1976

Genetic Behavior of Resistance to Lodging in Sugarcane.

Howard Preston Viator II

Louisiana State University and Agricultural & Mechanical College

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The Louisiana State University and Agricultural and Mechanical College, Ph.D., 1976
Agronomy

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GENETIC BEHAVIOR OF RESISTANCE TO LODGING
IN SUGARCANE

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy
in
The Department of Agronomy

by

Howard Preston Viator, II
B. S., University of Southwestern Louisiana, 1969
M. S., Louisiana State University, 1974
May, 1976
ACKNOWLEDGMENTS

The writer wishes to express his sincere appreciation to his major professor, Dr. M. T. Henderson, Professor of Agronomy, Louisiana State University, for his encouragement in the beginning, his assistance in the planning of this study, and his help in interpreting the results and in preparing this manuscript.

Acknowledgments are made to Dr. W. H. Willis, Head, Department of Agronomy, and to the American Sugarcane League for providing financial assistance in the study.

Special thanks are extended to Dr. Charlie Richard, Gene Boquet, and Gilbert Landry, Jr., for their help in collecting and recording data.

Thanks are also extended to many other people who helped make this investigation possible, especially Dr. R. D. Breaux, Research Agronomist, U.S. Sugarcane Laboratory, Houma, Louisiana; Dr. Kenneth Koonce, Associate Professor, Department of Experimental Statistics, Louisiana State University; Dr. M. J. Giamalva, Professor, Sugar Station, Louisiana State University; and to the staff of the St. Gabriel branch of the Louisiana Agricultural Experiment Station.

The author's most sincere appreciation is due his mother, Rena, and sister, Ruth, for their encouragement and assistance throughout the course of the study and preparation of this manuscript.

The writer will be forever grateful for the patience shown and encouragement given him by his wife, Laney.
Finally, the author wishes to acknowledge the faith his father, now deceased, had in him throughout the years.
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ABSTRACT

From 1972 through 1975, a study of the genetic behavior of resistance to lodging in sugarcane, *Saccharum* sp., was conducted. In the experiment, 100 randomly chosen clones from the progenies of each of 8 biparental crosses along with 5 or 6 replications of the parental clones were grown in 10-foot clonal plots. Four crosses were harvested 3 times from 1972 to 1973, and another 4 crosses were harvested in each year from 1973 to 1975.

Data on erectness were taken each year by either or both the conventional system and a newly devised % lodging system. The % lodging system was based on a visual estimate of the percentage of stalks lodged severely enough to affect harvestability. A comparison of the 2 systems clearly demonstrated the superiority of the % lodging system in the ability to differentiate certain varieties known to have opposing lodging habits. Furthermore, the new % lodging system recognized differences between clonal plots in the percentage of severely lodged stalks and in degrees of erectness related directly to harvestability. Only % lodging data were used to interpret genetic behavior of the progenies.

Other economic traits for which data were taken were stalk length, stalk weight, stalk diameter, stalk brittleness, estimated fiber percent in cane, and juice quality.

The data clearly indicate that crosses involving erect parents produce the highest frequency of erect segregates. This can be shown by the fact that the cross CP 52-68 x L 65-69 had over 10%
more erect segregates than the cross CP 65-357 x L 65-69, indicating the superiority of an erect parent over a moderately erect parent in the ability to transmit genes for erectness to the progenies.

Even though lodging is a quantitative character influenced strongly by the environment, its behavior was not that of a typical quantitative trait. For one difference, the population of the progenies derived from the 8 crosses did not fit a normal curve. In fact, all lodging classes tended to have similar numbers of segregates.

There was a marked tendency in the progenies for the frequency of clones susceptible to lodging to exceed that of resistant clones.

Although the results were not statistically significant, there was evidence that transgressive segregation occurred since 19% of the clones in the progenies were outside the ranges of the parental clones.

The average r value for 1 group of 4 crosses between % lodging in 1 year and the mean % lodging of both years was a positive, highly significant .84. This is an indication of heritability and suggests that selection of erect clones from small, unreplicated clonal plots in a single season would be reasonably effective.

Since only 20% of the clones erect in a normal lodging year were also erect the following year in which a hurricane occurred, it is evident that selection under normal lodging conditions would not be effective in identifying those clones that would remain erect after severe lodging has occurred. However, the data indicate that extremely decumbent clones could be effectively discarded.
An undesirable positive association was found between lodging and stalk length. As expected, there was a measurable tendency for the tallest clones in the progenies to undergo the greatest lodging. This emphasizes the need for early selection for erectness.

No association was found between erectness and stalk diameter, stalk brittleness, estimated fiber percent in cane, brix, or sucrose.
INTRODUCTION

Since the advent of the soldier-type mechanical harvester in Louisiana, stalk erectness has been of utmost importance to the sugar industry. Growers need erect varieties because of the detrimental effect that lodged cane has on juice quality and harvestability.

However, growers also insist that varieties possess, along with erectness, the capacity to produce high yields per acre. Although high tonnage, erect varieties such as CP 65-357 exist today, as the industry strives towards higher tonnage varieties, the task of developing varieties acceptable in erectness will become increasingly difficult.

Therefore, it was felt that a study should be conducted to gather data that would provide information on the manner in which erectness is inherited in order to determine the effectiveness of selecting for that trait. Also it is desirable to identify any association between erectness and other characters which might hinder the ease by which erect varieties could be developed.

In 1972 the writer initiated a study of the unselected progenies of 8 biparental crosses in order to evaluate the genetic behavior of lodging resistance in sugarcane.

The main objectives of the investigation were:

a. To develop and evaluate a new system for classifying clonal plots based on the percentage of stalks which are lodged
b. To determine the genetic behavior of lodging resistance


c. To determine associations between stalk erectness and other important economic characters.
REVIEW OF LITERATURE

In 1957 Lauden (30) stated that lodging occurs to some extent in all varieties when yields reach 30 to 35 tons of cane per acre. Improved harvesting methods, he suggested, would allow selection of varieties with greater lodging but higher yields.

Hicks (24) found, after surveying the Louisiana sugarcane growers in 1972, that they considered harvestability the number one desirable varietal characteristic.

Causes and Prevention of Lodging

Geerts (20) reported in 1924 that some varieties are more predisposed to lodging than others. He postulated that a lack of sufficient moisture early in the growing season, accompanied by unwise application of fertilizer, were additional causes of lodging. He listed as preventive measures variety selection, planting systems, tying adjacent rows together at their tops, stripping the lower leaves off young cane and removing the tops, but stated that these preventive measures reduced yields.

Ramanayya and Satyanarayana (43) in 1937 stated that, under normal environmental conditions, lodging of sugarcane is a varietal trait.

In 1950 Brandes (8) noted from a worldwide study that in the temperate zone some clones exhibited temporary acceleration of growth during the summer months, and that this resulted in structural weaknesses of the stem causing a tendency for those clones to lodge. He further stated that in Houma, Louisiana, hybrid clones with S. robustum genes displayed a pronounced tendency to lodge.
In his manuscript published in 1952, Van Dillewijn (53) wrote that lodged stalks tend to develop suckers. He postulated that this phenomenon was due to a weakening of top dominance resulting from a horizontal position of the stalk. Noting that fiber content of the stalk decreased and lodging increased with each successive application of nitrogen, he assumed that low fiber content of the stalk contributed to lodging. In addition, he speculated that lodging may result from heavier tops due to excess nitrogen fertilization. Van Dillewijn further wrote that Honig found an association between lodging and starch formation in the concave side of the stem.

In 1955 King (28) suggested that a possible solution to the lodging problem might lie in lengthening the time between fallows in order to deplete more rapidly the available plant food reserves. Plant food depletion could be accomplished by additional ratoon crops. He believed an alternate long range solution would be to develop less vigorous, higher sucrose varieties.

Rao and Rao (44) reported from India in 1956 on new lodging prevention measures which could reduce the cost over other systems already in practice. They recommended the double operation of trench planting and "trash twist propping." The system consists of twisting older leaves of adjacent rows together to bamboo stakes periodically during the growing season on sugarcane planted in trenches 16 inches wide and 12 inches deep.

In 1960 Skinner (48) presented results of experiments in which he attempted to measure lodging resistance. Lodging resistance, he concluded, is at a minimum when root anchorage is reduced by
water saturated soils. He also stated that ratoon crops have shallower root systems and are therefore more subject to lodging. Lodging, he suggested, probably is influenced by the roots to shoots ratio because of support reasons.

Bhoje and Mathur (5) in 1962 recommended earthing-up and binding as lodging prevention measures. Earthing-up consists of placing additional soil along row sides and surrounding clones to provide better anchorage. Binding is very similar to the "trash twist propping" suggested by Rao and Rao (44) in 1956.

In 1965 Nath and Mathur (40) presented experimental data which showed that earthing-up and binding prevented lodging and the resulting deterioration of juice quality, while achieving maximum increases in yield.

Buzacott (13) expressed the opinion in 1965 that in the long run little yield gain, if any, would be realized by replacing lodging susceptible varieties with erect varieties because he insisted that the lodging susceptible varieties lodged badly only in exceptional years. Environment, he claimed, is a most important factor in lodging because of its inconsistency from place to place and year to year.

In 1971 Hosur (25) described the trash-twisting method of propping sugarcane. It is a method which has evolved throughout the years to curtail losses due to lodging. Propping consists of fastening clumps of adjacent rows together using twine constructed from older leaves. By constructing 2 trash-twisted ropes 2 to 3 months apart, the crop is effectively protected.
Effects of Lodging

In 1924 Geerts (20) reported the purity and sucrose content of fallen sugarcane were on the average 5.28 and 3.21, respectively, lower than standing cane of the same variety. Lodged cane was also accompanied by a smaller average stalk weight.

Batham and Nigam (3) observed in 1935 a difference in the sucrose content of juice from lodged and from standing cane. They showed a general difference of between 1.84 and 2.77%, thereby indicating the extent of deterioration which takes place.

Srivastava (50) the same year using a different variety found the percent loss of sucrose to be essentially the same as that found by Batham and Nigam (3).

Buzacott (11) observed in 1937 that stalks which were either in contact with the ground or covered with trash did not exhibit the same degree of rind hardness as erect stalks. He concluded that this phenomenon could account for the increased susceptibility of lodged stalks to borer damage.

Ramanayya and Satyanarayana (43) stated the same year that, once lodged, cane juice quality is depressed, the extent of depression depending upon the physiological condition of the cane. They also concluded that the degeneration of juice was a function of time and a result of sucrose disintegration.

By forcing lodging with excessive applications of nitrogen, Borden (6), reporting in 1942, found a significant sugar loss of approximately 25% only from stalk segments already mature when lodging occurred. He also measured a definitely poorer juice quality
from fallen cane, which resulted in a loss of recoverable sugar. Millable shoots arising after lodging also seemed to be affected.

Parthasarathy and Rao (42) reported in 1953 that an inclination of 90 degrees to the vertical produced the maximum loss of juice quality in lodged canes. They showed a lessened effect on juice quality as the inclination angle decreased. After lodging, recovery of sugar accumulation for the top portion was greater than that of the bottom portion of the stalk; however, neither the top nor bottom portions recovered fully.

In 1954 Vaidyanathan (52) presented experimental data showing that deterioration in juice begins within 3 days after lodging. Erect canes of the varieties tested weighed more, contained more sugar, and improved in juice quality at a faster rate than lodged canes. Losses in sugar were also noted for broken canes.

Bhoje and Mathur (5) in 1962 cited data showing the overall effects of lodging. Their study indicated the following effects: 1) deterioration of juice quality; 2) stalk weight loss because of heavy drain of reserve food material for new bud growth; 3) difficult handling at harvest; 4) rapid rate of sprouting of buds, particularly in the upper half of the stalk; 5) aerial roots resulting from root primordia in contact with moist soil; 6) unfit cane for seed purposes because of sprouting buds; and 7) pest damage.

Agnihotri (1) in 1965 reported his conclusions on lodging resulting from various fertilizer treatments. Varieties receiving double doses of nitrogen exhibited a larger percentage of area lodged, a significant increase in the number of tillers in the lodged canes
and an increase in invert sugars. On the other hand, applications of large amounts of phosphate reduced the extent of lodging. Lodging had a deleterious effect on height, girth, weight, and purity while simultaneously increasing the invert sugars. Unlike Parthasarathy and Rao (42), Agnihotri found no relationship between sucrose and the angle of inclination to the vertical.

In 1966 Davidson and Irvine (15) presented data on the effects of lodging resulting from a hurricane. Losses incurred that year, they concluded, were partly due to low stalk weights resulting from severely reduced growth rates following the storm. Low stalk volume and density accounted for the reduced weight.

**Anatomical Studies**

Garber and Olson (19) wrote in 1919 that Albrecht in 1908, working with wheat, reported some consistent associations between total area of a cross section of fibrovascular bundles and the breaking strength of wheat. Garber also reported that Moldenhawer, experimenting with wheat and barley, presented data showing that vascular bundle number could be used as a criterion for selecting lodging and nonlodging sorts.

Also in 1919, Garber and Olson (19) reported the results of a study made on correlations between lodging behavior and average number of fibrovascular bundles for wheat, oats, barley, and winter rye. They found no close relation and concluded that no one factor seemed to be correlated closely enough with lodging to be used as a selection index.

Brady (7) reported in 1934 on the association between strength of straw and lodging resistance of cereals. The data indicated that
morphological characters associated with strength of straw—tillering, length of straw, lengths of internodes, diameter of the fifth internode, thickness of culm wall, number of vascular bundles, width of lignified tissue in a cross-section, and thickness of sclerenchyma cell walls—were also characteristics of lodging resistant cereal varieties. He qualified his conclusion by stating that soil type influenced the association between straw strength and lodging resistance, and that soil variation must be taken into consideration when selecting for lodging resistant varieties.

Das (14) concluded from work presented in 1936 that, in plants receiving heavy applications of nitrogen, the woody supporting tissue is less developed, indicating less lignification and sclerenchymatic tissue.

In 1939 an anatomical study on the hardness of the sugarcane rind was presented by Khanna and Panje (27). They found that 3 major factors contributed in the greatest measure to rind hardness: the number of vascular bundles per unit volume of the rind, the lignification of the cell-walls of the vascular sheaths, and the lignification of the inter-vascular parenchyma.

Loh and Tseng (31) in 1952 performed extensive anatomical studies comparing "hard" cane, "soft" cane—with respect to rind hardness—and bamboo. "Hard" varieties have more small vascular bundles per unit area in the periphery of the internode and more developed sclerenchyma of the cortex than "soft" varieties of sugarcane; but bamboo was considered to have a desirable vascular bundle distribution pattern which imparts ideal elasticity and plasticity. They concluded
that an increase of elasticity, attributable to the development of sclerenchyma and the increase of density of vascular bundles in the cortex, may not proportionally increase percentage of fiber in the sugarcane stalk.

Stem anatomy of *Saccharum spontaneum* L. for both erect and lodging forms was compared by Negi and Khanna (41) and their results were reported in 1961. Cross sections of top, middle, and bottom internodes were utilized. Their study indicated that erect forms of *S. spontaneum* exhibit a lesser density of vascular bundles in the basal peripheral region of the internode, larger vascular bundles in the central region, but have an abundant development of lignified tissue in the peripheral region. They also noted that the loss in lignification of the peripheral bundles from bottom to middle internodes was greater in lodging forms, whereas the loss of lignification from middle to top internodes was greater for erect forms. Although the vascular bundle count was significantly greater in the bottom internodes for lodging forms, there was no significant difference in bundle count between erect and lodging forms for both the middle and top internodes. They insisted that lodging resulted directly from clones having an abundance of parenchymatous tissue at the expense of lignified tissue and smaller vascular bundles.

By means of histological examination, Tanimoto (51) in 1957 found that the average number of bundles per internodal cross section varied from 1092 to 1386 among 10 varieties. He postulated that, provided enough counts are made for any variety, the average number would appear to be the same for the 10 varieties tested. Therefore, any
variation did not appear to be varietal. He concluded that any variation in vascular bundle concentration per unit area would be a direct result of stalk diameter.

James and Smith (26) presented data in 1970 on factors affecting strength and flexibility of sugarcane stalks. Their results suggested that there is considerable variation in location of fibrovascular bundles among sugarcane clones, but that its association with stalk strength was negligible when holding the stalk diameter constant, as shown by partial correlation coefficients. Standard partial regression coefficients showed that percent fiber, stalk diameter, outer/inner bundle number,* and total bundle number accounted for 77 percent of the variation in strength of the stalk as opposed to 1 percent of the variation in stalk flexibility.

Breeding Studies for Stalk Erectness

In 1935 Sartoris (46) stated that for scoring stalks for erectness he used a system consisting of a 90 degree angle divided into equal portions of 9 degrees each. Erect stalks were scored at 10, stalks inclined at an angle of 45 degrees were scored at 5, and completely decumbent stalks were scored at 1, etc.

Bell (4) observed in 1938 that effective rating of stalk erectness was not possible in single row plots, whether replicated or not. He recommended utilization of multirow plots for assessment of stalk erectness.

*Number of fibrovascular bundles in the inner and outer one-half of a 35 degree segment of the stalk transverse section.
de Sornay (16) reporting the same year from Mauritius on criteria for evaluating single stools derived from seedlings, found that, although erectness was considered to be a desirable character, its heritability seemed to be low. However, single stools which were lodged but were not discarded because they possessed other desirable traits produced clones which were more erect when subsequently propagated. He noted that a single stool with a high number of tillers of average length resisted damage from cyclones better than seedlings with few tillers of above average length.

At the advent of mechanical harvesters in 1942, Arceneaux (2) reported on a method for classifying varieties according to their lodging habits. The method consisted of a measurement of the discrepancy between total stalk length and the straight distance between the 2 extremities. Therefore, discrepancy measurements reported as percent differences were considered as measurements of crookedness.

King (29) observed excessive lodging for 2 successive years and noted in 1956 that an urgent need existed for lodging resistant varieties. He expressed a need for canes which would not fall merely due to their top-heaviness or reaction to water saturated soils.

In 1956 Singh (47) reported there was no significant correlation between percent fiber in the stalk and erectness of the stalk in any of 7 crosses investigated. He found correlation coefficients ranging from -.031 to .104.

Hebert (21) reported in 1956 on studies involving some important agronomic characters among the progeny of 7 crosses of sugarcane.
He found positive significant correlations for stalk erectness for all crosses between single stools and the plant cane crop of clones derived from them, and between single stools and the first stubble crop of clones derived from these single stools. The r values between single stools and plant cane and single stools and first stubble averaged .33 and .38, respectively, for all crosses. Although all of the r values were significant, they tended to be low and, therefore, were considered unimportant, indicating poor agreement between single stools and clones derived from them. There was an average r value of .39 for all crosses between clones grown as plant cane and the same clones as first stubble. This r value, also, was considered low and indicated an extremely high genotype-season interaction. Hebert concluded from his data that rigid selection for erectness either in the single stool stage or among clones in one season would be ineffective.

Hebert (21) found no important associations between stalk erectness and stalk diameter, erectness and number of stalks per stool, erectness and brix, or erectness and sucrose. After analyzing the progeny of the crosses, he found differences in respect to the average erectness of the progeny and to the percentage of the progeny in the various erectness classes. Therefore, he noted that at least one of the parents of a cross should be an erect type if selection for erectness is to be made among the progeny.

Skinner (48), noting the absence of any completely successful method of estimating lodging resistance, conducted research in 1957 on the physical lodging resistance of sugarcane. He measured the
tension required to pull stalks from the vertical through an angle of 16 or 20 degrees with a spring balance attached one third from the top of the millable cane. The physical lodging resistant measurements showed a positive association with lodging. No association was discovered between physical lodging resistance and yield, sugar content, number of stalks per stool, stalk length, or stalk weight. He considered the character to be genetical and that selection for it would be as effective as selection for yield in replicated trials.

Hebert and Henderson (22) concluded in 1959, from Hebert's previous study of important agronomic characters in progenies of 7 crosses, that selection for erectness in the original single stool nurseries was relatively ineffective, although selection for erectness was vigorously practiced previous to these findings. They suggested more clonal plots be established yearly from a more liberal selection among single stools.

In 1958 Murphy et al. (38) presented results comparing the "snap test" and the "lodging resistance factor method" for testing lodging resistance in oats. The results indicated that a closer association exists between the "snap test" method and the percentage of lodged plants.

Dunckelman (17) in 1959 suggested reducing in the breeding programs rigid selection practices designed to supply the Louisiana industry with nonlodging varieties. He contended that its removal as a prime requirement would provide selectivity freedom for higher tonnage clones, disease and insect resistance, cold tolerance, lower fiber content and higher sucrose.
Nagi and Mishra (39) in 1960 said that for *S. spontaneum* clones the tendency for erectness or lodging seemed to be inherent.

The following year Loupe (32) revealed his studies to determine the effectiveness of selecting varieties from either the plant cane seedlings or the stubble cane seedlings. Correlations calculated for erectness between stubble cane seedlings and plant cane clones indicated a close association between the 2 crops and reconfirmed the effectiveness of making initial selections from the stubble cane of seedlings. It was shown that it would be impractical to select for erectness in the plant cane crop of seedling plots. Highly significant correlations were found between erectness and the following: number of stalks, brix, diameter of stalk, weight of stalk, height of stalk, and sucrose.

Brett (10) reported in 1962 that lodging is the most commonly occurring agronomic defect for which seedlings are discarded in Natal. Roach stated during a discussion of Brett's paper that he had obtained negative phenotypic correlations between erectness and yield.

In an article on seedling defects in the same year Buzacott (12) wrote that erectness is a criterion for selection because of the adverse influence lodged cane has on harvesting. He further wrote that special rich-land selection plots are utilized in the development of erect varieties for certain areas.

Although Morri11-O1avari1eta (37), in 1963, found a correlation of .64 for erectness between single stool planted seedlings and their respective 5-foot plant cane clonal plots, he considered it was not high enough to allow selection from one crop. He concluded that lower minimum selection standards should be practiced initially to allow
inclusion of more genetically variable types.

In 1965 Buzacott (13) reported there seemed to be a lack of a meaningful correlation between erectness and fiber percent but stated it was likely that where long canes are concerned, higher fiber clones would be associated with greater lodging resistance.

The same year, Matherne et al. (35) stated that during a 10-year period ending in 1963 only 1 percent of the potential varieties were discarded because of lodging.

In 1968 Roach (45) published a study of quantitative characteristics in 8 F₁ populations of crosses between S. officinarum and S. spontaneum. The results indicated that when breeding for erectness only the noble parent seemed to be a reliable guide to performance of the progeny. By comparing means of n₁ + n and 2n₁ + n progenies, Roach concluded that the greatest degree of erectness was exhibited by the progenies of the 2n₁ + n hybrids. Repeatability estimates, although possibly upward biased, indicated the reliability of selection for erectness.

Skinner (49) wrote in 1971 that, unlike the economically important characters which are mainly quantitative and continuous in expression under normal environmental conditions, lodging regularly shows discontinuous expression but maintains an underlying continuous variability.

Mariotti (33), the same year, reported results from a study on the associations between stalk erectness and yield components. His study showed stalk weight seemingly determined lodging tendency more frequently than either length or diameter of stalk. However, large
stalk diameter appeared to be related to more erect varieties. No significant correlation could be found between erectness and yield.

From 1965 to 1969, Breaux (9) conducted an erectness study among the unselected progeny of a biparental cross grown as plant cane single stools, first stubble single stools, 6-foot plant cane clonal plots, 15-foot plant cane and first stubble plots, and, finally, as plant cane and first stubble crops in replicated yield trials. The purpose of the study was to examine closely the selection for erectness already practiced in the breeding program and to determine associations between erectness and certain important yield components. His study showed that selection for erectness should be continued in the early test stages for clones that remain erect under normal conditions; but he found that this was not the case for sorting out varieties that would remain erect under conditions inducive to severe lodging. Many varieties included in replicated yield trials are susceptible to lodging under extreme conditions. He suggested that those potential varieties which are highly susceptible to lodging might be identified more effectively by measuring physical lodging resistance recommended by Skinner (48), if Skinner's method be proved reliable under Louisiana conditions. Delaying selection in line trials until extreme lodging occurs, naturally or artificially induced by heavy irrigation, may increase the effectiveness of selection for erect varieties.

Breaux (9), with the exception of stalk length and stalk weight, found no significant associations between erectness and the important commercial characters. He considered the relationship of erectness
to both stalk weight and stalk length to be a handicap but one that could be overcome by wise selection. He concluded that the low but significant positive correlation found between erectness and tons of cane per acre in the badly lodged yield trials presents a serious limitation on rigid selection for erectness.

In 1972 Mariotti (34) reported that erectness of stalk should not be selected for early in the breeding program because of the low repeatability estimate obtained for that character.
MATERIALS AND METHODS

The materials used in this study included the unselected progenies of 8 biparental crosses and the 16 parental varieties. Four of the biparental crosses—CP 52-68 x CP 48-103, L 61-67 x CP 62-258, CP 61-37 x L 62-96, and L 60-25 x CP 57-614—were grown together as plant cane, first stubble, and second stubble and hereafter will be referred to as Group I crosses. The other 4 biparental crosses—CP 65-357 x CP 62-258, L 60-25 x CP 66-346, CP 52-68 x L 65-69, and CP 65-357 x L 65-69—were also grown together as plant cane, first stubble, and second stubble and hereafter will be referred to as the Group II crosses.

The crosses of Group I had been made at the U.S. Sugarcane Field Station, Canal Point, Florida, during the 1968 crossing season, and the seed was sent to the U.S. Sugarcane Laboratory at Houma, Louisiana. Early in 1969, seedlings were established in flats in the greenhouse and were later individually transplanted to peat pots. The seedlings were transplanted individually into the field at the Houma station in the spring with a 16-inch spacing between seedlings along the row. The plants that develop from these separately spaced seedlings are commonly referred to as "single stools." These single stools were grown in 1969 and 1970, the latter being the first stubble crop. The planting of seed, transplanting of seedlings, and the care of the single stool seedling crops were done by Dr. R. D. Breaux and his staff.

In the fall of 1970, 100 single stools were chosen from each of the 4 crosses. The 400 single stools were selected at random except
for the requirement that each have at least 4 stalks and be free of visible symptoms of mosaic. Each selected single stool was identified by an assigned number.

A 10-foot unreplicated clonal plot was established from each of the 400 single stools at the St. Gabriel branch of the La. Agricultural Experiment Station. All 4 stalks harvested from each single stool were planted in the 10-foot plots. Six replications of each of the 8 parental varieties, harvested as 25 stalk samples at Houma, were scattered among the plots of the 400 experimental clones.

The Group II crosses had been made at the U.S. Sugarcane Field Station, Canal Point, Florida, during the 1970 crossing season. Dr. R. D. Breaux supervised the planting of seed, transplanting of seedlings, and care of the single stools as he did for the Group I crosses.

In the fall of 1972, 100 single stools from each bi-parental cross were selected and subsequently planted at the St. Gabriel station using the same procedure as outlined for the Group I crosses.

Fertilization, pest control applications, and other recommended cultural practices were adhered to throughout the experiment.

The writer began investigations of the material in the fall of 1972. From October 16 to October 25, 1972, samples of the progenies and parental varieties from the Group I crosses were collected from the first stubble clonal plots. A late harvest of the first stubble crop of the Group I crosses was also made from November 27 to December 4. Samples from the second stubble clonal plots of the Group I crosses and the plant cane clonal plots of the Group II
crosses were collected from October 15 to October 18, 1973, and from November 12 to November 16, 1973, respectively. The first stubble crop of the Group II crosses was harvested from December 2 through December 4, 1974. Although the second stubble crop of the Group II crosses was not harvested as the other crops were, certain data were recorded on the standing cane during the winter months of 1975 and 1976.

For each crop except the Group II second stubble crop, a 10-stalk sample was cut from each clonal plot, hand cleaned, bundled, tagged for identification, and removed from the field to the St. Gabriel station laboratory. Many of the clonal plots had no stalks or had less than 10. If the plots had a minimum of 8 stalks, they were harvested. For all years data were obtained for stalk erectness, and for all harvests data were recorded for mean stalk weight, laboratory brix, sucrose, purity, and an estimate of percent fiber in the cane. Stalk length and diameter measurements were taken for both first stubble crop harvests of the Group I crosses and for the plant cane crop harvest of the Group II crosses. Additionally, stalk diameter was recorded on standing cane for the second stubble crop of the Group II crosses. Also, stalk brittleness determinations were made among the progeny of the cross L 60-25 x CP 57-614 and all 8 Group I parental varieties prior to the late first stubble harvest.

Procedures for Measuring Characters

Characters for which data were obtained in this study were:

1. Erectness of stalks
2. Mean stalk length
3. Mean stalk diameter
4. Mean stalk weight
5. Laboratory brix, sucrose percent, and purity
6. Estimated fiber percent in cane
7. Brittleness of stalks

1. Erectness of stalks

For classifying the clonal plots in the first stubble crop of the Group I crosses, erectness of stalks was based solely on the conventional subjective rating scale used by the USDA at the Houma station, as described and illustrated by Hebert and Henderson (22). Although the conventional system consists of 5 ratings, only ratings 1 through 4 were utilized in this investigation. The scale is as follows:

1 = very superior; 2 = superior; 3 = average; and 4 = inferior. The conventional system of classification is based on a subjective rating of the degree of erectness. A clone must have at least a 3 rating to be adapted to the soldier-type mechanical harvesters used in Louisiana.

In 1973 a different system was devised to classify the clonal plots. Instead of basing the classification on the degree to which the stalks deviated from the vertical—the conventional system used previously—in the new system a visual estimate was made for each plot of the percentage of stalks which were lodged, with lodged stalks defined as those which lean from the completely upright or vertical position by at least 45 degrees. The new rating system, along with the conventional system, was used in 1973 to classify each
clonal plot of the second stubble crop of the Group I crosses and the
plant cane crop of the Group II crosses.

Only the new system, which was termed the % lodging system, was
used to classify both the first and second stubble crops of the
Group II crosses.

Stalk erectness ratings were recorded a few days prior to harvest
for each crop except the Group II second stubble crop. Erectness
determinations for the Group II second stubble crop were recorded on

2. Mean stalk length

Stalk length measurements were taken for all stalks in the samples
harvested. Stalks obviously affected by the sugarcane borer Diatraea
saccharalis F. were not measured. The length measurements were made
for each stalk of the harvested sample on a precalibrated platform and
the data were recorded. The mean stalk length was then determined
for each 10-foot clonal plot.

3. Mean stalk diameter

Stalk diameter measurements were obtained for all samples har-
vested by measuring with a Vernier caliper the diameter at the approx-
imate mid-point of the middle internode. The diameter was recorded
in millimeters. Mean stalk diameter was calculated by averaging the
results of 5 randomly selected stalks. Stalks which showed an inter-
node size obviously reduced because of apparent borer infestation
were excluded. A similar procedure for obtaining mean stalk diameter
was utilized on standing cane for the Group II second stubble crop.
4. Mean stalk weight

The hand cleaned samples were weighed to the nearest ounce, and mean stalk weight was then obtained for each 10-foot clonal plot.

5. Laboratory brix, sucrose percent, and purity

Juice quality studies were made from the same samples that were used for the measurements of stalk length, stalk diameter, and stalk weight. All juice quality determinations were made from samples milled in a 3-roller mill with 1,100 lb pressure in the St. Gabriel laboratory.

The brix hydrometer, standardized at 20 C, was used to obtain observed brix. Temperature corrections were made according to Table 21 in the ninth edition of the Cane Sugar Handbook by Spencer and Meade (36).

Horne's method, which employs dry salt for clarification, was used to analyze sucrose percent. A portion of the juice of the milled sample was placed in a container with 3 to 4 grams of dry lead subacetate. After the samples were clarified and filtered with dicalite, the filtrate was then polarized in a Bausch and Lomb Polariscope. The sucrose percent of the juice was then obtained from Schmitz's table (36).

By dividing the sucrose percent by its brix, then multiplying by 100, purity was calculated for each sample.

6. Estimated fiber percent in cane

Fiber percent estimations were also made from the same samples milled for juice quality studies. The procedure outlined by Henderson et al. (23) was used to obtain the fiber percentages of the samples.
Both juice and bagasse were collected from the samples milled at approximately 60% juice extraction. Brix determinations were made from the juice samples. The bagasse was bagged, tagged for identification, and weighed shortly after milling. The weights were recorded. The bagged bagasse was then dried in a gas-fired drier at approximately 150°F. The bagasse samples were weighed periodically until they had reached constant weight. The difference between the weight of dried bagasse and the original weight of bagasse represented the moisture which had remained in the bagasse after milling. It was assumed that the remaining moisture contained the same concentration of soluble solids, or brix, as the juice analyzed. Therefore, the amount of soluble solids remaining in the bagasse was computed by multiplying the brix times the moisture remaining in the bagasse. The difference between soluble solids remaining in the bagasse and the weight of the dried bagasse represented an estimate of the weight of fiber in the samples. The fiber percent of the samples was obtained by dividing the estimated weight of fiber by the weight of the sample, then multiplying by 100.

7. Britteness of stalks

Britteness, as measured in inches of deflection, was determined for all 10 stalks with the use of a stalk deflection instrument described by Fanguy (18).

An analysis of variance was calculated to reveal significant differences, if any, for erectness based on both the conventional and % lodging systems among the parental varieties in individual years and as a mean of all or certain years. Tukey's Honestly Significant
Difference test was used to test significance for mean differences among the parental varieties. In addition, coefficients of variation, based on the generalized experimental error, were computed for each analysis of variance.

Frequency distributions for erectness based on the % lodging system were constructed to facilitate the evaluation of the genetic behavior of lodging of each biparental cross for individual years and for an average of certain years.

In order to demonstrate the association between years for % lodging of the experimental clones of each biparental cross, correlation coefficients were calculated. Correlation coefficients were also obtained to indicate the association of % lodging between experimental clones in individual years and mean % lodging of clones as an average of certain years.

Furthermore, in order to determine which and how many clones, if any, were either significantly lower or significantly higher in % lodging than the Group II parental varieties as an average of certain years, an analysis of variance was calculated using individual years as replications. Tukey's Honestly Significant Difference test was used to test the significance of mean differences. Coefficients of variation, based on the generalized experimental error, were computed for each analysis of variance.

Correlation coefficients were obtained to indicate the association between % lodging and the other economically important characters for which data were recorded. The most reliable average of the characters were used to determine associations.
Nearly all of the statistical analyses were conducted by the LSU Computer Research Center.
RESULTS AND DISCUSSION

Comparison of the Conventional and % Lodging Systems

In using the conventional system for classifying small clonal plots for erectness, the author had difficulty in interpreting the subjective rating scale. In part, the dilemma involved whether to base the classification rating upon the lodging behavior of the majority of the stalks or upon the number of most severely lodged stalks. The erectness classes, illustrated by Hebert (21), gave no indication of which approach should be used to classify a clonal plot, such as depicted in Fig. 1, in which the majority of stalks were completely upright and only a few stalks were severely decumbent.

Furthermore, the conventional system made distinctions between degrees of erectness among clonal plots which are not related to an important extent with harvestability. For example, Fig. 2 shows an erect clonal plot of CP 65-357 and Fig. 3 shows a clonal plot of CP 52-68 which exhibited a few, slightly decumbent stalks. By classification with the conventional system, the plot of CP 65-357 would have been rated in class 1 whereas the plot of CP 52-68 would have been rated in class 2 or 3. However, neither clonal plot would present problems in harvesting, and, therefore, the conventional system provides a distinction of little importance.

In addition, the conventional classification system did not distinguish among clonal plots exhibiting varying degrees of severely lodged stalks. The 2 clonal plots shown in Fig. 4 and 5 were not differentiated by the conventional system as they both would have been given the same, very inferior erectness rating. However, it
Fig. 1. An experimental clone in which the majority of stalks were completely upright and only a few stalks were severely decumbent

Fig. 2. An erect clonal plot of CP 65-357
can be seen that the percentage of severely lodged stalks is greater for the clonal plot in Fig. 5 and, therefore, should be distinguished from the clonal plot in Fig. 4.

Fig. 3. A clonal plot of CP 52-68 which exhibited a few, slightly decumbent stalks

Besides these defects, the conventional system did not adequately differentiate certain varieties according to their known lodging habits. Tables 1 and 2 contain the results from classification by the conventional system of the Group I parental varieties as a combination of the first and second stubble crops and the Group II parental varieties in the plant cane crop, respectively. Note in Table 1 that there was some overlapping in erectness class values of the replications of certain varieties which are known to differ in their lodging habit. For example, a less than adequate distinction is shown between CP 52-68 and CP 61-37, because of the overlap of
Fig. 4. A clonal plot which exhibited approximately 50% lodged stalks

Fig. 5. A clonal plot which exhibited 100% lodged stalks
replications in class 3. However, CP 52-68 is known as a very erect variety which presents few problems in harvesting, whereas CP 61-37 is known to be susceptible to lodging.

Table 1. Frequency distributions in erectness classes based on the conventional system of classification for the 8 Group I parental varieties as a combination of the first and second stubble clonal plots.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. of replications in each of the following erectness classes</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CP 52-68</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>CP 48-103</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>L 61-67</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>CP 62-258</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>CP 61-37</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>L 62-96</td>
<td>11</td>
<td>4.0</td>
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<tr>
<td>L 60-25</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>CP 57-614</td>
<td>2</td>
<td>8</td>
</tr>
</tbody>
</table>

Furthermore, Table 2 shows a similar overlap of replications in class 3 between 2 erect varieties, CP 52-68 and CP 66-346, and the susceptible variety L 60-25.

Although stalk erectness is only one of several factors which contribute to harvestability, it is safe to assume that an erect clone presents fewer problems than a lodged clone in harvesting regardless of other contributing factors. For this reason, perhaps the most serious defect encountered in the conventional system was that the erectness classes, as pointed out earlier, were not closely related to the degree of harvestability of the plots.

Because of the defects in the conventional system, the clonal plots of both the Group I and Group II parental varieties were reexamined. It was noted that varieties known to be resistant to
lodging, such as CP 52-68, CP 57-614, and CP 66-346, had very few stalks lodged sufficiently to cause problems and losses in harvesting, whereas varieties known to be susceptible to lodging, such as L 60-25, CP 61-37, and L 65-69, had a significant percentage of severely lodged stalks.

Table 2. Frequency distributions in erectness classes based on the conventional system of classification for the 6 Group II parental varieties in the plant cane clonal plots.

<table>
<thead>
<tr>
<th>Variety</th>
<th>No. of replications in each of the following erectness classes</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 65-357</td>
<td>9 3</td>
<td>3.3</td>
</tr>
<tr>
<td>CP 62-258</td>
<td>2 4</td>
<td>5.7</td>
</tr>
<tr>
<td>L 60-25</td>
<td>2 4</td>
<td>5.7</td>
</tr>
<tr>
<td>CP 66-346</td>
<td>2 4</td>
<td>2.7</td>
</tr>
<tr>
<td>CP 52-68</td>
<td>2 4</td>
<td>2.7</td>
</tr>
<tr>
<td>L 65-69</td>
<td>12</td>
<td>4.0</td>
</tr>
</tbody>
</table>

Because of what the author considers as defects in the conventional classification system for lodging, it was considered desirable to devise a different classification system that would more effectively distinguish between varieties in their tendency to lodge. In developing a new system, it was felt that certain features are required of a satisfactory system for classifying small clonal plots in respect to degree of lodging. As pointed out earlier, the system must be able to differentiate adequately between varieties known to differ in both resistance to lodging and harvestability. The differentiation provided by the method must be between degrees of erectness which are related to an important extent with harvestability. But, most importantly, the classification system must recognize differences between clonal plots in the percentage of severely lodged stalks, thereby giving an indication of harvesting difficulties.
In the new system, which was termed the % lodging system, lodging was defined as a condition in which stalks were leaning enough to create problems in harvesting and lead to losses of cane. Only stalks which had an angle of inclination to the vertical of 45 degrees or more were classified as lodged. In this system, stalks which leaned to only a limited degree and would not have created problems and losses in mechanical harvesting were not differentiated from those that remained completely upright. For each clonal plot of both the Group I and Group II parental varieties, a visual estimate was made of the percentage of the stalks which were lodged by the above definition, and this visual estimate was adopted as the new lodging classification.

The results of the reclassification of both the Group I and Group II parental varieties in 1973 based on the new lodging classification are presented in Table 3. It is apparent that the new lodging classification provided more useful and accurate results since it effectively differentiated the varieties according to their known lodging behavior. Note in Table 3 that all 11 replications of CP 52-68 and all 6 replications of CP 66-346 had no stalks leaning enough to affect harvestability adversely. In contrast, most of the replications of the susceptible variety CP 61-37 had severely lodged stalks and most would have been difficult to harvest. The overlap among these varieties with the conventional system is lacking with the % lodging system.

To further indicate the superiority of the % lodging system to differentiate varieties, Table 4 shows that, whereas only CP 52-68,
CP 62-258, and CP 57-614 were significantly more erect than the other varieties with the conventional system in 1973. 2 additional varieties, CP 48-103 and L 61-67 were significantly superior with the % lodging system. Furthermore, whereas the conventional system in 1973 indicated that CP 66-346 and CP 52-68 were significantly superior to all the remaining varieties, except CP 65-357, which was not significantly different, Table 5 shows that CP 65-357, in addition to CP 52-68 and CP 66-346, was significantly superior to L 65-69, and not significantly different from CP 62-258 and L 60-25, with the % lodging system.

Table 3. Frequency distributions for % lodged stalks of the 8 Group I varieties in the second stubble clonal plots and the 6 Group II varieties in the plant cane clonal plots.

<table>
<thead>
<tr>
<th>Variety</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Mean</th>
</tr>
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<tbody>
<tr>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
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<td></td>
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</tr>
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<td></td>
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<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24.0</td>
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<tr>
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<td></td>
<td></td>
<td>1</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24.0</td>
</tr>
<tr>
<td>CP 62-258</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td>1</td>
<td>3</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
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<tr>
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<td></td>
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<td>84.0</td>
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<td></td>
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<td></td>
<td></td>
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<td>0.0</td>
</tr>
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<td></td>
<td>6</td>
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<td></td>
<td>64.2</td>
</tr>
</tbody>
</table>

It was concluded that the classification system based on estimates of the percentages of severely lodged stalks is relatively simple to
use, is applicable to small plots, and provides a reasonably reliable indication of the harvestability of clones insofar as lodging is concerned.

Lodging Behavior of the Parents of the 8 Biparental Crosses

The lodging habits of the parental varieties of both the Group I and Group II crosses were known to range from very erect to very decumbent.

Table 4 includes mean erectness classifications for the 8 Group I parental varieties in the 1972 first stubble crop and the 1973 second stubble crop for the conventional system and in the 1973 second stubble crop for the % lodging system.

The erectness classification values by the conventional system of the 8 Group I parental varieties in the 1972 first stubble crop ranged from 2.7 to 4.0. The coefficient of variation, based on the generalized experimental error from the analysis of variance, was 11%. Although CP 52-68 and CP 57-614 were not significantly different, only CP 57-614 was significantly superior to the other 6 varieties. These 6 varieties were more susceptible to lodging and were not significantly different. Only 1 of the 4 Group I crosses, cross 4, showed a significant difference between the parental varieties.

For the second stubble crop in 1973, the ranking of the parental varieties and the erectness classification values were similar to the 1972 first stubble crop. The erectness classification values ranged from 2.6 to 4.0, and had a coefficient of variation of 12%. The most erect varieties, CP 52-68, CP 57-614, and CP 62-258, were not significantly different but were significantly superior in erectness
to the other 5 varieties. There were no significant differences among these other 5 lodging-susceptible varieties. For 1973, 3 of the 4 Group I crosses, crosses 1, 2, and 4, had parents significantly different.

Table 4. Mean erectness classification for the 8 Group I parental clones in each of the 2 years, 1972 and 1973, for the conventional system and in 1973 for the % lodging system.

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CP 52-68</td>
<td>3.3 ab&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2.6 a</td>
<td>00.0 a</td>
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<tr>
<td></td>
<td>CP 48-103</td>
<td>4.0 b</td>
<td>3.6 b</td>
<td>24.0 a</td>
</tr>
<tr>
<td>2</td>
<td>L 61-67</td>
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<td>3.6 b</td>
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</tr>
<tr>
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<td>CP 62-258</td>
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<td>3.4 a</td>
<td>12.0 a</td>
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<td>3</td>
<td>CP 61-37</td>
<td>3.5 b</td>
<td>4.0 b</td>
<td>62.0 b</td>
</tr>
<tr>
<td></td>
<td>L 62-96</td>
<td>4.0 b</td>
<td>4.0 b</td>
<td>64.0 b</td>
</tr>
<tr>
<td>4</td>
<td>L 60-25</td>
<td>3.8 b</td>
<td>4.0 b</td>
<td>84.0 b</td>
</tr>
<tr>
<td></td>
<td>CP 57-614</td>
<td>2.7 a</td>
<td>3.2 a</td>
<td>8.0 a</td>
</tr>
<tr>
<td></td>
<td>HSD .05 =</td>
<td>.77</td>
<td>.86</td>
<td>36.89</td>
</tr>
<tr>
<td></td>
<td>C.V. =</td>
<td>11%</td>
<td>12%</td>
<td>52%</td>
</tr>
</tbody>
</table>

<sup>1</sup>Means within each column followed by the same letter are not significantly different at the 5% probability level according to the Honestly Significant Difference test.

On the other hand, classification of the Group I parental varieties in the 1973 second stubble crop, according to the % lodging system, showed that there was a significant difference between parents in only cross 4. For this year, the range in % lodging classification values was from 0 to 84% and there was a coefficient of variation of 52%. This very high coefficient of variation was evidently due to the wide range of % lodging classification values among the replications of some varieties. Five varieties, CP 52-68, CP 48-103, L 61-67,
CP 62-258, and CP 57-614, were not significantly different but were significantly more erect than the 3 varieties, CP 61-37, L 62-96, and L 60-25. These latter 3 varieties were not significantly different.

Mean erectness classifications for the 6 Group II parental varieties in each of the 3 years, 1973, 1974, and 1975, and as an average of only 1973 and 1974, for the % lodging system and in 1973 for the conventional system are shown in Table 5.

In 1975, the clonal plots were not classified for erectness until late in January to allow time for the parents to lodge in a manner that would indicate their true behavior. Unfortunately, the behavior of the parental varieties in 1975 did not provide adequate distinction between lodging types nor was it relative to their behavior in the previous two years. Therefore, it was felt that the 1975 data should be evaluated separately from the 1973 and 1974 data.

The erectness classification values by the conventional system for the 6 varieties in the plant cane crop in 1973 ranged from 2.7 to 4.0 with a coefficient of variation of 13%. The 2 sets of plots of CP 65-357, as well as CP 66-346, and CP 52-68 were the most erect varieties. Although these 3 varieties were not significantly different, only CP 66-346 and CP 52-68 were significantly superior to all the other 3 varieties, CP 62-258, L 60-25, and L 65-69. These 3 most lodging-susceptible varieties were not significantly different. Only the most erect set of plots of CP 65-357 was significantly better than L 65-69. There were significant differences between the parents for 3 of the 4 crosses, crosses 6, 7, and 8, according to the conventional system in 1973.
**Table 5.** Mean erectness classification for the 6 Group II parental clones in each of the 3 years, 1973, 1974, and 1975, and as an average of 1973 and 1974 for the % lodging system and in 1973 for the conventional system.

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>CP 65-357</td>
<td>18.3 a&lt;sup&gt;1&lt;/sup&gt;</td>
<td>46.7 ab</td>
<td>8.3 a</td>
<td>32.5 ab</td>
<td>3.3 abc</td>
</tr>
<tr>
<td></td>
<td>CP 62-258</td>
<td>38.3 ab</td>
<td>55.0 bc</td>
<td>46.7 b</td>
<td>46.7 bc</td>
<td>3.7 bc</td>
</tr>
<tr>
<td>6</td>
<td>L 60-25</td>
<td>31.7 ab</td>
<td>91.7 c</td>
<td>26.7 ab</td>
<td>61.7 c</td>
<td>3.7 bc</td>
</tr>
<tr>
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<td>CP 66-346</td>
<td>00.0 a</td>
<td>48.3 ab</td>
<td>23.3 ab</td>
<td>24.2 ab</td>
<td>2.7 a</td>
</tr>
<tr>
<td>7</td>
<td>CP 52-68</td>
<td>00.0 a</td>
<td>15.0 a</td>
<td>1.7 a</td>
<td>7.5 a</td>
<td>2.7 a</td>
</tr>
<tr>
<td></td>
<td>L 65-69</td>
<td>61.7 b</td>
<td>76.7 bc</td>
<td>21.7 ab</td>
<td>69.2 c</td>
<td>4.0 c</td>
</tr>
<tr>
<td>8</td>
<td>CP 65-357</td>
<td>13.3 a</td>
<td>51.7 ab</td>
<td>8.3 a</td>
<td>32.5 ab</td>
<td>3.2 ab</td>
</tr>
<tr>
<td></td>
<td>L 65-69</td>
<td>66.7 b</td>
<td>71.7 bc</td>
<td>18.3 ab</td>
<td>69.2 c</td>
<td>4.0 c</td>
</tr>
</tbody>
</table>

HSD<sub>.05</sub> = 41.7  
C.V. = 79% 37% 99% 33% 13%

<sup>1</sup>Means within each column followed by the same letter are not significantly different at the 5% probability level according to the Honestly Significant Difference test.
In comparison, only 2 of the 4 crosses, crosses 7 and 8, had parents significantly different in % lodging classification values for the % lodging system in 1973. For this year, the % lodging classification values ranged from 0 to 66.7%, and, again, there was a high coefficient of variation of 79%. The most erect varieties, CP 65-357, CP 66-346, CP 52-68, CP 62-258, and L 60-25, were not significantly different but only CP 65-357, CP 66-346, and CP 52-68 were significantly more erect than the 2 sets of plots of L 65-69.

On September 7, 1974, Hurricane Carmen caused early and severe lodging among the plots of the Group II crosses in the first stubble crop. However, by December 1, 1974, the plots of the parental varieties exhibited behavior that was similar to their known lodging habits and data on erectness were taken. Also, the ranking of the parental varieties was somewhat similar to that of the plant cane crop. However, the % lodging classification values ranged from 15 to 91.7% and the coefficient of variation was 37%. For this year, the 3 varieties, CP 65-357, CP 52-68, and CP 66-346, were not significantly different but only CP 52-68 was significantly more erect than all the other varieties. CP 66-346 and CP 65-357 were significantly superior to only L 60-25. CP 62-258, L 60-25, and L 65-69 were not significantly different. The % lodging classification values were higher than in the 1973 plant cane crop. Likewise, only 2 of the 4 crosses, crosses 6 and 7, had parents significantly different in erectness.

On the other hand, only 1 of the 4 crosses, cross 5, had parents significantly different in 1975. The % lodging classification values
ranged from 1.7 to 46.7%, with a coefficient of variation of 99%.
Although CP 52-68, L 60-25, CP 66-346, CP 65-357, and L 65-69, were
not significantly different, only CP 52-68, and CP 65-357 were sig-
ificantly better in erectness than CP 62-258. As pointed out earlier,
the unreliable nature of the 1975 data was such that it was decided
to evaluate it separately.

The % lodging classification values as a mean of 1973 and 1974
showed that there were significant differences among the parents for
3 of the 4 crosses, crosses 6, 7, and 8. The % lodging classification
values ranged from 7.5 to 69.2% and there was a coefficient of varia-
tion of 33%. CP 52-68 was significantly superior to CP 62-258, L 60-25,
and L 65-69 but was not significantly different from CP 66-346 and
CP 65-357. CP 66-346 and CP 65-357 were significantly more erect
than L 60-25 and L 65-69. The most lodging-susceptible varieties,
CP 62-258, L 60-25, and L 65-69 were not significantly different.
The ranking of the Group II parental varieties in each year, 1973 and
1974, was somewhat similar to the ranking of the parental varieties
as a mean of both years according to the % lodging system.

Determination, By Use of the % Lodging System,
of the Genetic Behavior of Lodging Resistance

Tables 6 through 9 contain frequency distributions, based on the
% lodging system, for the parental and experimental clones of each
Group I cross in the 1973 second stubble crop. For the % lodging
system in individual years, experimental clones occurred in one of 11
lodging classes, ranging from 0 to 100%. The frequency distributions
contain the number of clones and the percent of the progeny which
occurred in each class. The parental varieties are presented in the frequency distributions as the number of replications which occurred in each class.

Since the experimental clones in the progenies of the crosses were unselected, some were too short to be of potential value in a breeding program. Because of the possibility that these unacceptably short clones might tend to be more resistant to lodging due to their short stature, the data included in the frequency distributions are limited to the clones with mean stalk length of 6 feet or greater.

Lodging behavior in the parents and progeny of the cross CP 52-68 x CP 48-103.

In Table 6 are presented the frequency distributions for erectness based on the % lodging classification for the parents, CP 52-68 and CP 48-103, and the experimental clones in the 1973 second stubble crop.

Although, according to the Honestly Significant Difference test, the parental varieties were not significantly different, they obviously differed in % lodging in that all 5 of the replications of CP 52-68 were in the 0% lodging class whereas only 1 replication of CP 48-103 was in the 0% lodging class. The other 4 replications of CP 48-103 ranged in a continuous manner from 10 to 50%. The mean of CP 48-103 was 24%. Thus, the results indicate that CP 52-68 was more lodging resistant than the moderately susceptible variety CP 48-103.

The results in 1973, based on % lodged stalks, are in agreement with the long term behavior of these 2 standard varieties in yield trials and wide scale commercial production. CP 52-68 is usually very
erect while CP 48-103 is somewhat, though not extremely, susceptible to lodging.

Table 6. Frequency distributions in % lodging classes for the parents, CP 52-68 and CP 48-103, and the experimental clones of the progeny in the second stubble crop in 1973.

<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 52-68</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>CP 48-103</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>24.0</td>
</tr>
<tr>
<td>Progeny(no.)</td>
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<td>6</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>87</td>
<td>17.1</td>
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<td>Progeny(%)</td>
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<td>3</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Behavior of the parents of this cross indicates that the progeny, grown under comparable conditions and classified by the same procedure, should provide reasonably reliable information concerning the genetic behavior of resistance to lodging in a cross between resistant and moderately susceptible parents.

The range in % lodging classes of the 87 experimental clones of the progeny was from 0 to 100%. Some of this variation was unquestionably environmental, but the wider range than that of the parents indicates that an appreciable degree of genetic variation also occurred. Although, for both the parental replications and the experimental clones, there were a number of phenotypic classes exhibiting continuous variation, there were certain traits uncharacteristic of a normal distribution and atypical of a quantitative character.

The frequency distribution was strongly skewed with the 0% lodging class containing a disproportionately large number of experimental clones: 54 clones, or 62% of the progeny. Furthermore, the remaining clones appeared to be distributed uniformly among the 10
classes from 10 to 100%. Also, 12 clones, or 14% of the progeny, were outside the range of CP 48-103 and appeared to be even more susceptible than CP 48-103.

The unusually high percentage of clones in the 0% lodged class suggests that the cross should be desirable from the standpoint of breeding for erectness. This presumably is due to genes for erectness contributed by CP 52-68, considered to be a standard for erectness in the Louisiana sugar industry. However, it is also probable that some genes for erectness are contributed by CP 48-103.

Although the data in Table 6 do not provide a procedure for estimating heritability, a general conclusion appears to be warranted. Since all 5 of the replications of the very erect parent CP 52-68 were free of lodged stalks, it is probably reasonable to conclude that any clones of the progeny which possess the genetic tendency of this parent to remain erect would also be free of lodged stalks. However, 1 of the replications of moderately susceptible CP 48-103 was also fully erect. Thus, it cannot be assumed that all of the clones with 0% lodging are equal to CP 52-68 in genes for erectness. Consequently, selection of the unreplicated clones of the progeny that have 0% lodging would not prove completely effective but should at least be moderately effective.

Lodging behavior in the parents and progeny of the cross L 61-67 x CP 62-258.

Table 7 contains the frequency distributions for erectness based on the % lodging classification for the parents, L 61-67 and CP 62-258, and the experimental clones of the progeny in the 1973 second stubble crop.
Both parents of this cross have been moderately susceptible to lodging in yield trials and behaved as such in this experiment. L 61-67, with a mean of 24%, had 2 replications in the 0% lodged class but the other 3 ranged from 30 to 50%, whereas CP 62-258, with a mean of 12%, may have been somewhat more resistant, with 3 replications in the 0% class, 1 in the 20% class, and 1 in the 40% class. The parents were not significantly different according to the Honestly Significant Difference test. The parents of this cross were distinctly more susceptible to lodging than CP 52-68 and resembled CP 48-103.

Since both the parents and the progeny were grown and classified in the same year by the same procedures, it is logical to assume that this cross, between 2 moderately susceptible parents, should provide reasonably reliable information concerning the genetic behavior of lodging resistance.


| No. of clones and percent of progeny in each of the following % lodging classes |
|---------------------------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Population                     | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 | Total | Mean |
|--------------------------------|---|----|----|----|----|----|----|----|----|----|----|-----|-------|------|
| L 61-67                        | 2 | 1   | 1   | 1   |     |     |     |     |     |     |     | 5     | 24.0  |
| CP 62-258                      | 3 | 1   | 1   |     |     |     |     |     |     |     |     | 5     | 12.0  |
| Progeny(no.)                   | 27| 1   | 6   | 4   | 7   | 2   | 7   | 3   | 8   | 3   | 4    | 72    | 35.7  |
| Progeny( % )                   | 37| 1   | 8   | 6   | 10  | 3   | 10  | 4   | 11  | 4   | 6    |       |       |

As for the first cross, the 72 experimental clones of this cross ranged from 0 to 100% and part of this variation was undoubtedly genetic in nature since the experimental clones exhibited a wider range than that of the parents. Here, also, lodging behaved as a
quantitative trait because the progeny occurred in a large number of phenotypic classes exhibiting continuous variation. However, as in the progeny of the CP 52-68 x CP 48-103 cross, there were certain traits atypical of a quantitative character. This distribution did not fit a normal curve as 27 clones, or 37% of the progeny, had 0% lodged stalks. Also, as in the previous cross, the frequency of clones in each of the other 10 classes, ranging from 10 to 100%, was similar. In addition, 25 clones, or 35% of the progeny, appeared to be even more susceptible than L 61-67 as they were outside the range of this parent.

As would be expected from the behavior of the parents, the progeny was inferior to that from the first cross in the frequency of erect clones. Although 37% of the clones had 0% lodging, this is approximately the frequency of completely erect plots that occurred in the parents. Thus, the data do not provide evidence that any clones equal to CP 52-68 in lodging resistance occurred in the progeny. Furthermore, there was a much higher relative frequency of highly susceptible clones than in the first cross. Whereas in the progeny of CP 52-68 x CP 48-103 (Table 6), only 22% of the progeny had 40% or higher lodging, in the L 61-67 x CP 62-258 progeny the relative frequency of these highly lodged clones was 47%.

The data in Table 7 provide very little basis for an estimate of heritability. The distributions of the replications of the parents show the strong effect of environment on expression of % lodging and suggest that selection in this cross for resistance to lodging based on the behavior of unreplotted clonal plots would have limited value.
For example, it is questionable whether any of the 27 clones in the progeny which had 0% lodging were genetically superior to the parents. It can probably be concluded, on the other hand, that these clones would prove acceptable in respect to lodging. It can probably be concluded also that the 25 clones with 60% or higher lodging would be unacceptable since no replications of the parents were lodged this severely.

Lodging behavior in the parents and progeny of the cross CP 61-37 x L 62-96.

The frequency distributions for erectness based on the % lodging classification for the parents, CP 61-37 and L 62-96, and the experimental clones in the 1973 second stubble crop are presented in Table 8.

Unlike the 2 previous crosses, the parents of this cross, CP 61-37 and L 62-96, were both very susceptible to lodging. Their behavior in this experiment was not unlike their behavior over the years in commercial production. The difference between the parents was not significant, according to the Honestly Significant Difference test.

The replications of L 62-96 ranged in a continuous manner from 40 to 100%, with a mean of 64%, whereas the replications of CP 61-37 ranged in a like manner from 40 to 70%, with a mean of 62%.


<table>
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<td>1</td>
<td>3</td>
<td></td>
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<td>5</td>
<td>62.0</td>
</tr>
<tr>
<td>L 62-96</td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
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<td></td>
<td>5</td>
<td>64.0</td>
</tr>
<tr>
<td>Progeny(no.)</td>
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<td>1</td>
<td>3</td>
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<td>6</td>
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<td>4</td>
<td>11</td>
<td>10</td>
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<td>54.1</td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>20</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>7</td>
<td>9</td>
<td>9</td>
<td>9</td>
<td>6</td>
<td>16</td>
<td>14</td>
<td></td>
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</tr>
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</table>
As for the 2 previous crosses, this cross, between 2 susceptible parents, should provide reasonably reliable information concerning the genetic behavior of lodging resistance, since both the parents and the progeny were grown and classified together.

For this cross, also, lodging behaved as a quantitative trait as both the parental and experimental clones occurred in a number of continuously varying phenotypic classes. The 69 experimental clones ranged continuously from 0 to 100%, indicating the strong influence that environment has on the expression of erectness. However, the wider range of the progeny than that of the parents suggests that, in part, this variation is genetic in nature. Again, there were features atypical of a quantitative character. In contrast to the 2 previous crosses, but still uncharacteristic of a normal distribution, the progeny was not as strongly skewed, with only 14 clones, or 20% of the progeny, in the 0% lodging class. Furthermore, a uniform distribution of the remaining clones occurred among the 10 classes from 10 to 100%. However, 48 clones, or 70% of the progeny, exhibited 40% or greater lodged stalks, with 30% of the progeny in the 90 and 100% lodging classes.

Although the relative frequency of erect clones is lower than for the 2 previous crosses, the 21 clones in % lodging classes below the range of the parents provide evidence that genes for lodging resistance exist within the parents and were transmitted to the segregates.

Even though the data in Table 8 are not suitable for estimating heritability, the behavior of the parents indicates that the few clones with 0% lodging could be assumed to possess some resistance to lodging.
The difference that parents make in breeding for resistance to lodging is shown clearly by a comparison of the progeny from CP 61-37 x L 62-96, 2 parents which are both highly susceptible to lodging, with that from CP 52-68 x CP 48-103 (Table 6) in which one parent is highly resistant. In the cross CP 61-37 x L 62-96, 70% of the progeny was in the 40 to 100% classes and probably should be considered unacceptably susceptible to lodging. However, in the cross CP 52-68 x CP 48-103 only 21% of the progeny was in the 40 to 100% classes. This marked difference is due primarily to the genes for resistance to lodging contributed by the very erect CP 52-68. Furthermore, the behavior of the progeny from CP 61-37 x L 62-96 suggests that crosses of this nature, in which both parents are highly susceptible to lodging are of questionable value if any emphasis is to be given to lodging in selection of experimental clones.

Lodging behavior in the parents and progeny of the cross L 60-25 x CP 57-614.

In Table 9 are presented the frequency distributions for erectness based on the % lodging classification for the parents, L 60-25 and CP 57-614, and the experimental clones in the 1973 second stubble crop.

This is the only one of the 4 crosses in which the parents were significantly different according to the Honestly Significant Difference test. The parental replications did not overlap as 3 replications of CP 57-614 were completely erect and 1 each occurred in the 10 and 30% lodging classes for a mean of 8%; whereas the replications of L 60-25 ranged in a continuous manner from 50 to 100%, with a mean of 84%. L 60-25 was the most lodging-susceptible variety.
in the 1973 experiment and its behavior was in agreement with its known behavior in other experiments. Likewise the lodging resistant variety, CP 57-614, behaved as expected from observations in yield trials.


<table>
<thead>
<tr>
<th>Population</th>
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<th>30</th>
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<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 60-25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
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<td></td>
<td>5</td>
<td>84.0</td>
</tr>
<tr>
<td>CP 57-614</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
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</table>

This cross between moderately resistant and highly susceptible parents should provide reliable information concerning the genetic behavior of resistance to lodging, since both the parents and the progeny were grown and classified together.

The range in % lodging classes of the 86 experimental clones was from 0 to 100%. Unlike the 3 previous crosses, there were no clones outside the range of either parent for this cross, which is an indication of the strong influence that the environment has on the expression of erectness and is further indication of the quantitative nature of lodging behavior.

Even though the variation exhibited by the parental and experimental clones was continuous in nature, the frequency distribution of the progeny did not resemble a normal curve. Classes 10 through 90% contained a uniform distribution of clones whereas both the 0 and
100% lodging classes contained disproportionately high numbers of clones—24 and 15% of the progeny, respectively.

As would be expected of a cross between a moderately erect and a highly susceptible variety, there was a smaller percentage of 0% lodged clonal plots than for the cross, CP 52-68 x CP 48-103, between an erect and a moderately susceptible variety. Furthermore, 59%, compared to 21% for the first cross, of the progeny was in classes ranging from 40 to 100% lodged stalks.

Again, the data in Table 9 provide little basis for an estimate of heritability. Not unlike the second cross, L 61-67 x CP 62-258, the 2 plots of the parent CP 57-614 which had lodged stalks indicate that not all clones exhibiting 0% lodging can be considered as erect as CP 52-68. On the other hand, the behavior of the highly susceptible parent L 60-25 suggests that all clones with 50% or more lodged stalks would be unacceptable. Therefore, selection among those clonal plots with 0% lodging would be, at best, only moderately effective.

Tables 10 through 21 contain frequency distributions based on the % lodging system for the parental and experimental clones of each Group II cross in individual years and for the mean of 1973 and 1974.

For the % lodging system, experimental clones occurred in one of 11 lodging classes, ranging from 0 to 100%, for individual years. For the mean of both years, each lodging class represents a range of 10%, except the first and last lodging classes. The first class represents a range of 0 - 5% and the last class represents a range of 96 - 100%. These 2 classes are presented in the tables as 0 and 100% lodging, respectively, in order to facilitate the comparison of individual
years to the mean of both years. For the remaining 9 classes, class centers are used in the tables to represent each % lodging class for the mean of both years.

As pointed out earlier, although Hurricane Carmen caused severe lodging early in 1974, the relative behavior of the parents later in the year was in general agreement with the 1973 behavior. However, due to very light lodging in 1975, the behavior of the parental varieties did not provide adequate distinction between lodging types in 1975 nor was it related to their behavior in the 2 previous years. Therefore, it was concluded that the 1975 data should be evaluated separately from the 1973 and 1974 data.

As for the Group I crosses, the segregates of the crosses were unselected and because of the possibility that those with mean stalk length of less than 6 feet might tend to be more resistant to lodging due to their short stature, the data included in the frequency distributions are limited to the clones with mean stalk length of 6 feet or greater.

Lodging behavior in the parents and progeny of the cross CP 52-68 x L 65-69.

Table 10 contains the frequency distributions for erectness based on the % lodging system for the parents, CP 52-68 and L 65-69, and the experimental clones in the 1973 plant cane crop and the 1974 first stubble crop.

The behavior of the parents of this cross was similar in both years despite the occurrence of a hurricane in 1974. For both years, the parents were significantly different and their behavior was in agreement with their known behavior in long-term observations.
CP 52-68, known as a standard for erectness under Louisiana conditions, was the more erect parent in both years with a mean of 0% in 1973 and 15% in 1974; whereas L 65-69, considered one of the most lodging susceptible varieties, was lodged more severely, with a mean of 61.7% in 1973 and 76.7% in 1974. Replications of the parents did not overlap in either year.


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First stubble, 1974

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</table>
In addition, a correlation coefficient of .34 was obtained to indicate the agreement of lodging behavior between experimental clones in 1973 and 1974. The highly significant r value was positive and indicated a moderately low association. This means that there was a moderately low tendency for clones exhibiting a particular behavior in 1 year to exhibit the same behavior in the other year.

Because of the consistent behavior of the parental varieties and the agreement, although moderately low, of clones between years, it is felt that averaging the 2 years for the purpose of interpreting the behavior of the progeny would provide a more accurate evaluation of the inheritance of lodging behavior. Therefore, mean erectness as an average of both years was obtained for the parents and the progeny of this cross.

Presented in Table 11 are the frequency distributions for erectness based on the % lodging system of classification for the parents, CP 52-68 and L 65-69, and the experimental clones as a mean of the 1973 plant cane crop and the 1974 first stubble crop.

The parental replications did not overlap. One replication of CP 52-68 was in the 0% class and the other 5 replications ranged from 5 to 15% lodged stalks, with a mean of 7.5%. The parents obviously differed in % lodging as L 65-69 ranged in replications from 50 to 85%, with a mean of 69.2%. The results, as for individual years, were in agreement with long-term behavior of these 2 varieties under Louisiana conditions. Again, CP 52-68 is considered one of the most erect varieties in Louisiana, whereas L 65-69 is one of the most lodging susceptible varieties in most years. According to the
Honestly Significant Difference test, the parents were significantly different.

The behavior of the parents suggests that the progeny, grown under the same conditions and classified by the same procedure, should provide reliable information concerning the genetic behavior of resistance to lodging for a cross between lodging resistant and lodging susceptible parents.

The 88 experimental clones ranged in % lodged stalks from 0 to 100%. Just as for the parental replications, the variation among the phenotypic classes of the progeny was continuous. Although the variation was indicative of a quantitative trait, the population exhibited certain features uncharacteristic of a normal distribution. The class center which contained the most clones was 20% with 17 clones, or 19% of the progeny. The progeny mean was intermediate to the parents and approximately the same as the arithmetic average of the 2 parental means. Also, 42 clones were below the arithmetic average of the 2 parental means, whereas 46 clones were above. However, 24 clones, or 27% of the progeny, had 20% or less lodged stalks, which is considered acceptable in erectness.

Five experimental clones were outside the parental range in % lodging. All 5 were above the range of L 65-69. An analysis of variance, using the 2 years as replications, was calculated among the progeny and the parents of this cross. A highly significant F value for the clones source of variation indicated that genetic differences occurred among the segregates and the parents. Furthermore, a high coefficient of variation of 63%, based on the generalized
experimental error, and the highly significant F value for the years source of variation in the analysis of variance indicated the very strong influence that environment has on the expression of erectness.

However, according to the Honestly Significant Difference test, there were no clones significantly superior in erectness to the mean of CP 52-68 or significantly inferior in erectness to the mean of L 65-69. There were 8 clones numerically lower in erectness to the mean of CP 52-68, although none were significantly lower; whereas there were 16 clones numerically higher than the mean of L 65-69, although none were significantly higher.

Despite the lack of statistical support for transgressive segregation, it is evident that there were some clones among the progeny that were probably equal in erectness to CP 52-68. Since all the replications of CP 52-68 had 20% or less lodged stalks, considered acceptable, it is probable that the 24 experimental clones exhibiting 20% or less lodged stalks possess the genetic tendency of CP 52-68 to remain erect. Furthermore, the range of the replications of L 65-69 suggests that all experimental clones with 50% or greater lodged stalks would be unacceptable. Nevertheless, the data indicate that this cross, CP 52-68 x L 65-69, between lodging resistant and susceptible parents would be a suitable source of erect segregates in a breeding program.

It is evident from the r value of .34, presented earlier between clones in separate years that limited success would be realized for selection of erect clones based on 1 year's results. For a more accurate estimate of heritability, or the proportion of the total
variation that is genetic in nature, correlation coefficients between
erectness classification values of clones in individual years and the
mean erectness classification values of both years were calculated.
The r values were .80 and .83, respectively, between the mean of both
years and that of each year—the 1973 plant cane crop and the 1974
first stubble crop. These r values were positive, highly significant,
and could be interpreted as meaning that most clones erect in either
year tended to be erect as an average of both years. Hence, for
either year, the relatively high heritability estimate indicates that
selection for lodging resistance among the experimental clones of
this cross would be reasonably effective.

Another measure of the effectiveness of selection based upon 1
season's results is a comparison of the frequency of erect clones
of the entire progeny to the frequency of erect clones of a selected
progeny. Of the 88 clones in the unselected progeny, 24 clones, or
27%, had 20% or less lodged stalks as an average of both years. If
selection had been practiced among the clones of the plant cane crop
in 1973 for all clones with 20% or less lodged stalks, 65 clones, all
with 0% lodging, would have been acceptable. Of these 65 clones, 23
were also acceptable as an average of both years. Therefore, 35% of
the progeny selected in 1973 would have been acceptable as an average
of both years. This represents a net gain of only 8% for the selected
progeny over the unselected progeny.

The gain from selection in 1973 would have been of little value
in obtaining clones which would prove to be resistant to lodging. It
is apparent that the negligible gain from selection for erectness in
1973 was due to the fact that many susceptible clones in the progeny failed to lodge despite their susceptibility. Note that 65 of the 88 clones in the progeny had 0% lodging. This failure of susceptible clones in the progeny to lodge in 1973 is surprising in view of the behavior of the 6 replications of L 65-69, all of which had at least 50% lodging. However, it is also unrealistic to assume, as the 1973 data suggest, that 65 of a total of 88 clones from the cross CP 52-68 x L 65-69 would be as resistant to lodging as the erect CP 52-68 parent. It is obvious, therefore, that not all of the 65 clones acceptable in 1973 were indeed resistant to lodging.

A far greater gain would have been realized if selection had been practiced in the first stubble crop in 1974. In 1974 only 13 clones had 20% or less lodging because of the effect of Hurricane Carmen. All 13 clones, or 100% of the progeny selected in 1974, would have exhibited 20% or less lodging as an average of both years. This represents a gain of 73% for the selected progeny over the unselected progeny. Since all clones erect in 1974 were considered erect as an average of both years, it is evident that clones that remain erect after severe lodging has occurred could be effectively selected.

In contrast, 19 clones had 50% or greater lodging in 1973. All 19, or 100%, were among the 31 clones with 50% or greater lodging as an average of both years. Furthermore, of the 31 clones exhibiting 50% or greater lodging as an average of both years, 30 were from among the 63 clones with 50% or greater lodged stalks in 1974. Therefore, 48% of the clones considered very susceptible in 1974 were also
susceptible as an average of both years.

As pointed out earlier, it is felt that the data resulting from 1973 and 1974 would provide a more accurate evaluation of the inheritance of lodging behavior if considered collectively. However, the occurrence of the hurricane in 1974 provides an opportunity to evaluate the genetic behavior of lodging resistance under extreme lodging conditions. Therefore, the 1974 data were examined separately.

Note in Table 10 that there was a distinct difference between the parents as the parental replications did not overlap. The replications of CP 52-68 ranged from 0 to 30% lodging, with a mean of 15%. In contrast, the replications of L 65-69 ranged from 40 to 100% lodging, with a mean of 76.7%. The behavior of the parents, although influenced by hurricane conditions, was not unlike their behavior in normal years. CP 52-68 was distinctly more lodging resistant as the plots of L 65-69 were consistently more decumbent than the plots of CP 52-68. According to the Honestly Significant Difference test, the parents were significantly different.

The range among the 88 segregates was from 0 to 100% lodging. As would be expected in a hurricane year, there was a strong environmental influence on the expression of erectness. Indicative of a quantitative trait, the variation among the phenotypic classes was continuous. However, there were certain features of the frequency distribution which were atypical of a normal distribution. The frequency distribution was somewhat skewed with lodging classes 80, 90, and 100% containing 48% of the experimental clones. The remaining classes contained a somewhat uniform distribution of experimental
clones. The progeny mean was intermediate to the parent means but was above the arithmetic average of the parental means. Twenty-five clones were below the arithmetic parental average, whereas 63 clones were above. As further indication of the strong influence that environment has on the expression of erectness, there were no clones outside the range of either parent.

Seventy-two clones, or 82% of the progeny, had 40% or greater lodged stalks, whereas only 13 clones, or 15% of the progeny, had 20% or less lodged stalks. The unusually high percentage of unacceptable clones in this cross, indicate that, under conditions conducive to severe lodging, even a cross involving a highly resistant parent would contain very few segregates resistant to lodging.

Nevertheless, it is probable that all clones with 0 to 30% lodged stalks would be acceptable in erectness since the replications of CP 52-68 ranged from 0 to 30% and no clones of the susceptible parent, L 65-69, exhibited less than 40% lodged stalks. Also, it can probably be concluded that these acceptable clones could be effectively selected since they remained erect under severe lodging conditions.

Furthermore, of the 65 clones with 20% or less lodging in 1973, only 13 clones, or 20%, had 20% or less lodged stalks in 1974. Conversely, of the 19 clones with 50% or greater lodging in 1973, all but 1, or 95%, were among the experimental clones exhibiting 50% or greater lodging in 1974.

It can be concluded that, for this cross, selection under normal lodging conditions of clones in small, unreplicated plots would not
be effective in identifying those clones that would remain erect after severe lodging has occurred. However, it appears that clones decumbent under normal conditions would also be decumbent after severe lodging has occurred.

As referred to earlier in this manuscript, it was felt that the 1975 data should be evaluated separately from the 1973 and 1974 data. Because of the very light lodging in that year the behavior of the parental varieties did not provide adequate distinction between the 2 nor was it related to their behavior in the 2 previous years.

Table 12 contains the frequency distributions for erectness based on the % lodging system of classification for the parents, CP 52-68 and L 65-69, and the experimental clones in the 1975 second stubble crop.

Table 12. Frequency distributions in % lodging classes for the parents, CP 52-68 and L 65-69, and the experimental clones in the 1975 second stubble crop.

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</table>

Note in Table 12 that, although there was some distinction between the variation in replications of each parent the difference between the parental means did not provide enough distinction to differentiate the varieties adequately. In 1975 the mean for L 65-69 was 21.7%, whereas the means for L 65-69 in 1973 and 1974 for this cross were 61.7 and 76.7%, respectively. Therefore, since the normally susceptible
L 65-69 behaved as resistant in 1975, it is probable that the obviously mild lodging which occurred was not proper lodging conditions for a genetic study of the behavior of lodging.

**Lodging behavior in the parents and progeny of the cross L 60-25 x CP 66-346.**

The frequency distributions for erectness based on the % lodging system for the parents, L 60-25 and CP 66-346, and the experimental clones in the 1973 plant cane crop and the 1974 first stubble crop are presented in Table 13.

Even though the hurricane in 1974 caused more severe lodging than in 1973 the parental behavior of this cross was similar in both years. In each year, the parents were distinctly different and their behavior was consistent with both yield trial and commercial production data. CP 66-346 was, as expected, the more lodging resistant parent in both years with a mean of 0% in 1973 and 48.3% in 1974. Considered one of the most lodging susceptible varieties, L 60-25 displayed more severely lodged stalks, with a mean of 31.7% in 1973 and 91.7% in 1974. Only in 1973 did the parental replications overlap.

As further evidence of the association between years, the agreement of lodging behavior between experimental clones in 1973 and 1974 was estimated by calculating a correlation coefficient. The r value obtained, .41, was highly significant, positive, and indicated a moderate association. This can be interpreted as meaning that there was a moderate tendency for clones exhibiting a particular lodging behavior in 1 year to exhibit the same behavior in the other year.

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</tr>
<tr>
<td>CP 66-346</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>48.3</td>
<td></td>
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</tr>
<tr>
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<td>6</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>8</td>
<td>22</td>
<td>15</td>
<td>83</td>
<td>69.2</td>
</tr>
<tr>
<td>Progeny( % )</td>
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<td>1</td>
<td>2</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>27</td>
<td>18</td>
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</tr>
</tbody>
</table>

As a result of the moderate agreement of clones and the consistent behavior of the parental varieties between years, it is felt that a more accurate evaluation of the inheritance of lodging behavior could be derived from interpretation of the behavior of the progeny as an average of the 2 years. Therefore, mean erectness as an average of both years was obtained for the parents and the progeny of this cross.

In Table 14 are presented the frequency distributions for erectness based on the % lodging system of classification for the parents, L 60-25 and CP 66-346, and the experimental clones as a mean of the 1973 plant cane crop and the 1974 first stubble crop.

As evidence of the distinct difference between parents, the parental replications did not overlap. The replications of CP 66-346 spanned from 10 to 35% lodging, with a mean of 24.2%. In contrast, L 60-25 ranged in a continuous manner from 45 to 75% lodging, with a
mean of 61.7%. As for individual years, the parental behavior was in accordance with extensive observations under Louisiana conditions. The parents were significantly different according to the Honestly Significant Difference test.


<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
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<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
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</thead>
<tbody>
<tr>
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<td>1</td>
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<td>61.7</td>
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<tr>
<td>CP 66-346</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>24.2</td>
</tr>
<tr>
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<td>8</td>
<td>11</td>
<td>11</td>
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<td>14</td>
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<td>44.3</td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>5</td>
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<td>13</td>
<td>13</td>
<td>14</td>
<td>17</td>
<td>8</td>
<td>10</td>
<td>4</td>
<td>4</td>
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</tr>
</tbody>
</table>

Since both the parents and the progeny were grown and classified at the same time by the same procedures, it is logical to assume that this cross should provide reasonably reliable information concerning the genetic behavior of lodging resistance between moderately lodging resistant and lodging susceptible parents.

The range of the 83 experimental clones was from 0 to 100%. For the experimental clones as well as for the parental replications there were several phenotypic classes exhibiting continuous variation, which is indicative of quantitative traits. However, the distribution did not resemble a normal curve, as there were certain features uncharacteristic of a normal distribution. The class center which contained the most clones was 50% with 14 clones, or 17% of the progeny. The progeny mean was intermediate to the parents and essentially the same as the arithmetic average of the 2 parental
means. In addition, 37 clones displayed erectness that was superior to the mean of the 2 parents, whereas 46 clones were inferior in erectness to the arithmetic parental mean.

As would be expected from this cross, the number of clones with 20% or less lodged stalks was similar to the cross having CP 52-68 as a parent. Eighteen clones, or 22% of the progeny, had 20% or less lodging.

Fourteen percent of the progeny was outside the parental range in % lodging. Four clones were below the range of CP 66-346 and 8 clones were above the range of L 60-25. With the 2 years serving as replications, an analysis of variance was calculated among the 83 experimental clones and the parental clones. A highly significant F value was obtained for the clones source of variation, indicating genetic difference among the parental and experimental clones as an average of both years. The strong influence that environment has on the expression of erectness was indicated by a highly significant F value for the years source of variation and a high coefficient of variation of 51%, based on the generalized experimental error.

However, application of the Honestly Significant Difference test revealed that no clones were either significantly lower than the mean of CP 66-346 or significantly higher than the mean of L 60-25. There were 18 clones numerically below the mean of CP 66-346 but only 4 clones were numerically above the mean of L 60-25. None of these clones numerically different from the parental means were significantly different.

Although transgressive segregation was not indicated in the
statistical analysis, it is evident that some of the experimental clones were probably superior in erectness to CP 66-346 and even equal in erectness to CP 52-68. Since none of the replications of CP 66-346 had 0% lodged stalks, it is probable that the 4 fully erect clones in the progeny can be assumed to possess genotypes for greater erectness. Also, the range of replications for the moderately erect parent, CP 66-346, suggests that those clonal plots containing from 10 to 35% lodging could be considered as erect as CP 66-346 and acceptable in lodging habit. Also, the range in replications of the susceptible parent, L 60-25, implies that all experimental clones with 45% or greater lodging and especially the clones with 80% or greater lodged stalks would be unacceptable. Although the percentage of clones with 20% or less lodged stalks is comparable for the first 2 crosses, the first cross, CP 52-68 x L 65-69, contained a greater percentage of acceptable clones and indicates the superiority of CP 52-68 as a parent over the moderately erect CP 66-346 in transmitting genes for resistance to lodging. Nevertheless, there were a sufficient number of clones acceptable in erectness for this cross and therefore its value in a breeding program would be unquestionable.

The r value of .41, presented earlier between clones in separate years suggests that moderate but not complete success would be realized for selection of erect clones based upon 1 year's results. Heritability, as estimated by correlation coefficients between erectness classification values of clones in individual years and the mean erectness classification values of both years, was calculated in
order to provide a more accurate estimate of heritability, or the proportion of the total variation that is genetic in nature. The $r$ values between the mean of both years and that of each year—the plant cane crop in 1973 and the first stubble crop in 1974—were .83 and .85, respectively. As for the first cross, both $r$ values were positive, highly significant, and could be interpreted as meaning that most clones erect in either year tended to be erect as an average of both years. Thus, for either of the 2 years, the relatively high heritability estimates indicate that selection for lodging resistance among the experimental clones of this cross would be reasonably effective.

Comparison of the frequency of erect clones of the entire progeny to the frequency of erect clones of a selected progeny, is another measure of the effectiveness of selection for erectness based upon 1 season's results. Of the 83 clones tested, 18, or 22%, had 20% or lower lodging as an average of both 1973 and 1974. This percentage can be taken as the relative frequency of clones with satisfactory erectness in the L 60-25 x CP 66-346 cross and the relative frequency of erect clones that would be obtained without selection in small, unreplicated plots. In 1973, 56 clones had no more than 20% lodging. If these 56 clones had been selected from the small plots in 1973, they would have produced 18 clones which were highly erect as an average of both years, a frequency of 32%. Therefore, 32% of the progeny selected in 1973 would have been acceptable as an average of both years. This represents a gain of only 10% for the selected progeny over the unselected progeny.
The situation was similar to the first cross in that the gain from selection in 1973 would have been of little value in securing clones truly resistant to lodging. The small gain from selection of lodging resistant clones in 1973 is apparently a function of the many susceptible clones that escaped lodging in that year. Although it can be noted in Table 13 that 52 experimental clones in 1973 were fully erect, the 1 replication of the susceptible variety, L 60-25, with 0% lodged stalks suggests that not all of the 52 clones were actually resistant to lodging. In contradiction to what the 1973 data suggest, it is obvious that not all of the experimental clones acceptable in 1973 were resistant to lodging.

If selection had been practiced in the first stubble crop in 1974, a greater gain would have been realized. In 1974, of the 6 clones with 20% or less lodged stalks, all 6, or 100% of the progeny selected in 1974, would have exhibited 20% or less lodging as an average of both years. This represents a gain of 78% for the selected progeny over the unselected progeny.

It is evident, therefore, that selection for lodging resistance after severe lodging has occurred would be very effective, since all erect clones in 1974 were also erect as an average of both years.

Conversely, of the 18 clones with 50% or greater lodging in 1973, all 18, or 100%, were among the 37 clones with 50% or greater lodging as an average of both years. In addition, there were 64 clones with 50% or greater lodged stalks in 1974. Thirty-seven clones exhibited 50% or greater lodged stalks as an average of both years and all were from among the 64 clones considered unacceptable in 1974. Therefore,
58% of the progeny considered very susceptible in 1974 was considered so as an average of both years.

Although it is felt that the data resulting from 1973 and 1974 would provide a more accurate evaluation of the inheritance of lodging behavior if considered collectively, the occurrence of the hurricane in 1974 allows the opportunity to evaluate the genetic behavior of lodging resistance under extreme lodging conditions.

It can be seen in Table 13 that in 1974 the parental replications did not overlap. However, replications of CP 66-346 ranged from 20 to 70% lodging with a mean of 48.3%, and would have to be characterized as being moderately susceptible to lodging in the hurricane year. L 60-25 behaved as expected and ranged in replications from 80 to 100% lodging, with a mean of 91.7%. Although the parental behavior was influenced by hurricane conditions, they were significantly different according to the Honestly Significant Difference test.

As would be expected in a hurricane year, there was a strong environmental influence on the expression of erectness. The 83 experimental clones ranged in a continuous manner from 0 to 100% lodging, indicative of a quantitative trait. However, as for the first cross, CP 52-68 x L 65-69, there were certain features uncharacteristic of a normal distribution. The progeny was skewed towards lodging susceptibility with lodging classes 80, 90 and 100% containing 54% of the experimental clones. The remaining 46% of the progeny was uniformly distributed among the other % lodging classes. However, the progeny mean was intermediate to the parents and almost identical to the arithmetic average of the 2 parental means. Thirty-three
clones were below the arithmetic average of the 2 parental means, whereas 45 clones were above.

Only 6 clones, or 7% of the progeny, had 20% or less lodged stalks, whereas 57 clones, or 69% of the progeny, had 60% or greater lodging. It is apparent, therefore, that, under severe lodging conditions, not even this cross involving a moderately susceptible parent would contain very many experimental clones satisfactory in erectness.

However, the 4 clones with 10% or less lodged stalks could probably be effectively selected since they remained erect under extreme lodging conditions and they were outside the range of the most erect parent, CP 66-346.

Furthermore, of the 56 clones with 20% or less lodged stalks in 1973, only 6 clones had 20% or less lodging in 1974. On the other hand, of the 18 clones with 50% or greater lodging in 1973, all were among the severely lodged clones in 1974.

The conclusion can be drawn, that, for this as well as for the first cross, selection in 1 year based on small, unreplicated clonal plots of clones erect under normal lodging conditions would not be very effective in identifying those clones that would remain erect after severe lodging has occurred. But, the data suggest that elimination of clones susceptible to lodging under normal conditions would be of value in eliminating highly susceptible clones.

As for the previous cross, it was felt that the 1975 data for this cross should be evaluated separately from the 1973 and 1974 data. Again, because of the light lodging in 1975 there was not a clear
distinction between the behavior of the 2 parental varieties.

In Table 15 are presented the frequency distributions for erectness based on the % lodging system of classification for the parents, L 60-25 and CP 66-346, and the experimental clones in the 1975 second stubble crop.

Table 15. Frequency distributions in % lodging classes for the parents, L 60-25 and CP 66-346, and the experimental clones in the 1975 second stubble crop.

<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
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<th>30</th>
<th>40</th>
<th>50</th>
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<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 60-25</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>6.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP 66-346</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>3.3</td>
<td></td>
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</tr>
<tr>
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<td>15</td>
<td>10</td>
<td>8</td>
<td>10</td>
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<td>7</td>
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<td>4</td>
<td>4</td>
<td>0</td>
<td>83</td>
<td>34.8</td>
</tr>
<tr>
<td>Progeny( % )</td>
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<td>18</td>
<td>12</td>
<td>10</td>
<td>12</td>
<td>11</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be seen in Table 15 that there was very little distinction between the parental varieties as the mean for L 60-25 was 26.7% and the mean for CP 66-346 was 23.3%. However, these 2 parental varieties are known to have opposing lodging habits. L 60-25 is known as a variety normally very susceptible to lodging, but its mean of 26.7% in 1975 suggested the opposite. Furthermore, the means for L 60-25 were 31.7% in 1973 and 91.7% in 1974.

Although the means for L 60-25 were similar in 1973 and 1974, it was lower in 1975 which is further indication of the light lodging that year. Therefore, as for the previous cross, the erect nature of a supposedly lodging susceptible parental variety suggests that the lodging conditions in 1975 were not suitable for a genetic study of the behavior of lodging.
Lodging behavior in the parents and the progeny of the cross CP 65-357 x CP 62-258.

Table 16 contains the frequency distributions for erectness based on the % lodging system for the parents, CP 65-357 and CP 62-258, and the experimental clones in the 1973 plant cane crop and the 1974 first stubble crop.

The erratic behavior of the parents in each year indicates the extent to which environment influences the % lodging among the replications of the same genotype in small clonal plots.

Despite the hurricane in 1974, CP 65-357 was the more lodging resistant parent in both years with a mean of 18.3% in 1973 and 46.7% in 1974, whereas CP 62-258 was slightly more susceptible in both years with a mean of 38.3% in 1973 and 55% in 1974. According to the Honestly Significant Difference test, the parents were not significantly different in either year. CP 65-357 is a high tonnage variety which is normally erect in most years, whereas CP 62-258 has behaved as a moderately susceptible variety in yield trials.

Even though the parental behavior was somewhat inconsistent between years, the agreement of experimental clones between years was evident as a correlation coefficient of .47 was obtained between the experimental clones in 1973 and 1974. The r value was highly significant, positive, and indicated a moderate agreement in lodging behavior. This can be interpreted as meaning that most clones exhibiting a particular lodging habit in 1 year tend to exhibit the same habit in the other year.

Because of the moderate agreement of clones between years and the fact that the mean differences between the 2 parental varieties
were relative in both years, it is felt that interpretation of behavior of the progeny as an average of the 2 years would provide a more accurate evaluation of the inheritance of lodging behavior than the individual years.


<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
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<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
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<th>70</th>
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<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
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<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18.3</td>
<td></td>
</tr>
<tr>
<td>CP 62-258</td>
<td>2</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td>6</td>
<td>38.3</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>2</td>
<td>6</td>
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<td>2</td>
<td>5</td>
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<td>6</td>
<td>1</td>
<td>12</td>
<td>76</td>
<td>38.9</td>
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<tr>
<td>Progeny( % )</td>
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<td>3</td>
<td>8</td>
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<td>3</td>
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<td>8</td>
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<td>16</td>
<td>65.5</td>
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</tr>
<tr>
<td>First stubble, 1974</td>
<td>CP 65-357</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>46.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP 62-258</td>
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<td>7</td>
<td>6</td>
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<td>12</td>
<td>19</td>
<td>76</td>
<td>65.5</td>
<td></td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>8</td>
<td>7</td>
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<td>16</td>
<td>25</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The frequency distributions for erectness based on the % lodging system of classification for the parents, CP 65-357 and CP 62-258, and the experimental clones as a mean of the 1973 plant cane crop and the 1974 first stubble crop are presented in Table 17.

Unlike the 2 previous crosses, the parental replications overlapped and a distinct difference between parents did not exist. Five of the replications of CP 65-357 ranged from 15 to 35% lodging, 1 replication had 70% lodged stalks, and the mean was 32.5%. The replications of CP 62-258 ranged from 20 to 60% lodging with a mean of 46.7%. The parents were not significantly different according to
the Honestly Significant Difference test. As for individual years, the range among the replications of the parents suggest that CP 65-357 was somewhat more lodging resistant than CP 62-258.

Table 17. Frequency distributions in % lodging classes for the parents, CP 65-357 and CP 62-258, and the experimental clones as a mean of the plant cane crop in 1973 and the first stubble crop in 1974.

<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
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<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 65-357</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>32.5</td>
<td></td>
</tr>
<tr>
<td>CP 62-258</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>46.7</td>
<td></td>
</tr>
<tr>
<td>Progeny(no.)</td>
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<td>7</td>
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<td>7</td>
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<td>4</td>
<td>10</td>
<td>3</td>
<td>8</td>
<td>76</td>
<td>52.5</td>
<td></td>
</tr>
<tr>
<td>Progeny( %  )</td>
<td>8</td>
<td>9</td>
<td>8</td>
<td>9</td>
<td>12</td>
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<td>13</td>
<td>4</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The behavior of the parents suggests that the progeny, grown and classified together by the same procedure, should provide reliable information concerning the genetic behavior of resistance to lodging for a cross between moderately lodging resistant and moderately lodging susceptible parents.

The range in % lodging of the 76 experimental clones was from 0 to 100%. The variation among phenotypic classes was continuous, which is indicative of quantitative traits. However, the frequency distribution did not resemble a normal curve, and there were other features uncharacteristic of a quantitative trait. There was a tendency for all classes to contain approximately the same number of clones. The class center which contained the most experimental clones was 80% lodging with 10 clones, or 13% of the progeny. The progeny mean was higher than that of either parent and higher than the arithmetic average of the 2 parental means. Furthermore, there was
an apparent tendency for most of the clones to be inferior in erectness to the 2 parents since 26 clones, or 34% of the progeny, were below the arithmetic average of the 2 parental means, whereas 50 clones, or 66% of the progeny, were above.

Over 1/3 of the progeny was outside the parental range in % lodging. Of these, only 7 clones, 9%, were below the range of CP 65-357. An analysis of variance was calculated among the 76 experimental clones and the parental clones, with 1973 and 1974 serving as replications. A highly significant F value was obtained for the clones source of variation, indicating genetic differences among the parental and experimental clones as an average of both years. The F value for the years source of variation was also highly significant and the coefficient of variation, based on the generalized experimental error, was a high 51%, indicating the strong environmental influence on the expression of erectness.

However, application of the Honestly Significant Difference test revealed that no experimental clones were either significantly lower than the mean of the moderately resistant parent, CP 65-357, or significantly higher than the mean of the moderately susceptible parent, CP 62-258. There were 23 clones numerically above the mean of CP 65-357, although none were significantly superior; whereas there were 41 clones numerically below the mean of CP 62-258, although none were significantly inferior.

Although the statistical procedures used did not indicate the occurrence of transgressive segregation, it can be seen in Table 17 that there were some clones among the progeny that were superior in
erectness to CP 65-357. It is probable that the 7 clones with 10% or less lodged stalks possess genotypes for remaining erect, since all the replications of the moderately erect parent, CP 65-357, had 15% or greater lodged stalks. On the other hand, although 3 of the 6 replications of CP 65-357 were acceptable in % lodged stalks, the 3 replications that were not would suggest that not all clones with from 10 to 25% lodging could be considered to possess satisfactory resistance to lodging.

Also the 1 replication of the moderately susceptible parent, CP 62-258, with acceptable erectness is further evidence of the suspect behavior of those clones in the progeny considered somewhat resistant to lodging. In addition, it is likely that the 24 clones above the range of either parent would be unacceptable. The percent of clones with 20% or less lodged stalks is almost identical for this cross and the cross involving L 60-25 and CP 66-346. This can probably be interpreted as meaning that the capacity to provide segregates acceptable in erectness would be comparable between a cross with resistant to moderately resistant and susceptible parents and a cross with moderately resistant and moderate susceptible parents.

The r value, .47, presented earlier between clones in separate years implies that moderate, but not complete success, would be realized for selection of erect clones in unreplicated clonal plots based on 1 year's results. A more accurate estimate of heritability, or the proportion of the total variation that is genetic in nature, would enhance the effectiveness of selection of clones resistant to lodging. Therefore, heritability, as estimated by correlation
coefficients between % lodging values of clones in individual years and the mean % lodging values of both years, was calculated. The \( r \) values between the mean of both years and that of each year—the plant cane crop in 1973 and the first stubble crop in 1974—were .88 and .83, respectively. Both \( r \) values were positive, highly significant, and could serve to indicate that most clones exhibiting a particular behavior in 1 year would tend to exhibit the same behavior in the other year. These relatively high heritability estimates indicate that selection for lodging resistance among the experimental clones of this cross on a single year's basis would be reasonably effective.

Furthermore, another measure of the effectiveness of selection based on 1 season's results is a comparison of the frequency of erect clones of the entire progeny to the frequency of erect clones of a selected progeny. Seventeen clones, or 22% of the progeny, had 20% or less lodged stalks as an average of both years. This is the proportion of the progeny in the cross, CP 65-357 x CP 62-258, with acceptable erectness that would have been obtained without selection in the 10-foot unreplicated clonal plots. If the 35 clones with no more than 20% lodging had been selected from the small, unreplicated plots in 1973, 17 of them would have been acceptable in erectness as an average of both years. Therefore, 49% of the selected progeny would have been acceptable as a mean of both years, representing a net gain of 27% of clones resistant to lodging in the selected population over the unselected population.

The gain from selection in 1973 for this cross would have been
of more value than for the 2 previous crosses in obtaining clones which would prove to be resistant to lodging. However, the gain was only moderate and can most probably be accounted for by the fact that many susceptible clones in the progeny failed to lodge in 1973. Thirty-two of the 35 clones with no more than 20% lodging had 0% lodging. The failure of some of the 32 fully erect clones to lodge in 1973 can be explained by the fact that the relative frequency of these experimental clones with 0% lodging was essentially the same as that which occurred for the moderately susceptible parent CP 62-258. For this reason, it is evident that not all of the 32 clones in 1973 were indeed resistant to lodging.

If selection had been practiced in the first stubble crop in 1974, a larger gain would have resulted. In 1974 only 10 clones had 20% or less lodging because of the effect of Hurricane Carmen. Eight of the 10 clones, or 80% of the progeny selected in 1974, would have had 20% or less lodging as an average of both years. Therefore, a gain of 58% for the selected progeny over the unselected progeny would have been realized. Since 80% of the clones with satisfactory erectness in 1974 were also considered satisfactory as an average of both years, it is unquestionable that, as for the 2 previous crosses, selection for lodging resistance after severe lodging has occurred would be reasonably effective.

On the other hand, of the 34 experimental clones with 50% or greater lodging in 1973, 33 clones, or 97%, were among the 41 clones with at least 50% lodging as an average of both years. Also, of the 41 clones exhibiting 50% or greater lodging as an average of both
years, 38 were from among the 55 clones with 50% or greater lodged stalks in 1974. Therefore, 69% of the clones considered susceptible in 1974 were also susceptible as an average of both years.

As pointed out earlier, it is felt that the 1973 and 1974 data would provide a more accurate evaluation of the inheritance of lodging behavior if considered collectively. However, the occurrence of Hurricane Carmen in 1974 provides an opportunity to evaluate the genetic behavior of lodging resistance under severe lodging conditions.

Note in Table 16 that the parental replications overlapped considerably and as a result a distinct difference did not exist between the parents. Both parents behaved as moderately susceptible to lodging in the hurricane year. Replications of CP 65-357 ranged from 10 to 70% lodging with a mean of 46.7%, whereas CP 62-258 was slightly more susceptible as it ranged from 30 to 90% lodging with a mean of 55%. As for 1973, the parents were not significantly different, according to the Honestly Significant Difference test.

The strong environmental influence, as expected in a hurricane year, was evident as the 76 experimental clones ranged in a continuous manner from 0 to 100% lodging. However, although the variation among clones was indicative of quantitative traits, there were certain features uncharacteristic of a normal distribution. Similar to the 2 previous crosses, the frequency distribution was somewhat skewed towards lodging susceptibility with lodging classes 90 and 100% containing 41% of the progeny. The remaining 9 classes contained a uniform distribution of experimental clones. The progeny mean was above either parental mean and above the arithmetic average of
the 2 parental means. Twenty-eight clones were below the arithmetic parental mean, whereas 48 clones were above.

Only 10 clones, or 13% of the progeny, had no more than 20% lodging, whereas 48 clones, or 63% of the progeny, had 60% or greater lodging. Surprisingly, the percentage of acceptable clones for this cross involving moderately susceptible parents was essentially the same as that for the cross in which CP 52-68 was a parent. However, the 1 replication of CP 65-357, moderately susceptible in this year, which exhibited 10% lodging indicates that probably only the 3 clones which remained fully erect after the hurricane could have been effectively selected.

Furthermore, of the 35 clones with 20% or less lodging in 1973, only 8 clones had no more than 20% lodging in 1974. In contrast, of the 34 clones with 50% or greater lodging in 1973, 30 were among the experimental clones exhibiting at least 50% lodging in 1974.

This cross provides further evidence that selection in 1 year based on small, unreplicated clonal plots under normal lodging conditions would not be very effective in identifying those clones that would remain erect after severe lodging has occurred. However, the data further suggest that elimination of clones decumbent under normal conditions would be effective in eliminating highly susceptible clones.

Although, for the 2 previous crosses it was obvious that the lodging conditions in 1975 were such that the data for the parental varieties were considered unreliable, the data for the parental varieties of this cross were somewhat inconsistent with these findings.
Table 18 contains the frequency distributions for erectness based on the % lodging system of classification for the parents, CP 65-357 and CP 62-258, and the experimental clones in the 1975 second stubble crop.

Table 18. Frequency distributions in % lodging classes for the parents, CP 65-357 and CP 62-258, and the experimental clones in the 1975 second stubble crop.

<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 65-357</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>8.3</td>
</tr>
<tr>
<td>CP 62-258</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>46.7</td>
</tr>
<tr>
<td>Progeny(no.)</td>
<td>16</td>
<td>8</td>
<td>4</td>
<td>8</td>
<td>9</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>75</td>
<td>40.9</td>
</tr>
<tr>
<td>Progeny(%)</td>
<td>21</td>
<td>11</td>
<td>5</td>
<td>11</td>
<td>12</td>
<td>8</td>
<td>4</td>
<td>4</td>
<td>9</td>
<td>5</td>
<td>9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In 1975 the mean of CP 62-258 was 46.7%, whereas the means for CP 62-258 in 1973 and 1974 were 38.3 and 55%, respectively. Since the 2 previous crosses provided information suggesting the mild nature of the lodging conditions in 1975, the fact that the mean for CP 62-258 was greater in 1973 than 1975 indicates the probable unreliability of the 1975 data. Also the means of CP 65-357 in 1973, 1974, and 1975 were 18.3, 46.7, and 8.3%, respectively. A comparison of the means of CP 65-357 among the 3 years further indicates the mild lodging conditions which occurred in 1975.

Therefore, again it is probable that the lodging conditions in 1975 were not proper for a genetic study of the behavior of lodging.

Lodging behavior in the parents and progeny of the cross CP 65-357 x L 65-69.

The frequency distributions for erectness based on the % lodging system for the parents, CP 65-357 and L 65-69, and the experimental
clones in the 1973 plant cane crop and the 1974 first stubble crop are presented in Table 19.

As for the previous cross, CP 65-357 x CP 62-258, the erratic behavior of the parents of this cross indicates the strong influence that environment has on the % lodging among replications of the same genotype in small clonal plots.

Although the normally moderately erect CP 65-357 was the more lodging resistant parent in both years, with a mean of 13.3% in 1973 and 51.7% in 1974, it behaved as susceptible to lodging in the hurricane year of 1974. Furthermore, although L 65-69 was more severely lodged in both years with a mean of 66.7% in 1973 and 71.7% in 1974, the inconsistent nature of the variation among replications in 1974 was evident as 1/3 of the plots of L 65-69 exhibited acceptable erectness in a hurricane year.


<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant cane, 1973</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP 65-357</td>
<td>5</td>
<td>1</td>
<td>6</td>
<td>13.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>L 65-69</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>66.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progeny(no.)</td>
<td>40</td>
<td>92</td>
<td>34.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>43</td>
<td>82</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First stubble, 1974</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CP 65-357</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>6</td>
<td>51.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L 65-69</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>71.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progeny(no.)</td>
<td>0</td>
<td>92</td>
<td>73.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>0</td>
<td>36</td>
<td>36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As for the previous cross, even though the parental behavior was somewhat inconsistent between years, the agreement of experimental clones between years was apparent as a correlation coefficient of .42 was obtained between the experimental clones in 1973 and 1974. A moderate agreement in lodging behavior was indicated as the positive r value was highly significant. This moderate association means that most clones exhibiting a particular lodging behavior in 1 year tend to exhibit the same behavior in the other year.

Due to the moderate agreement of clones between years and the fact that the difference between the parental means was similar in both years, it is felt that a more accurate evaluation of the inheritance of lodging behavior could be derived from interpretation of the behavior of the progeny as an average of the 2 years. Therefore, mean erectness as an average of both years was obtained for the parents and the progeny of this cross.

In Table 20 are presented the frequency distributions for erectness based on the % lodging system of classification for the parents, CP 65-357 and L 65-69, and the experimental clones as a mean of the 1973 plant cane crop and the 1974 first stubble crop.


<table>
<thead>
<tr>
<th>Population</th>
<th>No. of clones and percent of progeny in each of the following % lodging classes</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 65-357</td>
<td>1 1 3 1</td>
<td>6</td>
<td>32.5</td>
</tr>
<tr>
<td>L 65-69</td>
<td>2 4</td>
<td>6</td>
<td>69.2</td>
</tr>
<tr>
<td>Progeny(no.)</td>
<td>5 7 7 10 16 9 10 8 4</td>
<td>92</td>
<td>54.4</td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>5 8 8 11 17 10 11 9 4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Unlike the first 2 crosses, but similar to the previous cross, the parental replications overlapped. However, there was a distinct difference between the 2 parents as they differed significantly according to the Honestly Significant Difference test. CP 65-357 ranged from 15 to 60% lodging with a mean of 32.5%, whereas L 65-69 ranged from 45 to 85% lodging, with a mean of 69.2%. CP 65-357 behaved just as it did in the previous cross, as the means were identical. Likewise, the mean for L 65-69 in this cross was identical to the mean of L 65-69 in the first cross.

Since both the parents and the progeny were grown and classified at the same time by the same procedures, this cross should provide reliable information concerning the genetic behavior of resistance to lodging for a cross between moderately lodging resistant and susceptible parents.

The variation among phenotypic classes was continuous as the range in % lodging of the 92 experimental clones was from 5 to 100%. As for the 3 previous crosses, the frequency distribution did not resemble a normal curve. The class center which contained the most clones was 50% with 16 clones, or 17% of the progeny. The progeny mean was intermediate to the parents and was essentially the same as the arithmetic average of the 2 parental means. In addition, 49 clones, or 53% of the progeny, were below the arithmetic average of the 2 parental means, whereas 43 clones, or 47% of the progeny, were above.

Twenty-two percent of the progeny was outside the parental range in % lodging. Of these, 8 clones were below the range of CP 65-357,
whereas 12 clones were above the range of L 65-69. An analysis of variance was calculated among the 92 experimental clones and the parental clones, using the 2 years as replications. The F values for both the clones and years sources of variation were highly significant indicating that genetic differences occurred among the experimental and parental clones and the strong influence that environment has on the expression of erectness. In addition, as further indication of the influence that environment has on % lodging, there was a high coefficient of variation of 49%, based on the generalized experimental error.

However, application of the Honestly Significant Difference test showed that no experimental clones were either significantly lower than the mean of CP 65-357 or significantly higher than the mean of L 65-69. There were 21 clones numerically lower in percent lodging than the mean of CP 65-357, although none were significantly lower; whereas there were 32 clones numerically higher than the mean of L 65-69, although none were significantly higher.

Despite the lack of statistical evidence for transgressive segregation, the 8 clones with no more than 10% lodging were probably superior in erectness to CP 65-357 since none of the replications of CP 65-357 had less than 15% lodging. However, not unlike the previous cross, although 2 of the replications of CP 65-357 were acceptable in % lodging, the remaining replications that were not would suggest that not all clones with 10 to 25% lodging could be considered to possess acceptable erectness. Furthermore, the range in replications of L 65-69 suggests that the 12 clones with 90% or greater lodging
would be unacceptable. This cross had the least amount of clones exhibiting 20% or less lodging with only 16% of the progeny considered acceptable. It can be assumed that since L 65-69 was common to this and the first cross, the erect CP 52-68 would be of more value in providing erect segregates than the moderately erect CP 65-357 in a breeding program.

The r value of .42, presented earlier between clones in separate years indicates that moderate but not complete success would be realized for selection of erect clones based upon 1 season's results. Heritability, as estimated by correlation coefficients between erectness classification values of clones in individual years and the mean erectness classification values of both years, was calculated in order to provide a more accurate estimate of heritability, or the proportion of the total variation that is genetic in nature. The r values between the mean of both years and that of each year—the plant cane crop in 1973 and the first stubble crop in 1974—were .86 and .82, respectively. These r values were similar to those of the other crosses, positive, highly significant, and could serve to indicate that most clones erect in either year tended to be so as an average of both years. Hence, for either of the 2 years, the relatively high heritability estimates indicate that selection for lodging resistance among the experimental clones of this cross would be reasonably effective.

Comparison of the frequency of erect clones of the entire progeny to the frequency of erect clones of a selected progeny, is another measure of the effectiveness of selection for erectness based on 1
year's results. Of the 92 clones in the unselected progeny, 15 clones, or 16%, had no more than 20% lodged stalks as an average of both years. If selection had been practiced among the clones of the plant cane crop in 1973 for all clones with 20% or less lodging, 44 clones would have been chosen. Of these 44 clones, 15 were also acceptable as an average of both years. Therefore, 34% of the progeny selected in 1973 would have been acceptable as an average of both years. This represents a net gain of 18% for the selected progeny over the unselected progeny.

As for the previous cross, the gain in this cross was somewhat higher than for the first 2 crosses. However, again the gain was minimal and would have been of little value in securing truly resistant clones. The small gain from selection of erect clones in 1973 is apparently a function of the many susceptible clones that escaped lodging in that year. There were 40 completely erect clones in 1973. It is therefore probable that not all of the 44 clones acceptable in 1973 were indeed resistant to lodging.

A much larger gain would have been realized if selection had been practiced in the first stubble crop in 1974. In 1974 only 10 clones had no more than 20% lodging as a result of the hurricane. Nine of the 10 clones, or 90% of the progeny selected in 1974, would have had 20% or less lodged stalks as an average of both years. This represents a gain of 74% for the selected over the unselected progeny. Since 90% of the clones erect in 1974 were erect as an average of both years, it is evident that clones that remain erect after severe lodging has occurred could be effectively selected in small, unrepli-
cated clonal plots.
In contrast, 40 clones had 50% or greater lodging in 1973. Thirty-seven clones, or 93%, were among the 57 clones with at least 50% lodging as an average of both years. In addition, of the 57 clones with at least 50% lodging as an average of both years, all were from among the 74 clones with at least 50% lodged stalks in 1974. Hence, 77% of the clones considered very susceptible in 1974 were also susceptible as an average of both years.

It is felt, as pointed out earlier, that a more accurate evaluation of the inheritance of lodging behavior would result from a collective consideration of the 1973 and 1974 data. However, the occurrence of the hurricane in 1974 provides an opportunity to evaluate the genetic behavior of lodging resistance under extreme lodging conditions. Therefore, the 1974 data were examined separately.

It can be seen in Table 19 that there was not a distinct difference between the parents as the parental replications overlapped. However, CP 65-357 behaved as moderately susceptible and L 65-69 behaved as susceptible. The replications of CP 65-357 ranged in a continuous manner from 30 to 70% lodging, with a mean of 51.7%, whereas L 65-69, with a mean of 71.7%, had 1 replication each in the 20 and 30% classes and 2 replications each in the 90 and 100% classes. According to the Honestly Significant Difference test the parents were not significantly different.

The variation among the phenotypic classes was continuous. The range among the 92 segregates was from 10 to 100% lodging. Although the variation among experimental clones was indicative of quantitative
traits, there were certain features of the frequency distribution
which were atypical of a normal distribution. Similar to the first
3 crosses, the frequency distribution was skewed towards lodging
susceptibility with lodging classes 90 and 100% containing 52% of
the progeny. The remaining classes contained a somewhat uniform
distribution of experimental clones. The progeny mean was above both
parental means and above the arithmetic average of the 2 parental
means. Twenty-seven clones were below the arithmetic parental
average, whereas 65 clones were above.

Only 10 clones, or 11% of the progeny, had no more than 20%
lodged stalks, whereas 68 clones, or 74% of the progeny, had 60% or
greater lodging. Again as for the previous cross, it is surprising
to note that the percentage of apparently resistant clones for this
cross involving moderately susceptible and susceptible parents was
essentially the same as that for the cross in which CP 52-68 was a
parent. However, the 1 replication of the susceptible variety
L 65-69 that had 20% lodged stalks suggests that only the clones
with 10% lodged stalks would have been considered to be acceptable
in erectness.

In addition, of the 44 clones with 20% or less lodging in 1973,
only 9 clones, or 20%, had no more than 20% lodging in 1974. On the
other hand, of the 40 clones with at least 50% lodging in 1973, all
but 2, or 95%, were among the experimental clones exhibiting 50% or
greater lodging in 1974.

It can be concluded that, for this as for the other crosses,
selection under normal lodging conditions of clones in small, unrepli-
cated clonal plots would not be effective in identifying those clones that would remain erect after severe lodging has occurred. However, it appears the clones susceptible under normal conditions would also be susceptible after severe lodging has occurred.

For this cross also, it was felt that the 1975 data should be evaluated separately because of the light lodging conditions in that year. Again the behavior of the parental varieties did not provide an adequate distinction between the 2 nor was it related to their behavior in the 2 previous years.

Table 21 contains the frequency distributions for erectness based on the % lodging system of classification for the parents, CP 65-357 and L 65-69, and the experimental clones in the 1975 second stubble crop.


<table>
<thead>
<tr>
<th>Population</th>
<th>0</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>40</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
<th>90</th>
<th>100</th>
<th>Total</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 65-357</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>8.3</td>
</tr>
<tr>
<td>L 65-69</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>18.3</td>
</tr>
<tr>
<td>Progeny(no.)</td>
<td>17</td>
<td>14</td>
<td>9</td>
<td>14</td>
<td>10</td>
<td>6</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td>92</td>
<td>32.9</td>
</tr>
<tr>
<td>Progeny( % )</td>
<td>18</td>
<td>15</td>
<td>10</td>
<td>15</td>
<td>11</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note in Table 21 that the difference between the 2 parental means in 1975 was inadequate since it did not provide enough distinction to indicate their known opposing lodging habits. In 1975 the mean of L 65-69 was 18.3%, whereas the means for L 65-69 in 1973 and 1974 were 66.7 and 71.7%, respectively.
Similar to the first cross involving L 65-69, the normally susceptible variety behaved as resistant in 1975 and it is therefore likely that the mild lodging conditions were not suitable for a genetic study of the behavior of lodging.

Association Between % Lodging and Other Economically Important Characters

Associations, as shown by correlation coefficients, between % lodging and other important economic characters were determined. Table 22 contains the correlation coefficients for crosses 1 through 4 between % lodging in 1973 and the most reliable averages of the other economically important characters. Also contained in Table 22 are the correlation coefficients for crosses 5 through 8 between the average % lodging of 1973, 1974, and 1975 and the averages of the other economically important characters. Since measurements were not recorded in all harvests for the other characters, the means for some are based on fewer than 3 harvests.

For the crosses 1 through 4, correlation coefficients between % lodging in 1973 and mean stalk length of the 2 harvests in 1972 ranged from .26 to .51, whereas for crosses 5 through 8, the correlation coefficients between % lodging as an average of 1973, 1974, and 1975 and mean stalk length in 1973 ranged from .24 to .32. All of the r values were positive, 3 were significant, and 5 were highly significant. The r values indicated a moderately low degree of association. This means there was a moderately low tendency for taller clones to lodge more than shorter clones.
This association can be shown more clearly by comparing the mean stalk length of the clones to their % lodging. Presented in Table 23 are % lodging means for each of 3 mean stalk length classes—4.5 - 5.9 ft, 6.0 - 7.4 ft, and 7.5 - 8.9 ft—for the 742 experimental clones from all 8 crosses. Also included in Table 23 are the number of clones used to calculate the lodging means for each class. There were 9 clones 9 feet or greater in mean length included in the third class. Note in Table 23 the trend for mean % lodging to increase as mean stalk length increases. For example, the 177 clones ranging in mean length from 4.5 to 5.9 ft exhibited a mean % lodging of 24.4%, which would be considered an acceptable percentage of lodged stalks. The 441 clones ranging from 6.0 to 7.4 ft had a mean % lodging of 36.8% and the 124 clones ranging from 7.5 to 8.9 ft had a mean % lodging of 52.4%. The means for the 2 latter classes are representative of slightly susceptible and susceptible behavior, respectively. The mean % lodging of those clones exhibiting 9 ft or greater mean stalk length was essentially the same as the mean % lodging of the 124 clones in the third mean stalk length class. Actually, the tendency for the shorter clones to lodge less than the taller ones was much stronger than suggested by the moderately low correlation coefficients. It is obvious from the data in Table 23 that selection for maximum height in sugarcane should be accompanied by selection for resistance to lodging.

This association between mean stalk length and % lodging could cause difficulty, especially if major emphasis is put on the selection of very tall clones in the early test stages. However, simultaneous
selection for both % lodging and mean stalk length should overcome the difficulty.

Table 22. Correlation coefficients between % lodging and several economically important characters measured for the clonal plots of the 8 biparental crosses.

<table>
<thead>
<tr>
<th>Characters correlated with % lodging</th>
<th>Correlation coefficients for cross number</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Stalk length</td>
<td>.26*</td>
</tr>
<tr>
<td>Stalk diameter</td>
<td>.01</td>
</tr>
<tr>
<td>Stalk weight</td>
<td>.07</td>
</tr>
<tr>
<td>Estimated fiber percent in cane</td>
<td>.07</td>
</tr>
<tr>
<td>Brix</td>
<td>.03</td>
</tr>
<tr>
<td>Sucrose</td>
<td>.07</td>
</tr>
<tr>
<td>Stalk brittleness</td>
<td></td>
</tr>
</tbody>
</table>

*Significant at the 5 percent level of probability
**Significant at the 1 percent level of probability

For crosses 1 through 4, correlation coefficients between % lodging in 1973 and the mean stalk diameter of the 2 harvests in 1972 ranged from -.01 to .07, whereas for crosses 5 through 8, the correlation coefficients for % lodging as an average of 1973, 1974, and 1975 and the mean stalk diameter as an average of 1973 and 1975 ranged from -.17 to .15. None of the r values were either significant or indicated an important degree of association. Therefore, selection of erect clones with acceptable diameter should be possible with no difficulty.

Correlation coefficients for crosses 1 through 4 between % lodging in 1973 and the mean stalk weight of 1972 and 1973 ranged
from .07 to .24, whereas for crosses 5 through 8, the correlation coefficients between % lodging as an average of 1973, 1974, and 1975 and mean stalk weight as an average of 1973 and 1974 ranged from .11 to .35. Although 3 of the r values were not significant, 5 r values were significant with 3 of them highly significant. Some of these r values suggest that clones with heavier stalks tend to lodge more than lighter clones. It is interesting to note that, since the 2 components of stalk weight are stalk length and stalk diameter, the lack of association between stalk diameter and % lodging suggests that the positive weight-% lodging association is due for the most part to the positive length-% lodging association.

This suggests that no consideration need be given to stalk weight in conjunction with selection for erectness. Attention should be directed instead to stalk length.

Table 23. Mean % lodging for each of three mean stalk length classes for the experimental clones of the 8 crosses.

<table>
<thead>
<tr>
<th>Mean stalk length classes (Ft)</th>
<th>Population</th>
<th>4.5 - 5.9</th>
<th>6.0 - 7.4</th>
<th>7.5 - 8.91</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>% lodging</td>
<td>% lodging</td>
<td>% lodging</td>
</tr>
<tr>
<td>Experimental clones of all 8 biparental crosses</td>
<td>Mean</td>
<td>No.</td>
<td>% lodging</td>
<td>No.</td>
</tr>
<tr>
<td>Experimental clones of all 8 biparental crosses</td>
<td>24.4%</td>
<td>177</td>
<td>36.8%</td>
<td>441</td>
</tr>
</tbody>
</table>

There were 9 clones with 9 feet or greater mean stalk length included in the third mean stalk length class.

Correlation coefficients for crosses 1 through 4 between % lodging in 1973 and the mean estimated fiber percent in cane of 1972 and 1973 ranged from .07 to .19, whereas the correlation coefficients
for crosses 5 through 8 between % lodging as an average of 1973, 1974, and 1975 and the mean estimated fiber percent in cane as an average of 1973 and 1974 ranged from -.08 to .11. No important degree of association was implied by the r values. This is further evidence to disprove the once widely supported theory that clones remained erect because of high fiber. The data indicate that there would be little difficulty in incorporating acceptable fiber percent into erect clones.

For crosses 1 through 4, correlation coefficients between % lodging in 1973 and the average of 1972 and 1973 for brix and sucrose ranged from -.14 to .19 and -.09 to .17, respectively, whereas for crosses 5 through 8 the r values between % lodging as an average of 1973, 1974, and 1975 and the average of 1973 and 1974 for brix and sucrose ranged from -.19 to .04 and -.16 to .05, respectively. Again, none of the r values were either significant or implied an important degree of association. Therefore, the development of high sucrose, erect clones will not be complicated by any association between these traits.

To indicate the association between stalk erectness and stalk brittleness, a correlation coefficient of .13 was obtained between stalk erectness based on the conventional system of classification and stalk brittleness of the clones of the fourth cross, CP 57-614 x L 60-25, in 1972. Although the r value was positive, it was not significant and, consequently, did not indicate any degree of association. However, since stalk brittleness is an integral part of harvestability, it is felt that the association between stalk
brittleness and erectness as well as other characters should be studied further on a wide genetic basis.
SUMMARY

Results of a comparison of the conventional and the newly devised % lodging systems for classification of small, unreplicated clonal plots for stalk erectness demonstrated that the % lodging system was superior in several respects.

The % lodging system differentiated adequately between varieties which were known to have opposing lodging habits. Most of the differentiation provided by the new method was between degrees of erectness which are related to an important extent with harvestability insofar as lodging is concerned. That the new system recognized differences between clonal plots in the percentages of severely lodged stalks was a most important improvement.

The data suggest that the mean % lodging of the progenies of crosses was a function of the average % lodging of the 2 parents. In general, the parents with the lowest lodging means tended to produce the highest frequency of erect segregates. However, it is also evident that a surprising number of segregates acceptable in erectness occurred among the progenies of crosses involving susceptible or moderately susceptible parents.

Inheritance of resistance to lodging was quantitative in nature, as evidenced by the broad range among the parental replications as well as for the fact that the experimental clones occurred in a large number of continuously varying phenotypic classes. However, there were certain features of the frequency distributions which were atypical of a quantitative trait. Foremost among these features was a marked tendency for the frequency distributions not to fit a
normal curve.

It was felt that because the data for the Group I crosses were based on only 1 year, the data for the Group II crosses based on an average of 2 years were considered more reliable.

For 3 of the 4 Group II crosses the progeny mean was intermediate to the parental means and essentially the same as the arithmetic average of the 2 parental means, whereas for 1 cross the progeny mean was slightly above the parental means and the arithmetic average of the 2 parental means. As an average of all crosses for both years, 45% of the experimental clones occurred below the arithmetic average of the 2 parental means whereas 55% occurred above.

Despite the lack of statistical evidence for transgressive segregation, it was evident that there were some clones among the progenies that were equal to or lower than the most erect parent in % lodging. However, as an average of the 4 Group II crosses for both years, there were over twice as many segregates above the range of the more susceptible parent than below the range of the more erect parent.

For the Group II crosses, estimates of heritability, as determined by correlation coefficients between % lodging of clones in individual years and mean % lodging of the clones as an average of both years, demonstrated that the proportion of the total variation that is genetic in nature was moderately high. The average $r$ value of all Group II crosses between % lodging in either year and the mean % lodging of both years was a positive, highly significant .84. Consequently, it can be concluded that selection for erect clones from small,
unreplicated clonal plots would be effective based on 1 year's results.

The data suggest that selection under normal lodging conditions would not be effective in identifying those clones that would remain erect after severe lodging has occurred. As an average of the progenies of the 4 Group II crosses, only 20% of the clones erect in a normal lodging year were erect the following year in which a hurricane occurred. However, 95% of the unacceptable clones in the normal lodging year were considered unacceptable the following hurricane year. It was further concluded, however, that clones decumbent under normal lodging conditions would also be decumbent after severe lodging has occurred, and could, therefore, be effectively discarded.

The data indicated that tall, heavy stalked clones tend to lodge more than clones with shorter, lighter stalks. However, the lack of association between stalk diameter and erectness suggests that the positive weight-erectness association is due to the positive length-erectness association since stalk diameter and length are the components of stalk weight. The fact that the mean % lodging of experimental clones with mean stalk length of 7.5 ft or greater was 15% higher than for experimental clones with mean stalk length ranging from 6.0 to 7.4 ft indicates that selection for maximum stalk length in sugarcane should be accompanied by selection for resistance to lodging.

Since no other economically important character was undesirably associated with stalk erectness, it was concluded that there would
be no difficulty in selecting erect clones which have desirable stalk diameter, stalk length, stalk weight, brix, sucrose, or lack of brittleness, provided attention is given simultaneously to stalk length and erectness.
REFERENCES


VITA

Howard P. Viator, II, was born January 17, 1947, in Franklin, Louisiana. He graduated from Franklin High School in Franklin, Louisiana, in May, 1964. He attended the University of Southwestern Louisiana at Lafayette and received a Bachelor of Science degree in Agronomy in May of 1969.

He entered the Graduate School at Louisiana State University in January of 1972 as a graduate assistant in the Department of Agronomy.

On December 22, 1973, he was married to Marlaine Marie Mundt of New Orleans, Louisiana.

In August of 1974 he received his Master of Science degree in the Department of Agronomy at Louisiana State University.

He is presently a candidate for the degree of Doctor of Philosophy in Agronomy at Louisiana State University.
EXAMINATION AND THESIS REPORT

Candidate: Howard Preston Viator II
Major Field: Agronomy
Title of Thesis: Genetic Behavior of Resistance to Lodging in Sugarcane

Approved:

[Signatures]
M.T. Henderson
Major Professor and Chairman
James A. Frankum
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]
Earl P. Barrier Jr.
Joe E. Seabrook Jr.
Ray Rignall
St. John P. Chilton

Date of Examination: April 12, 1976