SAMPLING VARIABILITY IN AND RELEVANCE OF CANE MATURITY INDICES

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INTRODUCTION

Maximum sugar yields can be obtained only when the sugarcane crop is harvested when the average sugar content of the field is highest. Several indices have been developed to estimate optimum maturity within a field and to establish harvesting schedules for several fields of similar age. In order to ensure an adequate estimation of maturity it is highly essential that the index used closely correlates with the actual sugar yields, and the samples taken for this purpose truly represent all the millable stalks in the field.

Maturity indices currently in use in various areas of the world include brix and sucrose in juice, top-bottom sucrose ratios, leaf sheath and 8-10 stalk moisture, 8-10 sugars and the HSPA preharvest sampling method based on tons cane per ton of pol. These methods have been used with some success to estimate the optimum age for harvesting. All except the pol ratio take only full grown stalks into consideration. When the sugarcane crop is harvested there will be stalks of several different ages and different stages of maturity. Also, due to unequal distribution of sunlight in the crop canopy, variations in topography, soil type, texture and fertility, there may be stool to stool, site to site and field to field variations.

The preharvest sampling method is a very laborious procedure and, therefore, usually only two to four samples are taken per 100 acres. Repeated sampling at intervals is often not done because of the high labor requirements. When evaluating the relative maturity of the fields which are of similar age, only one to a few samples are taken from each field. It is likely that the small number of samples reduces the reliability of the pol ratio method as an estimator of maturity within or between fields.

Leaf sheath moisture is used mainly as an indicator of ripening within a field although it has also been used to indicate relative maturity between fields. As with the preharvest sampling method, usually only one sample is taken from fully developed stalks per 20 to 50 acres. Infield variability resulting from uneven irrigation water distribution and soil and topography variation would appear to make this an inadequate number of samples. Also, the leaf sheath moisture samples are taken only from primary and first season suckers and, therefore, do not represent the total stalk population. Because of the abovementioned deficiencies in the various maturity indices, there appeared to be a need to develop a simple and more sensitive index of cane maturity.

A cane maturity study was carried out in field No. 145 (1) (area 11.31 acres) of Oahu Sugar Company with the following objectives:

(1) To study the variation between stalks within the same stool, between two adjacent stools at the same location and between stools in different locations in the field.

(2) To compare the sensitivity of top/bottom sucrose ratio, leaf sheath moisture, 8-10 moisture and sucrose/reducing sugars and pol ratio indices as estimators of cane maturity.

(3) To study the possibility of evolving a simpler and more sensitive index of cane maturity which could detect the relative maturity of fields of similar age.

REVIEW OF LITERATURE

The advantages of harvesting sugarcane at its peak maturity are well known. Several indices have been devised to estimate maturity with varying degrees of success. Analysis of juice for brix, sucrose or pol and purity were the indices utilized by the early workers. The results of the work done on maturity of sugarcane in various countries were presented at the 5th Congress of the International Society of Sugarcane Technologists held at Brisbane in 1935.

Stevenson (1935) in Barbados analyzed the sucrose in juice in different varieties by harvesting them in early medium and late periods. This lead to the recognition of early medium and late maturing varieties.

Dodds (1935) reported that at the Experiment Station, Natal, South Africa, maturity was estimated by the analysis for sucrose, purity and reducing sugars of the juice. He criticized the use of the hand refractometer because the total solids in the juice vary considerably in different parts of the stalk.

Nath and Kashi Nath (1935) followed the progressive accumulation of solids in the individual internodes of the sugarcane stalk at successive stages of its growth. From this work they developed the top/bottom ratio method of estimating cane maturity. The top/bottom ratio concept postulates that as the sugarcane ripens, the ratio of the total solids in the juice in top and bottom halves of the stalk tends to approach unity. Nath (1919) devised a technique for extracting small quantities of juice from a growing cane stalk in the field. The brix was determined by means of a hand refractometer. Using this technique they worked out the top/bottom brix (T/B brix) ratio for the cane of various ages. The ratio varied from 0.67 at eight months to 1.01 at 12 months for a one year cane crop. They also presented data from first, second, third and fifth shoots showing that T/B brix ratio approached unity with advancing age. Rao (1917) reported T/B brix ratio ranged from 0.89 to 1.7 for a one year crop of 'Saretha' cane kept in the field for 16 months. The value 0.89 indicated that the cane was immature, a ratio of about 1.00 was considered to be optimum and 1.7 overmature.

Data of the Sugarcane Research Station, Lucknow, India, cited by Humbert (1967), reported variations in juice pol for different sections of the stalk -- bottom, penultimate bottom, middle, top and penultimate top -- throughout the harvesting season. The T/B pol ratio continued to increase as the cane matured. On overmaturity, the ratio became greater than one.

Kerr (1935) reported that cane maturity studies in Queensland resulted in the following facts:

> Brix: With immature cane, the brix of the juice from top, middle and butt sections of the stalk increased progressively in the order named. At maturity, it was found that juice from the middle sections showed the highest value, with that from the tops and butts practically identical and about one unit below the figure for the middle sections. With overmature stalks, the brix of the butt juice declined most rapidly, followed by that for middles, so that the original position was reversed. The use of brix alone as a criterion of maturity was discouraged since variations in two week intervals were generally slight, and small analytical

discrepancies might lead to erroneous conclusions.

Pol: The pol determinations followed the brix values very closely, although the range between extreme values was greater. Overmaturity was immediately reflected in a substantially reduced pol value as a result of sucrose inversion. This criterion was therefore much more sensitive than brix.

Reducing sugars: This factor was considered to be the most useful individual value for maturity estimations. The range of variation from very immature cane to the point of maximum sugar content was practically 100 percent, and the value varied from 5% in immature stalks to 0.10% in fully ripened cane.

The effects of age were studied at the HSPA Experiment Station (1957) by evaluating the quality of juice expressed from primaries, secondaries and suckers at the time of harvesting (24 months of age). The primaries were found to have passed their prime and were deteriorating in quality. The effect was most apparent in the basal portion. The secondaries were in the prime condition, while the suckers were superior to the primaries but not quite equal to the secondaries.

Crop logging of cane was introduced in the 1930's and lead to the use of leaf sheath moisture, 8-10 internode moisture and 8-10 sucrose reducing sugar. Clements and Kubota (1943) recorded the progress of the crop from planting until harvest. The record was designed to give an integration of climate and physiology in such a way that alterations in irrigation and fertilizer management could be made while the crop was growing. Clements (1948) reported that the quality of the normal cane crop was correlated with sheath moisture content, not only at harvest time but throughout the second season of growth. The crops in the second season were classified as being high, intermediate or low in moisture. It was reported that high moisture crops could be ripened satisfactorily but required a much longer period than those low or intermediate in moisture. At seven months before harvest, the fields were placed on the harvesting schedule. Leaf sheath samples were collected at periodic intervals, usually every two weeks. A drying line was established from approximately 82% leaf sheath moisture seven months prior to harvest to a desired optimum of 74% at harvest time. Drying below 74% resulted in an increasing percentage of dead cane. Clements (1948, 1962 and 1968) also related nitrogen to cane crop maturity. High levels of nitrogen in the leaf resulted in reduced levels of sucrose and purity.

Workers at the HSPA Experiment Station (1960) reported a correlation coefficient of 0.753 between 8-10 internode moisture and leaf sheath moisture for six month old cane. This coefficient decreased to 0.570 at 12 months. A correlation coefficient of 0.939 between 8-10 internode moisture and 8-10 sucrose was reported for fully mature cane. A $0.73 per sample cost advantage in favor of the 8-10 internode sampling method over the leaf sheath method was reported.

Payne and Mahon (1956) utilized the pol ratio (tons of cane required to yield a ton of sugar) method to evaluate cane quality. Actual sugar yields are estimated by this method as it includes an analysis of juice quality as well as the cane fibre content. The ensilage cutter pol ratio technique was reported to give better juice data and offer less operational difficulties to the factory than that of sampling crusher juice (Johan, 1962).

Eight-to-ten internode moisture levels were reported to be an extremely reliable index of cane maturity in Mexican fields (Humbert, 1968). An excellent correlation was obtained between sugar recovery per ton of cane and 8-10 internode moisture levels as the moisture content dropped from 84 to 73%. The fields at Los Mochis were laid out in approximately 20 ha blocks, all carefully graded, thereby ensuring relatively uniform cane. Whole stalk samples were collected at monthly intervals starting three months before the intended harvest date. Samples of 8-10 internode were processed for moisture, nitrogen and sucrose/reducing sugar ratios. The pol ratio was determined from the balance of the sample. Priorities for harvest were established on the basis of recent laboratory reports. The pol ratio data and stalk moisture indices have proven to be effective guides to harvest scheduling.

Yates (1969) discussed the effect of intercane variability on the sampling and harvesting of sugarcane stalks at Puerto Rico. He analyzed individual cane stalks for brix, pol and fibre and calculated percent yield, percent fibre and weight per stalk. He concluded that the desired sample size to estimate quality (sugar content) varied from 12 to 618 canes. Large samples were required to accurately estimate quality only in 19-20 month crops and the size of the sample required was related to the degree of deterioration. In a 12 months old crop, the sample size was found to be related to the degree of lodging with the largest sample (an 81-cane sample) being required for a very heavily lodged crop. The deterioration of individual stalks was attributed to the lodging of old, non-vigorous canes.

MATERIALS AND METHODS

Sampling Procedure

Cane maturity studies were carried out in field No. 145 (1) Block I (Figure 1) area (11.31 acres) of the Oahu Sugar Company. The cane crop was a first ratoon of variety 50-7209, although the HSPA Genetics Department confirmed suspicions that at least two other varieties were also present. Four sampling sites (marked as X on the map) were selected to represent approximately each one fourth of the field. Site one was located off of the first level ditch from the "haul cane road," about 200 ft. in from the main ditch (towards Kunia road) and about 30 ft. inside the field. The second site was off of the third level ditch from the "haul cane road," about 100 ft. from the main ditch (towards Kunia road) and about 30 ft. inside the field. The third site was located along Kunia road on the Wahiawa side of the "haul cane road." The site was just opposite the first telephone pole above the "haul cane road" and about 75 ft. into the field. Access to the fourth site was off Kunia road at the first level ditch towards Waipahu from the "haul cane road" and approximately 150 ft. in from Kunia road. The site was about 30 ft. into the field off of the level ditch.

Four samples, each consisting of two adjacent stools, were taken at various stages of cane maturity from the abovementioned sites. The adjacent stools at each sampling date were taken consecutively from the same furrow to ensure an unbiased sample. As field 145 (1) was scheduled to be harvested in August, 1968, the first sample was taken approximately five months prior to harvest on April 11, 1968. Sampling

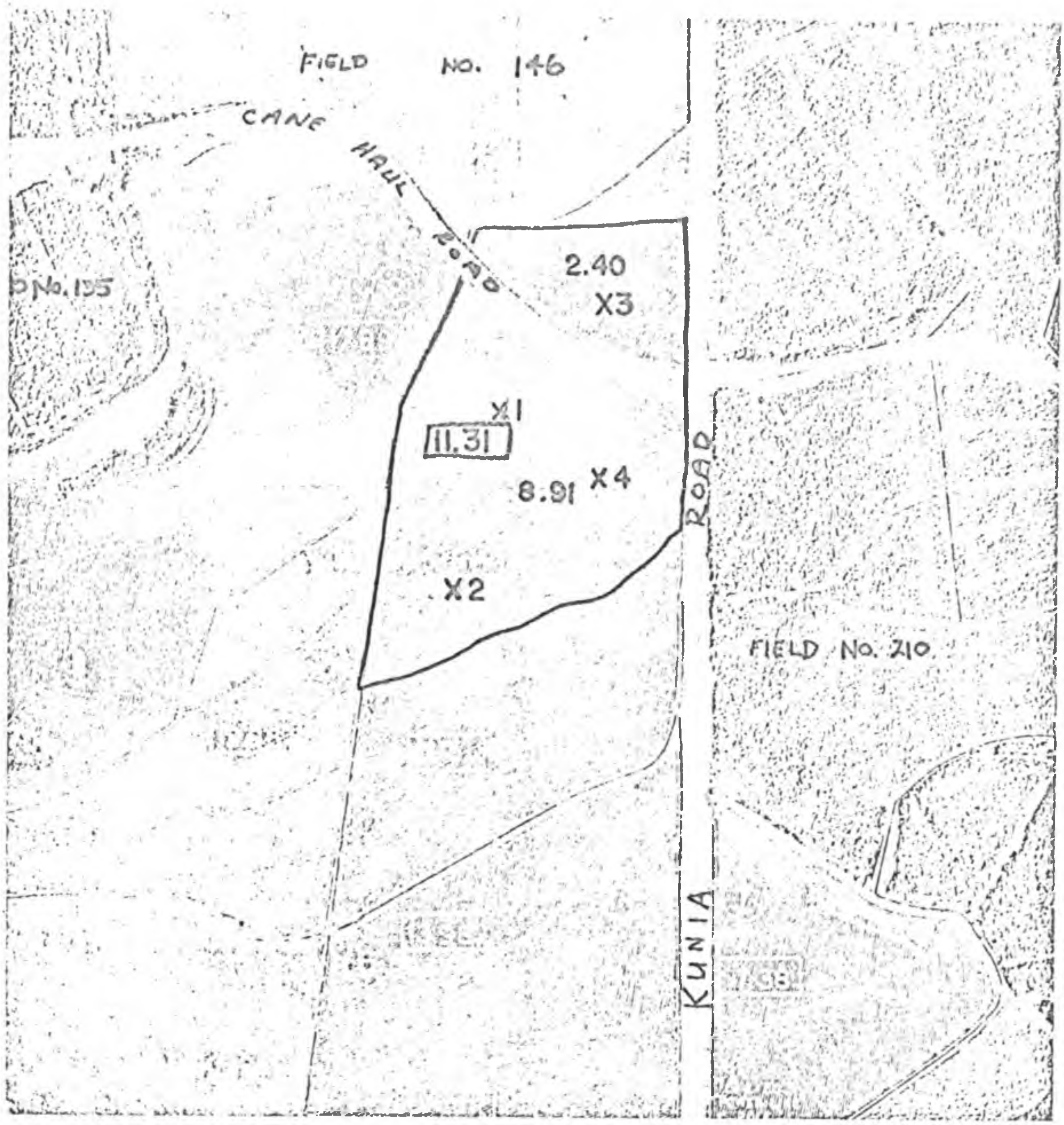

FIGURE 1. FIELD NO. 145 (1) BLOCK I (AREA 11.31 ACRES) OF OAHU SUGAR COMPANY.

was repeated at about monthly intervals with the last sample being taken the day before the field was harvested on August 9, 1969. The stalks of each stool were separated into the following categories or stalk orders.

Primary stalks (Primaries): Stalks, including tillers, present approximately three months after planting, distinguished by the small diameter of the basal internodes and more or less prostrate near the base.

First season suckers (1st S.S.): Tillers which were initiated between 4-12 months after planting, distinguished from primaries by a basal internode diameter approximately twice that of primaries.

Second season suckers or "bull shoots" (2nd S.S.): Tillers which develop more than 12 months after planting and distinguished from the above by their length. They are usually much shorter and have a diameter greater than that of first season suckers and a completely erect orientation.

All primaries, 1st S.S. and 2nd S.S. of selected stools were marked and sampled separately.

The damaged stalks were classified as follows:

Dead cane: Entire stalk dead.

Dead tops: Stalks with dead tops with or without lalas (shoots developed from near apical axilliary buds).

Souring: Stalks characterized by their sour smell and discoloration.

Tasselled: Stalks with a developed or developing inflorescence.

False tasselled: Stalks having a bunchy top or flag leaf and indicating some but insufficient stimulus for flowering.

Rat damaged: One or more internodes damaged by rats.

Borer damaged: Stalks with holes and channels indicating the presence of or damage due to boring insects.

No sample was taken from stalks less than 3 ft. in length on the assumption that their contribution to the yield would be negligible. Also it was considered to be unlikely that they would reach the mill under normal harvesting methods.

The sheaths from leaves No. 3, 4, 5 and 6 (counting the spindle leaf as No. 1) of each stalk were removed and sealed in plastic bags. After the fresh weights were determined in the laboratory, the sheaths were dried in a draft oven at 80-85°C and their moisture contents were determined. The top of each stalk was cut at the 7th and the 11th internodes (the internodes found below the 7th and 11th leaf sheaths) and the stalk section containing internodes 8, 9 and 10 (8-10) was removed and sealed in plastic bags. The 8-10 were chilled as rapidly as possible with cracked ice and transported in insulated containers to the laboratory where they were frozen. In the laboratory 6 to 10 uniformly thin slices were cut from the center of each internode of the 8-10 section. The slices were weighed and collected in nonabsorbent wire mesh containers. The slices were dried to a constant weight (5 to 6 hours) in a draft oven at 80-85°C. The dry weight was obtained and the percentage of moisture on a fresh weight basis was calculated.

The dried samples were ground in a Wiley Mill to pass through a 20 mesh screen and utilized for the determination of reducing sugars and sucrose.

For the July and August samples, in addition to leaf sheath and 8-10 samples, each cane stalk was collected and transported to the laboratory. The length of each stalk was measured, separated into top, middle and bottom thirds and each third was weighed separately. The stalks less than 6 ft. in length were not sampled for pol ratio. Those less than 10 ft. long were divided into bottom and top portions only. The 8-10 portion was divided lengthwise into two halves. One half was utilized for the determination of 8-10 moisture and sucrose/reducing sugar ratio. The other half was added to one-half of the top one third of the stalk which had been divided, lengthwise, into two halves. The other half of the top one third of the stalk was discarded.

Site No. 2 was selected at random for individual stalk analyses, whereas the top, middle and bottom thirds of the stalks of the stools from other sites were grouped into various stalk orders for pol ratio analysis. Prior to the pol ratio analysis, the stalks were chopped into pieces about one inch length. The chopped cane was thoroughly mixed and a subsample of about 1000 grams was taken, sealed in a thick plastic bag and stored frozen. Where one third of an individual stalk (usually the top third) weighed less than 1000 grams, the entire stalk portion constituted the sample.

Analytical Procedures

Determination of reducing sugars:

The volumetric methylene blue method of Lane and Eynon (1925) as modified by H.S.P.A. (1944) for leaf sheath was modified and adopted for analysis of 8-10 sucrose and reducing sugars. The following procedure was followed:

Two and one-half grams of ground 8-10 tissue was weighed out and placed in a 250 ml volumetric flask. One-third of the small hornspoonful of calcium carbonate, CP powder was added. About 150 ml of distilled water was added and flask was shaken on a mechanical shaker at room temperature for about 30 minutes. The flask was made up to volume with distilled water. It was shaken vigorously and filtered. The filtrate was titrated against a measured volume of standardized Fehlings solution using methylene blue (1.0%) as the indicator. The volume of the filtrate used was measured and the percentage of reducing sugars was read directly from tables prepared by the HSPA Experiment Station Chemistry Department.

Determination of total sugar:

Fifty ml of the extracted filtrate was pipetted into a 250 ml volumetric flask. Invertase was added, the neck of the flask was washed with distilled water and the solution left overnight at room temperature for hydrolysis of sucrose. The flask was made up to volume with distilled water and the solution titrated against Fehling's solution as for reducing sugars. The volume of the extract used was noted and the percentage of total reducing sugars was obtained directly from the tables. The sucrose percentage was calculated as follows:

(Percent total sugars in terms of reducing sugars - percent reducing sugars)

X 0.95 = Percent sucrose

Pol ratio:

The disintegrator method of cane analysis recommended by HSPA Experiment Station was adopted. A sample of approximately 900 grams of prepared cane was put into a disintegrator and 2000 grams of water was added. A 10 minute period was allowed for disintegration, after which a sample of the liquid was withdrawn, filtered and analyzed for refractometer solids and pol. Then the fibre was put into a pan with a screen bottom, washed, pressed and dried. The calculations for pol ratio, fibre (the dry, water insoluble fibrous material), absolute juice pol percent, refractometer solids (brix) and purity were made as follows:

Weight of cane	966 grams
Weight of water added for disintegration	2000 grams
Refractometer solids percent, diluted juice	4.46
Pol percent diluted juice	3.92
Fibre	102.0 grams
Absolute juice 966-102 =	864 grams
Pol in diluted juice (864+2000)0.04 =	114.6 grams
Pol percent cane, 100x114.6/966 =	11.56
Fiber percent cane, 100x102/966 =	10.56
Absolute juice, purity = 100x3.92/4.46 =	87.90
Absolute juice, Pol percent = 100x114.6/864 =	12.93
Refractometer solids percent = 100x12.93/87.9=	14.69
Pol ratio = 100/11.56 =	8.65

The pol ratios for whole stalks and stalk orders were calculated by adding the contributions of the top, middle, and bottom thirds to obtain total stalk or stalk order pol ratio values. The following relationship was used to calculate the pol ratios.

$$\text{Whole Stalk (Order) Pol Ratio} = \left[\frac{\text{wt. top}}{\text{total wt. (top + middle + bottom)}} \times \text{Pol Ratio (top)}\right] + \left[\frac{\text{wt. middle}}{\text{total wt.}} \times \text{Pol Ratio (middle)}\right] + \left[\frac{\text{wt. bottom}}{\text{total wt.}} \times \text{Pol Ratio (bottom)}\right]$$

Similar relationships were used in computing the pol ratio combinations for the whole stool.

The absolute juice, pol percent in the top and bottom thirds of the stalks and stalk orders was used to calculate a top to bottom pol ratio (T/B ratio).

RESULTS AND DISCUSSION

Ripening of Field

Stalk counts and samples for sheath moisture, 8-10 internode moisture and sucrose/reducing sugars were taken monthly from April to August and pol ratio analyses were made in July and August at each of the four sites. Stalk counts were totaled and percentage damaged and dead stalks obtained. Moisture and sucrose/reducing sugar ratios were averaged to follow the ripening of the field (Table I and Figure 2). The data for each site at each month are shown in Appendix A.

No trends in percentage damaged stalks were apparent; however, the percentage dead stalks increased with increasing age of the crop. Sheath and 8-10 moisture declined with increasing age of the crop reaching values of 75.3 and 75.5 percent respectively, just prior to harvest. According to the crop logging method developed by Clements (1943 and 1948) leaf sheath moisture should drop to approximately 74% at the time of harvest. The sucrose/reducing sugar ratio had a gradual rise except for the month of May when this ratio was affected by irrigation and rainfall. This was in accordance with the findings of H.S.P.A. (Anonymous, 1960).

Average pol ratio for all sites decreased from 7.61 in July to 7.22 in August (Table II). Pol ratio samples taken by the Oahu Sugar Company from this field (Sample Sta. No. 3) gave a pol ratio 7.34 in July and 7.49 in August. The actual pol ratio of the whole field No. 145 was 7.86. Separate information for the 11 acre plot 145 (1) was not available.

TABLE I. AVERAGE STALK COUNTS AND RIPENING INDICES FOR 4 SITES OF FIELD NO. 145 (1) BLOCK I OF OAHU SUGAR COMPANY

Month	Total Stalks	Damaged Stalks	Damaged Stalks %	% Dead Stalks	Sheath Moisture	8-10 Moisture	8-10 Suc/red Sugar Ratio
April	51	26	51	6	81.06	80.05	2.64
May	45	19	42	9	81.11	80.53	1.70
June	74	24	32	8	79.59	80.67	2.31
July	71	39	55	13	77.67	77.74	3.61
August	90	30	30	12	75.29	75.50	5.56

TABLE II. POL RATIO VALUES FROM 4 SITES IN FIELD 145 (1) BLOCK I OF OAHU SUGAR COMPANY

		Site				
Month	Stool	I	II	III	IV	Average
July	1	6.54	7.04	7.81	9.37	
	2	6.51	6.70	7.53	9.27	
Average		6.52	6.94	7.78	9.31	7.61
August	1	6.73	8.44	7.06	9.01	
	2	6.38	8.68	8.52	6.46	
Average		6.42	8.47	7.94	8.70	7.22

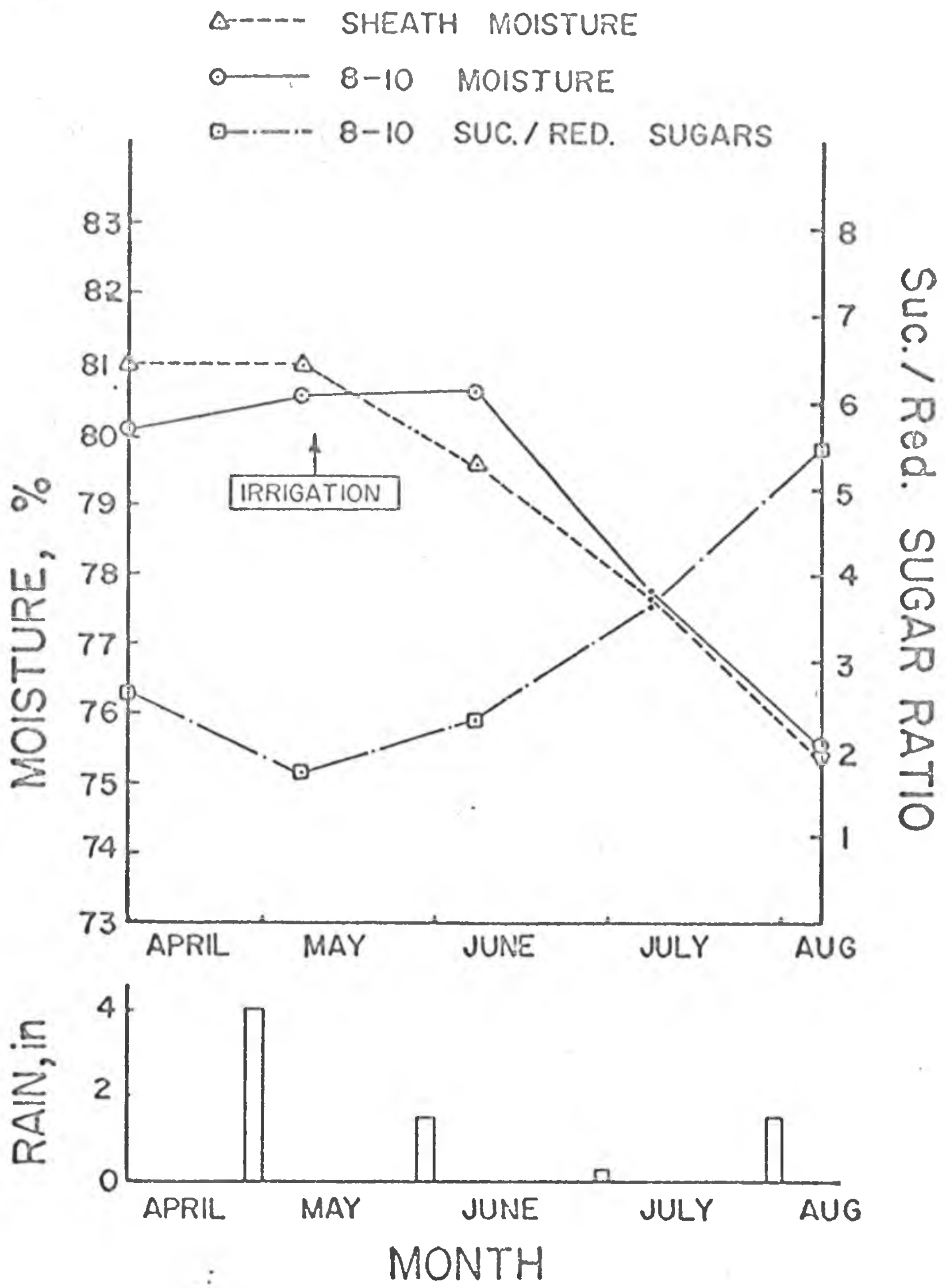

FIGURE 2. PERCENTAGE SHEATH MOISTURE, 8-10 INTERNODE MOISTURE AND 8-10 SUC/RED. SUGARS WITH PROGRESSIVE MATURITY.

Variability in Cane

In July and August, the individual stalks at site 2 and the stalk orders at sites 1, 3 and 4 were analyzed for pol ratio. The pol ratio data for August, a few days before harvest, were used to study the variability among stalks, stalk orders, stools and sites.

Variability in Stalks of Adjacent Stools:

The coefficients of variation were calculated to give a measure of variability within the various stalk orders. The coefficients of variation increased with the age of the stalk (Table III), but were within acceptable limits for an experiment of this type.

TABLE III. MEANS, STANDARD DEVIATIONS AND COEFFICIENTS OF VARIATION OF POL RATIO WITHIN STALK ORDERS FOR ALL STALKS HARVESTED FROM SITE 2

Stalk Order	Number	Mean	Standard Deviation	Coefficient of Variation
Primaries	9	8.06	1.25	15
1st S.S.	3	6.93	0.71	10
2nd S.S.	5	12.00	0.91	7

The differences in pol ratio of primary stalks of two adjacent stools were nonsignificant (Table IV) and show that stools at any one site were not different.

TABLE IV. ANALYSIS OF VARIANCE OF PRIMARY STALKS OF TWO ADJACENT STOOLS

Source	D.F.	M.S.
Between stools	1	0.96 N.S.
Within stools	7	1.56
Total	8	

Stalk order and site variability:

Stalk order and site variations were evaluated with analysis of variance based on pol ratio data (Table V). The four sites were not different from each other although significant differences between sites probably could be expected if a large field with considerable soil and topographic variations were randomly sampled. The unweighted mean pol ratio for 8 stools collected from four sites was 7.66 ± 1.1. The coefficient of variation was 14.4% and indicates that variation among the stools was relatively high. Stalk orders were found to be different from each other and the differences between stalk order means were further examined with Duncan's multiple range test. The pol ratio mean for 1st S.S. (7.04) was significantly different from the 2nd S.S. mean (9.21); the difference between primary (8.02) and 1st or 2nd season sucker means were not significant. Although the differences between primaries and first season suckers were not significant, the higher pol ratio for primaries would indicate overmaturity. These results are similar to those reported by H.S.P.A. (1957) where primaries were found to be overmature and 1st S.S. at optimum maturity.

TABLE V. ANALYSIS OF VARIANCE OF SITES AND STALK ORDERS

Source	D.F.	M.S.
Site	3	2.92
Order	2	6.49*
Site X order	6	2.39
Error	5	0.83

*Significant at 5% level of probability.

Comparison of Indices

In order to establish a reliable index which can be easily sampled in the field, comparisons of various indices were made. The pol ratio of individual stalks, stalk orders and stools was taken as the standard. The indices compared with the pol ratio were sheath moisture, 8-10 internode moisture, 8-10 sucrose/reducing sugar, top/bottom absolute juice percent ratio (T/B ratio) and pol ratio of top, middle and bottom thirds of the stalk and stalk orders.

The available literature does not clearly specify what parts of the stalk have been used in determining the top/bottom sucrose ratio. In this study, stalks and stalk orders were divided into equal thirds for analysis and a top to bottom ratio was calculated from pol percent in absolute juice in the top and bottom thirds of the stalks and stalk orders.

Simple correlation coefficients were calculated for July and August data to establish the degree of relationship between the pol ratio and the other maturity indices.

Individual stalk comparisons:

Correlation coefficients were calculated for all possible pairs of variables for the 18 primaries and 1st S.S. harvested in July and August at site 2 (Table VI and Appendix B). Five 2nd S.S. which were less than 9 ft. in length and had zero values for the middle third were excluded. Sheath moisture, 8-10 moisture and pol ratio of thirds of the stalk were positively correlated with the pol ratio of the stalk as all decreased as the cane matured. Negative correlations were obtained for 8-10 sucrose/reducing sugars and T/B ratio as these indices increased with the increasing cane maturity and decreasing pol ratio. Pol ratios of thirds of the stalks were found to be highly correlated with the pol ratios of the stalks; the top third was highest, followed by middle and bottom thirds, respectively. All other correlation coefficients with pol ratio were not significant. Other significant correlation values among the various indices emphasize that indices based on the same fraction of the stalk are correlated with each other as was reported by H.S.P.A. (1960) for sheath moisture and 8-10 internode moisture and sucrose. High correlations between top and bottom thirds and whole stalk pol ratios and low correlations of other indices were also obtained when the five 2nd S.S. (n = 23) for site 2 were included (Figures 3, 4, 5, 6, 7 and 8). These are evident from the deviations of the various observations from the linear regression line.

TABLE VI. CORRELATION MATRIX FOR MATURITY INDICES OBTAINED FOR INDIVIDUAL STALKS (n = 18)

Variable Number	Pol Ratio 1	Sheath Moisture 2	8-10 int. Moisture 3	8-10 Suc/Red. 4	T/B Ratio 5	Pol Ratio		
						Top 6	Middle 7	Bottom 8
1	1.000	0.293	0.364	-0.230	-0.266	0.726**	0.721**	0.686**
2		1.000	0.752**	-0.505*	-0.764**	0.684**	-0.277	-0.064
3			1.000	0.551*	-0.667**	0.646**	-0.021	-0.038
4				1.000	0.655**	-0.412	-0.181	0.308
5					1.000	-0.796**	0.186	0.420
6						1.000	0.189	0.141
7							1.000	0.551*
8								1.000

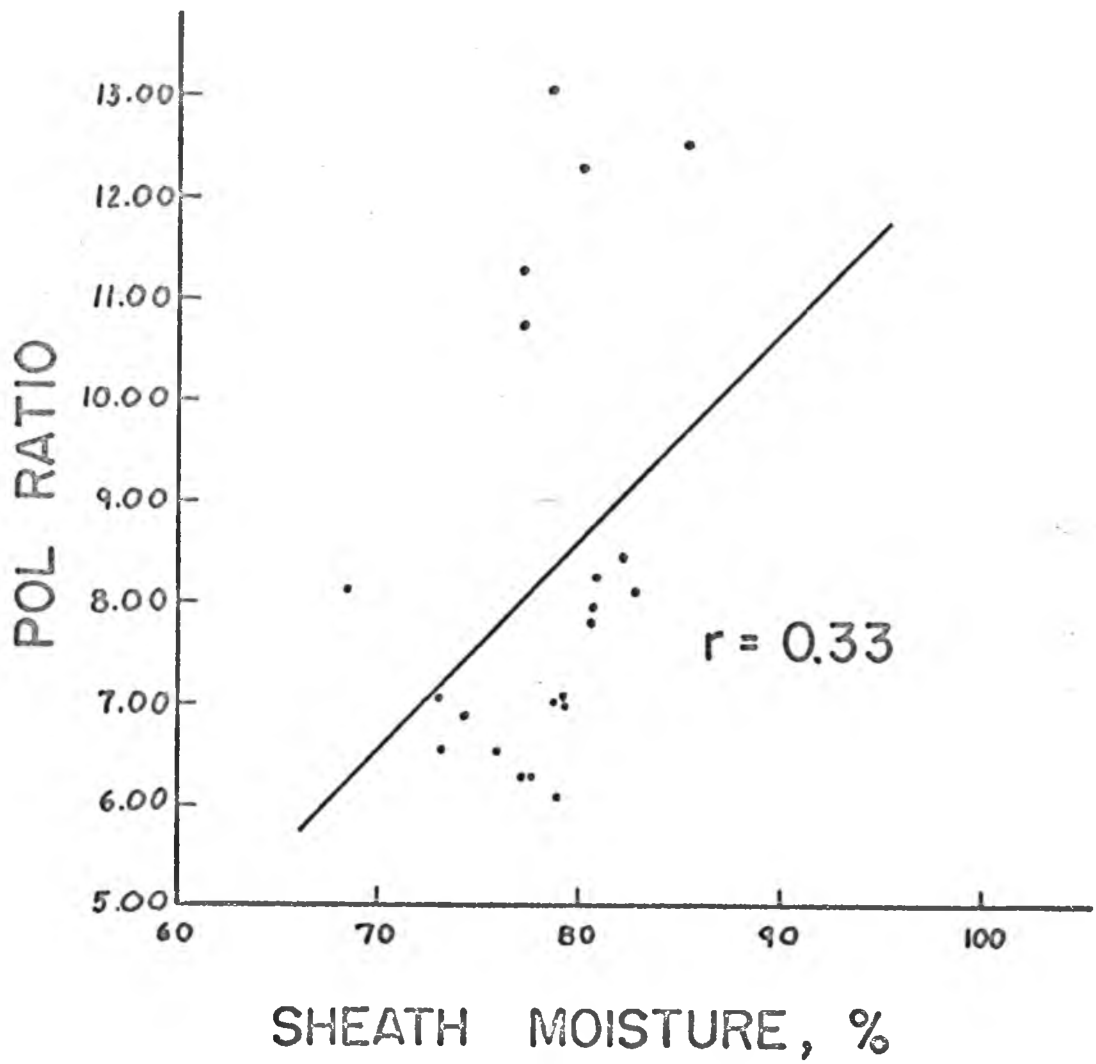

FIGURE 3. RELATIONSHIP BETWEEN SHEATH MOISTURE AND POL RATIO OF INDIVIDUAL STALKS.

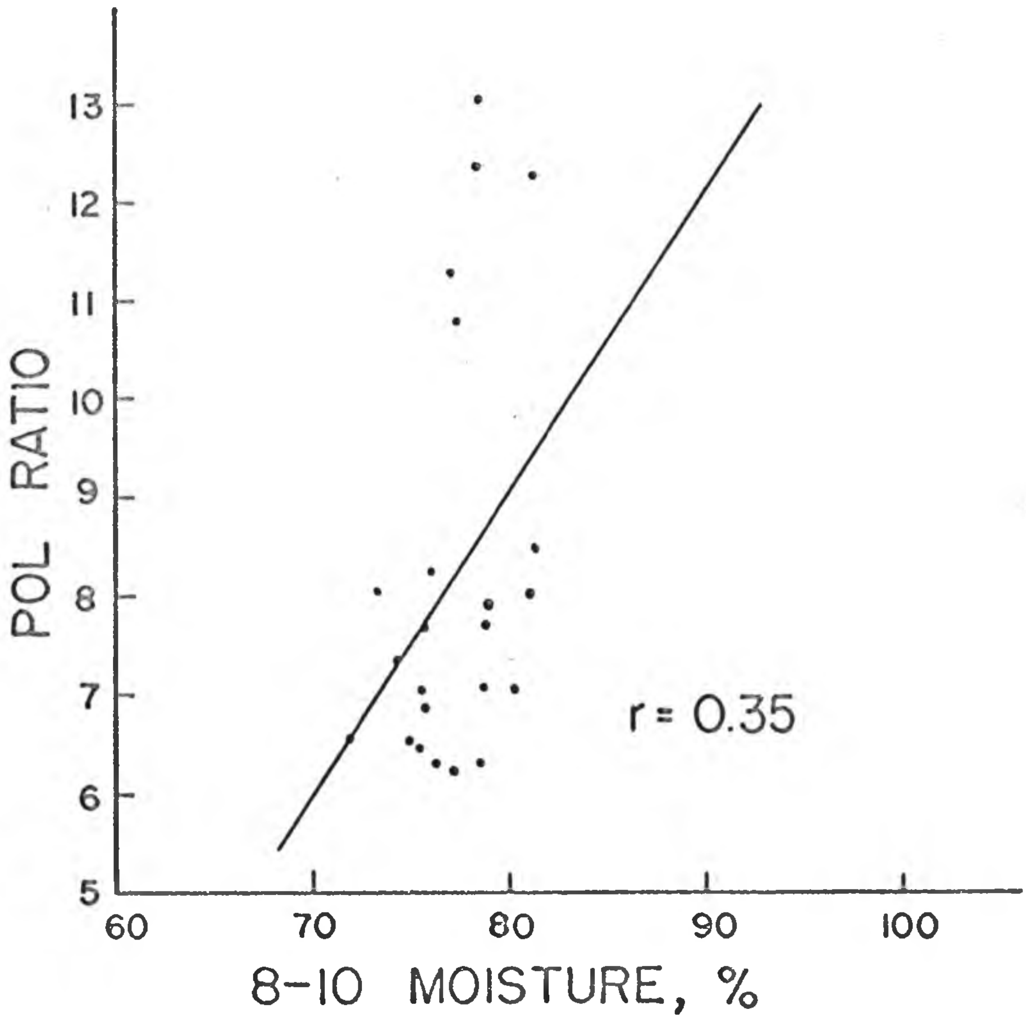

FIGURE 4. RELATIONSHIP BETWEEN 8-10 INTERNODE MOISTURE AND POL RATIO OF INDIVIDUAL STALKS.

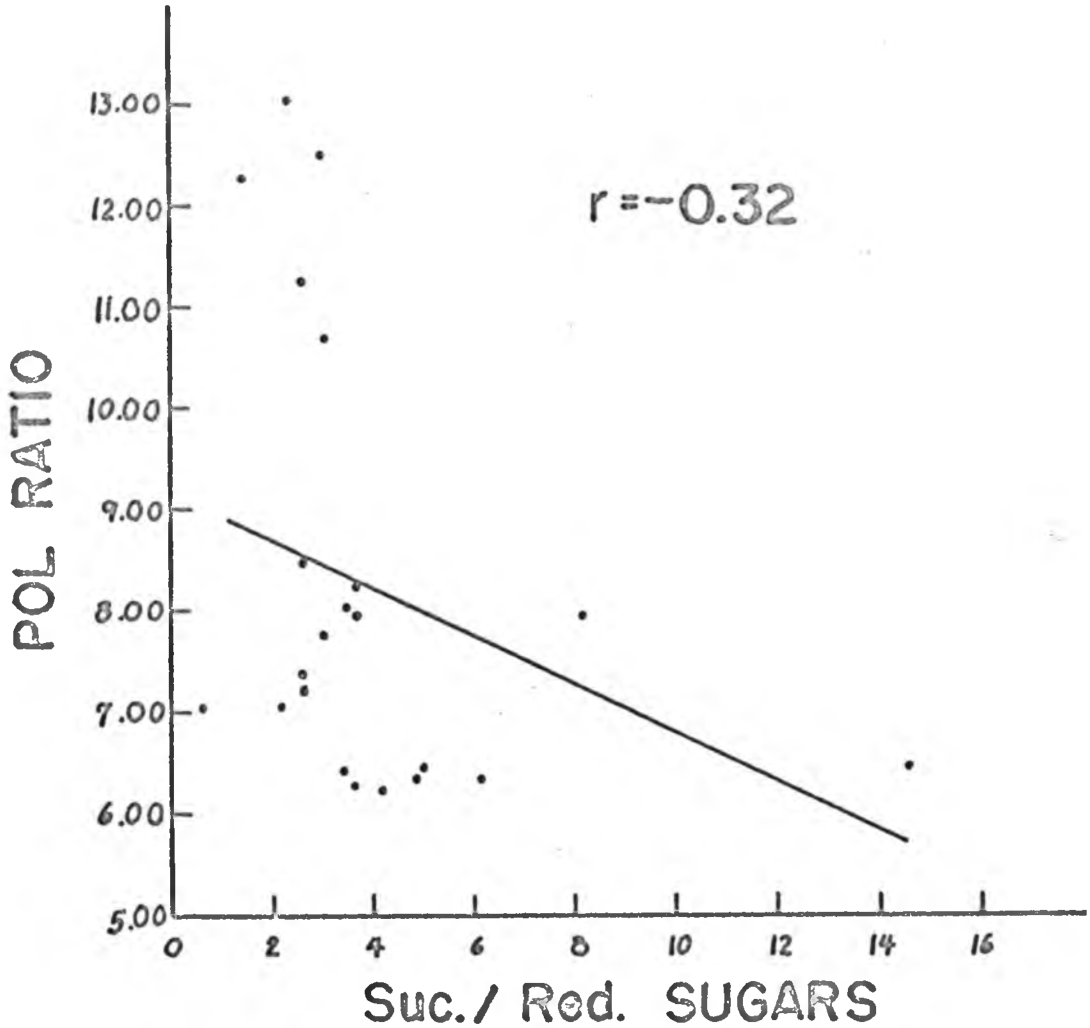

FIGURE 5. RELATIONSHIP BETWEEN 8-10 SUC/RED. SUGAR RATIO AND POL RATIO OF INDIVIDUAL STALKS.

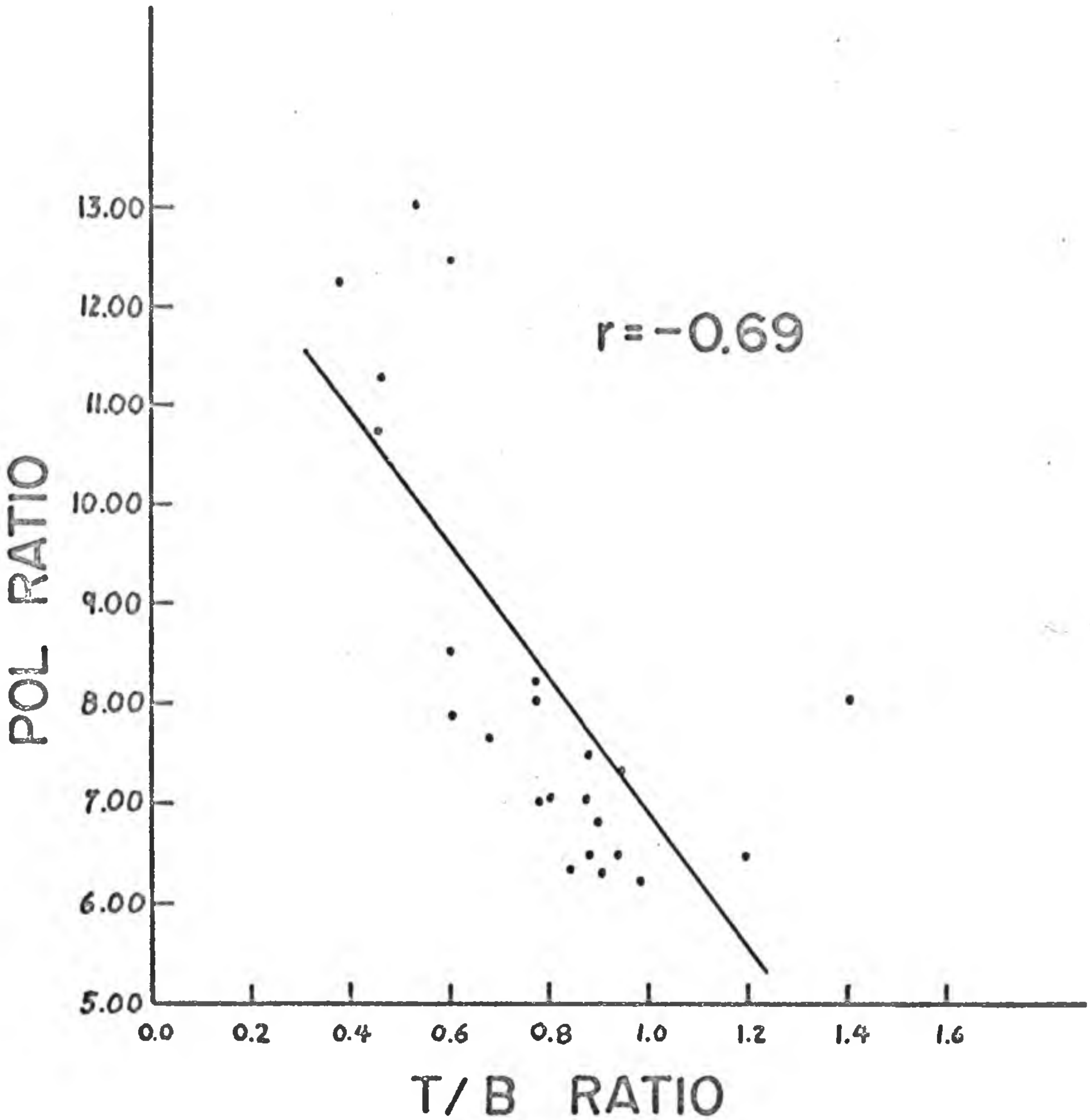

FIGURE 6. RELATIONSHIP BETWEEN TOP/BOTTOM ABSOLUTE JUICE RATIO AND POL RATIO OF INDIVIDUAL STALKS.

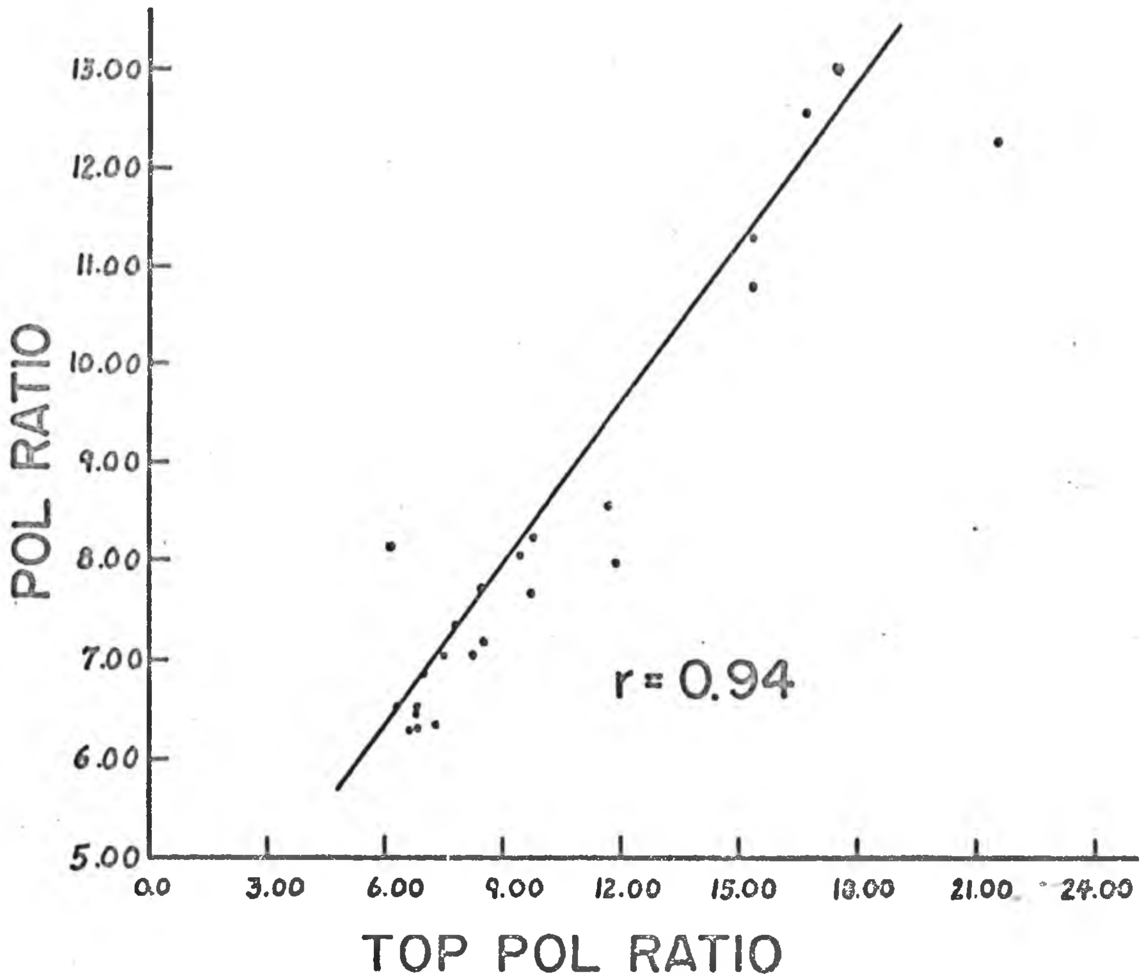

FIGURE 7. RELATIONSHIP BETWEEN TOP POL RATIO AND POL RATIO OF INDIVIDUAL STALKS.

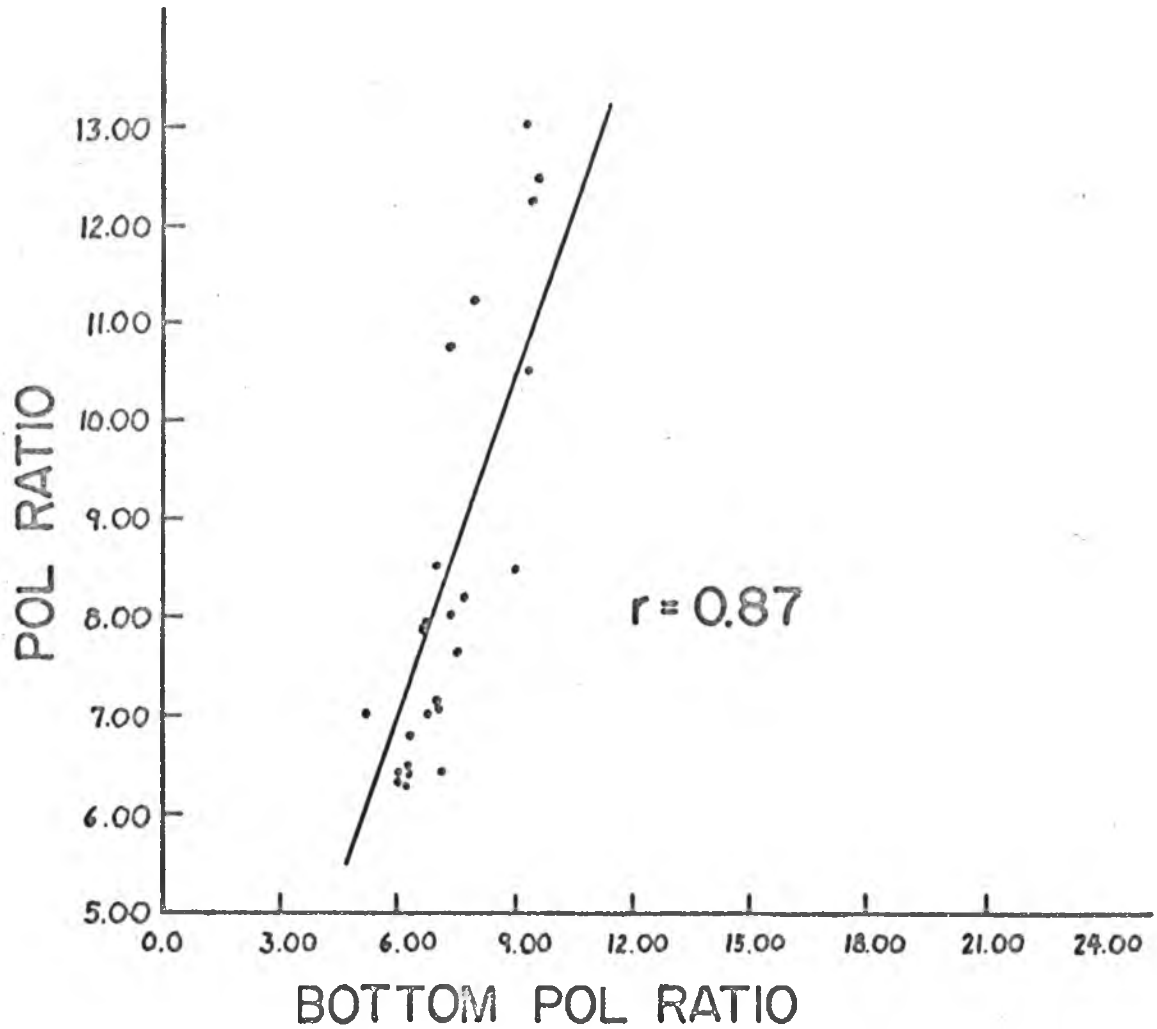

FIGURE 8. RELATIONSHIP BETWEEN BOTTOM POL RATIO AND POL RATIO OF INDIVIDUAL STALKS.

Stalk order comparisons:

The correlation coefficients for stalk orders sampled in July and August (Table VII and Appendix C) were similar but higher than the individual stalk values. Correlations among the various maturity indices generally were lower than those for individual stalks, however, the same coefficients were statistically significant. Highly significant correlations were obtained between the pol ratio of the top, middle or bottom thirds of stalk orders and those of the entire stalk orders. Correlation coefficients for top (0.846), middle (0.855) and bottom (0.839) are not considered to be different from each other. The sheath moisture correlation coefficient was much lower but was also significant at the 1% level. The lack of significant correlation between pol ratio and sheath moisture for individual stalks (Table VI) can be attributed to the fact that the 18 stalks at site 2 inadequately evaluate the effectiveness of sheath moisture as a maturity index. The 8-10 sucrose/reducing sugar ratio and T/B ratio were significantly correlated with pol ratio at the 5% level, but were lower than sheath moisture and very much lower than fractional pol ratio values.

Change in pol ratio correlations with maturity:

Correlation coefficients between entire and fractional stalk pol ratio values were calculated from the individual stalk and stalk order data for the months of July and August to evaluate the changes in correlation between fractional and the entire pol ratio values with increasing maturity (Table VIII). From July to August the correlation coefficients for top thirds increased with increasing maturity while those for the bottom decreased. Values for the middle increased for

TABLE VII. CORRELATION MATRIX FOR MATURITY INDICES OBTAINED FOR STALK ORDERS (n = 23)

Variable Pol Ratio	Pol Ratio 1	Sheath Moisture 2	8-10 Moisture 3	Suc/Red. Sugars 4	T/B Ratio 5	Top 6	Middle 7	Bottom 8
1	1.000	0.531**	0.371	-0.471*	-0.444*	0.846**	0.855**	0.839**
2		1.000	0.510*	-0.446*	-0.486*	0.600**	0.287	0.391
3			1.000	-0.796*	-0.525**	0.504*	0.182	0.228
4				1.000	0.577**	-0.595**	-0.294	-0.271
5					1.000	-0.795**	-0.051	0.013
6						1.000	0.470*	0.469*
7							1.000	0.911**
8								1.000

individual stalks and decreased for orders.

TABLE VIII. SIMPLE CORRELATION COEFFICIENTS BETWEEN THE ENTIRE AND FRACTIONAL STALK POL RATIO VALUES FOR THE MONTHS OF JULY AND AUGUST

	No. of Cases	Top	Middle	Bottom
Individual stalks				
July	10	0.567	0.707	0.842
August	8	0.885	0.757	0.442
Stalk orders				
July	14	0.719	0.925	0.935
August	16	0.847	0.825	0.784

Whole stool comparisons:

Sheath moisture, 8-10 moisture and 8-10 sucrose/reducing sugar ratios were not highly correlated with pol ratio of stalks or stalk orders, therefore they were not considered further. Twenty separate combinations of pol and pol ratio values from various parts of the stalks and stalk orders were made (Appendix D) and correlated with the pol ratio of the stools and with each other (Table IX). These combinations were made for 9 of 16 stools sampled in July and August which had both primaries and 1st S.S. As 2nd S.S. were found in a very few stools, only primary and 1st S.S. data were used in calculating correlation coefficients. The correlations were calculated to determine if an index could be developed which would correlate highly with the pol

TABLE IX. CORRELATION COEFFICIENTS OF VARIOUS COMBINATIONS OF STOOL AND ORDERS WITH POL RATIO OF STOOLS

Number	Index	Correlation Coefficient
1	Primary (Top + Mid) + 1st S.S. (Top + Mid)	0.9703**
2	Primary + 1st S.S.	0.9695**
3	Bottom (Stool)	0.9594**
4	Middle (Stool)	0.9535**
5	Primary (Mid) + 1st S.S. (Mid)	0.9483**
6	Primary (Mid)	0.9398**
7	Primary (Stool)	0.9293**
8	Primary (Top) + 1st S.S. (Top)	0.9292**
9	Primary (Bot) + 1st S.S. (Bot)	0.9192**
10	Top (Stool)	0.8908**
11	1st S.S. (Bot)	0.8353**
12	1st S.S. (Mid)	0.7858*
13	Primary (Top)	0.7795*
14	1st S.S. (Stool)	0.7551*
15	Primary (Bot)	0.7518*
16	1st S.S. (Top)	0.5427
17	T/B Absolute Juice (Stool)	0.3164
18	Primary Top/Bottom Pol Ratio	0.2312
19	1st S.S. Top/Bottom pol ratio	-0.2251
20	Stool Top/Bottom pol ratio	0.1629

ratio of the whole stool and require a minimum of labor to accomplish sampling.

Eleven combinations were highly correlated and significant at the 1% level, four at the 5% level and five, including 1st S.S. (top), T/B ratio and Top/Bottom pol ratio were not significant (Table IX). The high correlations were not unexpected as the pol ratio of the entire stool could be expected to correlate with the parts of the stool.

The highest 'r' value was obtained for the combination primaries (top + middle) + 1st S.S. (top + middle). The slightly lower value for the whole primaries + 1st S.S. (0.9695 vs. 0.9703) could be due to inversion of sucrose and an increased pol ratio in the butts of the primaries. Other fractions of the stools which included middle or bottom portions of the stalks were also very highly correlated with the whole stool but are quite difficult to sample. The difficulty of sampling and the very low correlations obtained between stool pol ratio and T/B ratio indices would essentially rule these out as estimators of cane maturity in Hawaii.

The 0.929 'r' value obtained for primaries (top) + 1st S.S. (top) and the ease of sampling the upper third of the stalks indicates that it would be worthwhile to investigate further the relationship between the top third or top half of the stool and the whole stool. The top of the stool may also form a comparatively more sensitive index of maturity within and between fields as indicated by the quite large improvement in the correlation from July to August (Table VIII). This research, as well as the results of Nath and Kashi Nath (1935) and others, show that the correlation between pol ratio of the tops and the whole stool can be expected to improve as ripening progress while the correlation for the bottom remains constant or declines. The sensitivity required to distinguish between two fields of similar age may be found only in the increasing pol ratio of the upper part of the stool. The reduction in labor required to sample only stool tops would allow several samples to be taken in a field for the same cost of acquiring one pol ratio value by present sampling methods.

SUMMARY AND CONCLUSIONS

A cane maturity study was undertaken to evaluate the sensitivity of various cane maturity indices and to explore the possibility of developing an easily sampled, sensitive index of cane maturity. Stalks were differentiated into orders and sampled for sheath moisture, 8-10 moisture, 8-10 sucrose/reducing sugar ratio, T/B ratio and pol ratio of the top, middle and bottom thirds. The above indices were compared with whole stalk, stalk order and stool pol ratio values. Stalk, stalk order and site variability were evaluated from pol ratio data. The results are summarized as follows:

1. Ripening of the field progressed normally as indicated by decreasing sheath and 8-10 moisture values and increasing 8-10 sucrose/reducing sugar ratios.

2. Variability within stalk orders increased in the order primaries, 1st S.S., and 2nd S.S., however, no coefficient of variation exceeded 15%. The pol ratio of 2nd S.S. was greater than for 1st S.S. but adjacent stools and sampling sites were not different from each other.

3. Pol ratio of thirds of the stalk was the only maturity index significantly correlated with the pol ratio of the whole stalk. Several maturity indices were correlated with stalk order pol ratio but were very much lower than fractional stalk pol ratio values. The correlation between the pol ratio of the top third and the whole stalk or stalk order increased with increasing maturity while those for the bottom decreased.

4. Correlations between the pol ratio of parts of the stool and the whole stool indicate that primaries and first season suckers provide the best estimates of the stool pol ratio. The results indicate that top + middle portion or the top alone of primaries and 1st S.S. may provide a more sensitive index of maturation than a combination which includes the stool bottom.

The pol ratio analysis is far superior to any other index as an estimator of cane maturity even when fractions of the stool are considered. The top portion of the stalk appears to be a more sensitive cane maturity index as its pol ratio increases with maturity while those of the middle and bottom remain essentially constant or decline. The high correlation obtained between whole stool pol ratio and primary + 1st S.S. tops and the ease of sampling the upper third of the stalks shows that the relationship between the top third or top half of the stool and the whole stool should be investigated further.

The reduction in labor required to sample only stool tops would allow several samples to be taken for the same cost of acquiring one pol ratio value by present sampling methods.

APPENDIX A. SHEATH MOISTURE, 8-10 STALK MOISTURE AND SUC/RED. SUGARS FOR FOUR SITES

Site No.	I			II			III			IV		
Months	Sheath Moisture	8-10 Stalk Moisture	8-10 Suc/Red.	Sheath Moisture	8-10 Stalk Moisture	8-10 Suc/Red.	Sheath Moisture	8-10 Stalk Moisture	8-10 Suc/Red.	Sheath Moisture	8-10 Stalk Moisture	8-10 Suc/Red.
April	81.42	79.38	2.55	81.20	79.49	2.93	80.30	81.37	2.23	81.36	79.10	3.12
May	80.92	80.25	1.67	81.87	80.59	1.93	80.06	81.35	1.21	81.54	78.55	1.48
June	79.21	79.25	2.93	81.37	82.73	1.54	80.47	80.77	2.04	82.29	85.92	0.85
July	76.47	77.39	3.63	78.03	76.81	4.28	78.12	78.79	3.23	76.74	76.20	3.17
August	73.48	74.16	7.00	78.26	77.37	3.67	75.26	77.86	3.62	78.58	77.70	3.13

APPENDIX B. CANE MATURITY STUDIES ON INDIVIDUAL STALKS FROM SITE II, OAHU SUGAR CO. FIELD 145(1)

Month	Stool	Order	Stalk	Pol ratio	8-10 Sheath Moisture	8-10 Stalk Moisture	8-10 Suc/Red.	A. J. Pol Top/Bottom	Pol Ratio Top	Pol Ratio Middle	Pol Ratio Bottom	Wt. of Stalk, g
July	1	1	1	8.16	68.62	73.50	7.98	1.41	6.15	9.65	8.49	5881
"	1	1	2	8.06	82.74	81.30	3.54	0.77	9.49	7.58	7.37	4166
"	1	1	3	6.36	78.88	78.30	6.16	0.84	7.36	5.95	6.03	4912
"	1	2	5	7.19	79.08	78.70	2.62	0.87	8.00	6.80	7.03	6580
"	1	2	6	6.44	78.93	75.30	3.38	0.89	6.83	6.62	6.06	7521
"	1	2	7	7.37	79.13	74.50	2.55	0.94	7.62	7.62	7.07	5241
"	2	1	1	6.83	74.17	75.70	4.88	0.91	7.07	7.28	6.28	5316
"	2	1	3	6.23	77.53	77.30	4.22	0.98	6.61	5.76	6.41	6196
"	2	2	1	7.94	80.46	78.90	3.69	0.61	11.90	7.15	6.71	3996
"	2	2	2	8.23	80.75	76.10	3.64	0.78	9.73	7.00	7.67	4690
August	1	1	2	7.01	72.97	75.50	0.63	0.77	7.49	7.88	5.73	5490
"	1	1	4	7.06	79.08	80.20	2.19	0.80	8.27	6.45	6.74	6869
"	1	1	5	6.29	77.29	76.20	3.67	0.91	6.85	5.95	6.15	5115
"	1	1	7	7.67	78.36	75.70	2.99	0.68	9.69	7.02	6.64	4530
"	1	2	2	7.76	80.50	78.70	3.07	0.88	8.40	7.35	7.50	2688
"	1	2	3	6.53	72.96	71.90	14.57	1.17	6.31	5.80	7.23	3553
"	1	2	4	6.52	75.86	75.00	5.12	0.95	6.74	6.62	6.33	5244
"	1	3	1	12.27	80.26	80.20	1.48	0.37	22.18	0.00	9.36	3429
"	1	3	2	10.78	77.28	77.40	3.33	0.46	15.38	0.00	7.39	2479
"	1	3	3	12.49	85.40	78.20	3.04	0.60	16.68	0.00	9.84	2317
"	1	3	4	13.10	78.47	78.50	2.34	0.53	17.49	0.00	9.25	2038
"	1	3	5	11.27	77.05	77.00	2.63	0.51	15.38	0.00	7.94	1864
"	2	1	4	8.54	81.93	81.30	2.61	0.61	11.62	7.86	6.95	4831

APPENDIX C. CANE MATURITY STUDIES ON STALK ORDERS FROM ALL SITES, OAHU SUGAR CO. FIELD 145(1)

Month	Site	Stool	Order of Stalk	Pol Ratio	Sheath Moisture	8-10 Stalk Moisture	8-10 Stalk Suc/Red. Sugars	A. J. Pol Top/Bottom	Pol Ratio Top	Pol Ratio Middle	Pol Ratio Bottom	Wt. of Stalks of Order
July	I	1	1	6.90	75.92	75.86	4.95	0.91	7.22	6.97	6.60	16,767
"	I	1	2	6.82	75.94	76.50	3.05	0.74	8.50	6.25	6.25	2,845
"	I	2	1	7.77	75.04	77.53	3.64	0.60	10.79	6.65	6.48	19,298
"	I	2	3	7.34	76.40	82.20	1.82	0.76	8.96	6.72	6.67	2,723
"	II	1	1	7.54	76.74	77.70	5.90	0.84	7.45	7.83	7.34	14,909
"	II	2	1	6.50	75.85	76.50	4.55	0.95	6.83	6.46	6.35	11,512
"	II	2	2	8.10	80.60	77.50	3.67	0.69	10.23	7.07	7.18	8,686
"	III	1	1	7.82	77.30	78.70	3.16	0.90	8.71	7.11	7.81	107,265
"	III	2	1	8.70	75.67	78.00	2.67	0.66	11.46	7.86	7.53	13,160
"	IV	2	2	7.69	74.07	76.60	3.59	0.93	8.26	7.49	7.49	4,607
August	I	1	1	6.73	75.46	76.15	4.11	0.95	7.19	6.30	6.81	25,124
"	I	2	1	6.18	74.02	74.05	7.93	0.97	6.62	5.80	6.20	84,786
"	I	2	2	6.50	73.27	73.56	7.12	0.97	6.70	6.26	6.57	96,084
"	I	2	3	7.97	76.22	77.70	2.90	0.62	10.33	7.54	6.50	2,940
"	II	1	1	7.74	76.92	76.90	2.37	0.88	8.48	7.60	7.21	34,980
"	II	1	2	6.81	76.44	75.20	7.59	1.00	7.14	6.52	6.87	11,485
"	II	1	3	12.01	79.69	78.26	2.56	0.49	17.36	9.36	8.59	12,127
"	III	1	2	6.37	75.54	77.00	4.43	1.06	7.43	5.97	6.10	7,239
"	III	2	1	8.48	74.87	76.82	3.45	0.91	8.48	9.35	7.64	20,862
"	IV	1	1	10.67	77.10	76.70	4.09	1.07	9.61	11.61	10.57	15,654
"	IV	1	2	7.18	78.06	76.80	4.28	0.81	8.49	6.83	6.87	7,442
"	IV	1	3	7.92	78.58	79.95	1.78	0.64	11.30	6.63	7.32	11,514
"	IV	2	2	6.46	75.05	74.70	5.50	0.87	7.09	6.45	6.01	4,682

APPENDIX B. CALCULATED STOOL, FRACTIONAL STOOL POL RATIO AND ABSOLUTE JUICE VALUES FOR JULY AND AUGUST

Month	Site	Stool	Pol Ratio	T/B Absolute Juice	Stool Pol Ratio: Top	Stool Pol Ratio: Middle	Stool Pol Ratio: Bottom	Order Pol Ratio: Primary	Order Pol Ratio: 1st Season Sucker	Order Pol Ratio: Primary & 1st Season Sucker	Order Pol Ratio: Primary Top	Order Pol Ratio: Primary Middle	Order Pol Ratio: Primary Bottom
July	I	1	6.89	0.93	7.42	6.89	6.56	6.90	6.82	6.89	7.22	6.97	6.60
"	II	1	7.44	0.91	7.87	7.58	7.04	7.56	7.39	7.44	7.65	7.83	7.34
"	II	2	7.19	0.82	8.52	6.70	6.70	6.50	8.10	7.19	6.83	6.46	6.35
"	IV	1	10.82	0.92	10.47	13.09	9.37	11.07	10.59	10.82	9.68	14.25	9.24
"	IV	2	9.33	0.97	10.60	9.44	9.27	10.28	7.69	9.53	12.95	9.96	9.96
August	I	2	6.38	0.85	6.73	6.04	6.40	6.18	6.50	6.35	6.62	5.80	6.20
"	II	1	8.44	0.79	10.55	7.47	7.51	7.76	6.81	7.51	8.48	7.60	7.21
"	III	1	7.06	0.94	7.66	6.40	7.25	7.72	6.37	7.06	7.87	6.77	8.58
"	IV	1	9.01	0.82	9.83	9.52	8.40	10.67	7.18	9.54	9.61	11.61	10.57
July	I	1	6.72	0.68	10.56	6.66	6.51	7.77	0.01	0.01	10.79	6.65	6.68
"	III	1	7.82	0.90	8.71	7.11	7.81	0.01	0.01	7.82	0.01	0.01	0.01
"	III	2	8.70	0.66	11.46	7.86	7.53	8.70	0.01	8.70	11.46	7.86	7.53
August	I	1	6.73	0.95	7.19	6.30	6.81	6.73	0.01	6.73	7.19	6.30	4.81
"	II	2	8.68	0.34	10.13	7.86	8.11	8.62	8.93	8.68	0.13	7.86	7.71
"	III	2	8.52	0.70	8.96	9.35	7.57	8.48	0.01	0.01	8.49	9.35	7.64
"	IV	2	6.46	0.87	7.09	6.45	6.01	0.01	6.48	6.48	0.01	0.01	0.01

Month	Site	Stool	1st Season Sucker Top	1st Season Sucker Middle	1st Season Sucker Bottom	Primary & 1st Season Sucker Top	Primary & 1st Season Sucker Middle	Primary & 1st Season Sucker Bottom	Primary & 1st Season Sucker Top & Middle	Stool Top/Bottom Pol Ratio	Primary T/B Pol	1st Season Sucker T/B Pol Ratio
July	I	1	8.50	6.25	6.25	7.42	6.89	6.56	7.09	1.13	1.09	1.36
"	II	1	8.09	7.48	6.93	7.87	7.58	7.04	7.70	1.12	1.01	1.17
"	II	2	10.23	7.07	7.18	8.52	6.70	6.70	7.52	1.27	1.38	1.42
"	IV	1	11.01	12.95	9.49	10.47	13.09	9.37	12.19	1.12	1.05	1.16
"	IV	2	8.26	7.49	7.49	10.60	9.44	9.27	9.93	1.14	1.30	1.10
August	I	2	6.70	6.26	6.57	6.64	6.04	6.40	6.32	1.05	1.07	1.02
"	II	1	7.14	6.52	6.87	8.21	7.35	7.11	7.76	1.40	1.18	1.04
"	III	1	7.43	5.97	6.10	7.66	6.40	7.25	6.92	1.06	0.92	1.22
"	IV	1	8.49	6.83	6.87	9.30	10.07	9.27	9.75	1.17	0.91	1.24
July	I	1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.62	1.64	
"	III	1	0.01	0.01	0.01	8.71	7.11	7.81	7.82	1.12	0.01	
"	III	2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.52	1.52	
August	I	1	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.05	1.06	
"	II	2	0.04	0.01	8.95	0.01	0.01	0.01	0.01	1.29	0.07	
"	III	2	0.01	0.01	0.01	0.01	0.01	0.01	0.01	1.18	1.11	
"	IV	2	7.09	6.45	0.01	0.01	0.01	0.01	0.01	1.18	0.01	

BIBLIOGRAPHY

Anonymous. 1957. Soil and plant material analysis by rapid chemical methods. IV. Hawaiian Planters' Records Vol. 48: 212-230.

Clements, H. F. 1948. Crop logging of sugarcane in Hawaii. Better Crops with Plant Food 32: 11-18; 45-48.

______________. 1962. Experience in Hawaii -- The ripening of sugarcane. SUGAR y AZ UCAR, March 1952: 29-33.

______________, Edison W. Putman and Gladys L. N. Yee. 1968. Tissue analysis -- The basis for crop logging and crop control. University of Hawaii Cooperative Extension Service Misc. Pub. 51: 17-32.

______________ and T. Kubota. 1943. The primary index, its meaning and application to crop management with special reference to sugarcane. Hawaiian Planters' Records Vol. 47: 257-297.

______________, G. Shigeura and E. K. Akamine. 1948. Ripening of sugarcane. Hawaii Agricultural Expt. Station Report, pp. 120-124.

Dodds, H. H. 1935. A note on the methods of maturity determinations in South Africa. Int. Soc. Sugarcane Tech. Proc. 5th Cong., pp. 165-166.

Hawaiian Sugar Planters' Association Experiment Station Annual Report, Vol. LVI, No. 1, 1960.

Humbert, Roger P. 1968. The growing of sugarcane. Revised edition. Elsevier Publishing Company, Amsterdam, London, New York.

Johan, Hance. 1962. Harvesting experiment plots of Pioneer Mill Co. Hawaiian Sugar Technologists' Report, 1962.

Kerr, H. W. 1935. Maturity determinations in Queensland. Int. Soc. Sugarcane Tech. Proc. 5th Cong., pp. 166-172.

Nath, B. V. 1919. Studies in the chemistry of sugarcane. Original unavailable. Information abstracted from Nath, B. V. and Kashi Nath, 1935. Int. Soc. Sugarcane Tech. Proc. 5th Cong., pp. 173-174.

__________ and Kashi Nath. 1935. The top/bottom ratio method of determining the maturity of sugarcane. Int. Soc. Sugarcane Tech. Proc. 5th Cong., pp. 172-189.

Official methods of Hawaiian Sugar Technologists for control of sugar factories - 1955. Hawaiian Sugar Technologists, Honolulu, Hawaii.

Pyne, J. H. and H. I. Mahon. 1956. The pol ratio method of evaluating the cane quality. Int. Soc. Sugarcane Tech. Proc. 9th Cong., pp. 436-447.

Stevenson, G. C. 1935. Note on maturity experiments being conducted in Barbadas. Int. Soc. Sugarcane Tech. Proc. 5th Cong., pp. 164-165.

Yates, R. A. 1969. Assessment of the effect of inter-cane variability on sampling and harvesting of stalks of sugarcane. Agronomy Journal 61: 113.