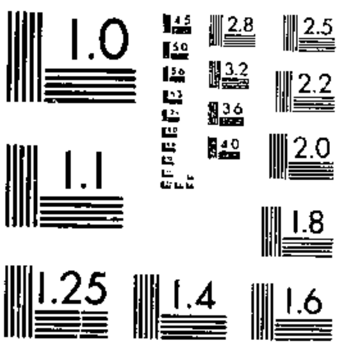
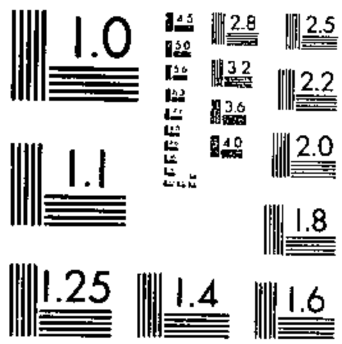
TB 1194 (1959) USDA TECHNICAL BULLETINS UPDATA
BREEDING BEHAVIOR OF CERTAIN AGRONOMIC CHARACTERS IN PROGENIES OF
HEBERT, L.P., HENDERSON, M.T. 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963 A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

BREEDING BEHAVIOR OF Certain Agronomic Characters in Progenies of Sugarcane Crosses

AT THE UNITED STATES SUGARCANE FIELD STATION, HOUMA, LA.

Technical Bulletin No. 1194

UNITED STATES DEPARTMENT OF AGRICULTURE
In cooperation with
Louisiana Agricultural Experiment Station

CONTENTS

Hebert, Leo P 1913–

Breeding behavior of certain agronomic characters in progenies of sugarcane crosses at the United States Sugarcane Field Station, Houma, La. [By Leo P. Hebert and M. T. Henderson. Washington, U. S. Govt. Print. Off., 1959]

54 p. illus. 24 cm. (U. S. Dept. of Agriculture. Technical bulletin no. 1194)

In cooperation with Louisiana Agricultural Experiment Station. "Literature cited": p. 54.

1. Sugar-cane[—Breeding] 2. Sugar-cane—Varieties. [2. Sugar-cane Hybrids] 3. Hybridization, Vegetable. I. Henderson, Merlin T., joint author. II. Title. (Series)

S21.A72 no. 1194 631.523 Agr 59-16

U. S. Dept. of Agr. Libr. for Library of Congress 1Ag84Te no. 1194

Washington, D. C. **Issued January 1959**

For sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 25 cents

BREEDING BEHAVIOR OF
Certain Agronomic Characters in Progenies of Sugarcane Crosses

AT THE UNITED STATES SUGARCANE FIELD STATION, HOUMA, LA.

By LEO P. HEBERT, research agronomist, *Crops Research Division, Agricultural Research Service, United States Department of Agriculture*, and M. T. HENDERSON, Professor of Agronomy, *Louisiana Agricultural Experiment Station* [1]

INTRODUCTION

Development of sugarcane varieties meeting the exacting demands of the Louisiana sugar industry presents many problems in a number of related fields of agricultural research, because conditions under which sugarcane is grown in this State differ from those of most sugar-producing countries. To be acceptable a variety normally must possess some degree of resistance to certain diseases, insects, and inversion of sucrose after cutting. In addition, major consideration is given to several agronomic and chemical characteristics that are associated with the ability of a new variety to produce relatively high yields of cane and sugar from two to three successive crops from one planting, and with its adaptability to mechanical harvesting.

Among the characters that determine yield of cane and sugar are stalk diameter, number of stalks per stool (tillering ability), resistance to lodging, Brix or density (total soluble solids), and percentage of sucrose in the juice.

Large stalks are also preferable from the standpoint of grower acceptance; of two varieties with equal yielding ability, the one having the stalks with the larger diameter is preferred. Good stooling, or profuse tillering, especially when occurring early in the growing season, is desirable, because it affords better coverage of the row surface and consequently more effective control of weeds in addition to contributing toward higher yields of cane. Quality of the juice as determined by the Brix and percentage of sucrose is a very important consideration in variety selection. The quality and quantity of the juice are important components of varietal performance.

To be adaptable to mechanical harvesting with the commercial machines now available (1957), a variety must be fairly erect in growth habit. Varieties satisfactory in other respects may be discarded, because they are not adapted to machine harvesting.

---

[1] The authors are indebted to L. G. Davidson, research agronomist, Crops Research Division, for collaborating in obtaining analyses of juice for Brix and sucrose.

Each year a large number of individual seedlings from crosses at the United States Sugarcane Field Station, Canal Point, Fla., and, more recently, from crosses made at Grand Isle and Baton Rouge, La., are grown as single stools by the United States Department of Agriculture at the Sugarcane Field Station, Houma, La., for the purpose of selecting varieties satisfying the requirements listed above. Considerable labor and funds are involved in this selection work each year. Information is needed that will make it possible to predict with a reasonable degree of certainty the manner in which important characters are inherited in progenies from different crosses and the behavior of these characters in single stools of individual seedlings and subsequently in clones established from these single stools. For example, with the characters commonly used in appraising the value of individual plants, which ones are reliable as criteria in making selections in any one year? Or, to state it in another way, what is the association between the performance of individual single stools and clones, or varieties established from the single stools?

A knowledge of the relation or association of different characters in single stools of individual seedlings and clones, and of the same character between these single stools and clones, would be of much value in the sugarcane breeding program.

The literature contains very little information on studies related to the performance of agronomic and chemical characters in sugarcane, especially in regard to their relative performance in single stools and clones. This is particularly true of the work in Louisiana, where an extensive breeding program has been in progress since 1919. The program brought the industry from practically total failure in 1925 to its highest cane yield per acre in Louisiana history during 1955. All but 2 percent of the sugarcane acreage in 1955 was planted to varieties produced at Canal Point, Fla., and tested in Louisiana, according to a survey made by Hebert (*10*).[2]

During the fall of 1953, a study of breeding behavior of the characters—stalk diameter, number of stalks per stool, erectness of stalks, Brix, and sucrose percentage in the juice—was begun at the Houma station with progenies of seven crosses made at the Canal Point, Fla., breeding station of the U. S. Department of Agriculture. The study was continued through the 1955 crop. It included observations of single stools as well as the plant cane, or first-year crop, and first stubble, or second-year crop, from the same planting of clones derived from these single stools.

[2] Italic numbers in parentheses refer to Literature Cited, p. 54.

REVIEW OF LITERATURE

Association of Characters Between Single Stools and Clones Established From Single Stools

In crosses between *Saccharum officinarum* and *S. spontaneum* the seedlings invariably had more tillers or stalks per plant than the clones derived from them, according to Raghaven (*14*), who studied the problem in India.

In Barbados, McIntosh (*12*) found that if a selection were made among the seedlings, workers usually selected only early-maturing ones and the clones established from the seedlings were all early maturing with a short growing season. To overcome this disadvantage in Barbados, all seedlings were replanted as clones at 10 months and allowed to grow until the following year, when selections were made from the clones. In Puerto Rico, Davis (*8*) eliminated all weak seedlings at the potting stage, and at 3½ months discarded all but the most vigorous ones. Davis reasoned that there was a close association between vigor in the seedling stage and in the clones.

Venkatraman (*17*) reported that a detailed inspection was not carried out with the original seedlings in India, because it was found that rankings of clones did not confirm ranking in the seedling stage. He also found that clones did not give results superior to those of the original stools, i.e., establishing clones from the single plants did not result in any improvement in the qualities of the plant.

Association Among Characters in the Same Year

Barber (*3, 4*) reported an inverse relation between sucrose and vigor and between purity and vigor with the material he studied in India. The smallest and least vigorous plants had the highest sucrose and purity. This was true whether the low yield was due to the genetic makeup of the plant or to diseases.

Mangelsdorf (*13*) reported a very high correlation between refractometer Brix and percentage of sucrose in the juice of cane.

Stokes[3] found low degrees of positive association between percent sucrose in the juice and percent fiber in the cane, sucrose and stalk height, sucrose and length of leaf, fiber and length of internode, fiber and diameter of stalk, fiber and stalk weight, and between fiber and stalk height, in varieties studied in Louisiana. A close association existed between stalk diameter and stalk weight, as might be expected.

Abbott (*1*) in Louisiana found that there was no association between vigor of cane and its susceptibility to red rot or between sucrose percentage and susceptibility to red rot among clones in advanced agronomic tests.

There was a correlation between cell size of the leaf and earliness of maturity, according to Dutt, Rao, and Hussainy (*9*). These investigators, working in India, observed that the size of the sto-

[3] STOKES, I. E. A BIOMETRICAL ANALYSIS OF CERTAIN CHARACTERS OF SACCHARUM OFFICINARUM. 34 pp. (Master's thesis, Tex. A. & M. College, College Station.) 1934.

mata in both upper and lower epidermis and the bulliform cells in the upper epidermis were smaller in early-ripening varieties and that this condition could be detected when seedlings were 3 months old.

Breeding Behavior of Characters

Venkatraman (*17*) evaluated the type of clones resulting from various combinations by making experimental crosses and growing small numbers of segregates resulting from them. He states that he was then able to determine which parents to employ for obtaining particular results.

Warner (*18, 19*) was of the opinion that selection percentage among the progenies tells only part of the story in respect to evaluation of clones as parents for use in Hawaii. Some parents that are highly sterile may yield few seedlings. In planning a crossing program he stated that special attention should be given to biparental crosses which bring together two elite parents, with particular emphasis on combinations in which the virtues and shortcomings of the two parents complement each other. He opposed selfing that reduces heterozygosity and recommended use as parents heterozygous clones that differed in economic characteristics, to insure highly variable populations from which to make selections.

Stevenson (*16*), in Barbados, cited a low correlation coefficient of -0.213 between stool weight and Brix, but he concluded that selection can be made on the basis of yield with a reasonable degree of certainty that some clones with high Brix will be taken. He maintained that the objective in a breeding program is to increase the percentage of individuals in a population that will be acceptable for commercial use. This can be done by selfing to purify the genotype, i.e., to eliminate all undesirable characters and develop breeding material for crossing in which the potentialities are predictable.

Dutt, Rao, and Hussainy (*9*) studied the inheritance of pithiness in sugarcane and found certain relationships associated with this character which depended on the combination of parents used. For example, in crossing 2 parents that had solid stalks, or did not have the pithy character, the progeny all had solid stalks; 2 parents that had the pithy character, or stalks that were not solid, bred true for that character; and in combinations of parents differing in degree of pithiness, the crosses in which the male parent was characterized with pithy stalks gave the higher percentage of pithy, or nonsolid, individuals, than the reciprocal.

Buzacott (*6*) found that progenies from crosses with Co. 290 generally have had low sucrose but that combinations of certain P.O.J. varities, such as 2727 and 2878, with Co. 290, gave progenies having high sucrose.

Brandes and Klaphaak (*5*) found that two mosaic-susceptible varieties selected from Chunnee crosses gave only susceptible seedlings when crossed together. The deleterious effect of mosaic was not great because of the Chunnee parentage. Kassoer, a natural hybrid of *Saccharum spontaneum* and *S. officinarum*, is resistant to mosaic and to most other diseases. In backcrosses of Kassoer to *S. officinarum* some susceptible and some resistant seedlings were obtained. The proportion of susceptible seedlings was greater in the second and third backcrosses than in the first backcross.

When Raghaven (*14*) crossed Co. 745, a clone selected from seedlings of *S. spontaneum* (Burma), with variety Co. 285, the offspring were all higher in Brix and sucrose than the *S. spontaneum* parent and many were as high as Co. 285 or higher.

Abbott (*1*) studied reaction of progenies to red rot in four crosses. Three of these crosses involved the resistant variety Co. 281, and one of the crosses was the resistant variety C. P. 1161 and the susceptible variety P.O.J. 2725. When Co. 281 was crossed with very susceptible varieties U. S. 1694 and C. P. 30–23, 25 to 30 percent of the progeny was resistant. In the cross of Co. 281 with moderately resistant P.O.J. 2878, almost 50 percent of the progeny was resistant. The crossing of resistant C. P. 1161 with very susceptible P.O.J. 2725 gave a larger proportion of very susceptible progeny than the cross of Co. 281 and U. S. 1694. Abbott considered Co. 281 × U. S. 1694 as being more desirable than P.O.J. 2725 × C. P. 1161, for the reason that the latter cross gave a higher percentage of very susceptible seedlings. In each case one susceptible and one resistant parent were involved. On the other hand, Co. 281 × P.O.J. 2878 was considered a better cross than Co. 281 × U. S. 1694 or P.O.J. 2725 × C. P. 1161 from the standpoint of yielding red-rot-resistant seedlings. From these data he concluded that resistance behaved as a recessive character and that genes for resistance were derived from *S. spontaneum*.

Azab[4] concluded that a variety need not be discarded as a potential parent in the breeding program because it is susceptible to red rot. He found that a variety may be able to transmit genes for resistance if at least a trace of *S. spontaneum* is present in its lineage, although the variety itself may be susceptible. According to Azab, resistance to red rot was inherited as a dominant character. *S. officinarum* lacks the dominant gene for resistance, and in addition it carries a dominant epistatic gene I which masks the expression of the gene for resistance of *S. spontaneum*. Arceneaux, Coleman, and Hebert (*2*), working with varieties in advanced agronomic tests, reported that individuals of the same progeny group varied widely as to the degree of injury from freezing. In every cross there were some seedlings that were more resistant than either of the parents, which suggested to them a typical case of multiple-factor inheritance. The study above was limited to 50 to 140 agronomic selections from each cross and did not represent random samples of the progenies of the various crosses, since the disease-susceptible and agronomically undesirable clones had been discarded.

---

[4] AZAB, Y. E. INHERITANCE OF RESISTANCE IN SUGARCANE TO MOSAIC AND RED ROT DISEASE. 304 pp. (Thesis, Ph.D., La. State Univ., Baton Rouge.) 1952.

MATERIALS AND METHODS

The study was made during the period 1953–55 of the progenies of 7 biparental crosses involving 11 clones of sugarcane, made in 1951 at the U. S. Sugarcane Field Station, Canal Point, Fla. The characters included were (1) stalk diameter, (2) erectness of stalk, (3) number of stalks per stool, (4) Brix by hand refractometer, and (5) sucrose by polarization. The crosses, parents of each cross, characteristics of the parents involved, and number of seedlings and of clones from each cross are given in table 1. Seedlings from the crosses were grown as individual plants in the field at the U. S. Sugarcane Field Station, Houma, La., as plant cane in 1952, and as first stubble in 1953 when the initial observations were made.

In the fall of 1953 records were taken on the first stubble of each single stool for stalk diameter, erectness of stalk, number of stalks per stool, and Brix. In November 1953 clones were established from first-stubble single stools of the 7 crosses. Sufficient material was used to establish 5-foot plots of each clone. When available, 150 clones of each cross were planted. Four plots of each parent were interspersed among the crosses. In November 1954 the clones were evaluated in the plant-cane crop for stalk diameter, erectness, and number of stalks per stool. In addition, Brix and the sucrose percentage in the crusher juice were determined for each clone and parent. In the fall of 1954, 75 clones from each of 2 of the crosses were planted in a randomized block experiment with 2 replicates of each clone and the parent variety. In November 1955 the clones that survived the winter were again evaluated in the first stubble crop for stalk diameter, erectness, number of stalks per stool, Brix, and sucrose percentage.

Stalk diameter was obtained by caliper measurements at the middle of the internode nearest the midpoint of the mature stalk. Values recorded represented the averages in millimeters of 5 or 6 stalks.

In ranking sugarcane as to erectness of stalk, a rating based on the following scale, in use at the Houma station for some time, was adopted: 1 = very superior; 2 = superior; 3 = average; 4 = inferior; and 5 = very inferior. Pictures illustrating those erectness classes are presented in figures 1 to 5. A variety must have at least a 4 rating to be adapted to mechanical harvesting in Louisiana.

Techniques for obtaining juice samples and for determining the Brix content of the juice have been described by Christianson (*7*) and Lennox (*11*). In this study Brix for all 3 years was determined in the field by hand-refractometer reading of the juice obtained with a Hawaiian-type punch. This special punch contains a reservoir in which juice from a number of stalks can be collected. Samples were taken from the center of the internode nearest the midpoint of the stalk. The juice from 5 different stalks was composited for each reading whenever 5 stalks were available.

TABLE 1.—*Sugarcane crosses, characteristics of parents, and number of individuals studied as single stools and as clones, Houma, La., 1953–55*

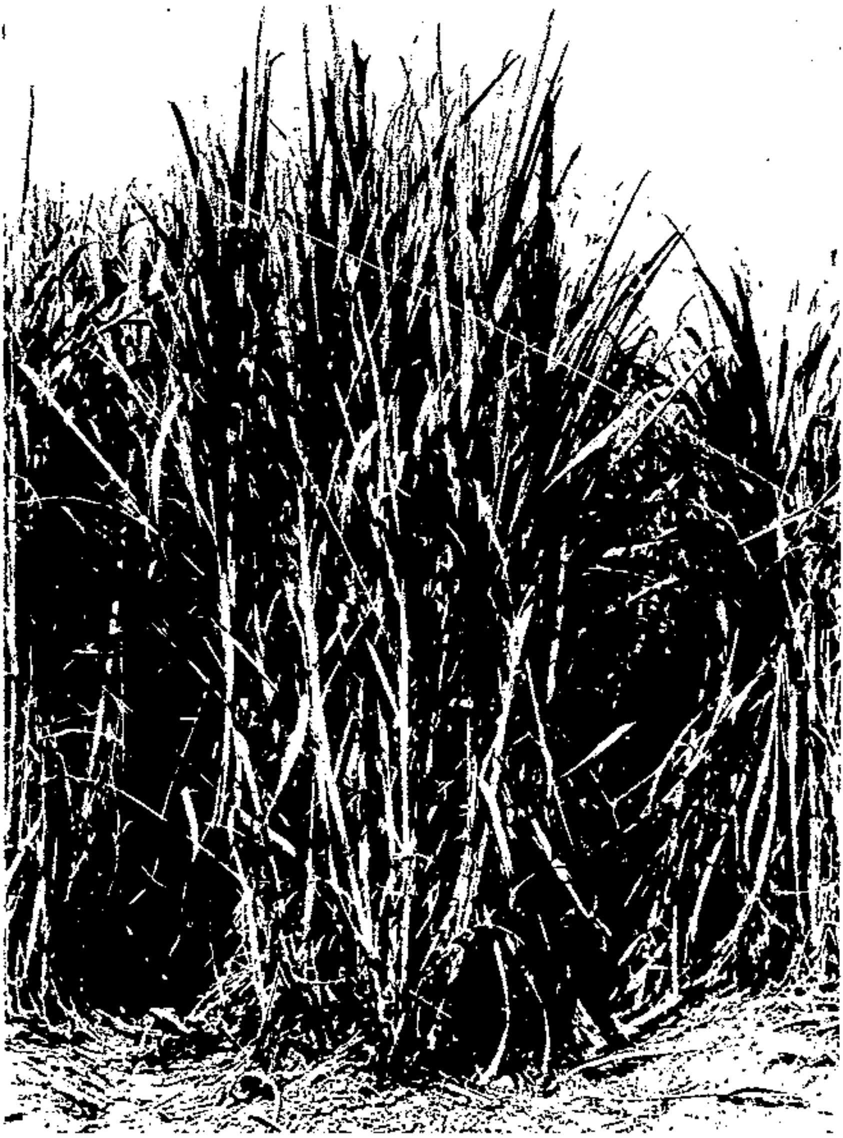
Cross No.	Number studied: Single stools, 1953	Number studied: Clones, 1954	Number studied: Clones, 1955	Parents and rating as to characters studied		
					C. P. 34–139 ×	**C. P. 36–105**
				Stalk diameter (mm.)	Medium large 22.2	Medium large 22.1
				Erectness of stalks [1]	Moderate 2.6	Nonerect 3.2
51–11	87	86	85	Number of stalks	High 13.2	Moderate 9.9
				Brix [2]	Medium high 16.9	Medium high 17.6
					C. P. 36–105 ×	**C. P. 38–34**
				Stalk diameter (mm.)	Medium large 22.1	Large 25.7
				Erectness of stalks [1]	Nonerect 3.2	Moderate 2.1
51–15	300	146	136	Number of stalks	Moderate 9.9	Moderate 8.0
				Brix [2]	Medium high 17.6	Low 15.9
					C. P. 36–105 ×	**C. P. 30–24**
				Stalk diameter (mm.)	Medium large 22.1	Large 25.2
				Erectness of stalks [1]	Nonerect 3.2	Erect 1.4
51–32	300	148	140	Number of stalks	Moderate 9.9	Few 5.7
				Brix [2]	Medium high 17.6	Low 15.7
					C. P. 29–103 ×	**C. P. 33–224**
				Stalk diameter (mm.)	Large 27.7	Large 27.0
				Erectness of stalks [1]	Moderate 2.0	Nonerect 3.7
51–49	233	139	119	Number of stalks	Moderate 10.2	Moderate 9.3
				Brix [2]	Low 15.6	Medium 17.5
					C. P. 33–224 ×	**C. P. 48–126**
				Stalk diameter (mm.)	Large 27.0	Large 25.0
				Erectness of stalks [1]	Nonerect 3.7	Moderate 2.5
51–72	160	144	143	Number of stalks	Moderate 9.3	High 12.5
				Brix [2]	Medium high 17.5	Medium high 17.1

TABLE 1.—*Sugarcane crosses, characteristics of parents, and number of individuals studied as single stools and as clones, Houma, La., 1953–55*—Continued

Cross No.	Number studied: Single stools, 1953	Number studied: Clones 1954	Number studied: Clones 1955	Parents and rating as to characters studied		
					C. P. 43–64 ×	**C. P. 44–154**
51–74	279	148	147	Stalk diameter (mm.)	Large 27.5	Small 20.0
				Erectness of stalks [1]	Erect 1.1	Nonerect 3.4
				Number of stalks	Low 5.0	High 11.4
				Brix [2]	High 19.1	High 18.5
					C. P. 47–191 ×	**C. P. 43–33**
51–148	104	99	99	Stalk diameter (mm.)	Small 18.2	Small 19.2
				Erectness of stalks [1]	Moderate 2.7	Erect 1.0
				Number of stalks	High 11.0	High 11.0
				Brix [2]	High 19.5	High 19.4
Total	1,463	910	869			

[1] Scale for rating erectness: 1=very superior; 2=superior; 3=average; 4=inferior; 5=very inferior.
[2] Brix reading obtained by hand refractometer.

BN-6703X
FIGURE 1.—Erectness of stalk: Rating 1, very superior. This type of growth is ideal for mechanical harvesting.



BN-6704x

FIGURE 2.—Erectness of stalk: Rating 2, superior. This type of growth is considered very good for mechanical harvesting.

BN-6706x

FIGURE 3.—Erectness of stalk: Rating 3, average. This type of growth is satisfactory for mechanical harvesting under most conditions.

BN-6705x

FIGURE 4.—Erectness of stalk: Rating 4, inferior. This type of growth presents certain problems in mechanical harvesting and some wastage of cane can be expected.

BN-6707X

FIGURE 5.—Erectness of stalk: Rating 5, very inferior. This type of growth is very difficult to harvest mechanically and appreciable loss can be expected.

In order to measure Brix in the laboratory, immediately after extracting the juice samples for field Brix tests, the stalks were cut, taken to the laboratory, and milled to levels of extraction ordinarily obtained with factory crusher rolls; i.e., approximately 65 percent with a variety similar to Co. 281. The Brix of the extracted juice in the sample was determined by hydrometer.

Sucrose was obtained by direct polarization of the undiluted juice after clarification with lead subacetate, and the polarization reading was converted to percentage of sucrose by use of Schmitz's table. Sucrose and polarization are frequently used synonymously in cane factory work to designate direct polarization. The Clerget polarization is called true sucrose to differentiate it from the direct polarization figure. Polarization is designated as "pol" and defined as the value determined by direct polarization of the normal weight solution in a saccharimeter (*15, p. 585*).

All stalks large enough for milling, whether damaged by wind or borers, were counted for the purpose of calculating the number of stalks for each year of the study. In the single stools the number of stalks in each stool was counted and recorded. In 1954 and 1955 all stalks in a clone were counted, and this number divided by the number of stools in the clone to obtain the average number of stalks per stool.

Scatter diagrams showing the association for the same character in different years were prepared for representative crosses in respect to each of the characters studied. Correlation coefficients were calculated for association between different characters in the same year and for the same character among different seasons for each cross separately and for the average of all crosses.

RESULTS AND DISCUSSION

Association Between Performance of Single Stools and Clones Derived From Them

Correlation coefficients were calculated for each of the four characters (stalk diameter, erectness of stalks, stalks per stool, and field Brix) studied (1) between first-stubble single stools grown in 1953 and the plant-cane crop of clones established from them in 1954, (2) between single stools in 1953 and the first-stubble crop of the clones derived from them in 1955, (3) between plant cane of clones grown in 1954 and first stubble of the same clones in 1955, and (4) between single stools in 1953 and the average of plant cane and first stubble of clones grown in 1954 and 1955. The single stools in 1953 were first stubble of individual plants that had been grown from seed in 1952. The plant-cane clones in 1954 and the first stubble of clones in 1955 were 5-foot plots established from cuttings taken from the single stools in the fall of 1953. They produced plant cane in 1954 and the same plantings produced first stubble in 1955.

Stalk Diameter

In respect to stalk diameter positive significant correlations for all 7 crosses were found between first stubble of single stools in 1953 and plant-cane clones derived from them in 1954; and between first stubble of single stools in 1953 and first stubble of clones in 1955 (tables 2 and 3, respectively). The correlation coefficients ranged from 0.44 to 0.67 between 1953 and 1954, with an average value of 0.54; and from 0.22 to 0.76 between 1953 and 1955, with an average value for all crosses of 0.50. Average values of r between 1953 and 1954 were essentially the same as r values between 1953 and 1955 for all crosses as a group. Values for crosses 32 and 49 were lower between 1953 and 1955 than between 1953 and 1954, suggesting that the agreement between single stools and clones was closer in plant cane than first stubble of the clones. On the other hand, the agreement for cross 11 was closer between 1953 and 1955 than between 1953 and 1954. The other 4 crosses showed essentially the same correlation in the 2 sets of comparisons. Because all r values were significant, the results indicate that selection for stalk diameter in single stools would be effective to some degree.

TABLE 2.—*Correlation coefficients (r) for stalk characters in 7 crosses between first-stubble single stools in 1953 and plant cane of clones established from them in 1954*

Character	Correlation coefficients [1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter	0.58**	0.54**	0.44**	0.52**	0.51**	0.59**	0.67**	0.54**
Erectness of stalk	.35**	.39**	.21**	.28**	.28**	.31**	.57**	.33**
Number of stalks per stool	.21*	.34**	.54**	.37**	.35**	.13	.32**	.33**
Brix (refractometer)	.28**	.48**	.32**	.72**	.24**	.69**	.70**	.48**

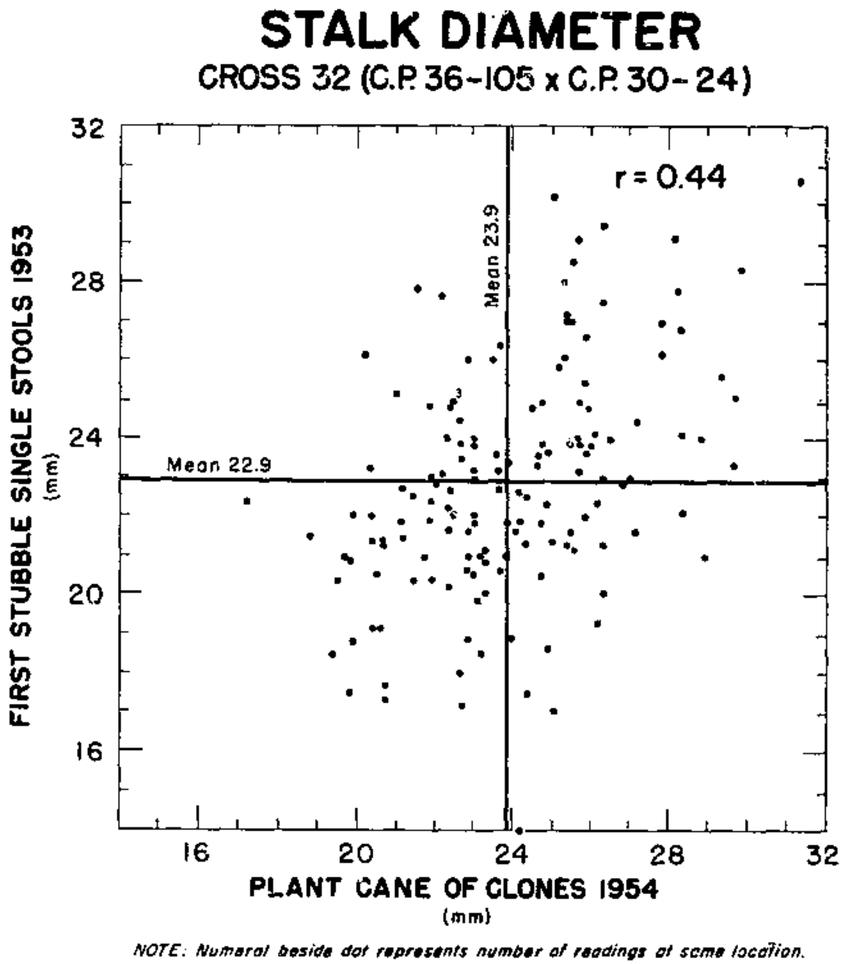
[1] * = Significant at 5-percent level; ** = significant at 1-percent level.
[2] See table 1 for parentage of crosses.

TABLE 3.—*Correlation coefficients (r) for plant characters in 7 crosses between first-stubble single stools in 1953 and first-stubble clones established from them in 1955*

Character	Correlation coefficients [1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter	0.76**	0.56**	0.22**	0.36**	0.51**	0.64**	0.64**	0.50**
Erectness of stalk	.28**	.42**	.29**	.39**	.26**	.49**	.56**	.38**
Number of stalks per stool	.21*	.46**	.37**	.42**	.41**	.35**	.51**	.40**
Brix (refractometer)	.21*	.30**	.22**	.48**	.32**	.63**	.53**	.38**

[1] * = Significant at 5-percent level; ** = significant at 1-percent level.
[2] See table 1 for parentage of crosses.

Cross 32 had the lowest correlation coefficient for stalk diameter between single stools in 1953 and clones from them in 1954 ($r = 0.44$). In this cross the percentage of superior clones (those having a diameter of 26 mm. or above) in the unselected population or entire 1954 progeny was 19 (fig. 6). If only single stools



BN-6715X

FIGURE 6.—Scatter diagram of cross 32, giving distribution according to stalk diameter of first-stubble single stools in 1953 and plant cane of clones established from them in 1954.

with diameters of 25 mm. or above had been selected and established as clones, the number of superior clones in this selected progeny would have been 33 percent. Thus, selection among single stools would have been somewhat less effective in cross 32, with a correlation coefficient of 0.44, than in cross 148, with a correlation coefficient of 0.67. There was an even lower correlation coefficient for cross 32 of 0.22 between single stools in 1953 and first stubble of clones established from them in 1955. However, even in the case of cross 32 selection of single stools for large diameter of stalk would have been sufficiently effective to warrant its use. It should be pointed out that in cross 32 almost all clones had large-diameter stalks because of the nature of the parents. The previous discussion of selection effectiveness in this cross refers to the possibility of obtaining the largest diameter clones available in the cross by selection among single stools.

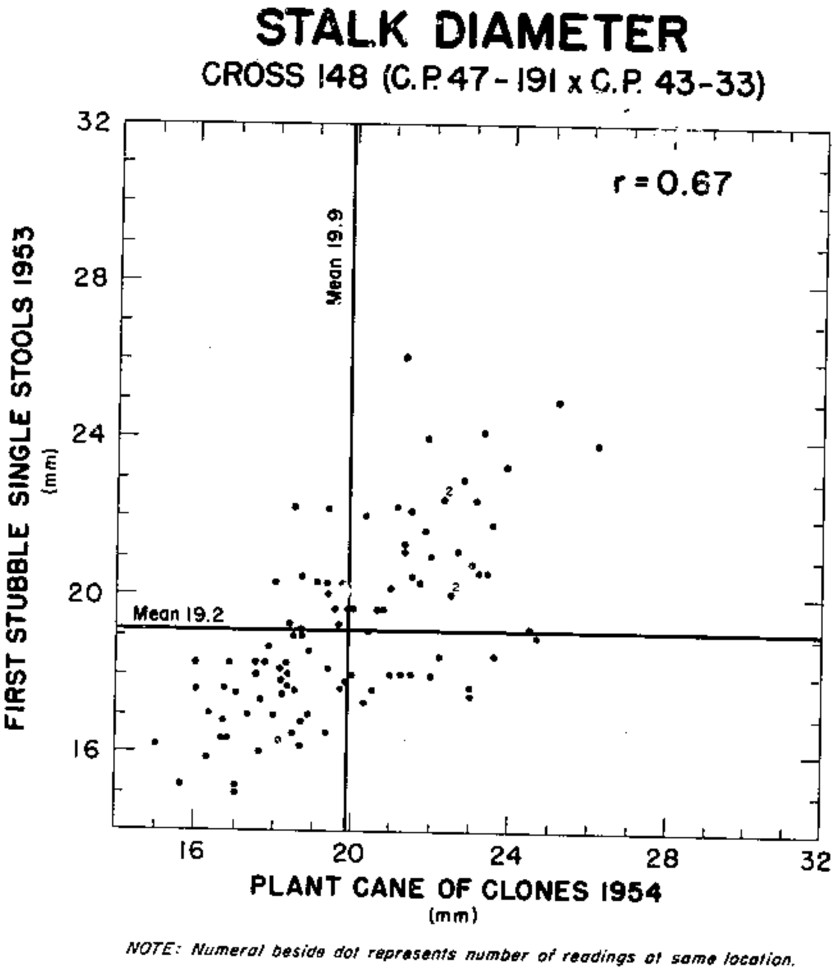
Table 4 gives the correlation coefficients by crosses among clones for stalk diameter between plant cane in 1954 and first stubble in 1955. Correlation coefficients for the same clones between plant cane and first stubble in the 2 seasons ranged from 0.56 to 0.71, and averaged 0.64 for all crosses. This shows a significant association, but correlation was not particularly high for the type of material involved. Apparently some clones did not give the same relative stalk diameter in the 2 seasons. In fact, r values for clones between plant cane and first stubble were not much higher than between single stools in 1953 and clones in 1954 and in 1955 in the average of all crosses.

TABLE 4.—*Correlation coefficients (r) for plant characters for 7 crosses between plant cane in 1954 and first stubble in 1955 of clones established from single stools*

Character	Correlation coefficients[1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter	0.66**	0.62**	0.66**	0.69**	0.56**	0.62**	0.71**	0.64**
Erectness of stalk	.28**	.49**	.21**	.55**	.40**	.35**	.58**	.39**
Number of stalks per stool	.43**	.47**	.21**	.65**	.70**	.46**	.61**	.48**
Brix (refractometer)	.61**	.50**	.47**	.70**	.48**	.61**	.69**	.57**
Brix (hydrometer)	.71**	.69**	.42**	.61**	.61**	.64**	.86**	.63**
Sucrose (direct polarization)	.71**	.68**	.65**	.73**	.60**	.64**	.69**	.66**

[1] ** = Significant at 1-percent level.
[2] See table 1 for parentage of crosses.

In order to obtain a more complete concept of the effectiveness of selection among single stools, scatter diagrams giving the distribution according to stalk diameter of the single stools in 1953 and the plant cane of the clones established from these single stools in 1954 are shown for crosses 32 and 148 in figures 6 and 7, respectively. These 2 crosses had the highest and lowest correlation among the 7 studied. Cross 148 had a relatively high correlation coefficient of 0.67. An examination of figure 7 shows that of the 99 clones grown of cross 148, 28 had diameters of 21.5 mm. or above in 1954. In respect to stalk diameter these 28 clones can be considered as superior, indicating that approximately 28 percent of this unselected population of cross 148 consisted of superior clones. It is apparent from figure 7 that a very high proportion



BN-6714x

FIGURE 7.—Scatter diagram of cross 148, giving distribution according to stalk diameter of first-stubble single stools in 1953 and plant cane of clones established from them in 1954.

of these large-diameter clones were derived from single stools that had large stalk diameters. In fact, all except 5 of the 28 superior clones were derived from single stools that were above average for this cross in stalk diameter. Furthermore, if selections had been made in this cross among single stools in 1953 for large stalk diameter, and only the 26 plants with diameters of 20.5 mm. and above had been kept and established as clones, the number of superior clones (21.5 mm. or above) would have been 16, or approximately 61 percent of the selections made. The increase from 28 to 61 percent in frequency of superior clones provides a measure of the relative effectiveness that selection among single stools in cross 148 would have had in obtaining clones with large stalk diameters.

That the failure of r values between single stools and clones derived from them to approach 1.00 was caused primarily by experimental error within seasons rather than season–genotype interaction is indicated by results obtained in an additional experiment (table 5). Two plots of each clone of crosses 49 and 72 were planted in 1954; in 1955 correlation coefficients of 0.66 and 0.63, respectively, were obtained for stalk diameter between the two plots of the same clone. Since this is essentially the same association as that found between the same clones when grown in separate years (table 4), the results indicate that genotype–season interactions were negligible.

It is concluded that selection among single stools should be practiced for large diameter of stalks. This selection will probably prove more effective in some crosses than others. However, selection among single stools or even among small plots of clones should not be extremely rigid, because of the experimental error involved in dealing with small plots. From results of this study it is expected that 40 to 60 percent of single stools with large diameter of stalks will produce clones having large-diameter stalks.

Erectness of Stalks

Significant correlations for erectness of stalk in all crosses were positive between single stools in 1953 and plant cane of clones in 1954, and between single stools in 1953 and first stubble of clones in 1955 (tables 2 and 3). Values of the correlation coefficients between 1953 and 1954 ranged from 0.21 to 0.57 and averaged 0.33 for all crosses; and values between 1953 and 1955 ranged from 0.26 to 0.56, with an average value of 0.38 for all crosses.

The average values of r for all crosses between 1953 and 1954 and between 1953 and 1955, as well as for each cross, were essentially equal. Only in the case of cross 74 was the agreement apparently closer between single stools and first-stubble clones than between single stools and plant-cane clones. This difference is relatively low, however, and probably not important.

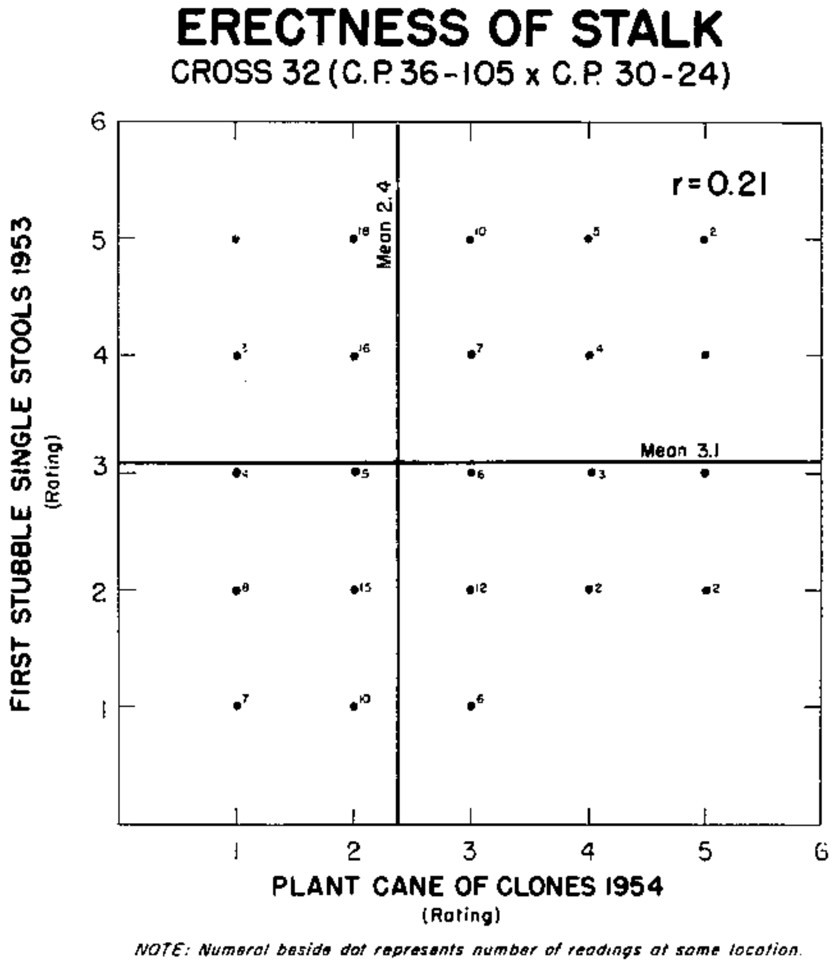
TABLE 5.—*Correlation coefficients (r) for plant characters for 2 crosses between 2 plots of the same clone grown as plant cane in 1955*

Character	Correlation coefficients [1] between 2 plots of the same clone for cross No.[2] — 49	72
Stalk diameter	0.66**	0.63**
Erectness	.30*	.49**
Number of stalks per stool	.17*	.31**
Brix (refractometer)	.20*	.50**

[1] * = Significant at 5-percent level; ** = significant at 1-percent level.
[2] See table 1 for parentage of crosses.

Despite the fact that all r values for erectness were significant between single stools and clones from them, many tended to be low, indicating relatively poor agreement between single stools and clones for part of the crosses. The primary reason for this poor agreement between single stools and clones grown in separate seasons can be found in table 4. The correlation between clones grown as plant cane in 1954 and the same clones grown as first stubble in 1955 were also relatively low, ranging from 0.21 to 0.58, with an average of only 0.39. Crosses 11 and 32 had r values less than 0.3; and only 2 crosses, 49 and 148, had r values above 0.5.

The low r values between the same clones in separate years were caused almost entirely by experimental error within each



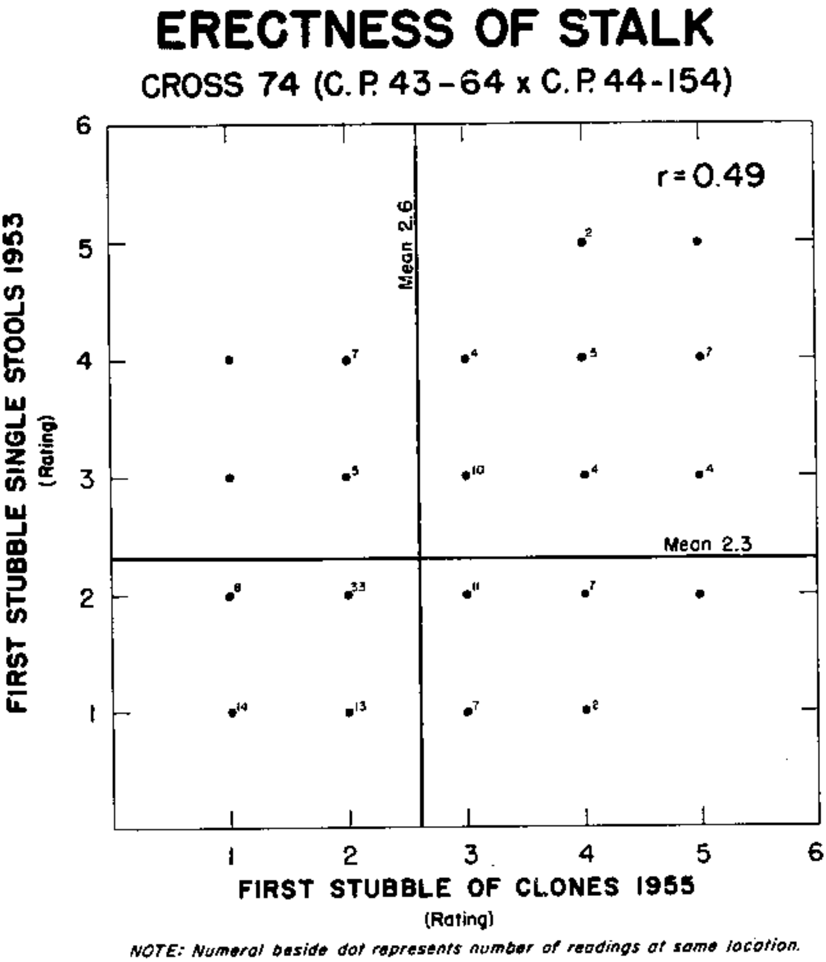
BN-07138

FIGURE 8.—Scatter diagram of cross 32, giving distribution according to erectness of first-stubble single stools in 1953 and plant cane of clones established from them in 1954.

season. Correlation coefficients between different plots of the same clone grown in the same season were only 0.30 and 0.49 for crosses 49 and 72, respectively (table 5). This indicates a very high experimental error in erectness of stalks for plots of the size used.

Throughout the experiment cross 148 behaved differently from the other 6 crosses in regard to erectness. Moderately high r values of 0.57 and 0.56 occurred between 1953 single stools and clones from single stools in 1954 and 1955, respectively, suggesting a considerably closer agreement than was found for the other crosses.

The wide variability in erectness of stalks among crosses in agreement between single stools and clones derived from them is illustrated in figures 8 and 9. Figure 8 shows the distribution of



BN-6712x

FIGURE 9.—Scatter diagram of cross 74, giving distribution according to erectness of first-stubble single stools in 1953 and first stubble of clones established from them in 1955.

the population of cross 32 for erectness in single stools in 1953 and in plant cane of clones established from them in 1954. The correlation coefficient in this population was 0.21. Among the 148 clones grown in 1954, 41 percent was classified as resistant to lodging (classes 1 and 2). If selection had been practiced among single stools in 1953 and only plants of classes 1 and 2 taken and established as clones, 45 percent of this selected population would have been classified as resistant to lodging. Thus, essentially no improvement in percentage of clones having resistance to lodging would have resulted from selection among single stools of cross 32.

Figure 9 represents a frequency distribution for single stools in 1953 and clones in 1955 of cross 74. The correlation coefficient was 0.49. There is a much closer agreement between performance as single stools and performance as clones than was found for cross 32. Among the 147 clones grown from cross 74, 82 clones (56 percent) were rated in classes 1 and 2. On the other hand, if selection had been practiced among single stools and only those in classes 1 and 2 had been kept, 82 percent of these selected clones would have been superior in resistance to lodging. Thus, in cross 32 selection among single stools would have had very little value, while in cross 74 it would have been moderately effective in obtaining a high proportion of erect clones.

On the whole, the data indicate that wide variation will occur among different crosses in effectiveness of selection for erectness of stalks in single-stool populations of sugarcane crosses. Because of the low degree of association between plots of the same clone, whether grown in the same season or in different seasons, it is doubtful that rigid selection should be practiced in the single-stool stage or even among clones for erectness on the basis of one season's results. It appears that, in general, selection for erectness in any one season, whether among the single stools or among clones, was not so effective as selection for large stalk diameter. This is borne out by the appreciably lower correlation for erectness of stalks in all crosses except No. 148; between single stools in 1953 and clones in 1954 (table 2); between single stools in 1953 and clones in 1955 for crosses 11, 15, 72, and 74 (table 3); between the same clones when grown in 1954 and 1955 for all crosses (table 4); and between different plots of the same clone for crosses 49 and 72 when grown in 1955 (table 5). The only consistent exception to the lower r value for erectness of stalk than for stalk diameter occurred in cross 148. As pointed out earlier, there was a consistently higher association for this cross in erectness of stalks between single stools and clones established from them than for the other crosses.

Stalks per Stool

Positive correlations in all crosses for number of stalks per stool occurred between single stools in 1953 and plant cane of clones in 1954, and between single stools in 1953 and first-stubble clones in 1955 (tables 2 and 3). In all crosses, except cross 74 in 1953 and 1954, the r values for association between single stools and clones were significant. Correlation coefficients ranged from 0.13

to 0.54 between 1953 and 1954, and from 0.21 to 0.51 between 1953 and 1955.

Effectiveness of selection among single stools for number of stalks per stool varied among the different crosses, but selection for number of stalks in most cases would not have been so effective as for stalk diameter. Despite the significant positive correlation of 0.37 for number of stalks per stool between single stools in 1953 and clones in 1954 for cross 49, selecting number of stalks among single stools had very little value (fig. 10). In selecting for number of stalks per stool, 5 is considered the acceptable minimum, while stools with 10 or more stalks would be rated as superior in this respect. In the unselected population of 139 clones of cross 49, 12 (9 percent) had an average of 10 or more stalks per stool

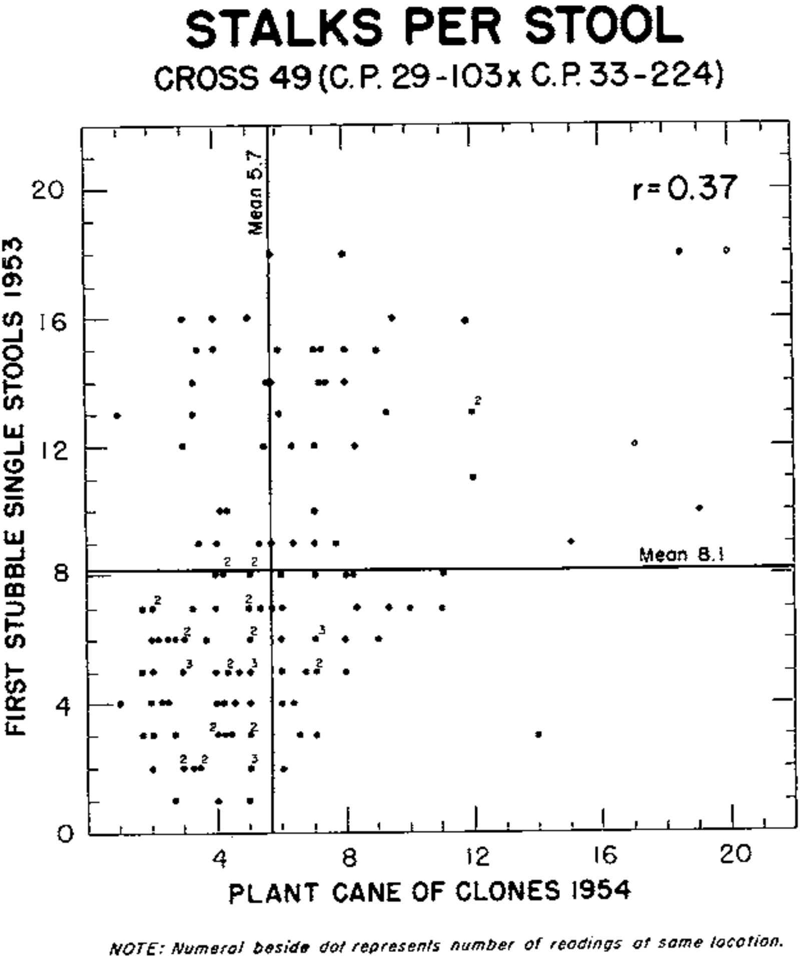
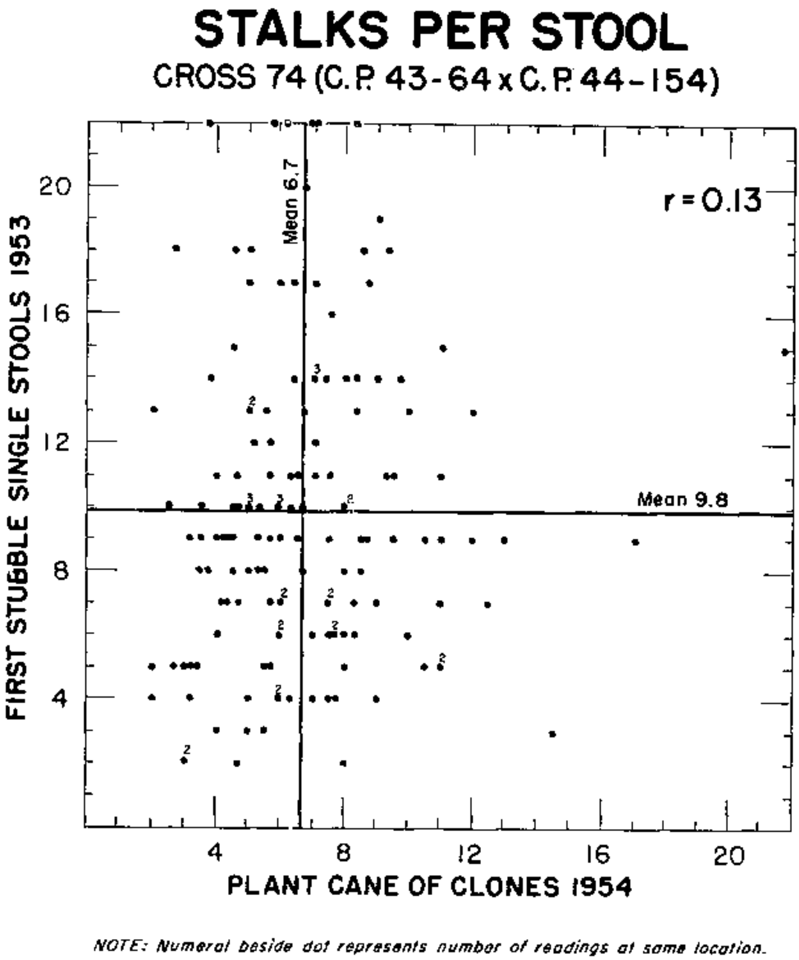


FIGURE 10.—Scatter diagram of cross 49, giving distribution according to number of stalks per stool in 1953 and plant-cane clones established from them in 1954.

and could be considered as superior clones in respect to number of stalks per stool. If in the selection among single stools in 1953 only the 38 plants with 10 or more stalks had been established as clones, the number of superior clones obtained from this selected population would have been 16 percent. Although this reflects some increase in the percentage of superior clones obtained in the selected population, it would still have been very low. Thus, if selection had been practiced among single stools for a high number of stalks per stool, 84 percent of the superior clones of cross 49 would have been discarded; i.e., there were 84 percent of the replants that did not meet the minimum requirements with respect to number of stalks per stool. In fact, 21 percent of the clones derived from selected single stools (10 stalks or more per stool)



BN-6710x

FIGURE 11.—Scatter diagram of cross 74, giving distribution according to number of stalks per stool in 1953 and plant-cane clones established from them in 1954.

had 4 or less stalks per stool and would have been distinctly inferior. Thus, as many inferior clones would have been obtained by selection among single stools for large number of stalks per stool as distinctly superior ones.

Figure 11 gives the distribution in number of stalks per stool for cross 74 as single stools in 1953 and plant cane of clones derived from them in 1954. The correlation coefficient for this distribution was 0.13. It is obvious from figure 11 that selection on the single-stool basis would have been valueless for obtaining high tillering clones in cross 74. In the unselected population of 148 clones of cross 74, approximately 11 percent had an average of 10 or more stalks per stool. If only single stools having 10 or more stalks each had been selected and established as clones, only 7 percent of the clones obtained would have been superior. The lower percentage for the selected population is probably due to chance. Of the clones obtained by selection among single stools for 10 or more stalks per stool, 18 percent would have had fewer than 4 stalks per stool and would have been considered inferior.

Table 4 gives the correlation coefficients among clones for the same characters in 2 different years. The association for stalks per stool between years for the clones was variable for the different crosses, ranging from 0.21 to 0.70. Most of the r values were relatively low, and the average r value for the 7 crosses was 0.48. The low correlation for most crosses between the same clone in separate years will account to a large extent for the low association between single stools and clones derived from them in respect to number of stalks per stool. Number of stalks per stool, whether among single stools or among clones, apparently is subject to a high degree of environmental variation (table 4). These results suggest that selection for number of stalks per stool, even among clones, will be limited in effectiveness.

The strong influence of environment on number of stalks per stool, even in clones, is shown more strikingly in table 5. The correlation between 2 plots of the same clone for crosses 49 and 72 were only 0.17 and 0.31, respectively. Although both r values are significant, they are very low. The reason for the lower r value for number of stalks per stool in table 5 than for those in table 4 was not apparent. It should be stated, however, that, as in the case of erectness, the number of stalks per stool had an extremely high coefficient of variability (data not shown).

Selection for number of stalks per stool in one season, either in single stools or among clones, was not so effective as selection for diameter of stalk, but probably was as effective as selection for erectness of stalks. It appears that if selection for stalks per stool is to be practiced in single stools, it should not be rigid, and relatively little emphasis should be given to this character at this stage of cane growth.

Field Brix

From correlation coefficients given in tables 2 and 3, positive, significant correlations in respect to field Brix occurred for all crosses between single stools in 1953 and plant-cane clones in 1954 and for all but one of the crosses between single stools in 1953 and first stubble of the clones in 1955, with r values ranging from 0.21 to 0.72. The averages for 1953 with 1954 and for 1953 with 1955 were 0.48 and 0.38, respectively. The generally lower values for the 1953 and 1955 data than those for the 1953 and 1954 for the averages of all crosses and for all individual crosses except one suggest that the agreement between single stools and clones was closer in plant cane than with single stools and first stubble. This may have been caused by a closer similarity between the 1953 and 1954 seasons as they affected Brix, or to a difference in plant cane and first-stubble crops.

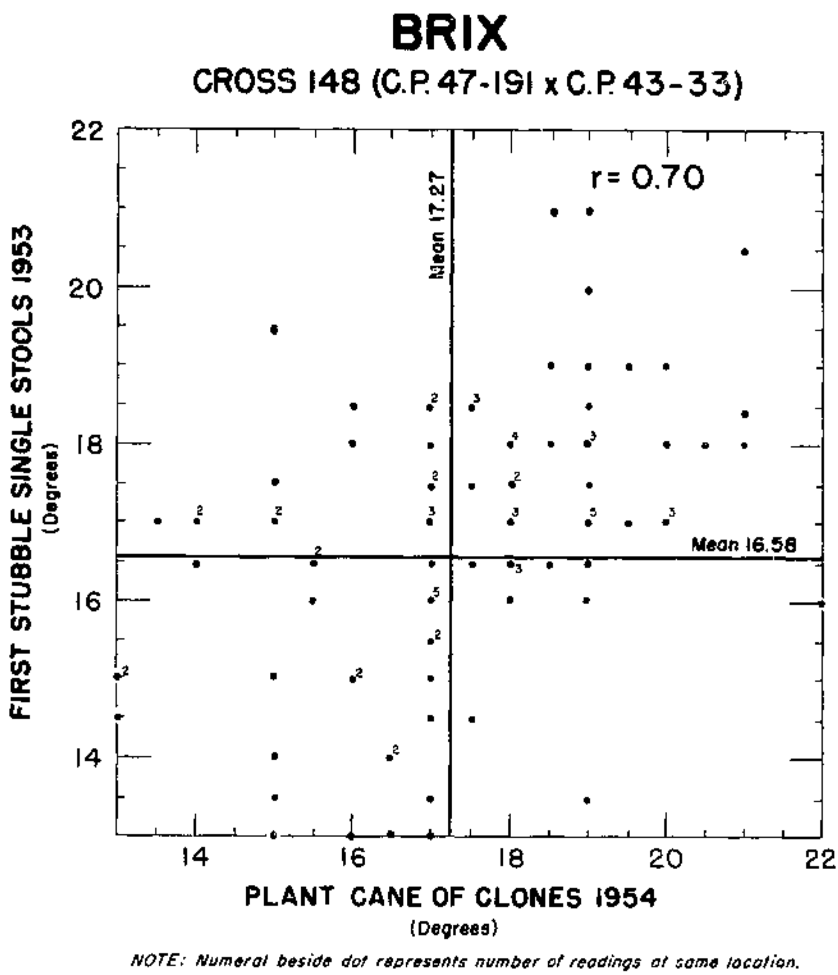
In both comparisons there was a wide range among the crosses in magnitude of the correlation coefficients between single stools and clones derived from them. For example, in the 1953 and 1954 comparisons 2 of the r values were below 0.3, while 3 were 0.69 or above. This suggests that the crosses differed greatly in the association between single-stool performance and clonal performance, indicating that selection for Brix among single stools would be considerably more effective in some crosses than in others. The data suggest that selection among single stools in crosses 11, 32, and 72 would have been of limited value, while selection in crosses 74 and 148 would have been at least moderately effective.

In 3 of the 7 crosses—49, 74, and 148—there was evidence that selection for Brix among single plants in 1953 would have been effective in obtaining clones high in Brix. In the other 4 crosses r values were low, and it is probable that selection for Brix in 1953 would have been of little value. Effectiveness of selection in the field on the basis of Brix would depend, then, on the particular cross involved, because the differences in r values among crosses were greater than in the case of stalk diameter.

Correlation coefficients for Brix between the same clone grown as plant cane in 1954 and first stubble in 1955 are given in table 4 for each cross. These correlation coefficients were all positive and significant, ranging from 0.47 to 0.70, with an average of 0.57. The fact that r values for some crosses were not high indicates that selection on the basis of clonal performance for 1 season only would not have been highly effective. In crosses 15, 32, and 72, there was considerable disagreement in the relative Brix of the clones involved for the 2 seasons. On the other hand, crosses 49, 74, and 148 showed high correlations, and apparently selection in either season alone would have been highly effective.

The data in tables 2, 3, and 4 indicate surprisingly that selection in crosses 74 and 148 for Brix on the basis of single stools in 1953 would have been as effective in obtaining clones with high Brix as selection on a clonal basis in 1954 or 1955. Correlation coefficients for these 2 crosses between seasons were high for all comparisons, including those between single stools and clones. This was decidedly not the case for most of the other crosses. For example, in cross 11 the correlation coefficients between single stools and clones for 1954 and 1955 were 0.28 and 0.21, respectively, while the r value for clones between 1954 and 1955 was 0.61. This further emphasizes the fact pointed out above that considerable variation occurred among the crosses in the relationship between single stools and clones. The low correlation found between plots of the same clone in 1955 for cross 49 (table 5) could not be accounted for.

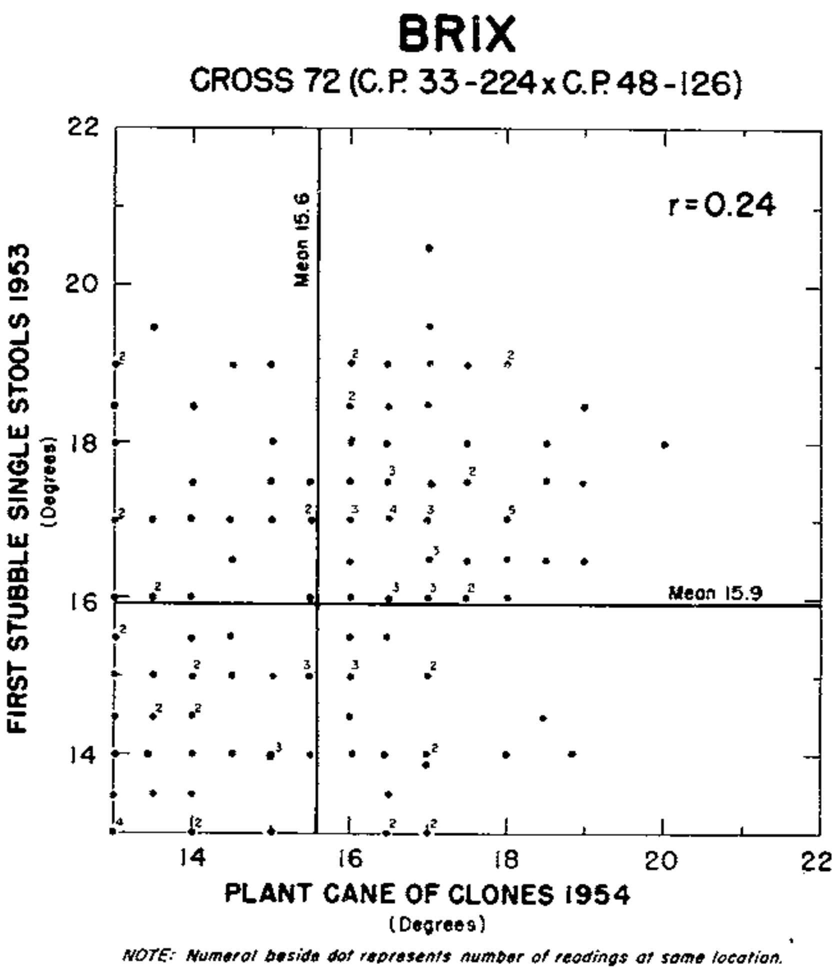
Figure 12 shows the distribution for Brix between single stools in 1953 and plant cane of clones from them in 1954 for cross 148. The r value for this distribution was 0.70. The agreement for Brix between single stools and clones was consistently close for both 1954 and 1955, suggesting that selection for high Brix among single stools in this cross would have been highly effective in obtaining high Brix clones. This is borne out by the distribution in the



BN-6709x

FIGURE 12.—Scatter diagram of cross 148, giving distribution according to Brix in juice of first-stubble single stools in 1953 and plant cane of clones established from them in 1954.

scatter diagram in figure 12. Among the total number of unselected clones in cross 148, the frequency of clones having Brix of 18.5 and above was 32 percent. If selection had been practiced among single stools in 1953 and only those with Brix of 18.5 or above had been established as clones, 59 percent of this selected population would have produced clones with Brix of 18.5 or above. This represents not only a considerable increase for the selected population over the unselected one, but the 59 percent constitutes a very high frequency of superior clones. Approximately 60 percent of the single stools selected from this cross would have been outstanding in Brix, as indicated by the performance of clones derived from them.



BN-6708X

FIGURE 13.—Scatter diagram of cross 72, giving distribution according to Brix in juice of first-stubble single stools in 1953 and plant cane of clones established from them in 1954.

On the other hand, cross 72 showed a consistently low correlation between single stools and clones, and selection in this cross on a single-stool basis would not be expected to prove very effective. Figure 13 gives the distribution of cross 72 according to Brix for single stools in 1953 and for plant-cane clones established from them in 1954. The correlation coefficient in this population was 0.24. The number of clones among the unselected population with Brix of 17 or above was 33 percent. In the selection if only single stools with Brix of 17 or above had been taken and established as clones, only 34 percent of these selected stools would have produced clones with Brix of 17 or above in 1954. Thus, there was essentially no improvement in the percentage of individual clones high in Brix obtained by selection in single stools over random selection.

Correlation Between Single Stools and the Average of 2 Years of the Clones Established From Them

Correlation coefficients were calculated by crosses for each of the 4 characters between performance of single stools in 1953 and the means of the clones derived from them for the 2 years 1954 and 1955. These *r* values are presented in table 6. The greater

TABLE 6.—*Correlation coefficients (r) for stalk characters in 7 crosses between first-stubble single stools in 1953 and the average of plant cane and first stubble of clones derived from them grown in 1954 and 1955*

Character	Correlation coefficients [1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter	0.75**	0.59**	0.47**	0.20**	0.58**	0.69**	0.81**	0.60**
Erectness of stalks	.39**	.48**	.31**	.20**	.30**	.45**	.63**	.39**
Number of stalks per stool	.07	.42**	.17*	.39**	.29**	.28**	.39**	.30**
Brix (refractometer)	.25*	.35**	.31**	.36**	.36**	.51**	.46**	.39**

[1] *=Significant at 5-percent level; **=significant at 1-percent level.
[2] See table 1 for parentage of crosses.

reliability of single stools in selecting for stalk diameter than in selecting for the other 3 characters is apparent in this table. With only one exception, the *r* values for the crosses were relatively high for stalk diameter, and the average *r* value for all crosses was 0.60. This is further evidence confirming the conclusions reached earlier that for the crosses as a whole, selection for stalk diameter on the basis of single stools would prove more effective than selection for erectness of stalks, number of stalks per stool, and Brix. Considerable variation among the crosses was shown for each of the other 3 characters. For example, the *r* values for erectness ranged from 0.20 in cross 49 to 0.63 in cross 148. These results also indicated that the degree of effectiveness of selection for erectness, number of stalks per stool, and Brix varies with the cross. In some crosses selection for a specific character will be at least moderately effective, while in others such selection will have little or no value.

The average *r* value for all crosses in number of stalks per stool was somewhat lower than those for erectness and Brix, suggesting that selection for this character would be the least effective. However, the lower average *r* value for number of stalks per stool was caused by very low values for crosses 11 and 32. In the other crosses, selection for number of stalks per stool, as based on the 2-year average, would have been as effective as selection for erectness and Brix. One of the surprising features of the study is the fact that correlations between single stools and clones were relatively low for Brix and on the average did not exceed the *r* values for erectness, a trait known to be affected greatly by environment. Although significant correlations between single stools and average of clones for 2 years in Brix were found for each cross, none of the values was especially high and the average for all crosses was only 0.39. Selection for high Brix among single stools will probably have value in any cross but will not be so effective as selection for stalk diameter.

Selection for a Combination of Four Characters

Any new variety developed in a sugarcane breeding program must meet certain minimum standards for several characters, such as yield, juice purity, and disease resistance. Consequently, the effectiveness of selection of single stools or clones would be based on the combined performance in regard to stalk diameter, number of stalks per stool, erectness of stalks, and Brix. Minimum levels of selection that have been commonly used in the sugarcane breeding programs in the United States would include 22 mm. for stalk diameter, 5 stalks per stool, rating 3 for erectness, and 17 for Brix. These levels are considered to be acceptable for agricultural varieties of sugarcane.

Some clones that meet these minimum requirements could have been obtained by chance without any selection among single stools for the 4 characters involved. Of the 869 experimental clones that were grown in both 1954 and 1955, 145, or approximately 17 percent, met the above requirements for stalk diameter, number of stalks per stool, erectness, and Brix as an average of both years. Thus, for the 7 crosses included in the present study as a group, 17 percent of the unselected clones would have been considered superior in a breeding program in respect to the 4 characters studied. This provides a basis for comparing the effectiveness that selection among single stools for the desired combination of the 4 characters would have had.

Among the 869 single stools of these crosses, 148, or approximately 17 percent, met the minimum requirements listed earlier for the 4 characters. If these 148 single stools had been selected and established as clones, 46, or 31 percent, would have produced clones that met the minimum requirements as an average of both years. Thus, rigid selection among single stools for all 4 characters would have raised the frequency of superior clones obtained from 17 percent to 31 percent of those grown. This is a very worthwhile increase in the frequency of superior clones and provides statistical proof that selection among single stools for all 4 characters together would have been valuable. However, the frequency of superior clones in respect to all 4 characters would still have been relatively low; 69 percent of the selected single stools would have produced unacceptable clones.

It is probably valid to use these percentages of superior clones in estimating the effectiveness of selection and number of superior clones that would be obtained in a typical breeding program as conducted in the United States. The data suggest that if 200 single stools are kept and established as clones from a population comparable with those studied, approximately 34 clones acceptable with respect to stalk diameter, number of stalks per stool, erectness of stalks, and Brix would be obtained with no selection whatever for those characters. With rigid selection for the 4 characters the number of acceptable clones among the 200 grown would be approximately 62. The 62 clones acceptable in these 4 characters would be a very small number from which to expect to obtain a superior variety or varieties when it is recalled that further elimination must be practiced for such important characters as yield, purity of juice, disease resistance, shading capacity, pithiness of stalks, inversion of sucrose, and insect resistance.

The probability of obtaining a variety superior in all respects from these 62 clones would be low. Even with rigid selection for the 4 characters included in this study, the original figure of 200 clones established from single stools would be far too few to enable a sugarcane breeder to obtain a new superior variety with any reasonable degree of probability. It would appear from the results of this experiment that even with rigid selection among single stools for stalk diameter, number of stalks per stool, erectness, and Brix, considerably more than 200 clones should be established and evaluated further.

If an experiment station could establish from single stools as many as 1,000 clones in small plots, the probability of obtaining new superior varieties would be increased considerably. In fact, if 1,000 clones were established from single stools without any selection whatever, 17 percent, or 170 clones, would be acceptable in respect to stalk diameter, number of stalks per stool, erectness, and Brix. Thus, more than twice as many acceptable clones for these 4 characters would be obtained from an initial number of 1,000 clones without any selection than in a typical breeding program with only 200 initial clones established from selected single stools. If the number of initial clones is increased to 1,000 and selection is practiced among single stools, approximately 310 acceptable clones, or 31 percent, should be obtained. However, it is doubtful that 1,000 single stools, which meet minimum standards for all characters for which selection is practiced, can be obtained from the 30,000 to 40,000 single stools normally grown each season in breeding programs in the United States. It would appear advisable either to (1) grow a much larger number of single stools from seed and maintain previous high standards in selection in order to obtain a larger number of initial clones, or (2) reduce somewhat the selection pressure among single stools for certain characters, such as number of stalks per stool and erectness, for which selection was found to be less effective. Probably a combination of these two steps would be most practical—increase the number of single stools grown to perhaps 80,000 to 100,000 and reduce selection pressure for certain of the characters.

Sucrose

Table 4 gives the correlation coefficient by crosses for percentage of sucrose for the same clones between plant cane in 1954 and first stubble in 1955. Correlation coefficients for all crosses were positive, significant, and relatively high. The range in r values was from 0.60 to 0.73, with an average of 0.66. The average correlation coefficient was as high as for any other character studied, and the r values were more consistent among the crosses than for any other character. This finding indicates that selection for sucrose among clones in any single season would have been very effective and that selection among clones could be more rigid for sucrose than for any of the agronomic characters studied. This is also true in respect to Brix determined under laboratory conditions.

Association Among Different Characters in the Same Season

Correlation coefficients for association between different characters in the same season were calculated among the 7 crosses for single stools in 1953 and for plant cane and first stubble of clones in 1954 and 1955, respectively. The correlation coefficients for association between (1) stalk diameter and erectness, (2) stalk diameter and number of stalks per stool, (3) stalk diameter and Brix, (4) erectness and number of stalks per stool, (5) erectness and Brix, (6) number of stalks per stool and Brix, (7) stalk diameter and sucrose, (8) erectness and sucrose, (9) number of stalks per stool and sucrose, (10) Brix and sucrose, and (11) number of stools per plot and number of stalks per stool are presented in tables 7, 8, and 9.

TABLE 7.—*Correlation coefficients (r) between characters for single stools in 7 crosses grown in 1953*

Characters correlated	Correlation coefficients[1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter and erectness of stalks[3]	0.09	0.25**	0.16**	0.35**	0.04	0.11	0.30**	0.19**
Stalk diameter and number of stalks per stool	.09	.01	.18**	−.03	.02	−.03	.21*	.05
Stalk diameter and Brix	.04	−.06	.02	.02	.08	.16**	.19*	.05
Erectness and number of stalks per stool[3]	.26*	.29**	.10	.15**	.38**	.22**	.18	.21**
Erectness and Brix[3]	.20	−.04	−.10	.08	.19**	−.02	−.10	.05
Number of stalks and Brix	.03	.09	.17**	.14*	−.02	.09	.01	.09**

[1] *=Significant at 5-percent level; **=significant at 1-percent level.
[2] See table 1 for parentage of crosses.
[3] *In rating for erectness, low values indicate type most resistant to lodging.*

TABLE 8.—*Correlation coefficients (r) between characters for clones in 7 crosses grown as plant cane in 1954*

Characters correlated	Correlation coefficients[1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter and erectness of stalks[3]	0.07	0.26**	0.15	0.12	0.11	0.002	0.24*	0.13**
Stalk diameter and number of stalks per stool	−.15	.16	−.03	.10	−.14	.03	−.19	−.02
Stalk diameter and Brix	−.01	.32**	−.23**	.002	.15	.004	−.23*	.07*
Stalk diameter and sucrose	.07	.09	−.17*	.11	.20*	.01	−.28**	.02
Erectness and number of stalks per stool[3]	.04	.08	.12	.26**	.02	.22**	.36**	.15**
Erectness and Brix[3]	−.04	.10	.04	−.09	.29**	.25**	.08	.05
Erectness and sucrose[3]	.10	.32**	.03	.13	.39**	.22**	.07	.19**
Number of stalks per stool and Brix	.05	.23**	−.08	.20*	.20*	.25**	.25*	.18**
Number of stalks per stool and sucrose	.05	.02	.04	.07	.11	.14	.20*	.09*
Brix and sucrose	.79**	.71**	.75**	.53**	.61**	.63**	.58**	.65**
Number of stools per plot and number of stalks per stool	−.37**	−.32**	−.51**	−.18**	−.36**	−.37**	−.44**	−.35**

[1] *=Significant at 5-percent level; **=significant at 1-percent level.
[2] See table 1 for parentage of crosses.
[3] In rating for erectness, low values indicate type most resistant to lodging.

TABLE 9.—*Correlation coefficients (r) between characters for clones in 7 crosses grown as first stubble in 1955*

Characters correlated	Correlation coefficients[1] for cross No.[2]—							
	11	15	32	49	72	74	148	Average
Stalk diameter and erectness of stalks[3]	0.07	0.13	0.03	0.09	0.11	0.08	0.27**	0.11**
Stalk diameter and number of stalks per stool	−.20	−.17*	−.11	−.03	−.09	−.11	−.05	−.11**
Stalk diameter and Brix	.004	−.08	−.09	−.01	.11	−.12	−.30**	−.05
Stalk diameter and sucrose	.001	−.13	−.12	−.03	.19*	.05	−.27**	−.04
Erectness and number of stalks per stool[3]	.32**	.18*	.13	.26**	.17*	.31**	.27**	.22**
Erectness and Brix[3]	−.05	.17*	−.14	.18*	.03	−.02	.06	.07*
Erectness and sucrose[3]	−.001	−.06	−.12	.25**	.02	.15	−.17	.02
Number of stalks per stool and Brix	.30**	.09	.16*	.26**	.37**	.13	.33**	.22**
Number of stalks per stool and sucrose	.13	.005	.16*	.34**	.55**	.36**	.21*	.25**
Brix and sucrose	.77**	.67**	.64**	.66**	.71**	.67**	.72**	.68**
Number of stools per plot and number of stalks per stool	−.38**	−.27**	−.43**	.04	−.25**	−.42**	.35**	−.29**

[1] * = Significant at 5-percent level; ** = significant at 1-percent level.
[2] See table 1 for parentage of crosses.
[3] In rating for erectness, low values indicate type most resistant to lodging.

Stalk Diameter and Erectness of Stalk

Correlation coefficients for all crosses of stalk diameter and erectness of stalk were positive for each year of the study, suggesting that large diameter of stalk is associated with tendency to lodge, as higher values for erectness indicate more recumbent stalks. It seems logical that the heavier stalks tend to fall down more easily than the thinner, lighter ones. This is not a close association, however, since 14 of the 21 comparisons were not statistically significant, and the 7 that were significant were relatively low and obviously not very important. The 7 significant r values ranged from 0.16 to 0.35. Even the highest of these does not indicate any important association. No special difficulty should be encountered in selecting large-diameter clones that are also erect in any of the crosses studied; as a matter of fact, many of the larger diameter clones were erect.

Stalk Diameter and Number of Stalks per Stool

Of the 21 correlation coefficients for association between stalk diameter and number of stalks per stool, 8 were positive, 2 being statistically significant, and 13 were negative, 1 being significant. In 1953 for the single stools, correlation coefficients between stalk diameter and number of stalks were significant for only 2 of the 7 crosses, 32 and 148. Both of these significant correlations were positive. However, both r values were very low and do not indicate an association of any importance. For the clones in 1954, none of the r values proved to be significant. The average r value for the 7 crosses in 1954 was negative, although not significant, and it can be concluded that no important association was found for that year.

For the clones in 1955, all r values were negative, and the average for all crosses was also negative and significant. However, the average r value for all crosses as well as the significant r for cross 15 were both very low and indicated no important relationships. It can be concluded from this study that no important association occurred between stalk diameter and number of stalks per stool.

It has been generally assumed that there is a close negative association between these two characters, i.e., clones with large diameter of stalk tend to have fewer stalks per stool. This assumption could not be confirmed in the present experiments. None of the 7 crosses in any of the 3 years showed an association of this type great enough to be considered important. The highest negative r value found was −0.20 for cross 11 in 1955. This value was not significant. The highest significant negative r value, for cross 15 in 1955, was only −0.17, an obviously unimportant value. Among the single stools in 1953, 2 positive, significant but still unimportant, r values were obtained among the 7 crosses.

These 2 characters were not even so closely associated as stalk diameter and erectness, and from this study it appears possible to select clones with both large diameter and high number of stalks. This is evidence that rigid selection could be practiced for stalk diameter among single stools or clones without an adverse effect on number of stalks per stool.

Stalk Diameter and Brix

Twelve of the 21 correlation coefficients for stalk diameter and Brix were positive, 3 being significant; and 9 were negative, 3 being significant. The 2 highest r values were +0.32 and −0.30, and 12 of the 21 were less than 0.10. Thus, the 2 characters showed no important association in this study, and no particular difficulty should be encountered in selecting single stools or clones that are both large in diameter and high in Brix.

Erectness and Number of Stalks

All 21 correlation coefficients for association between erectness and number of stalks were positive, and 14 of the 21 were significant at the 5-percent level of statistical significance. The significant correlation coefficients ranged from 0.15 to 0.38. Only 4 of the r values were above 0.30; thus, even the significant values were not important. Single stools or clones with a high number of stalks per stool tended to be less erect; but again, no special difficulty should be encountered in selecting varieties that have a relatively large number of stalks and that are also erect. The tendency for erectness of plants to be associated with smaller number of stalks per stool will lead to some handicap in a sugarcane breeding program, but selection for satisfactory expression of both characters at the same time should make it possible to overcome this difficulty.

Erectness and Brix

Of the 21 correlation coefficients between erectness and Brix, 12 were positive, 5 being significant, and 9 were negative, none being significant. All *r* values were less than 0.3 and were not considered important. The fact that all *r* values were low and in some of the crosses the 2 characters were positively associated in single stools and negatively associated in clones, while in others the association was negative in single stools and positive in clones, indicates that there was very little real association between the 2 characters and that no great difficulty should be met in combining erectness of stalk and high Brix.

Number of Stalks and Brix

Nineteen of the 21 correlation coefficients between number of stalks per stool and Brix were positive. Twelve of the 19 positive correlation coefficients were significant, but the 2 negative *r* values were not statistically significant. The range of the significant *r* values was from 0.14 to 0.37, but only 3 of the 12 significant *r* values were as high as 0.30. Of the 12 significant positive correlations between number of stalks and Brix, 10 occurred in clones in 1954 and 1955. Thus, 10 of the 14 *r* values for clones in the 2 years were positive and significant. Consequently, there was a slight, but well-defined, tendency among clones for a large number of stalks per stool to be associated with high Brix. This tendency would be of some advantage in a breeding program, but the association was relatively low and probably would not be of great value.

Stalk Diameter and Sucrose

Sucrose percentage was determined for clones in 1954 and 1955 only. The correlation coefficient between sucrose and other characters, including stalk diameter, are shown in tables 8 and 9.

Eight of the 14 correlation coefficients for association of stalk diameter and sucrose in clones were positive. Of the 8 positive *r* values 2 were significant, but relatively low, and 3 of the 6 negative values were significant, the highest being only 0.28. No important relationship exists between stalk diameter and sucrose.

Erectness of Stalk and Sucrose

Ten of the 14 correlation coefficients between erectness and sucrose during 1954 and 1955 were positive. Only 4 of the 10 positive *r* values were significant, all being relatively low, and none of the negative correlation coefficients were significant. The low *r* values together with the positive and negative values shown by different crosses in different years (for example, cross 15 had a significant positive correlation coefficient in plant cane but was negative in first stubble) strongly suggest that there was no real association between erectness of stalk and sucrose.

Number of Stalks per Stool and Sucrose

All 14 correlation coefficients between number of stalks per stool and sucrose were positive, but only 6 of these associations were statistically significant. In cross 72, the *r* value for association between the 2 characters was 0.55 in first stubble in 1955 but only 0.11 in plant-cane clones in 1954. The low average values for all crosses individually for both years indicated a relatively low but unimportant association between the 2 characters. The low but positive association between number of stalks and sucrose is in agreement with the results reported earlier between number of stalks and Brix. This association should prove to be an advantage in sugarcane breeding but probably not of great importance.

Brix and Sucrose

All correlation coefficients between Brix and sucrose were positive and significant. Values of *r* in the clones ranged from 0.53 to 0.79 in plant cane and from 0.64 to 0.77 in first stubble. This association is expected, since sucrose is a major component of Brix. The data indicated that sucrose values could be predicted reasonably well from the Brix values, but failure of correlation coefficients to approach 1.00 strongly suggests that the elimination of clones in early tests on the basis of Brix alone would be moderately reliable but not entirely so. These results confirm the validity of the currently and widely used practice of making selections for high sucrose on the basis of high Brix readings. The effectiveness of this selection among single stools was discussed previously.

Number of Stools per Plot and Number of Stalks per Stool

All but 1 of the correlation coefficients for association between number of stools per plot and number of stalks per stool were negative and significant at the 5-percent level. Value of *r* for association between these 2 characters was not significant in first stubble and was barely significant in plant cane in cross 49, but was statistically significant in all other crosses. Although the association was not close, as evidenced by the relatively low values, the data did indicate that there was a relationship between the number of stalks per stool and number of stools per plot of the same clone, and that the lower the number of stools in the plot the higher will be the number of stalks per stool. Competition for light, water, and nutrients would affect the number of stalks per stool within the clone.

Breeding Behavior of Characters Studied

From the standpoint of selection of parents for crosses, behavior of the 7 crosses in comparison with the performance of their parents for each of the characters was included in the study. For this purpose frequency distribution of each of the 7 crosses in each year was prepared individually for diameter of stalk, erectness of stalk, number of stalks per stool, and Brix.

Stalk Diameter

Frequency distributions for the progenies of the 7 crosses in respect to stalk diameter for 1953, 1954, and 1955 are shown in tables 10, 11, and 12, respectively. Among the crosses, the average stalk diameter of single stools in 1953 varied from a low of 19.1 mm. for cross 148 to a high of 24.1 mm. for cross 49. In percentage of the population having stalk diameter above 22 mm. the progenies ranged from 14 percent in cross 148 to 74 percent in crosses 49 and

TABLE 10.—*Frequency distribution according to stalk diameter for 7 crosses grown as first-stubble single stools in 1953*

Cross No.[1]	Distribution as to stalk diameter in millimeters										Percentage of population with stalk diameter over 22 mm.
	14.1 to 16.0	16.1 to 18.0	18.1 to 20.0	20.1 to 22.0	22.1 to 24.0	24.1 to 26.0	26.1 to 28.0	28.1 to 30.0	30.1 to 32.0	Average [2]	
11	3	9	14	28	18	10	5			21.3	38
15	1	5	18	53	79	76	41	16	11	23.9	74
32	3	12	30	92	88	43	22	8	2	22.5	54
49	4	6	20	30	56	45	40	23	9	24.1	74
72	2	3	11	34	37	41	23	6	2	23.5	69
74		6	34	68	78	56	27	7	3	22.9	61
148	5	36	29	19	12	2	1			19.1	14

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

TABLE 11.—*Frequency distribution according to stalk diameter for parents and progenies of 7 crosses grown as plant-cane clones in 1954*

Cross No.[1] or variety	Distribution as to stalk diameter in millimeters										Percentage of population with stalk diameter over—	
	14.1 to 16.0	16.1 to 18.0	18.1 to 20.0	20.1 to 22.0	22.1 to 24.0	24.1 to 26.0	26.1 to 28.0	28.1 to 30.0	30.1 to 32.0	Average [2]	22 mm.	26 mm.
11	2	1	13	28	25	17				21.9	49	0
15		1	1	15	28	48	38	13	2	25.1	88	36
32		1	8	25	47	40	15	11	1	23.8	77	18
49		2	3	12	24	32	32	18	16	25.8	88	47
72			2	10	35	41	38	13	5	25.3	92	39
74		1	17	37	48	24	17	4		23.0	63	14
148	4	20	33	21	17	3	1			19.8	21	1
C.P. 29-103							2	2		28.0		
C.P. 30-24						2	2			26.0		
C.P. 33-224						1	4	2		27.3		
C.P. 34-139				1	2	1				23.0		
C.P. 36-105				1	5	1				23.0		
C.P. 38-34							3	1		27.5		
C.P. 43-33			3	1						19.5		
C.P. 43-64						4				25.0		
C.P. 44-154				3		1				22.0		
C.P. 47-191			4							19.0		
C.P. 48-126							3	1		27.5		

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

TABLE 12.—*Frequency distribution according to stalk diameter for parents and progenies of 7 crosses grown as first-stubble clones in 1955*

Cross No.[1] or variety	Distribution as to stalk diameter in millimeters										Percentage of population with stalk diameter over—	
	14.1 to 16.0	16.1 to 18.0	18.1 to 20.0	20.1 to 22.0	22.1 to 24.0	24.1 to 26.0	26.1 to 28.0	28.1 to 30.0	30.1 to 32.0	Average[2]	22 mm.	26 mm.
11	6	6	29	22	17	3	2	----	----	20.3	26	2
15	----	11	18	40	47	14	7	1	----	21.9	50	6
32	----	5	26	55	37	14	7	2	----	21.8	41	6
49	1	----	5	25	33	21	20	7	----	23.8	72	24
72	1	1	10	20	41	28	23	19	----	24.2	78	29
74	2	6	45	53	27	12	2	----	----	20.9	28	1
148	17	31	27	14	6	3	----	----	----	18.4	9	0
C.P. 29–103	----	----	----	----	----	1	2	----	1	27.5	----	----
C.P. 30–24	----	----	----	----	1	3	----	----	----	24.5	----	----
C.P. 33–224	----	----	----	----	----	2	4	1	----	26.7	----	----
C.P. 34–139	----	----	----	3	1	----	----	----	----	21.5	----	----
C.P. 36–105	----	----	2	2	3	----	----	----	----	21.3	----	----
C.P. 38–34	----	----	----	----	3	----	1	----	----	24.0	----	----
C.P. 43–33	----	----	4	----	----	----	----	----	----	19.0	----	----
C.P. 43–64	----	----	----	1	3	----	----	----	----	22.5	----	----
C.P. 44–154	----	----	2	2	----	----	----	----	----	20.0	----	----
C.P. 47–191	1	1	2	----	----	----	----	----	----	17.5	----	----
C.P. 48–126	----	----	----	----	1	3	----	----	----	24.5	----	----

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

15. There was close agreement between the average of the single stools from a cross and the percentage of the population above 22 mm. in diameter. A similar wide range also occurred among the crosses when grown as clones for 1954 and 1955. For example, in 1954 one cross, 11, had no clones above 26 mm. in diameter while another cross, 49, had 47 percent of the clones with stalk diameters above 26 mm. Thus, the data for all 3 years indicated wide and important differences among the crosses in number and percentage of large-diameter individuals. In fact, some crosses were so distinctly inferior in stalk diameter of progenies, as to be essentially valueless. An example of this is cross 148, which had an extremely low percentage of acceptable individuals in all years. Cross 11 was also inferior, although not as distinctly so as cross 148. On the other hand, crosses 15, 49, and 72 gave a high percentage of superior progenies in all 3 years. The superiority of those 3 crosses in respect to stalk diameter was very marked.

Close agreement existed among the crosses in the performance of their progenies in single stools and as clones. Crosses 11 and 148 were inferior to the others in stalk diameter in single stools and both years as clones. Performance of these 2 crosses in the single-stool stage could have been used reliably as a basis for discarding the entire crosses. Furthermore, the superiority of crosses 15, 49, and 72 was as apparent in single stools in 1953 as in clones in 1954 and 1955. These 3 crosses could have been selected as superior ones on the basis of their performance in single stools. It apparently is not necessary to grow clones from a cross in order to decide whether that cross can provide an acceptable number of clones having large diameter of stalk. This decision can be made from the performance of a small number of single stools.

The average stalk diameter of the parents involved in the crosses determined, to a large extent, the stalk size of the progenies. The average diameters of the parents in crosses 49 and 72 for 1954 and 1955 were 27.3 and 26.5 mm., respectively (tables 11 and 12). These were the highest averages for any of the parents among the 7 crosses. As brought out previously, the progenies of these 2 crosses were superior in percentage of individuals having acceptable stalk diameter. Conversely, the average stalk diameters of the parents in crosses 148 and 11 were 18.7 and 22.1 mm., respectively, representing the smallest diameter parents in the study. Based on percentage of progeny having acceptable stalk diameter, these 2 crosses were classified as inferior. As indicated above they would have been discarded in the single-stool stage, because of the extremely low percentage of acceptable individuals.

Thus, there was close agreement between averages of the parents involved in a cross and the relative performance of its progeny in respect to stalk diameter. Crosses involving parents with large-diameter stalks produced high percentages of progeny in the large-diameter class. On the other hand, crosses between parents with small-diameter stalks were almost valueless for a breeding program in regard to stalk diameter, because of the low percentage of acceptable individuals. Crosses in which both parents had relatively large stalk diameters or one large and one no smaller than medium, such as 49 and 72, produced progenies 25 to 30 percent of which had stalk diameters over 26 mm.

Three crosses—15, 32, and 74—were somewhat variable. These were crosses involving one parent with small-stalk diameter, and the other parent with a medium- to large-stalk diameter. In the single-stool and in the plant-cane crop of the clones, these 3 crosses produced progenies with a moderately high percentage of stalks above 22 mm. in diameter. In the first stubble of the clones, however, the percentage of the progeny with stalk diameters 22 mm. or above was appreciably below that of the superior crosses 49 and 72. The percentage of clones with a satisfactory stalk diameter was sufficiently high from these 3 crosses to permit their use in a breeding program. These crosses were less desirable than such crosses as 49 and 72.

It appears from these results that a variety or clone having small-diameter stalks can be used as one of the parents in crosses, but only when the other parent has stalks of large or medium diameter. The data suggest that crosses between 2 small-diameter parents will be valueless when selection is to be made for large-stalk diameter. A very high percentage of the progeny will have acceptable stalk size when both parents in a cross have a large diameter. Crosses between small-diameter and large-diameter parents will present more difficulty, because of the lower frequency of acceptable segregates.

Erectness

Frequency distribution of erectness ratings for the progenies of the 7 crosses and parents for 1953, 1954, and 1955 are presented in tables 13, 14, and 15, respectively. As in the case of stalk diameter, appreciable differences occurred among crosses in percentage of the progeny in the 2 superior classes, 1 and 2. In all crosses a relatively high percentage of the single stools or clones was erect each year. There was good agreement between the average of the population in a cross and the percentage of the population in the different classes, i.e., the lower the average of the population the higher the percentage of the progenies in classes 1 and 2. Despite the fact that all crosses were relatively high in average erectness and differences among crosses were smaller than for diameter of stalk, some crosses were superior to others and were more desirable from a breeding standpoint. Crosses 49 and 74 were among the superior ones during all 3 years, based on percentage of the single stools or clones in classes 1 and 2. Cross 11 was among the poorest in this respect for all 3 years. However, there were some exceptions; cross 72, for example, was among the superior ones in 1953, but was classed as inferior in 1955.

Unlike the case of stalk diameter, the data from single stools in 1953 would not have been reliable as a basis for discarding entire crosses. In the single-stool stage, cross 32 had the lowest percentage of progeny classified as erect. In the average of clonal performance in 1954 and 1955, this cross was not inferior in percentage of erect clones to crosses 11, 15, 72, and 148. However, the superiority of crosses 49 and 74 in resistance to lodging was expressed in the single-stool stage.

For the 2 years 1954 and 1955 the parents of the 7 crosses ranged in average erectness from 1.0 to 3.7. Unfortunately, none of the 7 crosses involved 2 nonerect or 2 highly erect parents. All 7 crosses had one parent classified as erect or moderately erect. This probably accounts for the small differences among the progenies of the crosses in degree of erectness. Since no cross involved 2 nonerect parents, no distinctly inferior cross was expected, and none was found. Owing to the absence of erect × erect and nonerect × nonerect crosses among the combinations, this experiment is probably not suitable for determining any exact relationship between means of the parents for erectness and performance of the progenies. However, despite the small differences between the parents for the 7 crosses, there was some tendency for the mean of the parents to be associated with the frequency of erect individuals among the progeny. In general the parents having the lowest means tended to produce the highest frequency of erect progeny. Thus, the data suggest that a relationship exists between erectness of the parents and frequency of erect types in the progeny. They also indicate that a high percentage of erect clones will commonly occur among the progenies from crosses between erect and

nonerect parents. Presumably even higher percentages of erect clones should occur from crosses involving 2 erect parents.

TABLE 13.—*Frequency distribution according to erectness of stalks for 7 crosses grown as first-stubble single stools in 1953*

Cross No.[1]	Distribution as to erectness class[2]						Percentage of population in classes—	
	1	2	3	4	5	Average[3]	1 and 2	4 and 5
11	14	28	16	18	11	2.8	48	33
15	68	77	52	50	53	2.8	48	34
32	44	69	48	59	80	3.2	38	46
49	95	55	42	24	17	2.2	64	18
72	56	55	29	16	4	2.1	69	12
74	83	108	52	28	8	2.2	68	13
148	29	30	24	11	10	2.4	57	20

[1] See table 1 for parentage of crosses.
[2] In rating for erectness, low values indicate type most resistant to lodging.
[3] Weighted value, using midpoint of class interval.

TABLE 14.—*Frequency distribution according to erectness of stalks for parents and progenies of 7 crosses grown as plant-cane clones in 1954*

Cross No.[1] or variety	Distribution as to erectness class[2]						Percentage of population in classes—	
	1	2	3	4	5	Average[3]	1 and 2	4 and 5
11	9	32	21	16	8	2.8	48	28
15	36	49	30	18	13	2.5	58	21
32	23	64	41	14	6	2.4	59	14
49	44	58	21	10	6	2.1	73	12
72	20	63	33	18	10	2.5	58	19
74	55	64	22	6	1	1.9	80	5
148	34	31	9	18	7	2.3	66	25
C.P. 29–103		3	1			2.2		
C.P. 30–24	3		1			1.5		
C.P. 33–224			4	3		3.4		
C.P. 34–139	1	2	1			2.0		
C.P. 36–105			7			3.0		
C.P. 38–34	1	1	2			2.2		
C.P. 43–33	4					1.0		
C.P. 43–64	4					1.0		
C.P. 44–154		3	1			2.2		
C.P. 47–191	1		3			2.5		
C.P. 48–126		4				2.0		

[1] See table 1 for parentage of crosses.
[2] In rating for erectness, low values indicate type most resistant to lodging.
[3] Weighted value, using midpoint of class interval.

TABLE 15.—*Frequency distribution according to erectness of stalks for parents and progenies of 7 crosses grown as first-stubble clones in 1955*

Cross No.[1] or variety	Distribution as to erectness class [2]						Percentage of population in classes—	
	1	2	3	4	5	Average [3]	1 and 2	4 and 5
11	15	21	19	18	12	2.9	42	35
15	27	48	31	13	19	2.6	55	24
32	21	48	42	23	12	2.7	49	25
49	35	40	16	14	13	2.4	63	23
72	16	30	32	29	36	3.3	32	45
74	21	61	32	20	13	2.6	56	22
148	15	32	18	12	21	2.9	47	33
C.P. 29-103	2	1	1			1.7		
C.P. 30-24	3	1				1.2		
C.P. 33-224		1	1	2	3	4.0		
C.P. 34-139			3	1		3.2		
C.P. 36-105		1	3	2	1	3.4		
C.P. 38-34		4				2.0		
C.P. 43-33	4					1.0		
C.P. 43-64	3	1				1.2		
C.P. 44-154				2	2	4.5		
C.P. 47-191		1	2	1		3.0		
C.P. 48-126		2	1		1	3.0		

[1] See table 1 for parentage of crosses.
[2] In rating for erectness, low values indicate type most resistant to lodging.
[3] Weighted value, using midpoint of class interval.

Stalks per Stool

Frequency distribution for the 7 crosses in respect to number of stalks per stool for 1953, 1954, and 1955 are presented in tables 16, 17, and 18, respectively. The average number of stalks in single stools ranged from 7.7 in cross 49 to 13.4 in cross 11. The average number of stalks per stool in plant cane of clones ranged among the crosses from 5.5 to 8.3 in 1954 and from 9.1 to 14.2 in first stubble of clones in 1955. Thus, relatively wide differences occurred among the crosses in respect to average number of stalks per stool. In nearly all cases the crosses that had a high average number of stalks per stool also had a high percentage of the population with over 10 stalks per stool. Hence, there was good agreement between the average of the population for a cross and the percentage of the population with more than 10 stalks per stool for all 3 years of the study.

A surprisingly close agreement existed between average number of stalks per stool among the crosses of single stools in 1953 and and of clones in 1954 and 1955 (tables 17 and 18). For example, crosses 11 and 148 had the highest average number of stalks per stool among the single stools in 1953 and also produced clones with the highest average number of stalks per stool in both 1954 and 1955. On the other hand, cross 49 had the lowest average number of clones in 1954 and 1955 (tables 17 and 18). For example, well as among clones in 1954 and 1955. Thus, single-stool progenies

TABLE 16.—*Frequency distribution according to number of stalks per stool for progenies of 7 crosses grown as first-stubble single stools in 1953*

Cross No.[1]	Distribution as to number of stalks per stool											Percentage of population with 10 or more stalks
	1 to 3	4 to 6	7 to 9	10 to 12	13 to 15	16 to 18	19 to 21	22 to 24	25 to 27	28 to 30	Average [2]	
11	9	10	18	6	16	6	3	5	4	10	13.4	57
15	47	63	54	36	38	26	22	3	4	7	10.1	45
32	31	56	65	65	36	25	9	9	2	2	10.0	49
49	48	66	53	27	26	5	2	1	2	3	7.7	28
72	25	35	36	28	21	5	6	1	3	----	8.9	40
74	21	58	85	49	40	15	5	6	----	----	9.3	41
148	6	6	20	19	18	20	9	3	1	2	12.8	69

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

TABLE 17.—*Frequency distribution according to number of stalks per stool for parents and progenies of 7 crosses grown as plant-cane clones in 1954*

Cross No.[1] or variety	Distribution as to number of stalks per stool											Percentage of population with 10 or more stalks
	1 to 3	4 to 6	7 to 9	10 to 12	13 to 15	16 to 18	19 to 21	22 to 24	25 to 27	28 to 30	Average[2]	
11	6	20	33	19	4	4					8.2	31
15	16	56	47	19	7	1					6.9	18
32	8	72	49	11	6	1	1				6.8	13
49	37	62	28	7	2	2	1				5.5	9
72	16	58	43	16	6	1	3	1			7.1	19
74	19	66	46	13	2	1		1			6.4	11
148	4	27	35	25	6	1		1			8.3	33
C.P. 29-103			1	2	1						11.0	
C.P. 30-24		2	2								6.5	
C.P. 33-224		2	3	2							8.0	
C.P. 34-139			1	2	1						11.0	
C.P. 36-105		4	3								6.3	
C.P. 38-34		2	2								6.5	
C.P. 43-33		2	2								6.5	
C.P. 43-64	2	2									3.5	
C.P. 44-154			3	1							8.7	
C.P. 47-191			4								8.0	
C.P. 48-126		1		2	1						10.2	

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

TABLE 18.—*Frequency distribution according to number of stalks per stool for parents and progenies of 7 crosses grown as first-stubble clones in 1955*

Cross No.[1] or variety	Distribution as to number of stalks per stool											Percentage of population with 10 or more stalks
	1 to 3	4 to 6	7 to 9	10 to 12	13 to 15	16 to 18	19 to 21	22 to 24	25 to 27	28 to 30	Average [2]	
11	4	4	15	13	19	7	13	2	4	4	14.2	73
15	4	18	24	30	31	17	8		2	2	11.9	66
32	1	26	42	29	17	18	5	1		2	10.7	51
49	13	24	38	20	14	3	3	2		2	9.1	37
72	8	11	31	28	24	18	7	4	4	8	12.8	65
74	4	16	27	34	24	20	11	4	1	6	12.8	68
148	2	5	12	29	14	15	12	4	2	4	14.1	81
C.P. 29-103		1		3							9.5	
C.P. 30-24	1	2	1								5.0	
C.P. 33-224		2	1	1	2	1					10.6	
C.P. 34-139					3		1				15.5	
C.P. 36-105			1	2	1	3					13.6	
C.P. 38-34			2	2							9.5	
C.P. 43-33				1	1	1	1				15.5	
C.P. 43-64		2	2								6.5	
C.P. 44-154				1	2	1					14.0	
C.P. 47-191				1	2	1					14.0	
C.P. 48-126			2				1	1			14.7	

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

should prove sufficiently reliable for discarding entire crosses that will produce a low frequency of clones with acceptable number of stalks per stool or for selecting those crosses that will produce a high frequency of acceptable clones.

Crosses 11, 15, and 148 ranked consistently high in both single stools and clones, and cross 49 was consistently poor in all 3 years. The other 3 crosses, however, were not consistent in their behavior over the 3-year period.

The average number of stalks per stool for the 2 parents of a cross showed a definite relationship to number of stalks in the progeny. If the parents involved in the 7 crosses are ranked according to number of stalks per stool, this association becomes evident. The parents of crosses 11 and 148 ranked 1 and 2, respectively, in average number of stalks per stool, and the averages of their progenies consistently ranked 2 and 1, respectively, in all 3 years. On the other hand, the parents of cross 49 ranked 7 and the progenies of that cross ranked 7 in each of the 3 years of the study. The agreement between average numbers of stalks in the parents and in the crosses was essentially as close in cross 15. In the case of crosses 32, 72, and 74, the rank in the 3 years was not as consistent.

Thus, the stooling qualities of the parents affected the number of stalks per stool in their progenies—the more stalks per stool based on the average of the 2 parents, the higher the percentage of population with more than 10 stalks per stool, and the higher the average of all plants or clones in their progenies.

Brix

Tables 19, 20, and 21 give the frequency distribution for the 7 crosses according to juice density, or Brix, for 1953, 1954, and 1955, respectively. Brix range from 9.1 to 22.0 among the single stools and clones of the 7 crosses in the 3 years, and the percentage of the progenies with more than 18 Brix in the juice ranged from 0 to 60 among the crosses in single stools, from 6 to 60 in plant-cane clones in 1954, and from 3 to 46 in first-stubble clones in 1955. Average Brix of the progenies for the 7 crosses ranged from 12.8 in cross 11 to 18.2 in cross 74 among single stools; from 14.7 to 18.1 in 1954, and from 15.5 to 17.4 in 1955.

In general there was agreement among the 3 years in rank of the crosses for Brix. Crosses 74 and 148 had the highest means in 1953, 1954, and 1955. The rank among the other 5 crosses in the different years was not consistent. Cross 11 appeared to be inferior to all other crosses on the basis of average Brix in 1953, but both in 1954 and 1955 this cross was as high in Brix as the other 4 in the group. It appears from these results that the average performance of the single stools in a cross might be useful in determining which crosses have very high levels of Brix, but probably could not be used in distinguishing average crosses from poor crosses. The results also indicate that care should be exercised in discarding an entire cross on the basis of low average Brix of its progeny among single stools. In spite of the very low average for cross 11 in single stools in 1953, 20 to 25 percent of the clones from this cross were above 18 in Brix.

TABLE 19.—*Frequency distribution according to Brix for progenies of 7 crosses grown as first-stubble single stools in 1953*

Cross No.[1]	Distribution as to Brix														Percentage of population over 18 Brix
	9.1 to 10.0	10.1 to 11.0	11.1 to 12.0	12.1 to 13.0	13.1 to 14.0	14.1 to 15.0	15.1 to 16.0	16.1 to 17.0	17.1 to 18.0	18.1 to 19.0	19.1 to 20.0	20.1 to 21.0	21.1 to 22.0	Average [2]	
11	7	13	11	13	18	13	8	3	1			—	—	12.8	0
15	4	3	7	15	22	57	51	85	36	13	6	1	—	15.5	7
32	1	8	10	25	37	68	51	61	23	12	3	—	—	15.0	5
49	8	18	9	25	32	54	31	31	15	9	1	—	—	14.3	4
72	3	6	4	6	16	24	21	34	23	20	2	1	—	15.6	14
74			1	3	2	4	14	34	54	85	40	42	—	18.2	60
148				4	6	11	12	31	20	14	4	2	—	16.5	19

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

TABLE 20.—*Frequency distribution according to Brix for progenies of 7 crosses grown as plant-cane clones in 1954*

Cross No.[1] or variety	Distribution as to Brix														Percentage of population over 18 Brix
	9.1 to 10.0	10.1 to 11.0	11.1 to 12.0	12.1 to 13.0	13.1 to 14.0	14.1 to 15.0	15.1 to 16.0	16.1 to 17.0	17.1 to 18.0	18.1 to 19.0	19.1 to 20.0	20.1 to 21.0	21.1 to 22.0	Average[2]	
11	1		1	10	5	8	11	22	6	12	7	2	1	16.1	26
15	2	1	1	2	6	33	19	38	20	18	2	4	----	16.1	16
32		1	2	13	20	27	32	29	12	10	1	1	----	15.3	8
49	4	5	9	10	22	25	18	15	17	6	2	----	----	14.7	6
72		4	5	10	20	17	24	38	18	7	1	----	----	15.3	6
74			1		2	4	10	18	24	39	26	21	1	18.1	60
148				3	4	8	9	23	20	21	7	3	1	17.0	32
C.P. 29-103			1			1	1			1				15.0	----------
C.P. 30-24				1			1	2						15.2	----------
C.P. 33-224						1	1	1		2	2			17.5	----------
C.P. 34-139							1	2		1				16.7	----------
C.P. 36-105								1	4	2				17.6	----------
C.P. 38-34					1		1		1	1				16.2	----------
C.P. 43-33											2	2		20.0	----------
C.P. 43-64							1						3	20.0	----------
C.P. 44-154									2	2				18.0	----------
C.P. 47-191										3		1		19.0	----------
C.P. 48-126						1			2	1				17.0	----------

[1] See table 1 for parentage of crosses.

[2] Weighted value, using midpoint of class interval.

TABLE 21.—*Frequency distribution according to Brix for parents and progenies of 7 crosses grown as first-stubble clones in 1955*

Cross No.[1] or variety	Distribution as to Brix														Percentage of population over 18 Brix
	9.1 to 10.0	10.1 to 11.0	11.1 to 12.0	12.1 to 13.0	13.1 to 14.0	14.1 to 15.0	15.1 to 16.0	16.1 to 17.0	17.1 to 18.0	18.1 to 19.0	19.1 to 20.0	20.1 to 21.0	21.1 to 22.0	Average[2]	
11	1			2	9	13	20	17	8	9	5	----	1	16.0	18
15				5	7	24	30	40	22	8	7	----	----	16.1	10
32		1	1	5	13	31	31	44	15	4	1	----	----	15.6	3
49			4	5	17	13	19	29	19	6	4	2	----	15.8	10
72		2	2	16	10	25	25	26	21	13	1	----	----	15.5	10
74		1	1	1	3	19	17	29	32	23	17	4	----	16.9	30
148	1			1	4	9	10	11	17	24	15	5	1	17.4	46
C.P. 29-103						1	1	----	2	----	----	----	----	16.2	----
C.P. 30-24						----	1	3	----	----	----	----	----	16.2	----
C.P. 33-224					----	1	1	1	----	2	2	----	----	17.5	----
C.P. 34-139							----	2	2	----	----	----	----	17.0	----
C.P. 36-105						----		3	2	1	1	----	----	17.5	----
C.P. 38-34						3	----	----	----	1	----	----	----	15.5	----
C.P. 43-33							----	----	1	1	2	----	----	18.7	----
C.P. 43-64				----			----	----	1	3	----	----	----	18.2	----
C.P. 44-154							----	----	----	3	----	1	----	19.0	----
C.P. 47-191								----	----	1	1	1	1	20.0	----
C.P. 48-126							----	1	3	----	----	----	----	17.2	----

[1] See table 1 for parentage of crosses.
[2] Weighted value, using midpoint of class interval.

On the basis of average Brix of the parents for the 2 years 1954 and 1955, the crosses could be separated into 2 groups. Two crosses, 74 and 148, had high parent averages, while the other 5 crosses were about equal in the average of their parents and could be considered as intermediate. The average Brix of the parents involved in a cross affected the juice density of the progeny. The averages of the parents in crosses 74 and 148 were the highest of all parents in the 7 crosses, and the progenies of these 2 crosses had the highest averages for all 3 years of the study. The remainder of the crosses had similar parent averages for the 2 years and also did not differ appreciably in mean performance.

Thus, there was a relatively close agreement between average Brix of the parents and average Brix of the progeny from the cross. All crosses with high parent averages also had high progeny averages, while the crosses with intermediate parent averages produced progenies with intermediate means. Unfortunately, none of the 7 crosses had parents with low means for Brix and consequently no prediction is possible regarding performance of such crosses. Presumably, however, they would have low average levels of Brix.

If the parents are classified on the basis of their average Brix for the 2 years into 3 classes, low, medium, and high, only the combinations low × medium, medium × medium, and high × high were represented among the 7 crosses. Two of the crosses, 74 and 148, represented high × high combinations and, as indicated above, produced superior progenies with means ranging from 16.5 to 18.2 for the 3 years. The combinations low × medium and medium × medium gave progenies that were distinctly lower than high × high, but not consistently different from one another.

One of the outstanding features of the study was a high degree of transgressive segregation for Brix in all 7 crosses involved. This was particularly true in the case of low Brix percentage for all crosses. Clones were obtained in each cross that were much lower than either parent. On the other hand a large number of clones were obtained from crosses 11, 15, and 32 that were considerably higher in Brix than either parent. Through the influence of this strong degree of transgressive segregation some clones were obtained in all the crosses that were exceptionally high in Brix. For example, in cross 11 during 1954 10 clones had Brix higher than 19. The parents of this cross, C. P. 34–139 and C. P. 36–105, averaged 16.9 and 17.6 Brix, respectively.

The parental combinations in respect to Brix were limited in nature and permit only general conclusions concerning selection of parents for crosses. No combinations of low × low, low × high, or high × medium, were available. However, it is apparent from the data that a larger proportion of high-Brix clones will generally be obtained from crosses between high-Brix parents than between parents having medium or low Brix. Owing to transgressive segregation, however, some clones with exceptionally high Brix can be expected in the progeny of crosses between medium-Brix parents.

SUMMARY

A study of breeding behavior of certain agronomic characters with progenies of seven crosses of sugarcane grown as single stools in 1953 and as plant cane and first stubble of clones established from these single stools in 1954 and 1955, respectively, revealed the following:

Significant correlation coefficients for stalk diameter between single stools and plant cane of clones, between first stubble of single stools and first stubble of clones, and between plant cane of clones and first stubble of clones, were 0.54, 0.50, and 0.64, respectively, and indicate that selection among single stools for stalk diameter would be effective. Selection from single stools should be practiced, but this selection should not be rigid.

The relatively low correlation coefficients for erectness between single stools and clones and between crops of the same clones in 2 years strongly suggest that rigid selection should not be practiced for erectness or for adaptability to mechanical harvesting in either the single stools or any single crop of the clones. Only several years' results for erectness would provide an adequate basis for selection.

Correlation coefficients for number of stalks per stool were low between single stools and clones. Rigid selection for number of stalks per stool should not be practiced in single stools or in only one crop of the clones.

Although correlation coefficients for Brix between single stools and clones were significant and high enough to be of importance in the average of all crosses, there were wide differences among crosses as indicated by r values. These values range from 0.28 to 0.72 between single stools and plant-cane clones, and from 0.21 to 0.63 between single stools and first-stubble clones. It is concluded that due consideration should be given to this fact in the breeding program and that selection for Brix as determined by refractometer in the field should be practiced but should not be rigid.

Approximately 17 percent of the unselected population of clones met the minimum requirements of commercial varieties for the four characters—stalk diameter, erectness, number of stalks per stool, and Brix—in all 3 years of the study. However, if selection had been practiced among single stools, approximately 31 percent of clones obtained would have met these requirements. The difference between 17 and 31 percent is a measure of the efficacy of selection in the single stools. A suggested breeding program for development of varieties for Louisiana includes the growing of 80,000 to 100,000 seedlings and the lowering of selection standards previously followed in single stools to permit selection of approximately 1,000 single stools per year for establishment as clones and further evaluation.

Both sucrose by polarization and Brix by hydrometer, as determined in the crusher juice from five stalks, showed a high degree of association between plant cane and stubble of the clones, and it is concluded that selection for either character in a single season would be highly effective.

There was essentially no association between any of the following characters as indicated by nonsignificant or low significant correlation coefficients in all 3 years of the study:

(1) Stalk diameter and erectness of stalks;
(2) Stalk diameter and number of stalks per stool;
(3) Stalk diameter and Brix;
(4) Erectness of stalks and number of stalks;
(5) Erectness and Brix;
(6) Number of stalks per stool and Brix;
(7) Stalk diameter and sucrose;
(8) Erectness of stalks and sucrose;
(9) Number of stalks per stool and sucrose.

Based on 2 years' results, a negative and significant correlation between number of stools per plot and number of stalks per stool occurred in the average of all crosses, but this association was not very close and in the case of one cross was not statistically significant.

A close association exists between Brix and sucrose for the clones in both years. The average correlation coefficient was consistently high for each individual cross and averaged 0.72 in plant cane and 0.68 in first stubble for all crosses.

In general, progenies of crosses involving large-diameter parents were large in diameter, and, conversely, progenies of crosses involving small-diameter parents were small in diameter. There were exceptions, and many individual single stools in clones were either larger or smaller than either parent involved in the crosses.

Progenies of crosses between erect parents were generally erect and progenies of nonerect parents were generally nonerect. The average ranking of the two parents in respect to erectness agreed very closely with the average ranking of their progenies.

The number of stalks per stool in single stools or clones also agreed with the number of stalks per stool in the parents. The ranking of the parents in number of stalks per stool was about the same as that of the average of the progenies.

Progenies of crosses involving parents high in Brix were relatively high in Brix and progenies of low-Brix parents were low in Brix. There were examples of transgressive segregation for Brix in all crosses, as evidenced by the number of individuals in each cross either above or below either parent.

Thus, in respect to all characters studied, the general performance of the progeny derived from a cross could be predicted to a reasonably reliable degree from the performance of the parents. There were no instances in which inferior parents produced a superior progeny, or superior parents gave an inferior progeny.

LITERATURE CITED

(1) ABBOTT, E. V.
1938. RED ROT OF SUGARCANE. U. S. Dept. Agr. Tech. Bul. 641. 96 pp., illus.
(2) ARCENEAUX, G., COLEMAN, R. E., and HEBERT, L. P.
1950. EVIDENCE OF INHERITANCE OF RESISTANCE TO FREEZE INJURY IN SUGARCANE SEEDLINGS PRODUCED AT CANAL POINT, FLORIDA. Internatl. Soc. Sugar Cane Technol. Proc. 7: 116–127.
(3) BARBER, C. A.
1912. SEEDLING CANES IN INDIA. Agr. Jour. India 7 (4): 1–14.
(4) ———
1915. SOME DIFFICULTIES IN THE IMPROVEMENT OF INDIAN SUGAR CANES. Ann. Appl. Biol. 6 (3,4): 211–221.
(5) BRANDES, E. W., and KLAPHAAK, P. J.
1925. BREEDING OF DISEASE RESISTING SUGAR PLANTS FOR AMERICA. Refer. Book Sugar Indus. of the World 3 (3): 50–57, illus.
(6) BUZACOTT, J. H.
1953. THE PARENTAL PERFORMANCE OF SOME SUGARCANE VARIETIES IN QUEENSLAND. Internatl. Soc. Sugar Cane Technol. Proc. 8: 485–491.
(7) CHRISTIANSON, W. O.
1937. A STUDY OF THE APPLICATION OF THE HAND REFRACTOMETER TO MATURITY TESTING OF SUGAR CANE IN NATAL. So. African Sugar Technol. Assoc. Proc. 11: 100–114, illus.
(8) DAVIS, R. L.
1935. METHODS OF SELECTING SEEDLINGS. Internatl. Soc. Sugar Cane Technol. Proc. 5: 326–327.
(9) DUTT, N. L., RAO, J. T., and HUSSAINY, S. A.
1953. ON CERTAIN RECENT ASPECTS OF THE BREEDING PROGRAMME AT COIMBATORE. Internatl. Soc. Sugar Cane Technol. Proc. 8: 402–410.
(10) HEBERT, L. P.
1955. THE LOUISIANA SUGARCANE VARIETY CENSUS FOR 1955. Sugar Bul. 33: 333–334, illus.
(11) LENNOX, C. G.
1945. APPLICATIONS OF THE HAND REFRACTOMETER IN SUGAR CANE RESEARCH: FUNDAMENTAL STUDIES IN SAMPLING SUGARCANE FOR SUCROSE. Hawaii. Sugar Planters' Assoc. Rec. 39: 13–18, illus.
(12) McINTOSH, A. E. S.
1935. METHODS OF SELECTING SEEDLINGS AT THE SUGAR CANE BREEDING STATION IN BARBADOS. Internatl. Soc. Sugar Cane Technol. Proc. 5: 324–326.
(13) MANGELSDORF, A. J.
1935. SUGAR-CANE BREEDING IN HAWAII. Internatl. Soc. Sugar Cane Technol. Proc. 5: 348–357, illus.
(14) RAGHAVEN, T. S.
1953. SOME CYTOGENETICAL FEATURES AND BREEDING BEHAVIOR OF A SACCHARUM SPONTANEUM DERIVATIVE. Internatl. Soc. Sugar Cane Technol. Proc. 8: 475–485, illus.
(15) SPENCER, G. L., and MEADE, G. P.
1945. CANE SUGAR HANDBOOK. Ed. 8, 834 pp., illus. John Wiley & Sons, Inc., New York.
(16) STEVENSON, G. C.
1954. REFLECTIONS ON THE EVOLUTION OF HAWAII'S PHILOSOPHY OF SUGAR CANE BREEDING. Sugar 49 (6): 51–56, 65, illus.
(17) VENKATRAMAN, T. S.
1935. METHODS OF SELECTING SEEDLINGS AS ADOPTED AT COIMBATORE. Internatl. Soc. Sugar Cane Technol. Proc. 5: 344–348, illus.
(18) WARNER, J. N.
1953. THE PHILOSOPHY OF SUGARCANE BREEDING IN HAWAII. Internatl. Soc. Sugar Cane Technol. Proc. 8: 410–415.
(19) ———
1954. HAWAII'S CANE BREEDING PHILOSOPHY. Sugar 49 (11): 33–35, illus.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1958—477129

END