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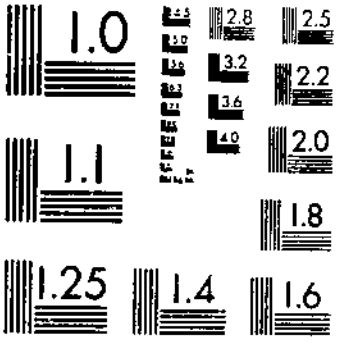

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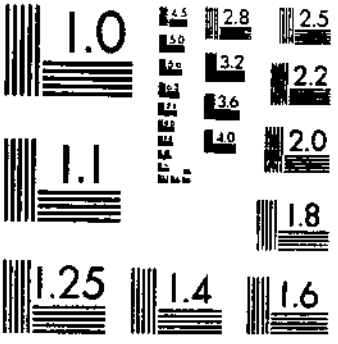

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NATIONAL BUREAU OF STANDARDS-1963-A

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Effects of Breakage on Plant Development and Field Production With Sugarcane[1]

By GEORGE ARCENEAUX, formerly *principal agronomist*, L. P. HEBERT, *associate agronomist*, and L. C. MAYEUX, JR., formerly *assistant agronomist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

CONTENTS

Breakage of stalks as a result of wind force, insect injury, and other causes is a common form of damage suffered by sugarcane. The actual proportion of stalks that are broken in the course of crop development will vary greatly, depending on variety and environmental conditions. Studies previously reported (*6*, *9*)[2] show that forms of sugarcane now cultivated in Louisiana differ widely as to susceptibility to breakage. In winds of gale or hurricane force, extremely susceptible varieties will commonly show from 8 to 10 times the extent of breakage suffered by the most resistant ones. Owing to their characteristic brittleness, varieties susceptible to wind breakage occasionally suffer extensive implement damage in the course of late-season cultivation.

Lateral shoots ordinarily developing on broken stalks complicate the problem of stripping sugarcane for satisfactory processing. In addition, it is known from practical experience that such damage is accompanied by important losses in yields of cane and sugar, but relatively little information has been available on the precise order of such losses in relation to the proportion of stalks broken. A search of the literature reveals that stalk breakage as a factor in reducing yields of cane and sugar has received relatively little critical attention.

Walter (*10*) appraised the effect of wind damage in Mauritius from a statistical analysis of the relation of crop yields to climatic factors over the period 1892–1906. For the 3 years in which wind velocities

[1] Submitted for publication April 10, 1952.
[2] Italic numbers in parentheses refer to Literature Cited, p. 14.

200417—52

of more than 40 miles per hour were recorded, calculated reductions in yield of cane per arpent (1.04 acres) from wind damage to one estate were 1.26, 4.04, and 13.80 tons, respectively. On the basis of theoretical production in the absence of wind damage, these calculated reductions range approximately from 7 to 55 percent.

Yamasaki and Ozaki (*11*) reported a significant correlation between hardness of rind and resistance to breakage at or near the ground surface. With varieties now cultivated in Louisiana, breakage under conditions of high wind velocity is largely confined to the region of immature joints immediately below the growing point. A systematic study has not been made of the problem, but from casual observation there does not appear to be any relationship between rind hardness and resistance to breakage at that level. In fact, C. P. 28/11, the commercial variety most highly susceptible to wind breakage, ranks among the highest for varieties with a hard rind and a high fiber content.

Studies reported herein were undertaken primarily to determine the influence of breakage at predetermined percentages of the stalk population on yields of cane and sugar. Attention was also given to other effects, such as development of lateral shoots and changes in fiber content of stalks.

PLAN OF THE EXPERIMENT

Damage comparable to that suffered under conditions of high wind velocity was artificially made on plant cane of three varieties of sugarcane on August 20, 1945. The tops were broken off by hand at nodes immediately below the growing point, the region where breakage from wind pressure normally occurs. Extent of breakage in individual series of plots was 0, 20, 40, 60, 80, and 100 percent of the stalks that normally could be expected to reach maturity. At that stage a shoot ordinarily has either reached relatively advanced development or has been suppressed as a result of competition. Thus, the shoots that will develop normally can be readily distinguished from those that will not. Stalks to be broken were systematically selected from normally developed shoots: in plots of 20-percent breakage, for example, every fifth one was broken.

Plots consisted of single rows 18 feet long, replicated three times in each treatment with each variety. Block plantings of the different varieties were subplotted for treatments. The experimental area consisted of Sharkey silty clay loam at the Houma, La., station (U. S. Sugar Plant Field Station). At harvest the stalks were cut and stripped as for milling purposes. Shoots that had developed from lateral buds were counted and removed; hence, they did not constitute a part of mill cane as herein reported. The experiment was repeated on first stubble of the same plots during 1946.

DEVELOPMENT OF AXILLARY GROWTH

Counts of lateral shoots on broken and unbroken stalks in plant cane and first stubble of the three varieties that were studied at each rate of breakage are summarized in table 1. The percentage of broken stalks that produced lateral growth increased consistently as the percentage of breakage increased. For instance, at 20-percent

TABLE 1.—*Development of lateral shoots on broken and unbroken stalks of sugarcane at different percentages of stalk breakage, 1945–46*

PERCENTAGE OF BROKEN STALKS WITH LATERAL SHOOTS AT HARVEST

Percentage of stalks broken [1]	Plant cane				First stubble				Mean of 3 varieties in 2 crops
	C. P. 29/120	C. P. 34/120	Co. 290	Mean	C. P. 29/120	C. P. 34/120	Co. 290	Mean	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
20	13. 6	26. 2	37. 8	25. 87	47. 2	65. 4	75. 0	62. 53	44. 20
40	22. 1	50. 0	42. 2	38. 10	64. 6	70. 2	76. 5	70. 43	54. 27
60	58. 2	67. 0	53. 9	59. 70	78. 0	91. 2	94. 3	87. 83	73. 77
80	65. 9	85. 9	75. 5	75. 77	83. 6	90. 2	96. 9	90. 23	83. 00
100	84. 2	90. 6	93. 1	89. 30	91. 5	94. 5	87. 9	91. 30	90. 30

PERCENTAGE OF UNBROKEN STALKS WITH LATERAL SHOOTS AT HARVEST

	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	2. 65	0	17. 56	6. 74	0. 5	1. 2	26. 5	9. 40	8. 07
20	3. 57	0	21. 15	8. 24	8. 9	1. 7	21. 7	10. 77	9. 50
40	9. 09	2. 44	30. 65	14. 06	1. 6	. 7	32. 5	11. 60	12. 83
60	31. 75	9. 09	60. 22	33. 69	. 9	1. 9	18. 4	7. 07	20. 38
80	29. 03	12. 28	46. 30	29. 20	8. 2	9. 3	45. 3	20. 93	24. 99

AVERAGE NUMBER OF SHOOTS PER BROKEN STALK WITH AXILLARY GROWTH

	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
20	1. 00	1. 37	1. 83	1. 40	1. 64	1. 76	2. 00	1. 80	1. 60
40	1. 31	1. 48	1. 66	1. 48	1. 76	1. 83	2. 58	2. 06	1. 77
60	1. 98	1. 57	1. 78	1. 78	2. 44	1. 97	3. 18	2. 53	2. 15
80	1. 78	1. 70	2. 01	1. 83	1. 94	2. 32	2. 57	2. 28	2. 05
100	2. 21	2. 07	2. 13	2. 14	2. 80	2. 99	2. 92	2. 90	2. 52

[1] Plant cane broken Aug. 20, 1945; first stubble, Aug. 19, 1946.

breakage the average percentage of broken stalks of plant cane and first stubble developing side shoots among the varieties studied ranged from 30.4 to 56.4, as compared with varietal values ranging from 87.8 to 92.5 percent where all stalks were broken. The number of shoots per broken stalk with lateral growth also increased rather consistently with an increase in extent of breakage. Minor discrepancies in this trend, observed in individual cases, are within the expected range of experimental variations. In almost all cases, the variety C. P. 29/120 gave the lowest average percentage of broken stalks developing lateral shoots, most conspicuous differences occurring at 20 and 40 percent breakage rates.

The percentage of broken stalks developing lateral shoots was, on the average, strikingly greater in first stubble than in plant cane. This was also true of the average number of shoots per stalk. It is not possible to determine from the results whether this difference is

TABLE 2.—*Yield of mill cane from broken and unbroken stalks at different percentages of breakage, 1945–46*

Percentage of stalks broken	Yield of mill cane per acre									
	Whole stalks			Broken stalks			All stalks			
	Co. 290	C. P. 29/120	C. P. 34/120	Co. 290	C. P. 29/120	C. P. 34/120	Co. 290	C. P. 29/120	C. P. 34/120	Mean of 3 varieties
	Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
TESTS OF PLANT CANE DURING 1945										
0	38.7	26.8	36.6				38.7	26.8	36.6	34.03
20	31.8	22.2	31.1	5.2	4.9	6.1	38.0	27.1	37.2	34.10
40	23.7	18.7	23.8	11.3	7.8	9.6	35.0	26.5	33.4	31.63
60	18.0	11.1	18.2	13.6	8.4	13.9	31.6	19.5	32.1	27.73
80	9.9	7.2	8.6	18.7	14.8	16.8	28.6	22.0	25.4	25.33
100				23.4	20.2	21.8	23.4	20.2	21.8	21.80
TESTS OF FIRST STUBBLE DURING 1946										
0	22.3	22.1	27.2				22.3	22.1	27.2	23.87
20	15.4	14.1	21.9	3.3	4.8	3.9	18.7	18.9	25.8	21.13
40	14.0	11.7	16.8	6.1	5.9	6.3	20.1	17.6	23.1	20.27
60	8.8	8.6	11.5	8.1	7.3	10.1	16.9	15.9	21.6	18.13
80	5.5	5.9	6.7	10.6	7.4	13.2	16.1	13.3	19.9	16.43
100				15.1	13.9	18.7	15.1	13.9	18.7	15.90
AVERAGE OF PLANT-CANE AND FIRST-STUBBLE TESTS										
0	30.50	24.45	31.90				30.50	24.45	31.90	28.95
20	23.60	18.15	26.50	4.75	4.85	5.00	28.35	23.00	31.50	27.62
40	18.85	15.20	20.30	8.70	6.85	7.95	27.55	22.05	28.25	25.95
60	13.40	9.85	14.85	10.85	7.85	12.00	24.25	17.70	26.85	22.93
80	7.70	6.55	7.65	14.65	11.10	15.00	22.35	17.65	22.65	20.88
100				19.25	17.05	20.25	19.25	17.05	20.25	18.85

characteristic of the crops (plant cane as compared with first stubble) or is attributable to prevailing differences in weather or other environmental conditions between the two growing seasons.

The proportion of unbroken stalks developing lateral shoots also increased as the percentage of broken stalks increased. In the average of all tests, 9.5 percent of the unbroken stalks developed lateral shoots in plots where 20 percent of the stalks had been broken, whereas 25 percent of the unbroken stalks developed lateral shoots where 80 percent of the stalks had been broken. The average number of unbroken stalks showing lateral growth in plots of 20-percent breakage was only slightly greater than those showing lateral growth in plots subject to no experimental breakage. Also, C. P. 34/120, while showing a relatively high proportion of broken stalks that produced side shoots at each rate of breakage, showed the least tendency to produce such growth on unbroken stalks.

Separate and also aggregate yields of cane per acre from broken and unbroken stalks obtained in plant cane and first stubble with each of three varieties at the several percentages of breakage are given in table 2. Averages of the varietal and crop yields under the different percentages of breakage are also shown. An examination of values given in table 2 shows that measurable decreases in yield of cane per acre occurred as a result of breakage, and that there was a consistent relationship between the extent of yield reduction and the proportion of stalks broken.

JUICE ANALYSES

At harvest representative samples of sugarcane from the experimental lots were taken for juice analysis. Each sample consisted of 30 stalks, except for a few, which, especially in cases of broken stalks from plots of 20-percent breakage and unbroken stalks from plots of 80-percent breakage, comprised substantially fewer than 30 stalks. Average results of the analyses are shown in table 3. Broken stalks were, in all cases, much lower in Brix (total solids), sucrose content, and purity of the juice than comparable stalks left unbroken. In plant-cane tests whole stalks from plots of no breakage showed the following juice analyses in the average of all varieties: Brix, 17.39; sucrose percentage, 14.65; purity, 84.2. Corresponding values for broken stalks of all breakage series were: Brix, 13.82; percent sucrose, 10.44; and purity, 75.5. Fairly similar relationships were maintained in first-stubble comparisons.

As the proportion of broken stalks in a plot increased, the Brix and percentage of sucrose in the juice from both broken and unbroken stalks decreased. This trend was maintained throughout the experiment, and was especially pronounced in plant-cane tests. However, juice purity within each category (broken or unbroken) was not consistently related to extent of breakage. The purity of the juice from the broken stalks under a given set of conditions tended to remain the same, regardless of breakage percentage; the same was true in the case of the unbroken stalks.

EFFECT OF BREAKAGE ON YIELD OF SUGAR

Yields of sugar per ton of cane and per acre can be calculated from data in tables 2 and 3 by using appropriate milling and recovery factors. In order to measure possible differences in milling qualities between broken and unbroken stalks, experimental milling tests, in accordance with the method previously described (*2*), were conducted on samples of cane of the following categories from each variety in each test: Whole stalks from plots of no breakage; broken stalks from plots of 20-percent breakage; broken stalks from plots of 60-percent breakage; and broken stalks from plots of 100-percent breakage. In most cases, sugarcane samples of 80 pounds each were used.

Essential data derived from results of milling tests on broken and unbroken stalks of different varieties are summarized in table 4. In arriving at percentage values shown for normal-juice extraction for mill cane and for the reduction factor for sucrose, the procedure outlined by Spencer and Meade (*8, chs. 34 and 35*) was followed. Fiber

TABLE 3.—*Analyses of crusher juice at harvest from samples of broken and unbroken stalks of different varieties taken from plots of various percentages of broken stalks, 1945–46*

TESTS OF PLANT CANE DURING 1945

Percentage of stalks broken [1]	Co. 290				C. P. 29/120				C. P. 34/120				Average of 3 varieties					
	Whole stalks		Broken stalks		Whole stalks		Broken stalks		Whole stalks		Broken stalks		Whole stalks			Broken stalks		
	Brix [2]	Sucrose	Brix [2]	Sucrose	Brix [2]	Sucrose	Brix [2]	Sucrose	Brix [2]	Sucrose	Brix [2]	Sucrose	Brix [2]	Sucrose	Purity	Brix [2]	Sucrose	Purity
		Percent		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*		*Percent*			*Percent*	
0	16.17	13.16			18.22	15.57			17.77	15.21			17.39	14.65	84.2			
20	16.32	13.38	13.85	9.86	17.61	14.90	14.06	10.85	17.84	15.25	15.65	12.12	17.26	14.51	84.1	14.52	10.94	75.3
40	16.86	13.94	12.91	9.33	17.13	14.55	14.38	11.24	17.36	14.90	15.94	12.60	17.12	14.46	84.5	14.41	11.06	76.8
60	16.83	13.88	12.31	8.79	16.40	14.06	13.69	10.59	17.21	14.75	15.41	12.08	16.81	14.23	84.7	13.80	10.49	76.0
80	15.49	12.58	12.20	8.83	16.80	14.23	13.44	10.38	16.77	14.09	14.86	11.61	16.35	13.63	83.4	13.50	10.27	76.1
100			11.74	8.24			13.55	10.30			13.32	9.76				12.87	9.43	73.3

TESTS OF FIRST STUBBLE DURING 1946

0	17.54	14.94			19.85	17.36			19.19	17.01			18.86	16.44	87.2			
20	17.54	15.12	14.59	12.04	18.81	16.76	15.02	12.28	18.89	16.74	16.59	14.06	18.41	16.21	88.0	15.40	12.79	83.1
40	17.21	14.65	15.67	12.95	19.23	17.01	15.97	13.09	18.70	16.29	16.06	13.22	18.38	15.98	86.9	15.90	13.09	82.3
60	16.89	14.48	14.79	12.11	19.01	17.15	15.09	12.56	18.23	16.04	15.69	13.14	18.04	15.89	88.1	15.19	12.60	82.9
80	17.55	15.06	14.69	11.90	19.07	16.99	15.64	12.87	18.06	15.73	15.50	12.82	18.23	15.93	87.4	15.28	12.53	82.0
100			14.55	11.92			14.66	12.16			15.92	13.61				15.04	12.56	83.5

[1] Plant cane broken Aug. 20, 1945; first stubble, Aug. 19, 1946.
[2] Total solids.

percentage of mill cane was determined by the direct method (*8, p. 573*). In calculating Brix of normal juice, a reduction factor of 0.985, found from previous tests to be applicable under prevailing milling conditions, was assumed for all lots of cane.

Results obtained with whole stalks (table 4) reveal the usual differences between varieties as to fiber content and normal-juice extraction. Mean varietal values for percentage of fiber content ranged from 11.35 with Co. 290 to 15.34 with C. P. 34/120, and for percentage of normal-juice extraction the values ranged from 75.35 with C. P. 34/120 to 81.30 with Co. 290.

TABLE 4.—*Summary of results of milling tests on samples of broken and unbroken stalks of different varieties, 1945–46*

NORMAL-JUICE EXTRACTION FROM MILL CANE

Variety	Plant cane					First stubble					Average of plant cane and first stubble	
	Whole stalks [1]	Broken stalks from plots of—			Mean	Whole stalks [1]	Broken stalks from plots of—			Mean	Whole stalks	Broken stalks
		20-per-cent breakage	60-per-cent breakage	100-per-cent breakage			20-per-cent breakage	60-per-cent breakage	100-per-cent breakage			
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Co. 290	82.5	80.0	85.3	87.0	86.3	80.1	80.9	82.3	81.3	81.5	81.30	83.88
C. P. 29/120	77.6	85.5	84.1	83.5	84.4	76.8	77.0	78.0	79.6	78.2	77.20	81.28
C. P. 34/120	75.9	81.1	82.1	83.3	82.2	74.8	78.0	79.3	77.0	78.3	75.35	80.23
Mean	78.7	84.2	84.0	84.6	84.3	77.2	78.6	79.9	79.5	79.3	77.95	81.80

FIBER FROM MILL CANE

Co. 290	10.66	8.79	8.67	8.31	8.59	12.02	10.74	10.74	10.70	10.73	11.35	9.66
C. P. 29/120	13.17	9.12	9.53	9.23	9.29	14.32	11.06	11.58	11.84	11.80	13.74	10.55
C. P. 34/120	14.82	11.22	10.81	10.90	10.97	15.87	13.02	12.44	12.78	12.75	15.34	11.86
Mean	12.89	9.71	9.67	9.48	9.62	14.07	11.91	11.59	11.77	11.76	13.48	10.69

REDUCTION FACTOR FOR SUCROSE [2]

Co. 290	0.984	0.981	0.985	0.986	0.987	0.976	0.981	0.985	0.981	0.983	0.980	0.985
C. P. 29/120	.975	.979	.982	.985	.982	.974	.968	.980	.982	.977	.974	.979
C. P. 34/120	.975	.974	.978	.980	.977	.967	.975	.980	.974	.976	.971	.977
Mean	.978	.978	.982	.987	.982	.972	.975	.982	.980	.979	.975	.981

[1] From plots with no breakage.
[2] To convert first milling juice to normal juice.

Significant differences with respect to fiber content and normal-juice extraction were observed between broken and unbroken stalks in the case of each variety. In plant-cane tests of the three varieties, the percentage of normal-juice extraction from cane averaged 84.3 from broken stalks as compared with 78.7 from unbroken stalks. In first-stubble tests broken stalks gave an average normal juice extraction of 79.3 percent as compared with an average of 77.2 obtained from whole stalks. Conversely, broken stalks were consistently lower in fiber content than stalks left unbroken.

In the average of all tests, the reduction factor for percentage of sucrose was 0.981 for broken stalks and 0.975 for unbroken stalks. A

TABLE 5.—*Calculated yields*[1] *of extracted solutes, extracted sucrose, and available sugar as related to percentage of broken stalks, 1945–46*

(Average of plant cane and first stubble)

EXTRACTED SOLUTES (BRIX) PER ACRE

Variety	Percentage of stalks broken					
	0	20	40	60	80	100
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Co. 290	8, 168	7, 456	7, 144	6, 015	5, 218	4, 210
C. P. 29/120	7, 022	6, 093	5, 673	4, 413	4, 300	3, 821
C. P. 34/120	8, 743	8, 478	7, 421	6, 870	5, 592	4, 663
Mean	7, 978	7, 342	6, 746	5, 766	5, 037	4, 231

EXTRACTED SUCROSE (POLARIZATION) PER ACRE

Co. 290	6, 740	6, 104	5, 800	4, 826	4, 084	3, 114
C. P. 29/120	6, 010	5, 123	4, 885	3, 710	3, 515	3, 003
C. P. 34/120	7, 500	7, 176	6, 213	5, 735	4, 543	3, 664
Mean	6, 750	6, 134	5, 633	4, 757	4, 047	3, 260

AVAILABLE 96° SUGAR PER ACRE

Co. 290	6, 425	5, 795	5, 488	4, 531	3, 781	2, 787
C. P. 29/120	5, 839	4, 932	4, 653	3, 572	3, 335	2, 788
C. P. 34/120	7, 295	6, 933	5, 969	5, 471	4, 295	3, 401
Mean	6, 520	5, 887	5, 370	4, 525	3, 804	2, 992

AVAILABLE 96° SUGAR PER TON OF CANE

Co. 290	210. 7	204. 4	199. 2	186. 8	169. 2	144. 8
C. P. 29/120	238. 8	214. 4	211. 0	201. 8	189. 0	163. 5
C. P. 34/120	228. 7	220. 1	211. 3	203. 8	189. 6	168. 0
Mean	225. 2	213. 1	206. 9	197. 3	182. 2	158. 7

[1] Combined yields, broken and unbroken stalks.

difference of this approximate order was maintained with each of the three varieties. There was no indication that differences in milling factors observed with broken stalks could be attributed to differences in percentage of breakage. In other words, with a given variety and crop, juice extraction and other milling factors for broken stalks tended to remain the same regardless of the actual percentage of breakage. Breakage greatly reduced the differences in fiber content and normal juice extraction between varieties.

Sugar extraction and recovery values for broken and unbroken stalks of each variety under the various conditions of the experiment were calculated from data shown in tables 2, 3, and 4. With the

information available it was possible to make allowances for differences in milling factors between varieties, between broken and unbroken stalks, and between crops (plant cane and first stubble). Calculated yields per acre of extracted solutes, extracted sucrose, and available 96° sugar (*8*), and the available sugar per ton of cane for each of the three varieties at each percentage of breakage tested in the average of plant cane and first stubble are shown in table 5.

Losses in yield of total solids and sugar caused by 100-percent breakage reduced extracted solutes per acre by approximately 47 percent, extracted sucrose by approximately 52 percent, available sugar by approximately 54 percent, and available sugar per ton of cane by approximately 30 percent.

TABLE 6.—*Average effect of breakage at different percentages of total stalks on actual reductions and percentage of reductions on yields of cane and sugar, 1945–46*

Percentage of stalks broken	Reduction in yield due to breakage					
	Actual			Percentage of check		
	Cane per acre	Available 96° sugar per ton of cane	Available 96° sugar per acre	Cane per acre	Available 96° sugar per ton of cane	Available 96° sugar per acre
	Tons	*Pounds*	*Pounds*	*Percent*	*Percent*	*Percent*
20	1. 33	12. 1	633	4. 6	5. 4	9. 7
40	3. 00	18. 3	1, 150	10. 4	8. 1	17. 6
60	6. 02	27. 9	1, 995	20. 8	12. 4	30. 6
80	8. 07	43. 0	2, 716	27. 9	19. 1	41. 7
100	10. 10	66. 5	3, 528	34. 9	29. 5	54. 1

YIELD REDUCTIONS IN RELATION TO EXTENT OF BREAKAGE

The study showed that breakage caused important reductions in yields of cane per acre, sugar per ton of cane, and sugar per acre. The exact order of such reductions with various proportions of breakage is shown in table 6. The value in each case is shown in actual weight and also as a percentage of the yield obtained on check plots. In the average of all tests (three varieties in plant cane and in first stubble), 20-percent breakage of cane caused a reduction of 1.33 tons of cane per acre, or 4.6 percent at the one extreme, and 100-percent breakage caused a reduction of 10.10 tons, or 34.9 percent at the other. Thus, the percentage of yield reduction was slightly less than one-fourth of the percentage of breakage at 20 percent and slightly more than one-third of the percentage of breakage at 100 percent. The average reduction of 633 pounds of available sugar per acre from 20-percent breakage is 9.7 percent of the yield from check plots, while the reduction of 3,528 pounds obtained from 100-percent breakage represents a drop of 54.1 percent. The percentage reduction in yield of

sugar per acre at the lower breakage rate, therefore, was slightly less than half of the breakage percentage, and at the upper limit slightly more than half of the breakage percentage. Hence, a rough estimate of percentage of loss in yield of sugar per acre from breakage could be obtained by dividing the percentage of breakage by 2.

Average reductions in yield of sugar per ton of cane ranged from 12.1 pounds, or 5.4 percent, at 20-percent breakage to 66.5 pounds, or 29.5 percent, at 100-percent breakage. Here, also, the ratio of percentage of reduction to percentage of breakage tended to increase with an increase in the percentage of breakage.

TABLE 7.—*Percentage of reduction in indicated yield of sugar per acre caused by breakage as observed with individual varieties in the average of plant cane and first stubble and for each crop in the average of all varieties, 1945–46*

Percentage of stalks broken	Varieties (average of 2 crops)			Crops (average of 3 varieties)	
	Co. 290	C. P. 34/120	C. P. 29/120	Plant cane	First stubble
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
20	9.8	5.0	15.5	4.4	16.5
40	14.6	18.2	20.3	13.8	22.5
60	20.5	25.0	38.8	28.7	33.0
80	41.2	41.1	42.9	41.3	42.1
100	56.6	53.4	52.3	58.7	48.2

Reductions in yield of sugar per acre as observed with Co. 290, C. P. 34/120, and C. P. 29/120 in the average of two crops and also results obtained with plant cane and first stubble in the average of the three varieties are given in table 7. Departures of varietal and crop values given in table 7 from average values shown in table 6 are the result, in part at least, of the usual experimental variations. In view of the order of magnitude, it may be assumed that the experimental variations account largely for differences in percentage of reduction observed between the different varieties at the 80- and the 100-percent breakage levels. On the other hand, at breakage percentages from 20 to 60, reductions for C. P. 29/120 were found to be rather consistently higher than those obtained with either Co. 290 or C. P. 34/120. Breakage within the 20- to 60-percent range also caused a consistently greater proportionate reduction in first stubble than in plant cane.

These results show that the relationship between percentage of breakage and percentage of reduction in crop yield was not strictly linear. The relative effect of breakage became progressively greater as the extent of breakage increased. For a mathematical expression of this relationship, as applying to yield of cane per acre and yield of sugar per acre, use was made of the equation (7, *pp. 144–145*), $y=a+bx+Cx^2$.

Constants [3] as determined for over-all average values shown in tables 2 and 5 were as follows:

Constant:	*Tons of cane per acre*	*Indicated pounds of 96° sugar per acre*
a	20. 16	6, 515. 0
b	−1. 659	−553. 9
c	−. 0896	−30. 55

A comparison of observed and calculated yields shows a very satisfactory agreement, as indicated in table 8.

TABLE 8.—*Observed and calculated yields per acre of cane and 96° sugar for the average of plant cane and first stubble of all varieties, 1945–46*

Percentage of stalks broken	Yield of cane per acre		Indicated yield of 96° sugar per acre	
	Observed	Calculated	Observed	Calculated
	Tons	*Tons*	*Pounds*	*Pounds*
0	28. 05	20. 16	6, 520	6, 515
20	27. 62	27. 41	5, 887	5, 931
40	25. 95	25. 48	5, 370	5, 285
60	22. 93	23. 38	4, 525	4, 578
80	20. 88	21. 09	3, 804	3, 811
100	18. 85	18. 63	2, 992	2, 982

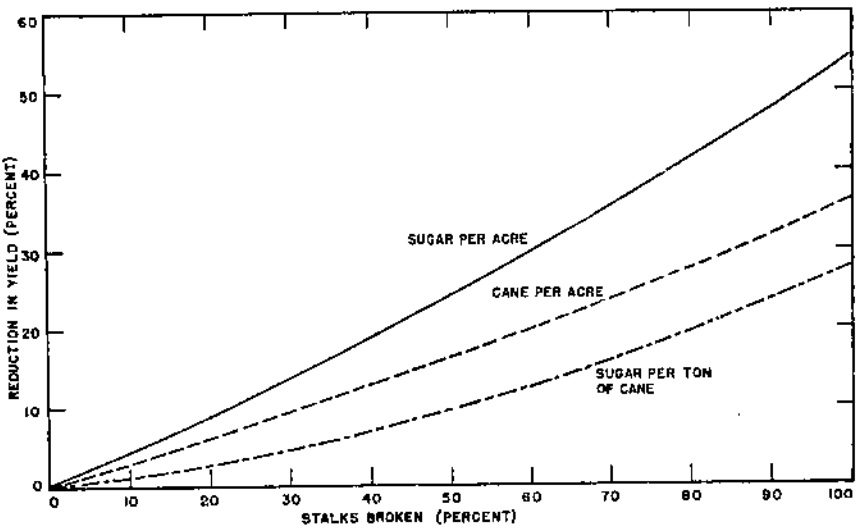

FIGURE 1.—Relation between percentage of broken stalks and percentage of reduction in crop yields (mean of 3 varieties).

Percentage of reductions in mean yields of cane of all varieties and sugar per acre in relation to extent of breakage, as based on calculated values given in table 8, are shown in figure 1. Shown also are indicated percentages of reductions in yield of sugar per ton of cane.

[3] For use with coded values; for example, 0 percent of stalks broken=0, 20 percent =1, 40 percent=2, 60 percent=3, 80 percent=4, and 100 percent=5.

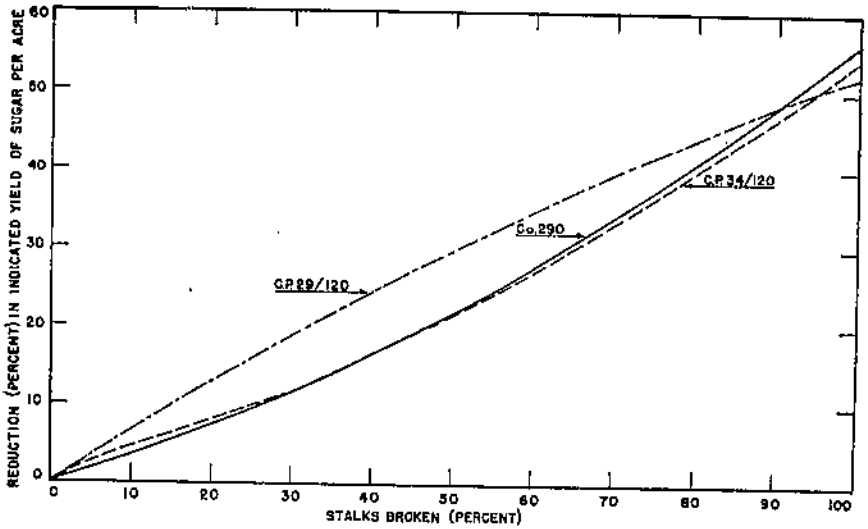

FIGURE 2.—Relation between percentage of broken stalks and percentage of reduction in indicated yield of sugar per acre with each of 3 varieties.

Percentages of reductions in indicated yield of sugar per acre from Co. 290, C. P. 34/120, and C. P. 29/120 at various percentages of breakage are illustrated in figure 2. Calculated reductions for Co. 290 and C. P. 34/120 are in close agreement throughout the range of the curves, but, as mentioned earlier, C. P. 29/120 suffered relatively heavier reductions than the other varieties from breakage at percentages from 20 to 60.

DISCUSSION

Of chief practical interest are the critical comparisons obtained regarding the effect of breakage at various percentages of the stalk population on yields of cane and sugar. Breakage lowered the quality as well as the quantity of cane produced. As a combined effect the production of sugar per acre was reduced in still greater proportion; however, the percentage of reduction was much less than the percentage of breakage. In part, this difference was caused by broken stalks that had accumulated some sugar at the time of breakage, but an additional factor was the stimulated growth of undamaged plants as a result, no doubt, of the reduced competition for light and other essentials. For instance, the data on the average of all plant-cane tests (table 2) in plots where 80 percent of the stalks had been broken, show that the remaining 20 percent yielded at the rate of 8.57 tons per acre. At that rate the yield from all stalks would have averaged 42.85 tons. The comparable yield from check plots was only 34.03 tons.

Demandt (4), in thinning experiments under Java conditions, found that when 5, 10, and 20 percent of the shoots were cut out at ages ranging from 6 to 10 months the losses in yield of sugar per hectare were 2.2, 4.8, and 11.4 percent, respectively. The compensation, approaching 50 percent in each case, was attributed to the decreased

mortality rate and the increased weight of remaining stalks. Evidence of compensation of a much higher order was obtained in a study of the effects of gaps in stand under Louisiana conditions (*1*).

In the experiments discussed, dates when breakage was caused (August 19 and 20) fall within the period in which expectancy of tropical disturbances over the Gulf coastal area is greatest. Therefore, the results are considered broadly representative of what may be expected from hurricane breakage under Louisiana conditions. But it is recognized that significantly different effects might be produced under a different set of conditions.

The tendency for broken as well as unbroken stalks to develop lateral shoots was affected by a number of factors, including varietal differences and extent of breakage. Under some conditions growth of lateral shoots on decapitated plants was widely suppressed. For instance, at 20-percent breakage 86 percent of the broken stalks of C. P. 29/120 plant cane failed to develop shoots. Such stalks ordinarily remained alive until harvest.

Observed increases in extent of lateral-shoot development on both broken and unbroken stalks with increases in percentage of breakage suggests that there was a progressive disintegration of the mechanism by which axillary growth is normally suppressed. In this connection studies of Brandes and Van Overbeek (*3*) revealed a close correlation between auxin level and apical dominance. It would seem reasonable to assume that the auxin level within the stool as a whole might be progressively reduced as a result of increases in extent of breakage, such as that induced step by step in this experiment.

The abnormally low fiber content and, by corollary, the high juice content of broken stalks are considered significant. Departures from normal values of the order observed would introduce a systematic bias of major importance in comparisons between broken and unbroken stalks based on juice analyses alone.

The percentages of sucrose and total solids (Brix) in juice from unbroken stalks decreased consistently as the percentage of breakage increased. Observed increases in extent of axillary growth on unbroken stalks associated with increased breakage may account, in part at least, for observed differences, but it is possible that the relationship was materially affected by translocation. Recent studies of Hartt and Burr (*5*) with radioactive CO_2 show that sugar is rapidly and extensively translocated between stalks of the same stool. With an increase in percentage of breakage and the consequent increase in the proportion of relatively inactive stalks of low concentration, diffusion of solutes from the stalks of higher photosynthetic activity and concentration could easily account for the above-mentioned reduction in percentage of sucrose and total solids in juice from unbroken stalks.

As previously stated the erect variety C. P. 29/120 suffered a relatively greater reduction in yield of sugar per acre from breakage at percentages ranging from 20 to 60 than did the varieties Co. 290 and C. P. 34/120, whereas varietal differences in this regard at higher percentages of breakage were insignificant. Ability to overcome in greater degree effects of breakage in the lower range by the two last-named varieties probably reflects a capitalization on their more recumbent foliage, permitting a more extensive utilization of surplus sunlight by undamaged stalks.

SUMMARY

Tests of the effect of breakage in proportions ranging from 20 to 100 percent of total stalks were made on plant cane and first stubble of sugarcane varieties C. P. 29/120, C. P. 34/120, and Co. 290. Average reductions in yield of sugar per acre ranged from 9.7 percent, where 20 percent of the stalks were broken, to 54.1 percent, where all stalks were broken. This reflects a reduction in quality as well as quantity of cane produced. The three varieties suffered reductions in yield that were relatively similar at breakage percentages of 80 and 100; however, within the range of 20- to 60-percent breakage, the erect variety C. P. 29/120 suffered relatively greater reductions in yield than did the more recumbent types Co. 290 and C. P. 34/120.

Broken stalks were abnormally low in fiber content, yielded juice of relatively low quality, and gave an average indicated yield of sugar per ton of cane approximately 50 pounds under that obtained from unbroken stalks. The Brix (total solids) and percentage of sucrose in the juice from unbroken stalks collected from the various plots decreased significantly as the percentage of breakage increased, but the purity was not affected by variations in rate of breakage. A somewhat similar trend was observed with broken stalks, but the effect on Brix and percentage of sucrose was not so great and the relationship was not so consistently maintained.

The tendency of both broken and unbroken stalks to develop axillary growth increased consistently as percentage of breakage increased. This and other evidences of mass influence emphasize the importance of determining effects of breakage from observations on entire groups of stalks rather than from comparisons between broken and unbroken stalks.

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