total acidity (0.1 N NaOH per 10 cc. juice)	Juice extraction	Brix	Sucrose	Purity	Total acidity (0.1 N NaOH per 10 cc. juice)	Juice extraction
		Degrees	*Percent*		*Cc.*	*Percent*	*Degrees*	*Percent*		*Cc.*	*Percent*	*Degrees*	*Percent*		*Cc.*	*Percent*
Co. 281	Dec. 22, 1943	15.94	12.35	77.5	3.30	49	17.92	15.60	87.1	2.45	49	19.42	17.02	87.6	2.00	50
	Dec. 30, 1943	15.10	11.58	76.7	4.10	61	17.10	14.97	87.5	2.75	59	17.62	15.94	90.5	2.00	56
	Jan. 10, 1944	14.24	9.30	65.3	5.50	54	15.39	12.20	79.3	3.45	60	16.19	14.30	88.3	2.90	58
	Jan. 17, 1944	13.74	7.65	55.7	8.80	54	15.29	10.92	71.4	5.55	59	16.19	13.90	85.9	3.05	62
Co. 290	Dec. 22, 1943	14.84	10.56	71.2	3.50	57	17.04	14.04	82.4	3.00	58	18.42	16.21	88.0	2.40	57
	Dec. 30, 1943	14.00	9.85	70.4	4.10	56	15.90	12.63	79.4	3.15	59	17.27	15.30	88.6	2.45	57
	Jan. 10, 1944	13.34	9.00	67.5	6.15	61	15.59	11.80	75.7	4.60	56	17.09	14.60	85.4	3.15	61
	Jan. 17, 1944	13.39	7.00	52.3	9.20	58	15.39	11.30	73.4	4.70	58	16.79	14.58	86.8	2.55	61
C. P. 28/19	Dec. 22, 1943	18.27	14.86	81.3	3.75	45	19.52	17.17	88.0	3.05	49	19.82	17.90	90.3	2.65	53
	Dec. 30, 1943	16.80	13.01	77.4	4.60	54	17.77	15.34	86.3	3.05	57	19.02	17.24	90.6	2.75	49
	Jan. 10, 1944	15.49	11.70	75.5	5.75	59	15.99	12.90	80.7	4.20	58	17.94	16.00	89.2	3.45	55
	Jan. 17, 1944	16.64	10.20	61.3	6.75	36	17.19	11.65	67.8	5.50	33	18.62	15.35	82.4	4.70	56
C. P. 34/120	Dec. 22, 1943	14.49	9.67	66.7	3.65	55	17.04	14.04	82.4	3.00	53	18.52	16.52	89.2	2.30	52
	Dec. 30, 1943	14.00	9.33	66.6	4.75	55	16.10	12.81	79.6	3.20	54	17.62	15.75	89.4	2.25	49
	Jan. 10, 1944	13.69	8.50	62.1	6.50	56	15.74	12.90	76.2	4.40	53	17.89	15.50	86.6	3.05	49
	Jan. 17, 1944	12.94	7.45	57.6	6.65	51	15.14	11.55	76.3	3.75	59	16.89	14.62	86.6	2.75	55

the the middles, and least in the bottoms in badly frozen cane (*9*). The degree of injury may be such in the upper part of the sugarcane stalk as to permit alcoholic fermentation and gum formation, although the lower part of the stalk may be only slightly injured or perfectly sound (*9*). The organisms responsible for either type of fermentation cannot penetrate sound tissue. The alcoholic fermenting organism or organisms can penetrate only badly injured cane, whereas the gum-forming organism penetrates only dead tissue.

Studies Made During the Harvesting Season of 1944–45

FREEZING TEMPERATURES

Minimum temperatures were taken in a shelter (3.5 to 4 feet above the ground) in the area in which the cane studied was located (fig. 4). The minimum temperatures on November 30 and December 11, 12, 13, 14, and 15 were 30.2°, 30.2°, 26.2°, 27.5°, 28.8°, and 24.0° F., respectively (table 11). On December 19 and 20 the temperatures went down to 30.4° and 27.8°.

THE CANE USED

The cane (plant cane) examined for injury and analysis came from black land (C–3–F) at the station. The planting consisted of two-row plots 150 feet long, buffered on one side by one row of Co. 290 and on the other side by two rows, one of Co. 290 and the other of Co. 290 and two unreleased varieties. One hundred feet of each pair of rows were windrowed November 24, and the remaining 50 feet left standing (fig. 4). The buffer rows also were left standing throughout the period of experimentation. The cane examined for injury was taken along the rows of standing cane; that used for analysis, from standing cane at the juncture of standing and windrowed cane and at a point midway along the row of standing cane.

EXPERIMENTAL DATA

Although the cane was not examined critically for injury between November 30 and December 11, there was no indication that it was injured by the 30.2° F. temperature of November 30.

In cane collected December 14 (table 11) there was considerable variation in the extent of terminal bud injury. All the buds in C. P. 36/1 were sound, but none remained sound in the varieties C. P. 36/85 and C. P. 38/23. The total number of dead eyes indicates a similar relation among these varieties. C. P. 34/139 with two sound terminal buds showed next to the highest number (2.8) of dead eyes per stalk. C. P. 38/26 with only one sound terminal bud showed 1.0 dead eye per stalk. C. P. 29/120, C. P. 34/120, C. P. 36/94, and C. P. 37/9 with four to five sound terminal buds showed 0.2, 0, 0.6, and 0.2 dead eyes per stalk. These data on differences between varieties are not regarded as significant except perhaps between C. P. 36/1 and the other varieties, particularly C. P. 38/23 and C. P. 36/85.

The temperature of December 15 was severe enough to kill all the terminal buds and most of the eyes. In cane collected December 15 and examined December 16, C. P. 36/1 again showed the least injury

TABLE 11.—*Terminal bud and average number of lateral buds (eyes) per stalk injured, killed, or remaining sound in cane collected from field plots following freezing temperatures of 30.2° 30.2°, 26.2°, 27.5°, 28.8°, and 24° F., November 30 and December 11–15, 1944*[1]

CANE COLLECTED DECEMBER 14 AND EXAMINED DECEMBER 14 AND 16

Variety	Stalks used	Terminal buds			Average number of lateral buds (eyes) per stalk			
		Sound	Injured	Dead	Total	Sound	Injured	Dead
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Co. 281	10	4	6	0	16.0	12.7	2.5	0.8
Co. 290	10	2	8	2	17.9	13.9	3.4	.6
C. P. 29/120	10	5	5	0	18.8	17.4	1.2	.2
C. P. 34/120	10	4	6	0	19.3	17.4	1.9	0
C. P. 34/139	10	2	8	2	18.4	14.8	3.8	2.8
C. P. 36/1	9	[2]0	9	0	19.3	18.6	.8	0
C. P. 36/85	9	0	6	3	19.8	16.4	1.7	1.7
C. P. 36/91	10	5	2	3	18.9	15.5	2.8	.6
C. P. 37/9	10	4	6	0	16.6	13.3	3.1	.2
C. P. 38/23	10	0	7	3	21.0	9.8	4.7	6.5
C. P. 38/26	8	1	6	1	18.4	15.4	2.0	1.0

CANE COLLECTED DECEMBER 15 AND EXAMINED DECEMBER 16

Co. 281	12	0	0	12	16.5	1.0	1.3	14.3
Co. 290	11	0	0	11	18.2	2.2	1.0	15.0
C. P. 29/120	12	0	0	12	20.1	4.1	1.8	13.9
C. P. 34/120	12	0	0	12	17.0	2.3	.9	14.7
C. P. 36/1	12	0	0	12	18.5	4.5	1.2	12.8
C. P. 36/94	11	0	0	11	19.5	3.3	1.6	14.6

CANE COLLECTED DECEMBER 20 AND EXAMINED DECEMBER 20 AND 21

Co. 281 (Lot No. 1)	10	0	0	10	15.9	1.8	1.1	13.0
Co. 281 (Lot No. 2)	8	0	0	8	17.6	1.0	.9	15.1
Co. 290 (Lot No. 1)	8	0	0	8	18.5	1.1	1.4	16.0
Co. 290 (Lot No. 2)	10	0	0	10	17.5	.8	.5	16.2
C. P. 29/120	8	0	0	8	20.6	4.6	1.5	14.5
C. P. 34/120	8	0	0	8	20.8	2.1	2.9	15.8
C. P. 34/139	9	0	0	9	18.2	2.0	1.7	14.6
C. P. 36/1	8	0	0	8	21.0	1.6	2.5	16.9
C. P. 36/85	10	0	0	10	20.0	4.1	1.2	14.7
C. P. 37/9	10	0	0	10	16.8	2.1	1.8	12.9
C. P. 38/23	10	0	0	10	20.8	1.2	.7	18.9
C. P. 38/26	10	0	0	10	19.8	2.3	1.1	16.4

[1] On the night of December 14 and the morning of December 15 the temperature was below 30° F. for 9 hours.

[2] One stalk bored a short distance below terminal bud.

of any of the varieties, but in cane collected December 20 C. P. 36/1 showed more injury than a number of varieties. C. P. 36/85, in which all the terminal buds were injured or killed and a number of eyes were killed as a result of freezing temperatures occurring before December 15, showed a fairly large number of sound eyes in cane collected December 20. C. P. 29/120 showed a moderate degree of injury in all lots. These data illustrate how difficult it is to find sharp differences in susceptibility of different varieties.

The chemical analytical data obtained in connection with varieties Co. 281, Co. 290, C. P. 29/120, C. P. 34/120, and C. P. 36/1 showed that there were no serious changes in Brix, sucrose, purity, pH, and acidity in standing cane during 2 weeks following the freezing temperatures of December 11 to 15. These results are in harmony with

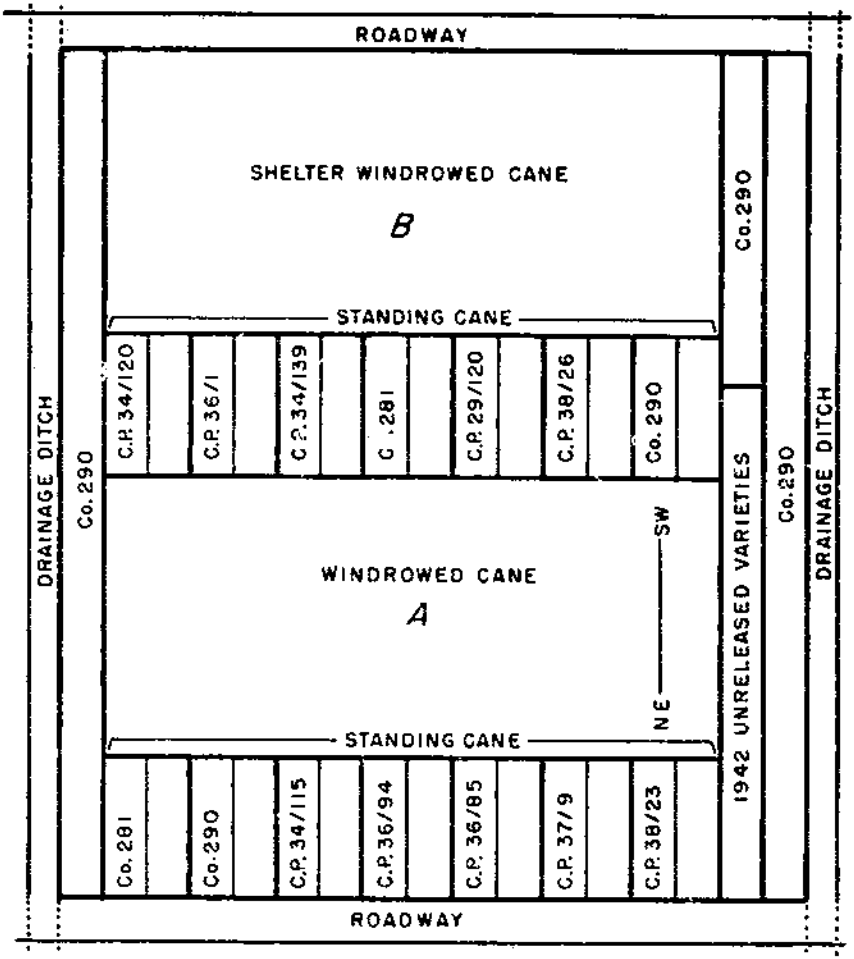

FIGURE 4.—Diagram of plots (two-row) used for studying freezing injury and chemical changes during 1944: *A*, Lot No. 1, and *B*, lot No. 2, used in obtaining data recorded in table 11.

those previously obtained (*9*) in showing that as long as a small number of eyes remain sound, serious deterioration does not begin for a considerable period.

STUDIES MADE DURING THE HARVESTING SEASON OF 1945–46

FREEZING TEMPERATURES

The freezing temperatures occurring at the station from November 23, 1945, to January 2, 1946, are given in table 12. They were recorded at three separate locations on most of the days. One of the locations was situated on sandy land not far from Bayou Black (Weather Station, fig. 5) and the other two on black land about 1,000 feet away (C–6–F and C–8–F, fig. 5). The minimum temperatures in the black land were from 2° to 4.2° F. lower than in light land, and there was some variation between the two stations on the black land. The dura-

tion of freezing temperature is given for most of the dates. The temperatures were at 32° and lower for longer periods than is normal for southern Louisiana.

TABLE 12.—*Freezing temperatures and their duration at the United States Sugar Plant Field Station at Houma, La., during the fall of 1945*

Date	Minimum temperatures at—			Length of time temperature was at 32° F. and below
	Weather Bureau station [1] (sandy land)	C–6–F [2] (black land)	C–8–F [2] (black land)	
1945	° *F.*	° *F.*	° *F.*	*Hours*
Nov. 23	30	----------	----------	10.25
24	27	24.0	24.5	12.00
Dec. 1	34	31.0	31.0	----------
2	34	31.8	31.8	----------
5	31	28.5	27.7	11.75
6	33	20.5	20.7	13.25
8	32	30.0	29.0	8.00
16	28	26.0	25.5	13.00
17	28	23.8	25.0	13.25
20	24	----------	----------	15.00
21	28	----------	----------	16.00

[1] The thermometer was located in a standard weather shelter on sandy land near Bayou Black (fig. 5).
[2] C–6–F and C–8–F indicate different plots in black land (fig. 5).

VARIETIES

Twelve commercial, or formerly commercial, and three unreleased varieties of cane (standing plant cane) were studied. They are listed in tables 13 to 16.

SOURCE OF CANE

The cane studied came from three locations on the station: (1) Sandy land (light land) (B–3–F, fig. 5); (2) black land (C–6–F, fig. 5); and (3) a second location in black land (C–8–F, fig. 5). The cane in sandy land consisted of four to five replicated plots of each variety. The planting was designed to study the rate of maturing of cane. The cane in the black land consisted of two-row plots of each variety 150 feet long. The plots were located side by side in two cuts, each of which had buffer rows of standing cane on each side of the cut. About 85 feet of each pair of rows were windrowed November 21. The remaining cane was left standing. The samples used for chemical analysis and the study of freezing injury were derived from standing cane.

SAMPLING

In the sandy land experiment, 10 tops, including growing points (terminal buds), were taken at random from the tops cut off from stalks used in the maturity samples from each replication following the freezing temperatures of November 23 and 24 and examined for terminal bud injury (table 13). After the maturity samples were selected, 5 whole stalks were taken from one of the replications and examined for eye and terminal bud injury (B–3–F, table 14).

The samples from cane in the black land that were examined for freezing injury were taken along the rows in standing cane (tables 14 and 15). Samples for chemical analysis were taken of 6 varieties (table 16). Two 20-stalk samples for making the initial and successive

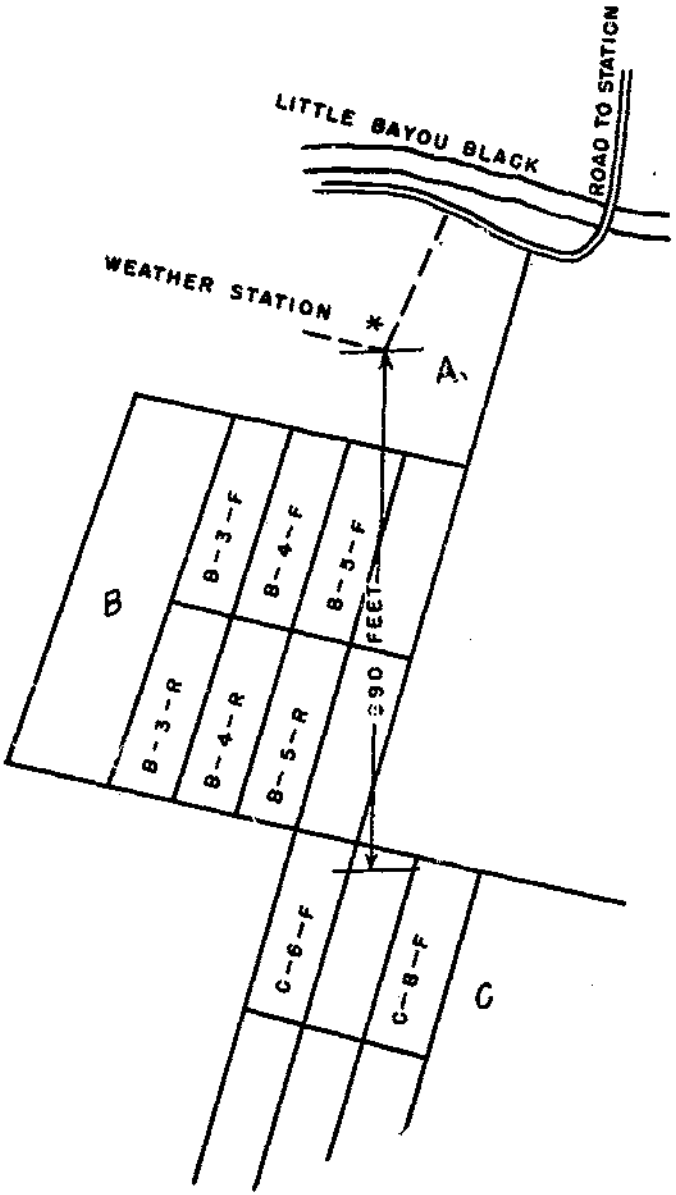

FIGURE 5.—Locations at the United States Sugar Plant Field Station at which temperatures were taken and at which cane studied during 1945 was grown.

analyses were taken from standing cane at the juncture of windrowed and standing cane, and 2 from midway the length of the standing cane.

FREEZING INJURY FOLLOWING FREEZING TEMPERATURES OF NOVEMBER 23 AND 24

As a result of the freezing temperatures of November 23 and 24 (table 12) most of the terminal buds in cane grown in light land were killed (tables 13 and 14). No sound terminal buds were found

in connection with whole stalks that were examined, except the two with tissue that were injured by a borer just below the growing point (terminal bud). The number of terminal buds examined in this case

TABLE 13.—*Terminal bud injury in standing cane*[1] *of certain commercial varieties as a result of freezing temperatures*[2] *of November 23 and 24, 1945*

Variety	Terminal buds				
	Total examined	Sound	Injured	Dead	Killed by borer
	Number	*Percent*	*Percent*	*Percent*	*Percent*
C. P. 28/19	50	10.0	8.0	72.0	10.0
C. P. 29/103	50	[3] 10.0	20.0	66.0	4.0
C. P. 29/120	49	[4] 4.1	2.0	89.8	4.1
C. P. 34/02	50	[4] 2.0	28.0	70.0	0
C. P. 34/120	50	2.0	16.0	78.0	4.0
C. P. 36/13	40	12.5	12.5	67.5	7.5
C. P. 36/105	48	0	6.1	89.8	4.1
C. P. 36/183	39	0	2.6	97.4	0
Total and averages	377	[5] 5.0	12.2	78.5	4.2

[1] From plot of sandy land, B-3-F, shown in figure 6.
[2] See table 12.
[3] 2 stalks were injured by borers just below the terminal bud.
[4] 1 stalk was injured by borer just below terminal bud.
[5] 4 stalks were injured by borers just below terminal bud.

TABLE 14.—*Injury to cane of different varieties in black and sandy land as a result of freezing temperatures*[1] *of November 23 and 24, 1945*

BLACK LAND (C-6-F,[2] U. S. SUGAR PLANT FIELD STATION)

Variety	Stalks used	Eyes					Terminal bud		
		Total	Sound	Sound	Injured	Dead	Sound	Injured	Dead
	Numbe	*Number*	*Number*	*Percent*	*Number*	*Number*	*Number*	*Number*	*Number*
Co. 281	5	76	35	46	12	29	0	0	5
Co. 290	5	89	40	45	24	25	0	0	5
C. P. 28/19	5	93	40	43	14	39	0	0	5
C. P. 29/103	5	93	63	68	4	26	0	0	5
C. P. 29/116	5	99	27	27	11	61	0	0	5
C. P. 29/120	5	100	70	70	7	23	0	0	5
C. P. 29/320	5	88	15	17	14	59	0	0	5
C. P. 33/243	5	103	49	48	22	32	0	0	5
C. P. 33/310	5	98	65	66	10	23	0	0	5
C. P. 34/120	5	95	66	69	10	19	0	0	5

BLACK LAND (C-8-F,[2] U. S. SUGAR PLANT FIELD STATION)

Co. 281	5	84	44	52	17	23	0	0	5
Co. 290	5	88	33	38	29	26	0	0	5
F. 31/710	5	84	44	52	17	23	0	0	5
C. P. 34/120	5	102	44	43	17	41	0	0	5
C. P. 36/13	5	100	64	64	6	30	0	0	5
C. P. 36/55	5	94	40	43	10	44	0	0	5
C. P. 36/183	5	85	56	66	6	23	0	0	5
C. P. 37/5	5	76	41	54	9	26	0	0	5

SANDY LAND (B-3-F,[2] U. S. SUGAR PLANT FIELD STATION)

C. P. 28/19	5	94	47	50	11	36	[3] 1	0	4
C. P. 29/103	5	93	67	68	7	24	0	0	5
C. P. 29/120	5	104	72	69	11	21	0	0	5
C. P. 34/02	5	87	35	40	14	38	0	0	5
C. P. 34/120	5	101	44	44	13	44	0	0	5
C. P. 36/13	5	91	66	73	10	15	[3] 1	0	4
C. P. 36/105	5	98	38	39	16	44	0	1	4
C. P. 36/183	5	95	74	78	5	16	0	0	5

[1] Temperatures on November 23 and 24 in the shelter were 30° and 27° F., respectively. The temperature in C-6-F went down to 24° on November 24 and in C-8-F to 24.5° F.
[2] C-6-F, C-8-F, and B-3-F represent the location from which the cane came (fig. 5).
[3] Stalk injured by borer just below terminal bud.

TABLE 15.—*Freezing injury to cane of different varieties following freezing temperatures of December 5 and 6, 1945; all terminal buds were killed*

BLACK LAND (C–6–F)

Variety	Stalks examined	Eyes sound	Eyes injured	Internal injury
	Number	*Number*	*Number*	
Co. 281	6	2	1	Tissue fairly clear to a moderate amount of water soaking.
Co. 290	6	0	2	Tissue fairly clear to considerable water soaking.
C. P. 28/19	6	0	0	Mostly a moderate amount of water soaking.
C. P. 29/103	6	4	0	Tissue fairly clear to a slight amount of water soaking.
C. P. 29/116	6	1	2	Moderate to a marked amount of water soaking.
C. P. 29/120	6	2	3	Tissue fairly clear to a moderate amount of water soaking.
C. P. 29/320	6	0	0	Tissue fairly clear to considerable amount of water soaking.
C. P. 33/243	6	0	0	Marked water soaking—some leaking.
C. P. 33/310	6	2	2	Tissue fairly clear to considerable water soaking.
C. P. 34/120	6	3	1	Tissue fairly clear to a moderate amount of water soaking.

BLACK LAND (C–8–F)

Co. 281	6	1	1	Tissue fairly clear to a moderate amount of water soaking.
Co. 290	6	0	1	Do.
F. 31/710	6	1	3	Do.
C. P. 34/120	6	1	1	Tissue fairly clear to a slight amount of water soaking.
C. P. 36/13	6	1	3	Do.
C. P. 36/55	6	1	1	Do.
C. P. 36/183	6	2	1	Do.
C. P. 37/5	6	0	1	Tissue fairly clear to considerable amount of water soaking.

TABLE 16.—*Changes in Brix, apparent sucrose, apparent purity, pH, and acidity in standing cane of certain varieties in cuts C–6–F and C–8–F at the United States Sugar Plant Field Station, Houma, La., 1945–46*

Location and variety	Date of analysis	Brix	Sucrose	Purity	Loss in Brix	Gain (+) or loss (−) in purity	pH	Total acidity (0.1 N NaOH per 10 cc. juice)	Juice extraction
C–6–F:		*Degrees*	*Percent*		*Degrees*			*Cc.*	*Percent*
C. P. 29/103	Dec. 4, 1945	18.65	15.29	82.0			5.25	2.20	52
	Dec. 10, 1945	18.27	15.32	83.9	0.38	+1.9	5.30	2.13	60
	Dec. 18, 1945	18.04	14.85	82.3	.61	+.3	5.30	2.23	62
	Jan. 2, 1946	17.64	14.31	81.1	1.01	−.9	5.10	2.64	56
C. P. 29/120	Dec. 4, 1945	17.90	15.06	84.1			5.25	2.00	54
	Dec. 10, 1945	17.66	14.46	84.8	.84	+.7	5.30	2.08	63
	Dec. 18, 1945	17.22	14.57	84.6	.68	+.5	5.30	2.23	60
	Jan. 2, 1946	16.49	13.52	82.0	1.41	−2.1	4.70	3.25	55
C. P. 34/120	Dec. 10, 1945	17.16	14.53	84.7			5.25	2.69	60
	Dec. 18, 1945	17.02	14.28	83.9	.14	−.8	5.30	2.84	60
	Jan. 2, 1946	16.38	13.00	79.7	.78	−5.0	4.65	4.52	57
C. P. 33/243	Dec. 4, 1945	16.76	14.19	84.7			5.25	1.95	54
	Dec. 10, 1945	16.41	13.72	83.6	.35	−1.1	5.30	2.33	62
C–8–F:									
C. P. 36/13	Dec. 4, 1945	18.32	15.42	84.2			5.25	2.35	57
	Dec. 10, 1945	17.66	15.10	85.0	.66	+1.8	5.30	2.18	62
	Dec. 18, 1945	18.10	15.21	84.0	.22	−.2	5.30	2.39	64
	Jan. 2, 1946	17.19	14.04	81.7	1.13	−2.5	4.70	3.36	62
C. P. 36/183	Dec. 4, 1945	18.81	16.13	85.8			5.25	2.50	55
	Dec. 10, 1945	18.61	15.97	85.8	.20	0	5.25	2.69	65
	Dec. 18, 1945	17.65	14.68	83.2	1.16	−2.6	5.25	2.74	62
	Jan. 2, 1946	17.48	13.92	79.6	1.33	−6.2	4.65	4.31	60

and the fact that the stalks came from only one replication may account for the discrepancy in the two lots. The discussion that follows relative to terminal bud injury in light land will be limited to the data recorded in table 13, because they are more representative than those in table 14.

The varieties in which the largest percentage of terminal buds escaped injury in light land, as indicated by the results in table 13, were C. P. 28/19, C. P. 29/103, and C. P. 36/13. All of the terminal buds were injured or killed in C. P. 36/105 and C. P. 36/183. The terminal bud injury is not of an order to clearly prove a varietal difference in susceptibility to freezing injury. All varieties showed a percentage of killing and none were free from injury. It will be noted that part of the terminal buds that remained sound had been attacked by the borer just a short distance below the growing point. This relation of borer injury to freezing injury of terminal buds had been observed in earlier years. It is believed that the escape from injury is due to drying out of the terminal tissue as a result of borer attack. The extent of injury to eyes in the different varieties is not entirely parallel to that of terminal bud injury. Table 13, for instance, shows that C. P. 36/183, which had the highest percentage of dead terminal buds and no sound ones, had the greatest number and percentage of sound eyes (table 14). C. P. 36/13, having the highest percentage of sound terminal buds (table 13), showed a high number and percentage of sound eyes (table 14). This variety also showed a high number and percentage of sound eyes in black land.

On the whole, more eyes remained sound in cane in the light than black land, although there were exceptions. In sandy land, C. P. 34/120 showed 44 sound eyes; in black land, it showed 44 in one instance and 66 in another (table 14). It is possible that the small number of stalks used may account for part of this discrepancy, but it is believed that they do not account for all the difference.

All the terminal buds examined in cane from black land were dead (table 14). Although these data may not justify the conclusion that there were no sound terminal buds in the black land cane, it would seem probable there were none from the fact that most of the terminal buds were killed in cane from the light land. In the three varieties (Co. 281, Co. 290, and C. P. 34/120) common to both locations in black land, the eye injury in both places was similar in Co. 281 and Co. 290 and dissimilar in C. P. 34/120 (table 14). As measured by the number and percentage of eyes that remained sound in cane from black land, C. P. 29/103, C. P. 29/120, C. P. 33/310, C. P. 34/120 (in C–6–F but not C–8–F), C. P. 36/13, and C. P. 36/183 showed the least injury. C. P. 29/116 and C. P. 29/320 showed the least number of sound eyes and the greatest number of dead eyes.

FREEZING INJURY AS A RESULT OF FREEZING TEMPERATURES TO AND INCLUDING DECEMBER 6

Only sound and injured eyes were counted; the remaining eyes were dead. On the basis of the number of sound and injured eyes, one might draw a distinction between varieties, but the distinction is not large nor is it always correlated with the degree of water soaking (table 15). The greatest distinction in injury was between C. P.

29/103, showing the least, and C. P. 33/243, showing the most. The behavior of C. P. 29/320, C. P. 28/19, Co. 290, and C. P. 37/5 approached that of C. P. 33/243. There was an element of judgment in estimating the extent of internal injury. In order to have made a more effective comparison, more stalks would have had to be used. The task of examining a large number of stalks is enormous and would have required much more time and labor than was available.

CHEMICAL CHANGES IN CANE FROM BLACK LAND

The loss in Brix between December 4, 1945, and January 2, 1946, indicated that all varieties of cane in black land were badly injured (table 16) as a result of the freezing temperatures of December 5 and 6 and those that followed (table 12). This loss of Brix and the maintenance of a relatively high purity, particularly during the first 2 weeks, indicated that an alcoholic type of fermentation was dominant. The later rapid changes in these values show that the freezing temperatures of December 16, 17, 20, and 21 (table 12) imposed additional injury to that present as a result of the freezing of December 5 and 6.

Gum formation (*4*, *6*, *9*) had set in, as shown by the difficulty experienced in filtering the juice January 2. The results relative to C. P. 33/243 did not cover a long enough period from which to draw any conclusion relative to gum formation. Among the remaining varieties, the juice of C. P. 29/120 clarified with the greatest ease and that of C. P. 34/120 with the greatest difficulty. Davidson found the same relation among other lots of these two varieties from other sources. Reports from sugar factories in the eastern part of the Sugar Belt were to the effect that more difficulty was experienced with the juice of C. P. 34/120 than with other commercial varieties. The total increase in acidity from the least to the greatest was in the order in which the varieties are listed: C. P. 29/103, C. P. 29/120, C. P. 36/13, C. P. 36/183, and C. P. 34/120. The increase in C. P. 34/120 and C. P. 36/183 was almost identical. This increase in acidity was not always associated with a similar degree of difficulty in clarification in the laboratory.

DISCUSSION AND CONCLUSIONS

Various criteria for measuring the degree of injury have been used with varying degrees of success: Injury to the spindle, foliage, terminal buds, and eyes; internal discoloration of stalk; the falling over of the tops; signs of fermentation; changes in Brix, sucrose, purity, acidity, and pH; the filterability and clarification of the juice; and other symptoms.

Under mild freezing temperatures, one of the first tissues of cane to show injury is that of the folded leaves (spindle) just above the growing point. Such injury may be the only symptom, and many plants may show no injury. Hence, statistically significant data on this symptom are difficult to obtain. It has not been used in these experiments.

Estimated foliage damage is not precise and involves large errors. To obtain precise and definite data on foliage injury, leaf measurements would have to be made. Such measurements are impracticable

because of the time consumed. Commonly, freezing temperatures occur on two or more successive nights; sometimes on one, two, three, four, and even five or more nights, but rarely for longer periods. These periods of freezing may be followed by short or long periods of nonfreezing weather. To obtain measurements of sound and dead leaf tissue following such successive freezes in a number of varieties would present an almost impossible problem.

The effects of mild freezing temperatures on terminal buds afford a simple and satisfactory standard of measurement of injury, if such freezing temperatures are followed by a period of nonfreezing temperatures of sufficient length to permit the examination of a number of varieties.

Injury to eyes is a fairly accurate indication of injury to stalks (*9*) and a measure of the millability of cane. Normally the upper eyes are the first to be injured. As more and more eyes are killed farther and farther toward the base of the stalk, the injury of the stalk becomes progressively greater. As the number of sound eyes approaches zero, alcoholic fermentation sets in (*5*, *9*). Such fermentation is characterized by heavy loss of Brix, the maintenance of a fairly high level of purity, and a slow increase in acidity. Beyond this stage of injury the cells of the stalk are completely killed and gum formation (*9*) is initiated and is followed by rapid destruction of sugar, a heavy drop in purity, rapid increase in acidity, and unworkability of the juice.

Both types of fermentation take place much more rapidly in the upper part of the stalk. With lesser degrees of injury, alcoholic fermentation may be initiated in the upper part of the stalk and may be followed by gum formation, depending on the degree of injury. In such cases and in badly frozen cane of a lesser degree, topping at a lower level for a limited period of time increases the millability of the cane. The accumulated evidence (*9*) indicates that sound stalk tissue below the injured tissue is not subject to fermentation for several weeks, although the upper part of the stalk is badly damaged and shows varying degrees of fermentation.

Internal discoloration is an indefinite symptom of injury and may change or tend to clear up at certain stages of injury. Only when the stalk is completely killed does it have a quantitative value, and then one cannot always tell (*9*) whether it is damaged enough for gum formation to start immediately or for alcoholic fermentation to dominate for a considerable period.

Alcoholic fermentation is definitely indicated by a rapid loss of solids, the maintenance of relatively high purities, and a slow increase in acidity. Such juice is handled readily by the mills.

Gum formation is first indicated by low filterability of the juice and poor clarification, rapid drop in purity, and rapid increase in acidity. Such juices are difficult and soon become impossible to handle in the factory.

Comparative data relative to terminal bud injury and killing by freezing temperatures, on the whole, show little if any difference in susceptibility to injury among the different varieties. In one experiment in light land, after 5 nights of freezing temperatures ranging

from 30.2° to 27.5° F., C. P. 36/1 showed no terminal bud injury or killing as compared with varying degrees of injury or killing in the other varieties examined (table 11). It likewise showed the least eye injury. After another night of freezing temperature (24° F.), two lots of samples of C. P. 36/1 and other varieties were selected and examined for injury. All the terminal buds in both lots were killed. In one lot C. P. 36/1 showed the least eye injury, but in the second lot it showed greater eye injury than a number of other varieties (table 11). The preponderance of evidence in case of C. P. 36/1 probably indicates it has slightly greater resistance to freezing injury within the limits of the freezing conditions indicated. More severe conditions might have wiped out the difference found. Further evidence is required for conclusive proof that this variety is more resistant than the other varieties tested.

In 1945 under the influence of moderate freezing temperatures (30° and 27° F.), C. P. 36/13 in light land showed the largest percentage of uninjured terminal buds as compared with other varieties (table 13). This escape from injury was associated with a low extent of eye injury in both light and black land (tables 13 and 14). As a result of the severe freezing temperature of December 6 (tables 12 and 15), which killed nearly all the eyes in all varieties in black land (table 15), the juice of C. P. 36/13 was more difficult to filter than that of C. P. 29/120, which had shown more terminal bud injury previous to December 6. The juice of C. P. 34/120 was more difficult to filter than that of the other varieties.

Less difficulty was experienced in filtering the juice of badly frozen cane in the case of C. P. 29/120 than in other varieties (table 16). As a result of the mild freezing temperatures previous to December 6, C. P. 29/120 showed a moderate extent of terminal bud injury as compared with the other varieties tested (tables 13 and 14).

On the whole, the difference in eye injury and terminal bud injury between varieties is not of such magnitude and consistency as to differentiate clearly between varieties Co. 281 and Co. 290, which appear to be similar in susceptibility to freezing temperatures. In badly frozen cane the behavior of Co. 281 and Co. 290 relative to deleterious changes was better than that of varieties C. P. 28/19 and C. P. 34/120 (fig. 3).

Windrowed cane of varieties Co. 281 and Co. 290, in which practically all the eyes were killed, kept better during 16 days than did standing cane (table 3). It is believed that the difference was due to a lower temperature in the windrow than that in standing cane. The average maximum air temperature for the period was 70.5° F. Cane of the same variety and the same degree of injury from the same cuts as the windrowed cane showed more rapid deterioration when stored at 75° and 90° F. than did standing and windrowed cane. The deterioration was greater at 90° than at 75° (table 6).

The results clearly indicate the difficulty involved in measuring the relative susceptibility of varieties of sugarcane to freezing injury. The differences in susceptibility are too small in all varieties studied to obtain consistently measurable distinctions regardless of the degree of injury, the many variables involved, and the criteria used in measuring the degree of injury. No one variety has been found with outstanding resistance as compared with other varieties studied. Considering that sugarcane is a tropical plant and that normally the

weather conditions under which it is grown are not conducive to hardening, it is amazing what extreme conditions of freezing it will withstand and still function with varying degrees of success.

SUMMARY

Extensive observations were made of freezing injury of sugarcane in commercial fields and experimental plots. A comparative study was made of symptoms of freezing injury in a large number of varieties under similar freezing conditions.

Varieties subjected to different levels of freezing conditions were compared with respect to the normal and deleterious chemical and physiological changes occurring in standing and windrowed cane and in cane stored at different temperatures.

Sharp differences in varieties with respect to symptoms and deleterious changes were not found. Minor differences were found, but they were not always consistent at different levels of freezing conditions. Badly frozen cane kept better in the windrow than when standing and at lower than at higher temperatures.

The results show that cane in which a rather high percentage of leaves and terminal buds are injured or killed, and in which a limited percentage of eyes are injured or killed by freezing temperatures, may under favorable conditions synthesize sucrose (table 9; fig. 3).

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