Breeding Behavior of Ratooning Ability in Sugarcane.

John Walter Dunckelman

Louisiana State University and Agricultural & Mechanical College

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BREEDING BEHAVIOR OF RATOONING ABILITY IN SUGARCANE

The Louisiana State University and Agricultural and Mechanical Col. Ph.D. 1982

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BREEDING BEHAVIOR OF RATOONING ABILITY

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

John W. Dunckelman
B.S., Nicholls State University, 1976
M.S., Louisiana State University, 1978
May, 1982
ACKNOWLEDGEMENTS

I would like to first thank my major professor, Dr. M. T. Henderson, for his guidance and sincere help in the preparation of this dissertation. He is now retired, and I am especially proud to have been his last graduate student in his long and illustrious career as professor of agronomy at Louisiana State University.

I extend my thanks to Dr. W. H. Willis, retired head of the Department of Agronomy at Louisiana State University, for his help in my academic program. I am grateful also to the present head of the Agronomy Department, Dr. J. P. Jones, who in a busy period of transition showed that he was for the students first, and who has been helpful and understanding of my situation.

I am grateful to Dr. Mike Giamalva, director of the LSU Sugar Station, and the staff of the St. Gabriel Experiment Station for their advice, guidance and assistance in the conduct of actual field work involved in collecting the data. Special thanks is due also to the American Sugar Cane League of the USA, Inc. for financial support of this experiment.

To Leslie, my wife, I owe special thanks for the support and encouragement she has given me throughout. It would have been immensely harder to stay in school and concentrate on studies without her help.
I thank my parents, Preston and Rose, for stressing the importance of education, and for helping me to obtain one.
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ABSTRACT

Ratoon decline of sugarcane, *Saccharum* spp., is a significant worldwide problem especially in temperate zone areas such as Louisiana. This study was begun with the object in mind to examine in detail the ratooning behavior within a sugarcane progeny of the type used in the Louisiana breeding programs since the 1930's.

The cross examined was L 65-69 X CP 65-357. Data were taken in plant cane, first ratoon and second ratoon crops on 210 clones established randomly from individual seedlings of this cross. Data included number of stalks per plot, mean weight of stalk, mean length of stalk, mean diameter of stalk, and sucrose percent of expressed juice. Yield was estimated as the product of number of stalks per plot X mean weight per stalk.

The ratooning ability of the progeny was examined in comparison to the parents' behavior for each trait individually and in combinations. There was a high incidence of clones with good ratooning ability for each of the individual yield components; however, only approximately 5% of the clones showed ratooning abilities of yield which equalled those of the parents. The severe second ratoon decline in yield of the progeny and parents was due to declines in all of the yield components studied. Certain negative interrelationships among traits, notably that of stalk diameter and stalk population ($r = -0.33$), appeared to be important factors in reducing the number of segregants showing good ratooning ability within the cross.
Although yield and its components showed high repeatability between the plant crop and ratoon crops, the correlations were not perfect, and all clones with acceptable plant cane behavior showed some yield loss in the second ratoon crop. Furthermore, the severity of second ratoon yield decline in clones could not be predicted from first ratoon data. Thus, the data indicated that second ratoon information on clones obtained at early stages of selection would be a useful adjunct to data normally taken at these stages.
INTRODUCTION

Ratoon failure of sugarcane crops in Louisiana was an important factor in the very serious decline of the Louisiana sugar industry of 1905 to 1926 (25). Despite greatly improved hybrid varieties it remains a problem to this date in Louisiana and many other areas of the sugarcane-growing world.

Numerous factors have been implicated in the cause of ratoon failure including low winter temperature, inadequate drainage and aeration, poor cultural practices, and high incidence of diseases and pests. Ratoon decline is generally considered a complex phenomenon not completely understood.

Although a relatively large volume of published research exists on the many causes of ratoon failure in sugarcane, most of this work has been done with established varieties, and little information exists concerning the behavior of ratooning ability in breeding populations. This study was originated in the hope of making a contribution in that area.

Today in the Louisiana breeding programs, rigid selection for high ratooning ability is not practiced until late stages of testing due mainly to time-limit considerations. As it now stands, at least 12 years must pass before a selected seedling can be thoroughly tested and released as a commercial variety. Within this lengthy period, second ratoon data obtained on clones are limited.
The sixth year of testing is the first year in which unreplicated second ratoon data are gotten in the second line trials. In the 6 years of testing remaining, second stubble data are gotten once from the replicated nursery and twice from replicated infield tests. By the twelfth year, second ratoon data are obtained during one year from the replicated outfield tests at several locations. Thus, there are adequate second ratoon data for clones in the breeding program, but only after the sixth year of testing, at which time as few as only 40 clones remain for testing from an original seedling population of 75 to 100 thousand plants. Furthermore, at the outfield stage of testing, where the most comprehensive second ratoon data are gathered, only 5 to 10 clones of the original population are included.

High ratooning ability has been recognized as an important breeding objective in the Louisiana sugarcane variety programs for many years; yet even the best current varieties show a severe degree of ratoon decline. This is especially true of the second and later ratoons; thus the importance of growing and testing potential varieties in second ratoon at some time in the selection process. With these facts in mind, the objectives of this study were:

1) To determine the breeding behavior of ratooning ability in a biparental cross of the type commonly employed in the Louisiana breeding programs.

2) To explore the possibilities for enhanced methods of selection for improved ratooning ability.

3) To study the bearing of yield component interrelationships on ratooning ability in sugarcane.
4) To obtain information concerning the value of or need for early testing of experimental clones for ratooning ability.
REVIEW OF LITERATURE

Definition And Importance Of Ratooning Ability

The origin of the word "ratoo" according to Webster's Third New International Dictionary (4) is from the Spanish "retoño" meaning fresh shoot or sucker. Its definition is given by the same source as "a stalk or shoot arising from the root or crown of a perennial plant: (a) a sugarcane sucker arising from the base of a harvested plant."

Winburn (89) defined "ratoo" as "a basal sucker for propagation as in sugarcane, pineapple, and banana."

Plucknett and his coworkers (67) stated in their 1970 review of the practice that ratooning cropping of plants basically implies "1. more than one harvest from a single planting, 2. regrowth from basal buds on the stem or crown, 3. total harvest ratooning (harvesting of most or all of the aerial portion of the plant) and, 4. selective harvest ratooning (harvesting of selected portions of the plant, e.g., fruit, leaves, portions of the stem or combinations of these)."

It is common practice in most sugarcane growing areas to harvest the mature stalks by cutting at ground level thus leaving the root stocks and underground parts of the stems undisturbed from which another crop springs in the fashion of perennial plants (6, 48, 67). A crop thus developed is known as a ratoon or stubble crop (81). Plucknett, et al. (67) have noted that in most instances
of ratoon cropping the first crop of the cycle is referred to as the plant crop; the first regrowth, or second crop, as the first ratoon; and the second regrowth, or third crop, as the second ratoon, etc.

In most sugarcane cropping schemes, the stubbles (roots and stumps remaining after harvesting) are plowed out and chopped into the soil following two or more ratoon crops and the field is either immediately replanted or fallow plowed for a period of time in order to control weeds and bring the soil into good tilth (6, 41, 59).

Ratooning of sugarcane is practiced in the tropics and subtropics including such areas of the world as the United States of America, Australia, India, the Caribbean, Southeast Asia, and many countries of South America and Africa (6, 87).

According to Plucknett et al. (67), Antoine and Ricaud have stressed the importance of growing and maintaining good ratoon crops of sugarcane in Mauritius where as many as 5 ratoons may be grown.

Rao (68) studied sugarcane ratoons in Andra State, India, and concluded that ratooning was a justifiable practice in that area provided that the ratoons were properly fertilized and cultivated. Rao viewed ratoon cropping as an Important factor to the economic success of commercial sugarcane agriculture in Andhra State.

King, in his Manual of Cane Growing, (48) made it evident that plant crops are less profitable than ratoons in pointing out the high cost of growing only a plant crop and no ratoons thus leaving but one crop to defray the high cost of seedbed preparation and planting. He related the stability of the Australian sugar industry to ratoon
cropping as a practice.

Whan (86) wrote that in Queensland, Australia, a typical crop cycle may involve as many as 4 or 5 differently aged crops growing together in a given year. According to him, the characteristic sugarcane crop cycle in Queensland starts with a planted crop and is generally followed by up to 3 ratoon crops and a leguminous fallow to aid in conditioning the soil. Whan has stated that Australian plant crops of sugarcane are generally grown over a period of 18 months, 12 months being the average growth period for ratoons.

Buzacott (13) outlined the ability of a variety to ratoon as an important selection objective in Australian sugarcane breeding programs. He stated a strong preference in Queensland for varieties with large, thick stalks and good tillering capacity, and noted that varieties were often rejected in the later stages of selection because of poor germination or inadequate ratooning ability. He said that since varieties are ratooned at least twice in Queensland, any varieties showing poor ratooning ability are immediately discarded. Buzacott tempered this last statement, however, in pointing out the difficulty of assessment of ratooning ability. He stated that harvest of seedling varieties in early selection stages was usually scheduled during the winter months when poor ratooning was most likely to occur thus optimizing the detection and early elimination of varieties with inherently poor ratooning ability. In the past, poor ratooning ability was a major cause for rejection of Australian canes but with modern interspecific hybrids, Buzacott stated that by 1962 it was
rarely a reason for rejecting a variety.

Skinner (74) in his 1972 review of selection in sugarcane wrote that good ratooning ability was still an important selection objective in Queensland insofar as agricultural characters were concerned.

Barnes (6) in the second edition of his treatise on sugarcane dedicated an entire chapter to a review of the sugarcane growing countries of the world and briefly described the salient and interesting features of each. In discussing the countries of Africa he states that in Egypt usually 2 but infrequently 3 ratoon crops are grown. At least 1 ratoon crop is generally grown in Mozambique, the Republic of South Africa, and Swaziland. In Nigeria, where cane growing is mainly a minor enterprise and most of the farming is by natives for the production of crude sugar cakes, or jaggery, Barnes has noted that ratoon crops are seldom grown.

In Thailand Barnes (6) wrote that 2 or 3 ratoons are commonly grown. In Java, where food needs control land use, he stated that the normal crop cycle with sugarcane is a single plant crop in rotation with rice and other food crops such as groundnuts or sweet potatoes in a three-year cycle.

Tang (84) mentioned a similar cropping system in Taiwan where only approximately 5 percent of cane was ratoons. Scarcity of arable land and high population, he stated, compels most farmers to follow a system of crop rotation with rice, growing only a plant crop of sugarcane per cycle. Tang hoped that the long-time ratooning
system would be adopted because ratoons produced a harvestable crop within 12 months whereas planted cane took as long as 18 months to produce when fall-planted.

In discussing South America, Barnes (6) remarked on ratoon cropping of sugarcane in Columbia, Peru, Brazil and Venezuela. He indicated that 3 is the usual number of ratoons grown in Brazil. In contrast he wrote that in Peru, where there are no extremes of temperature, plant cane is grown for 20 to 22 months and ratoons for 16 to 18 months within a cycle which includes 5 or 6 ratoons and extends over a period of about 10 years. Barnes attributed the abnormally low yields of small farms in Venezuela to ratooning over long periods with infrequent replanting.

In reviewing sugarcane growing in the Caribbean, Barnes (6) has reported that in Cuba cane has been ratooned as many as 25 times and that only bare areas of such ratoon fields were replanted using cuttings. His account of Puerto Rico showed 3 ratoons to be the usual number grown on irrigated lands while 7 ratoons were reported as the norm in the more humid regions of the island. He has described Barbados as the most easterly of the Caribbean islands at latitude 13° 4' and longitude 59° 37' having equable climatic conditions under regulation of the north-east trade winds. Barnes observed that as many as 4 or 5 ratoons could be profitably grown on the better agricultural lands of Barbados.

Chinloy and Shaw (19) wrote that several ratoon crops are normally grown from an original planting in Jamaica where plant
crops, first, second and other ratoons are all normally grown for an average of 12 months before harvesting. These researchers noted the problem of ratoon yield decline on the island and developed a formula for deriving the optimum replanting cycle based on profitability.

In the United States of America sugarcane is grown mainly in Louisiana, Florida, Hawaii, and Texas and ratooning is practiced in all these states where it plays an important role in the economics of sugar production (46, 59, 67, 70).

According to Matherne et al. (59), the typical crop cycle in Louisiana consists of a plant crop and 2 ratoons from each planting. These researchers stated that old cane stubble is usually destroyed following harvest of the last ratoon crop, after which time it is customary to cultivate frequently throughout the summer (fallow plow) in order to control weeds before replanting in late summer or early fall. They wrote that usually only the poorest ratooning fields are plowed out each year to allow a maximum carryover of ratoon cane into the following spring growing season.

Hebert (34), in studying the associations of yield components to yielding ability of sugarcane in Louisiana, said that based upon his observations initial selection at the seedling stage should be broad to include a large number of individuals. He stated that all plants meeting a minimum requirement for mosaic resistance, good vigor, acceptable diameter, and the ability to stubble should be selected. Hebert's opinion was that stubbling ability is automatically
selected for in the Louisiana variety development program in initial selection stages as selections are not made in plant cane but in first stubble of the seedling (single stool) stage of selection.

Matherne et al. (60) have shown that stubbling ability is a very important performance criterion for Louisiana varieties in later stages of selection as well, including unreplicated line tests, (varieties are analyzed here in plant cane and first ratoon) replicated infield experiments, and replicated outfield yield trials. Varieties in outfield yield trials are grown at least through first stubble before being considered for release and these researchers have shown low yield of cane, low sucrose percent, and poor stubbling ability to be the major reasons for rejection at this stage.

Dunckelman and Breaux (22) reported in 1969 on the possibility of increasing cold tolerance, borer resistance, mosaic resistance, and stubbling ability of Louisiana sugarcane varieties through the incorporation of additional Saccharum spontaneum (L.) germplasm into a narrowed genetic base of breeding stock from which no significant increases in yielding ability had been produced over 25 years of sugarcane breeding in Louisiana. They stated that most of the new S. spontaneum derivatives showed "excellent stubbling ability, fast early spring growth, and greatly increased stalk number when compared to standard commercial varieties."

The sugarcane growing area of Florida, the Everglades region, has been described by Barnes (6) as a subtropical area comprising the
worlds largest deposit of organic soils, and Kidder (46) has stated that the number of ratoon crops grown there ranges from 1 to 10 with the average at 2 to 3.

Plucknett et al. (67) stated that ratooning of cane in Hawaii is not practiced to the extent that it is in other areas of the United States with only one ratoon being common due partly to damage to the stools through mechanical harvesting and partly to soil problems, among which compaction is important. Mechanical harvesting of cane in Hawaii employs the Hawaiian-Rake Bulldozer Cane Cutter which according to Baver (7) consists of a bulldozer to which a large, tined rake with forward, stationary cutting edges is attached in the position which the blade would normally occupy. Baver states that as the machine moves down the row in harvesting, the cutting edges of the tines sever the cane from the row and it is pushed by the bulldozer into large piles to await loading into transport vehicles. The advantages of the system were said to be reduced machinery maintenance and a minimum requirement of skill for the operator while disadvantages included large amounts of dirt and trash being brought to the mill and uprooting of many stools during the harvesting process.

Warner (85) outlined the important defects leading to the discard of the majority of seedlings in an Hawaiian sugarcane breeding program and made no specific mention of ratooning ability as a requirement although lack of tillering was mentioned as grounds for rejection even though no absolute criteria were used
In assessing this character because of the strong influence of environmental factors upon it.

By account of Reeves, (70) the first harvest season in the newly opened sugarcane growing region in the Rio Grande Valley area of Southwest Texas was in 1973 to 1974. He stated that from then until 1976 the industry there had been hampered by inclement weather, including freezes during the harvest periods. For these reasons, and because of the short history of the Texas industry, Reeves stated that only limited data existed regarding the number of ratoons that may be profitably grown there.
Factors Influencing The Performance Of Ratoon Crops In Sugarcane

Stevenson (80) wrote that good ratooning ability of sugarcane varieties was strongly associated with the vigor and health of their stool bases and root systems at harvest time. He presented data which clearly showed marked differences in ratooning ability of the early noble varieties and differences among the newer, nobilized interspecific hybrids also. He noted that ratooning ability was greatly improved in the interspecific hybrids over that shown by the nobles and observed that the characteristic was not highly heritable, as demonstrated by large differences in its degree of expression even within the progeny of a single cross. He referred to the strong influence of climatic and other environmental factors upon stubbling ability and contended that the most critical phase of ratooning in sugarcane was that period between harvesting of the old crop and establishment of self-supporting shoot roots on the newly emerged ratoon tillers. He stated that varieties were highly subject to ratoon failure during this period especially under droughty conditions. Stevenson believed that ratoon yields in certain areas, such as some he had observed in Barbados, could be greatly enhanced through proper cultural care and irrigation during early stages of regrowth.

Some reasons for ratoon decline in sugarcane as stated by Barnes (6) are, 1. loss of tilth in the root zone, 2. disease and insect attack, 3. lack of moisture and soil nutrients, 4. shortened growth periods for ratoons as compared to plant crops in many areas.
of the world, and 5. ratoon stunting disease (RSD). King (48) was of the opinion that declining soil fertility under conditions of continuous cropping was probably an important cause.

Matherne and his coworkers (59) stated that severity of the winter, choice of variety and time of harvest were important factors affecting stubbling ability of sugarcane crops in Louisiana.

Plucknett et al. (67) presented anonymously authored data which first appeared in the Hawaii Planters' Monthly in 1911, which indicated steadily declining yields of successive ratoon cane in Negros, Philippines. The data showed a steady decline in yield of sugar per acre from plant cane (6.98 tons of sugar per acre) to fourth ratoon, (3.48 tons of sugar per acre) and the authors observed that similar patterns were found elsewhere. They noted that ratoon failure of sugarcane was a worldwide problem and was probably due to numerous reasons some of which were unclear.

Plucknett and his coworkers stated that among the unknown causes of ratoon decline should be listed the phenomenon of "varietal yield decline" of sugarcane in which well established commercial varieties tend to run out or degenerate, and become unprofitable to grow after a period of approximately 10 years or more of production.

Abbott (1) described varietal yield decline of sugarcane as "a more gradual loss of vigor and yielding ability over a period of years of commercial cultivation, the cause or causes of which are often obscure." Plucknett et al. (67) noted that the problem is rendered even more perplexing considering that sugarcane varieties
are clones of original seedling plants and as such should represent those plants genetically in every way and do so in physical appearance, but often do not in yielding and ratooning ability.

Other important reasons for ratoon decline of sugarcane mentioned by Plucknett, et al. (67) in their review of ratoon cropping include ratoon stunting disease and other diseases such as mosaic, chlorotic streak, sugarcane smut, and Fiji disease; tillering and root characteristics of varieties; the influence of environment — especially the adverse effects of drought and temperature; soil factors such as moisture, fertility, and compaction; the effects of weeds and insects; and the influence of crop management, good or bad, including the harvesting method used, time of harvesting and planting, cropping scheme employed, and other cultural practices.

Edgerton (24) described ratoon stunting disease as a viral disease of sugarcane causing retarded growth especially in the ratoon crops and noted the difficulty of diagnosing it. Its cause has more recently been ascribed to a distinctive bacterium (21), the presence of which is used as a diagnostic aid.

Hughes (39) noted that the indirect losses attributable to RSD included poor germination and ratooning but stated that the amount of such losses was difficult or virtually impossible to estimate. A more easily measured and more direct type of loss to RSD, Hughes stated, was premature plowing out of ratoons due to inadequate yields.

King (47), in Australia, emphasized the ease with which RSD may be transmitted by knives in hand cutting or mechanical harvesting
and Plucknett et al. (67) have called RSD "a major cause of ratoon failure in sugarcane."

Abbott (1) discussed the relationship of disease to varietal decline in Louisiana and stated that although ratoon stunting disease may have played a role in the decline and stubble failure of the noble-canapes in Louisiana during the mid-1920's, its effects were probably masked by more prominently noticeable diseases such as red rot, Pythium root rot, and mosaic.

In 1976, Koike (49) presented a synopsis of disease as a factor influencing Louisiana sugarcane yields during the previous decade. He stated, "Two major factors related to diseases may have contributed to declining cane yields in Louisiana during the past decade: (a) increase in mosaic disease incidence in the susceptible varieties like CP 52-68 and L 60-25 and in the moderately susceptible varieties like CP 61-37 and L 62-96; and (b) the release and cultivation of a variety like L 62-96 (or the recently released L 65-59) that is highly susceptible to injury by ratoon stunting disease (RSD)."

He stated that the status of red rot and root rot had not changed significantly over the period studied, that chlorotic streak, pokkah boeng, and red stripe were no longer considered serious threats with the varieties and conditions of the time; and that no apparent heat-resistant strain of RSD, nor any major change in the strain picture of the mosaic organism had been recorded. Koike noted that RSD had greater effects in ratoons than plant cane and provided data which showed, in plant cane and first ratoon, the susceptibility
to RSD of varieties L 62-96 and L 65-69 as compared to RSD-tolerant CP 52-68. Reductions in yield as a percentage of the control were shown for all three varieties in both crop stages but were statistically significant for L 62-96 and L 65-69, the susceptibles, only.

Edgerton (23), working in Louisiana in 1938, studied stubble deterioration which he defined as "failure of the ratoon or stubble pieces to produce a satisfactory number of vigorous shoots in the spring." He stated that in subtropical areas like Louisiana the buds on the stubble pieces could remain dormant for several months in which time many unfavorable factors could act to cause severe stubble deterioration. Factors which he attributed to be important in causing this deterioration were low winter temperatures, time of winter in which freezes occurred, winter rainfall, inadequate soil aeration due to poor surface drainage, condition of the cane at harvest time, time of harvest, and diseases such as the root rotting complex and red rot. Edgerton stated that stubble pieces were nothing more than the basal portion of the stalk, each consisting of 3 to 10 short joints having a bud at each node which was capable of sprouting into a shoot under favorable conditions. He pointed out that on account of polarity, or top dominance, the upper buds germinated first under normal conditions. He said, though, that under unfavorable conditions, which could easily occur and which could force the lower buds to germinate, that the chances of stubble deterioration became much greater. If these shoots had grown long enough to emerge and
expose the growing point above ground, the damage would be much more serious because the whole shoot would be killed in the event of a freeze. Only if such a shoot had progressed in growth to the stage of having its own underground buds before freezing occurred would the damage to the following ratoon crop from freeze injury be lessened. He observed that damage of this type could be minimized by careful timing of harvest as early-cut canes had time to develop large shoots which were damaged by December freezes, while late-harvested cane (November and December) did not have time enough to grow large shoots before December freezing occurred and consequently was damaged less than early-cut cane. He believed that excessive autumn rainfall was also related to the problem, as high moisture conditions in October and November led to profuse germination of stubble buds. He presented data showing the distribution of rainfall in Louisiana from October to March for the years 1929 to 1938 which indicated a strong degree of association between high winter rainfall and poor stubble performance in the succeeding year. Edgerton professed that varieties differed widely in their susceptibility to stubble deterioration some rarely producing satisfactory ratoons and others showing nearly as good a yield under most conditions in ratoons as in their plant crops. He proposed that canes thenceforth be tested very carefully for their reaction to stubble deterioration and only those reacting well be released to Louisiana growers.
Stokes in 1956 (82) studied the problem of stubble deterioration from the standpoint of what agronomic practices influenced it. He noted that stubble deterioration had been an important problem in the Louisiana sugar belt for many years and that in the syrup-producing areas of the southern United States such as Georgia, Alabama, and Mississippi it had become so serious a problem as to warrant the complete abandonment of the practice of growing ratoon crops. Stokes was mainly interested in studying the effects of different dates of harvest and fertility levels on stubble deterioration in Mississippi. The harvest dates tested were October 15, October 29, November 12, and November 26. Stokes showed that later harvests were superior especially as reflected in the reserve food supply of the stubble pieces from late-harvested cane as compared to those of early-harvested cane. There were no significant differences in stubble deterioration as a result of fertilizer N treatments of 0, 20, 40, and 60 lb N per acre.

Ricaud (71) has conducted recent experiments in cultural practices in Louisiana sugarcane. In one light-soil test he examined the effect of date of harvest of the plant crop on the subsequent yields of four varieties in the first ratoon. He found no great superiority of late harvests (November and December) over early harvests (September and October) on the yields of the first reatoons. Ricaud also examined the relationship of crop age with 5 different varieties. He found that 4 of the varieties showed marked stubble yield decline, especially after second ratoon. Only 1 variety in
the test, CP 61-37, showed acceptable yield up to and including the fourth ratoon crop. Ricaud concluded that there was a definite difference in the obtainable number of profitable ratoon crops which could be gotten from CP 61-37 as compared to the other varieties in the test.

In Louisiana, Carter and Floyd (16) and more recently Carter (15) studied the effects of water management on the yielding ability and longevity of sugarcane varieties. Their experiments were done using concrete-bordered 0.01 acre plots provided with subsurface drainage, in which the depth of the water table could be precisely regulated at various levels. Among the interesting effects of water management on ratoon performance, Carter and Floyd (16) showed significant reductions in ratoon yields due to high water tables during the dormant season, December through March. The experiment was not designed however, to determine the exact time at which the damage occurred. In 1978, Carter (15) reported that maintenance of a constant water table of 24, 32, 40, or 48 inches beneath the soil surface increased the number of high yielding ratoons to 4 from the usually grown 2 when compared to the control plots with no water table regulation. There were no significant differences in yield however, among the 24, 32, 40, or 48-inch water table treatments. In another part of his experiment, Carter verified his earlier work with Floyd by showing a marked adverse effect on ratooning by maintaining water levels of 12, 30, and 48 inches during the dormant season; for the three treatment levels, ratoon
yields the following growing season were 15, 26, and 33 tons of cane per acre, respectively.

Camp (14) conducted similar water control experiments but added an additional factor, row height. He used a conventional ridge with furrow and a flat-soil-surface planting and compared these in water-controlled, subsurface-drained test plots compared with naturally-drained control plots. When the water table level was controlled, the data showed higher plant populations and cane and sugar yields for the flat-planted cane as compared to conventionally planted ridge with furrow cane. Camp noted, however, that with poor internal soil drainage, such as that in the control plots, much greater damage to the stubbles could be expected for the flat-planting system.

Yang (92) reported in 1976 that ratooning of sugarcane in Taiwan had been severely limited prior to 1945 due to limited irrigation water, lack of varieties with good ratooning ability, and the inability of their growers to control incremental increases in pests and diseases over a ratooning cycle.

In Australia, Willcox (88) emphasized the role of forward planning in obtaining the maximum number of profitable ratoons. He stated that the spread of ratoon stunting disease could be minimized through sterilization of cutting blades on harvesting machines before moving from one field block to another or between farms. He said that chlorotic streak disease could have a serious effect on ratoons particularly under wet conditions, therefore, making good drainage
essential to good ratoon performance. He reported that inadequate drainage had a threefold, negative effect on ratooning - reduced aeration and therefore growth, increased liability of chlorotic streak, and a higher incidence of harvester damage to soil and stools under wet conditions. In addition, Willcox stressed the importance of soil insect (beetle grubs, soldier fly larvae, etc.) control through the recommended insecticidal practices, the correct choice of varieties adapted to specific soil types and moisture/climatic conditions and the necessity of irrigation, where possible, under dry conditions. Willcox concluded by stating that economics must remain the paramount consideration in the number of ratoons to grow and that a flexible farm plan was called for so that good ratoons could be continued. He conceded the difficulty of changing ratooning practices as this often required confusing changes in the rotational schedule but cautioned that plowing out of good second ratoons just to stay in rotation was unwise.

Plucknett et al. (67) have stated that buildups of pests including weeds and insects is a major disadvantage of ratoon cropping. They have noted that weeds are especially distressing in stating, "One major argument against ratoon cropping is buildup of troublesome weeds."

Lamusse, (51) in Mauritius noted that weeds seriously reduced sugarcane yields if allowed to compete for water, nutrients, light, and space, and in addition often harbored insect pests and diseases thus aggravating their adverse effects.
Lall, (50) in India emphasized the importance of weed control in that country noting that the fight against weed pests there involved the use of hand pulling and hoeing of weeds, use of bullock-drawn and tractor-drawn cultivators, and the use of herbicides. He noted that long growth of cane alone allowed for buildups of certain weeds, especially wild sugarcane, nutgrass, bermuda grass, and crabgrass, and stated that weeds were particularly problematic in the ratoon crops.

Stamper, (79) in Louisiana, has stated, "If weeds and grasses are allowed to grow in the plant cane crop, the stubble yield is poor," and; "Sometimes a second stubble crop cannot be produced economically unless weeds and grasses are controlled." He stated that germination of eyes could be lowered by as much as 22% in weed infested fields and said that if growers' weed control programs failed in any one year due to lackadaisical control practices that the final yield would show it.

The major weed pest of Louisiana sugarcane is johnsongrass Sorghum halepense L. (Pers.). Stamper (77) in a 1967 publication, gave the estimate of infestation in Louisiana in 1949 at approximately 50% of the total acreage and noted that yields in these areas had been measurably reduced. By 1966 he showed the same amount of acreage to be infested but to have lower infestation rates due mainly to improved chemical control. He indicated a need for chemicals which would effectively control rhizome johnsongrass in stubble cane.
By 1968, Stamper (78) placed the estimate of johnsongrass infestation at 80% of the Louisiana acreage with over 50% showing serious problems. He stated that seedling johnsongrass was the important problem in plant crops of sugarcane where seedling counts often reached levels as high as 5000 johnsongrass seedlings per sq ft of cane row. In stubble crops, Stamper said the problem revolved more around the control of johnsongrass growing from rhizomes which escaped chemical control in the previous growing season. He advocated fallow plowing between crop cycles to destroy seeds and rhizomes which germinated between plowings.

The 1977 recommendations of Loupe et al. (55) for control of johnsongrass and other weeds in Louisiana sugarcane reiterated the ability of johnsongrass to reproduce from seeds and rhizomes in stubble cane and stressed that control must be directed towards suppressing both sources of reinfestation. The authors advised the use of selective, translocated post-emergence herbicide to control rhizome johnsongrass in ratoon cane and noted that that type of chemical could be aerially applied.

Alam (3) reported in 1976 on a serious outbreak of white grubs of the brown hardback, Clempora smithi (Arrow), and sugarcane root borer, Diaprepes abbreviatus (L.), in Barbados which caused yield reductions through feeding on the root systems and stalks of sugarcane. In addition, he stated that the pests were of increased concern since the introduction of the BSPA/McConeal Cane Harvester as this machine harvested cane by pushing against and breaking off
the stalks at the base. This was responsible for uprooting of many stools under conditions of weakened root systems through insect attack and other causes. Both insects are generally root feeders but as they get larger they bore into underground stems also, often resulting in spectacular symptoms which can appear suddenly, especially under dry soil conditions. Alam observed that ratooning was prevented in many cases because of serious root damage from heavy infestations and that chemical control of the pests was difficult in the ratoons because the chemicals available for treatment were destroyed by light and had to be deeply incorporated into the soil to be effective.

In Taiwan, Hsia and Ou-Yang (38) reported on depressed sugar-cane ratoon germination and growth as a result of root attack by the nymphs of a cicada, Mogannia hebes (Walkers). They claimed that as a result, as many as 1000 hectares of ratoon cane had been abandoned in Taiwan from 1960 to 1969.

In Australia, Chardon (18) has reported similar ratoon decline due to the presence of the yellow cicada, Parnkalla muelleri. Chardon stated that most damage occurred to the second or older ratoons due to buildups in population beneath the stools over a crop cycle.

Wright, (91) in Australia, associated increased damage to sugarcane by the soldier fly, Altermetaponia rubriceps, with growth of a greater area of ratoons thus contributing to buildups of the pest. Chemical control using dieldrin was recommended before planting, with maintenance doses thereafter.
Mathews (61) recently reported on damage to ratoon crops in Australia from wireworms, the larvae of the click beetle (*Lacon variabilis*), in which the lateral buds of the stubble pieces were bored thus resulting in lower ratoon germination. Aldrin, 0.28 kg/ha was the recommended control and Mathews noted the difficulty of obtaining effective control in the ratoons.

Beetle grubs have caused problems with ratoon cropping in India also where Agarwal and his coworkers (2) reported buildups of grubs of the family Scarabidae, *Holotrichia consanguinea* (Blanch) and *Holotrichia insularis* (Brenske). High infestation levels in the ratoons resulted in severe root pruning and drastic yield reduction.

Summers (83) reported in 1978 on the destruction of Florida sugarcane, especially the ratoons, by 7 species of white grubs, the most destructive of which was *Bothynus subtropicus*. The damage to ratoon crops was attributed to reduced regenerative potential of the stubble pieces due to root pruning and damage to the underground stems and buds. Flooding was recommended for control, and Summers stressed the need for an early detection method in order to start control before the damage became obvious in the ratoon crops.

Winchester (90) reinforced the idea of nematode disease complexes when he stated that they undoubtedly existed widely. He noted that sugarcane, since a tropical crop, was often grown in environments especially favorable to nematode survival and reproduction and therefore often was seriously affected, more so at least than other
crops. Winchester compiled data from all the sugarcane growing areas of the world concerning the genera and species of parasitic nematodes found on cane and listed them by country. He listed 12 genera alone in the United States and said that to his knowledge, Florida was the only area with a nematode control recommendation in 1968.

Birchfield (10) reviewed Louisiana records and found that 14 separate genera of nematodes had been reported on Louisiana sugar-cane by 1969. He stated that stubble decline was partly due to nematode infestation and conducted nematicide experiments in searching for improved chemical control methods.

Rau and Moberly (69) described some problems of nematode control in ratoon crops of sugarcane grown on sandy soils of the Natal sugarbelt. They found that little information existed, as of 1976 regarding nematode control in sugarcane ratoons primarily because the widely used alkyl halide nematicides, EDB and DD mixture, tended to be phytotoxic and newer chemicals such as Temik lacked data relating to their effectiveness. Their tests showed Temik to be useful in treating nematode infested ratoons but they stated that ratoon yields still fell short of the climatic potential. They noticed a high coefficient of variation in ratoons which demonstrated variable effectiveness of nematode control which was attributed partly to poorer incorporation of the nematicide in the ratoon crops.

Humbert (40) studied soil as a factor in varietal yield decline especially as it related to root environment. He discussed poor soil physical condition caused either naturally or by overirrigation and
heavy equipment as it concerned the ability of the soil to provide water, air, and nutrients to sugarcane. Humbert stated that reductions in ratoon crop yields in Hawaii were often the result of soil compaction caused by heavy equipment in harvesting and transporting cane across wet soils. He said as much as 20% of field areas in Hawaii had been shown to be compacted to a degree large enough to result in ratoon crop reductions of as much as 3 tons sugar per acre. Humbert stated that when soil bulk densities became critical to the root environment, satisfactory reconditioning was essential, without which the yields of successive ratoon crops would be reduced. Humbert said that not only did compaction occur in the harvest of the plant crop but in the following ratooning operation as well, thus hastening the usually slow change of the soil from a loose, friable state to one of compact structurelessness. Humbert wrote of similar soils in the British West Indies where plant cane grown for 15 months produced 55 tons of cane per acre but yields in 12-month first and second ratoons produced only 35 and 25 tons of cane per acre, respectively, due to compaction. He said that additions of large quantities of organic matter to these soils had improved their structures considerably resulting in ratoon yield increases rather than decreases.

Matherne et al. (59) have stated that additions of organic matter to sugarcane soils in Louisiana are perhaps beneficial but not usually necessary as a stable organic matter content can be maintained, in their opinion, through usual and periodical chopping in of old stubbles and cane trash.
Baver, (8) in a short review, recently reported on information related to the development of cane roots in ratoon crops and based upon this information made conclusions concerning the practical applications of these facts to cultivation and fertilization of sugarcane ratoons. It was believed, he said, for many years that the roots of the plant crop continued to function after harvest. Based upon his work and that of other researchers he discounted this theory, stating that plant-cane stubble roots were physiologically active for only a short while after harvest after which time they ceased to function and died. Baver stated that each new ratoon shoot which developed from a stubble-piece bud quickly developed its own root system during which time the roots from the previous crop were deteriorating. Baver wrote that the practice of off-barring or cutting away the sides of the row after harvesting was a common ratooning practice in many cane growing countries and stated that it was originally intended to increase aeration, straighten the row, and loosen and warm the soil prior to the development of the ratoon crop. He said that off-barring was done in the hope of hastening the emergence of new ratoon shoots but stated that no beneficial effect of off-barring on yield of ratoon cane, at least in Hawaii, had ever been demonstrated. He emphasized that where off-barring was practiced it should be done as early as possible in order to avoid damage to newly developing ratoon roots. Another practical application of his observations on ratoon root development was in regard to fertilizer application in the ratooning operation. He said that more rapid
Ratoon regrowth could be effected by placement of fertilizers as close to the stubble stools as possible so that nutrients could be rendered immediately available to new ratoon roots.

Hebert and Matherne (37) discussed the practice of off-barring in Louisiana. They stated that it had been a common ratooning practice for many years and was originally done in order to leave as small a row area as possible for hand weeding or hoeing and to produce a trench next to the stubbles to facilitate good fertilizer placement for a rapid early start. They advocated the use of a modified off-bar method in which the row was plowed away as usual by disk ing but instead of letting the row remain on the off-bar it was immediately recovered. One main disadvantage of the old system which they related was that the extra soil thrown into the row middles by the operation could possibly impair drainage in the event of untimely rains. An advantage of the modified off-bar system was that fertilization of rat cons, they pointed out, no longer depended on solid nitrogen fertilizers but in most cases on aqua or anhydrous ammonia; therefore the off-bar furrow was no longer necessary for good ratoon fertilizer placement as the latter nitrogen forms could be applied with injection tools not requiring a furrow.

Ochse et al. (66) advised off-barring in order to encourage sprouting and growth of deeper-formed, more robust ratoon shoots. They stated that lack of aeration, especially on heavy clay soils, could easily cause death of underground stalk parts and was often the limiting factor in the length of time that ratoon fields would
continue to produce satisfactory yields. For this reason they commented that off-barring was most necessary on poorly-drained soils.

Also used in an effort to force sprouting of deeper ratoon shoots is the practice of stubble shaving (36, 67) wherein the stubble stumps are recut at or slightly below ground level at an early stage in the ratooning operation to remove the top-sprouting tillers and buds thus hopefully encouraging lower buds to sprout. Hebert and Matherne (36) have shown the practice to be of most use in Louisiana for cutting high stumpage back to the row level and to remove winter weeds from the row ridge. Plucknett et al. (67) have stated that stubble shaving may result in reduced yields and may prove to be too expensive in many cases.

Rao, (68) studied the ratoons of Co 419 in 1956 at the Sugarcane Research Station, Anakapalle, Andhra State, India in an effort to uncover the probable causes of general ratoon failures of sugarcane in that area. In his introduction Rao disclosed his view that in many areas of Andhra, ratoons were not given proper manurial and cultural care and tended to be looked upon as free or catch crops and were often ratooned too long to the point of uneconomic yields induced by buildups of diseases and pests. Rao's results showed yields of first ratoon crops capable of approaching that of plant crops under addition of 50 lb N per acre and frequent irrigations. However, the yield of the second ratoon even with additional N could not be increased to a level comparable to the plant or first
ratoon crop.

Plucknett and his coworkers (67) have also noted that "the temptation to treat ratoon crops as catch crops should be avoided." They have stated that "it is apparent that poor ratoon performance of crops such as sugarcane can often be attributed to poor management including declining soil fertility and poor irrigation practice. For most crops during the active stages of growth the fertilizer requirements for ratoon crops appear to be as high if not higher, than for plant crops."

Loupe and Ricaud (56) recently prepared for publication the recommended cultural practices for sugarcane production in Louisiana. Recommended ratooning practices still included the modified off-bar method. Other cultural practices recommended for Louisiana which are contributory to good ratoon growth included subsoiling where needed; maintenance of good surface drainage through land crowning, precision grading, and ditch upkeep; control of weeds through prudent use of herbicides and through fallow plowing throughout the spring and summer to destroy johnsongrass rhizomes; stubble shaving where called for to remove high stubble pieces and winter weeds and excess soil cover on the row, being careful not to shave too deep or too late after tillering starts in the spring; and, maintenance of good soil tilth through wise cultivation practices.

Louisiana fertilizer recommendations (20) for sugarcane stress the importance of soil testing in determining lime and fertilizer needs and recommend a higher rate of fertilization for ratoon cane as compared
to plant cane. This is based upon a demonstrated higher response of ratoon cane to fertilizers. It was reported that ratoon cane grown on heavy clay soils generally responded better to increased nitrogen, phosphorus, and sulphur than cane grown on lighter, sandier soils, which, however, responded better to potassium than cane grown in heavy clays. It was shown that additions of micronutrients were unnecessary for Louisiana sugarcane.
Methods Of Evaluating Ratooning Ability

Several researchers (25, 41, 81) have stated that differences exist between species and varieties of sugarcane in inherent ratooning ability. Plucknett et al. (67) have stated, however, that "finding a method to assess ratooning ability of sugarcane seedlings is not an easy task."

De Sornay (76), in 1957, in Mauritius, attempted to assess the ratooning ability of several Mauritius varieties of sugarcane by repeated cutting of the ratoons at 3 to 4 month intervals. In the 7th ratoon, the varieties were allowed to grow for the normal 10-month period after which time their yields were compared. De Sornay noted that frequent cutting induced high tiller formation in the test plots, especially in those varieties which he said appeared capable of producing the best yields in old ratoons. His opinion was, however, that harvesting the ratoons at short intervals had no important effect on the yield of the final ratoon of normal duration. He conjectured that perhaps his procedure only indicated a differential ability for survival under stressful conditions. In addition to this, his data showed comparisons in yield only for the final ratoons. No plant cane data with which to compare these ratoon yields were given. For these reasons, Plucknett et al. (65), who reviewed this work by de Sornay, were prompted to say that this work perhaps demonstrated a means of measuring relative tillering capacity rather than ratooning ability.
Lyrene (57), working in the Florida sugarcane area, recently studied and experimentally assessed the stubbling ability of sugarcane varieties whose actual stubbling abilities in field trials were known. Two experimental methods of estimating stubbling ability were used: 1. "measurements of shoot growth, root growth, and root/shoot ratio of plants grown from one-bud setts in greenhouse pots." 2. "field plots were cut at ground level four times at monthly intervals and the dried forage was weighed." Lyrene said that by the first method, good stubblers tended to show higher shoot weights, root weights, and shoot/root ratios than poor stubbling varieties although the method "did not appear to distinguish well enough among varieties to be practical." By the second method, however, Lyrene stated that enormous differences were shown among varieties, with the highest yielding 400% of the lowest in dried forage. In addition, there was good general agreement of varieties which produced the highest forage yields in the test plots to the same best stubbling varieties under field conditions.

In Louisiana, ratooning ability is an important varietal trait to be selected for within the sugarcane breeding programs (11, 58). The early assessment of ratooning ability is based primarily on visual and calculated estimates of reatoon yields in unreplicated infield test plots (so called first and second line trials) (11). Replicated infield test plots are subjected to a more stringent assessment of stubbling ability in that actual plot weights are recorded for plant and stubble crops (60).
Only the best varieties, by infield testing standards, are allowed to proceed to replicated outfield yield tests at several locations for further testing (60). In these tests, reliable yield estimates are obtained through replication and measurement of cane yields on a larger scale under conditions of commercial growth. Actual weights are taken using a tractor-mounted hydraulic weighing rig and varieties in these tests are carried through at least one ratoon crop before being considered for industry-wide release. Poor stubbling is a major defect for which Louisiana varieties are rejected even at this late stage of development (60).

Recent emphasis on increasing stubbling ability of Louisiana varieties has led to the increased use of wild canes, *Saccharum spontaneum* (L.) and *S. robustum* (Brandes and Jesw. ex. Grassl), in a program of basic crossing to noble-type, *S. officinarum* (L.), and interspecific hybrid canes in an attempt to incorporate additional germplasm for high yield and vigor into new breeding lines (22). In this respect Dunckelman and Breaux (22) have noted that some of these new wild cane derivatives show exceptional ratooning ability and appear, by their assessment, to be of promise in variety improvement in earlier spring growth and greater ratooning power.

A need to more efficiently categorize stubbling ability of Louisiana varieties using infield and outfield data was recently demonstrated during the 1980 varietal release committee meeting where the writer was present. A cooperative effort by workers of the United States Department of Agriculture, American Sugar Cane League and Louisiana
State University Agricultural Experiment Station has produced a formula for deriving an estimate of ratooning ability based on the performance of a variety in plant cane and ratoon crops. The formula is as follows:

\[
\text{Ratooning ability} = \frac{(1R/PC) + (2R/PC)}{2}
\]

where:
- \(1R\) = yield in first ratoon
- \(2R\) = yield in second ratoon
- \(PC\) = yield in plant cane

The formula gives the ratooning ability of a variety as the average performance of the first and second ratoons in comparison to the plant crop yield, and the answer is easily converted to a percentage performance rating.

An example of this procedure given at the 1980 varietal release committee meeting showed the following estimates of relative ratooning ability for some varieties:

<table>
<thead>
<tr>
<th>Variety</th>
<th>(average ratoon yield of the plant crop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP 61-37</td>
<td>79.94%</td>
</tr>
<tr>
<td>CP 65-357</td>
<td>80.71%</td>
</tr>
<tr>
<td>CP 72-356</td>
<td>87.76%</td>
</tr>
<tr>
<td>CP 72-370</td>
<td>85.93%</td>
</tr>
<tr>
<td>HSD (.05)</td>
<td>4.97%</td>
</tr>
</tbody>
</table>

The above results are based on data from 3 crop cycles in 13 separate infield and outfield tests. Although the method is not being used as a selection tool at the time of this writing, it does represent a desire on the part of Louisiana sugarcane researchers to find the best means available to rate ratooning ability of their varieties and
stresses the importance of ratooning ability and its proper assessment in our breeding programs.
Behavior Of Ratooning Ability In Advanced Yield Trials

Kidder (46), in Florida, used data from 8 years of testing in the final phase, stage IV, of the Florida variety development program in comparing the yield performance of ratoon crops of sugarcane to plant crop performance. Production differences between plant and ratoon crops grown in the same year were compared instead of comparing the yields of plant cane to successive ratoons grown from the same planting. Sugar per acre and tons of cane per acre produced in first and second ratoons were calculated for each year as the percentage of the plant cane crop.

In addition, Kidder compared the results of these 8 years of variety trial data to commercial production data compiled for the same 8 years and representing about 10 to 20% of the Florida sugarcane growing region.

For the variety trials, Kidder showed cane tonnage in the first and second ratoon as an average of the 8 years studied to be 80.6% (range = 69.8 to 91.0%) and 73.2% (range = 59.5 to 86.6%) of the plant crop, respectively. These figures compared well with the commercial data where values of 79.1% for first ratoon yield of plant cane, and 70.3% for second ratoon yield of plant cane were found as an average of the 8 years studied.

According to Fanguy (26), the main purpose of the Louisiana "outfield variety testing program is to determine the yield prospects of experimental varieties of sugarcane after they have been tested and selected in the seedling and infield stages of selection at Houma,
Giamalva (31) has stated that Louisiana variety selections have been tested for a minimum of 7 years in the seedling (single stool stage) and infield testing programs prior to the outfield stage of selection. He noted that the outfield tests are usually established at 10 light-soil locations and 3 heavy-soil locations for a total of 13 strategically situated locations throughout the Louisiana sugar-cane area from which data are obtained for plant cane, and first and second ratoon crops. The experiments are planted in 3 to 4-replicate randomized complete block designs in which each plot measures 3 rows wide (5.5 m or 18 ft) by 11.0 m long (36 ft). Yield data are taken by mechanically harvesting the plots and weighing the entire harvest from each. Twenty-stalk samples are obtained from all plots for sucrose analyses.

Fanguy and Richard (29) have noted that the responsibility for the supervision and analysis of the outfield yield trials is shared equally by researchers of the United States Department of Agriculture, Louisiana Agricultural Experiment Station, and the American Sugarcane League.

Data from the Louisiana outfield variety trials, authored by various researchers for the U.S.D.A. and Louisiana Agricultural Experiment Station, are published annually in the Sugar Bulletin, the bimonthly publication of the American Sugarcane League. Since these data contain information on plant cane, first stubble, and second stubble crops grown in the same year, and same locations, they are
useful in comparing the performance of ratoon crops to plant cane crops.

In Table 1, the results of the 1970 to 1979 variety trials (9, 26, 27, 29, 30, 31, 32, 42, 72, 73) are shown as the ratoon percentage yield of plant cane crops for several varieties within the same year and light-soil test locations.

For the 10 years shown, the overall average performance of first ratoon crops as a percentage of the plant crops was 92.1% and for second ratoons, 84.6%. Average yearly performance of the first ratoon crops ranged from a low of 72.0% in 1979 to 108.2% in 1973. Average yearly second ratoon performance ranged from 67.8% in 1978 to 95.2% in 1973.

Upon first inspection, the data seem to show some large differences between varieties in their stubbling ability. For instance, CP 65-357 appeared to be superior to most of the other clones in 1977; however, it did not show superior ratooning ability in the other years in which it was tested.

Similarly, the 113.5% second ratoon performance of L 60-25 in 1973 was inconsistent with its second ratoon performance in 1970, 1971, and 1972. In these years the data did not indicate superior ratooning ability of L 60-25 over the other varieties.

In summation, careful perusal of the 10 years of Louisiana outfield variety test data compiled in Table 1 showed no consistent differences in ratooning ability of the varieties when examined on the basis of more than one years data.
Table 1. Comparisons of varietal ratoon performance in outfield variety tests in Louisiana as ratoon percentage yield (cane tonnage) of the plant crop.

<table>
<thead>
<tr>
<th>Year</th>
<th>Variety</th>
<th>First ratoon</th>
<th>Second ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>CP 52-68</td>
<td>100.7</td>
<td>92.6</td>
</tr>
<tr>
<td></td>
<td>L 60-25</td>
<td>98.0</td>
<td>87.8</td>
</tr>
<tr>
<td></td>
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<td>84.9</td>
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<tr>
<td></td>
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<td>90.0</td>
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<tr>
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<td>85.2</td>
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<td>L 60-25</td>
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<td>113.5</td>
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<tr>
<td></td>
<td>CP 67-412</td>
<td>90.8</td>
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continued
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<tr>
<th>Year</th>
<th>Variety</th>
<th>First ratton</th>
<th>Second ratton</th>
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<td></td>
<td>CP 70-321</td>
<td>72.8</td>
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<tr>
<td></td>
<td>CP 70-330</td>
<td>90.7</td>
<td>87.2</td>
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<td>1978</td>
<td>CP 61-37</td>
<td>84.4</td>
<td>65.0</td>
</tr>
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<td>82.4</td>
<td>68.6</td>
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<td></td>
<td>CP 70-321</td>
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<td></td>
<td>CP 70-330</td>
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</tr>
<tr>
<td></td>
<td>CP 72-356</td>
<td>61.8</td>
<td>71.7</td>
</tr>
</tbody>
</table>
Seasonal and environmental fluctuations are apparent from year to year but it would seem for the most part that released varieties tend to be very similar in ratooning ability in Louisiana.
MATERIALS AND METHODS

The experimental material for this study consisted of 210 unselected progeny of the cross CP 65-357 X L 65-69 plus the parents. The progeny clones were randomly chosen from single-stool plantings established from seedlings of the true seed. The only requirement of the single-stool progeny was that each have at least 4 stalks with which to plant a 3 m clonal plot.

The experiment was conducted at the St. Gabriel branch of the Louisiana Agricultural Experiment Station located at St. Gabriel, Louisiana approximately 16 km south of Louisiana State University in Baton Rouge. The field area assigned for use in the experiment was prepared as for commercial growth using standard 1.8 m row spacing. Five rows were each divided into 44 3-m plots spaced 0.61 m apart on the row for a total of 220 plots. Each of the 210 experimental clones was planted into a separate plot. In addition, the parents were planted in contiguous plots, one parent to each plot, one set of parents per row, for a total of 5 replications of each parent randomly placed throughout the progeny. The entire field was protected by buffer rows on its sides and ends.

The experiment was grown through plant crop, first ratoon, and second ratoon from 1976 to 1978 during which time recommended fertilization, pest control, and cultural practices for commercial sugarcane production were adhered to as closely as possible.
Data were collected for each clone in all crops for important yield components including stalk population, stalk weight, stalk length, and stalk diameter. Data were taken each year for brix and sucrose percentage also.

Data collection began each year in September and October with repeated stalk population counts for all plots followed in mid to late November by sampling.

In order to eliminate bias of choice, the sampling method employed consisted of hand harvesting the first 20 stalks deemed millable in each plot. The stalks in each sample were first cut at ground level, topped at the last mature node, and laid in bundles in orderly fashion across the rows. After cutting, the samples were stripped of leaves, bundled with cord, tagged for identification, and brought in from the field to the mill shed for further measurements.

After sampling was finished each year, those canes remaining in the plots were machine harvested with a soldier-type mechanical harvester. Subsequent culture of the canes continued to follow standard farm practices.

Plant cane samples were harvested from November 29 to December 6 in 1976. First ratoon samples were harvested from November 11 to November 15 in 1977 and second ratoon samples were harvested from November 4 to November 5 in 1978. In all years, sampling was deliberately started as late in the harvest season as possible in order to diminish any date-of-harvest effects.
The specific procedures followed each year in measuring yield and its components are outlined below.

1) Estimated yield

Yield itself, was estimated in each year and for each clone as the product of stalk population × mean stalk weight per clone.

2) Stalk population

As stated earlier, stalk population was determined in each year for all clones through careful counting of all stalks in each plot. A mechanical tally meter was used and counts were repeated for accuracy. Counting was made more difficult in the first ratoon crop due to lodging caused by the winds of Hurricane Babe, a relatively mild hurricane, which nevertheless caused moderate to severe lodging in the Louisiana cane crop and sustained windspeeds in the Baton Rouge vicinity of approximately 60 km/h on November 5, 1977.

3) Mean stalk weight

As the cane samples were brought from the field to the mill shed, each was unloaded and weighed to the nearest ounce before stacking out of the way. Mean stalk weight was taken as the quotient of the bundle weight (converted to metric equivalents) of each sample divided by the number of stalks per sample.

4) Mean stalk length

The mean stalk length was obtained for each clone as the average of all stalks in a sample, each separately measured to the nearest centimeter on a precalibrated measuring platform.
5) Mean stalk diameter

In order to speed the collection of data the measurement of mean stalk diameter was obtained from only half the sample at the same time that stalk length was measured. As shown by Legendre et al. (52), 10-stalk samples have proved satisfactory for measurement of diameter, as mean stalk diameters derived from samples of this size showed surprisingly low coefficients of variation. All measurements of stalk diameter in the present study were obtained by measuring the diameter of the stalks at their approximately middlemost internode with a vernier caliper reading to the nearest 0.1 mm.

6) Laboratory brix and sucrose percent

Juice samples for sucrose determinations were crushed from the same samples used for measuring weight, length, and diameter of the clones. Ten stalks of each sample were crushed at approximately 75 kg/cm² roller pressure using the experimental 3-roller mill at St. Gabriel, and the juice analyses were conducted by the St. Gabriel laboratory staff. Brix, or total solids in the juice, was first determined by the use of the brix hydrometer standardized at 20°C.

Sucrose determinations were made using Horne's method (63), which uses dry lead subacetate for juice clarification. Filtration of the juice samples aided by diatomaceous earth (dicalite) was followed by measurements of polarity in an automatic polarscope designed especially for use with sucrose solutions (an automatic saccharimeter). Brix and polarity measures for each sample were then used in conjunction with Schmitz's table (63) in obtaining sucrose percent of the juice samples.
Sucrose data were not an especially important part of the study since ratooning ability of the clones was considered on the basis of cane tonnage and not sugar per ton. Sucrose analyses were performed mostly for additional data.

After each harvest, the data were keypunched, and much of the analysis was done on computer at Louisiana State University.

Means and other simple statistics were easily computed for the parents and progeny.

Analysis of variance was used in looking at differences between the parents within and among crops. Tukey's w procedure (HSD test) at the 5% probability level was used for multiple comparison testing.

Computer-generated frequency distributions, and computer correlations which would have been difficult to calculate by hand, were especially helpful in analyzing the behavior of yield and its components across the ratoons of the progeny.
RESULTS AND DISCUSSION

Ratooning Behavior Of The Parents

The parents of the cross studied in the experiment, L 65-69 and CP 65-357, represent the germplasm pool from whence genetic variation in ratooning ability of the progeny arose and are, therefore, logically studied first in regard to their ratooning behavior. This establishes a reference to which the experimental clones (the progeny) will be compared.

Of the parents, CP 65-357 is a high sucrose, early maturing, erect-standing variety which has good cold tolerance and yields equally well on both light and heavy soils (12). From its 1973 release to the Louisiana sugar industry, CP 65-357 quickly grew to occupy the majority of the acreage by 1978 (62). It remains the major Louisiana variety in 1980 (28).

The other parent, L 65-69, was released as a variety to Louisiana growers in 1972 (5, 17). It equaled CP 52-68 and L 60-25, the then standard varieties, in yield of cane and showed increased sucrose content over CP 52-68. In addition, L 65-69 showed resistance to mosaic. Its bad qualities, pointed out in its 1972 notice of release (17) and the 1976 variety recommendations for Louisiana (54), include high susceptibility and low tolerance to ratoon stunting disease, lodging habit, and lack of cold tolerance.

Throughout the growing history of CP 65-357 and L 65-69, CP 65-357 has often been described as a good stubbling variety and L 65-69 has
not (53, 54, 62). L 65-69 was dropped as a recommended variety in 1978 and the writer was present at the sugarcane meeting for extension and research personnel where the announcement that L 65-69 should be discontinued was made. Poor harvestability, poor cold tolerance and poor stubble yields were given as some reasons why L 65-69 should be dropped as a recommended variety for commercial production.

In 1975 when the experiment to study ratooning ability was established, the choice of parents, L 65-69 and CP 65-357, had already been made based in part upon the desire to use parents which supposedly showed sharp contrasts in their ratooning ability.

Of first importance in assessing the ratooning behavior of the parents used in the study is a close examination of their yield performances in plant cane, first ratoon, and second ratoon crops.

In Table 2 are presented, by crop and parental variety, the means for estimated yield of cane and each of its components: stalk population, stalk weight, stalk length, and stalk diameter. These means are taken as the average of 5 replications of each parent.

The data in Table 2 allow a comparison of estimated yield and its components for both parental varieties by each crop studied - plant cane, first ratoon, and second ratoon.

In order to study the significance of the differences among the check varieties and their crops in estimated yield and its components an analysis of variance was conducted as for a completely randomized design with factorial arrangement. The treatments were crops as a factor with 3 levels and varieties as a 2 level factor. By this approach
Table 2. Means of estimated yield and its components for both parents in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Estimated yield (kg/plot)</th>
<th>Stalk population (stalks/plot)</th>
<th>Mean stalk weight (kg)</th>
<th>Mean stalk length (m)</th>
<th>Mean stalk diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant</td>
<td>L 65-69</td>
<td>80.72</td>
<td>62.80</td>
<td>1.29</td>
<td>2.39</td>
<td>25.02</td>
</tr>
<tr>
<td>cane</td>
<td>CP 65-357</td>
<td>73.92</td>
<td>70.40</td>
<td>1.05</td>
<td>2.12</td>
<td>23.88</td>
</tr>
<tr>
<td>First</td>
<td>L 65-69</td>
<td>68.24</td>
<td>58.80</td>
<td>1.16</td>
<td>2.43</td>
<td>24.00</td>
</tr>
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<td>ratoon</td>
<td>CP 65-357</td>
<td>61.03</td>
<td>62.80</td>
<td>0.97</td>
<td>2.27</td>
<td>23.20</td>
</tr>
<tr>
<td>Second</td>
<td>L 65-69</td>
<td>30.19</td>
<td>39.60</td>
<td>0.76</td>
<td>1.77</td>
<td>22.60</td>
</tr>
<tr>
<td>ratoon</td>
<td>CP 65-357</td>
<td>29.83</td>
<td>45.00</td>
<td>0.67</td>
<td>1.69</td>
<td>21.24</td>
</tr>
</tbody>
</table>
to the statistical analysis not only can differences in estimated yield and its separate components be ascertained for between crops and between controls, but in addition, a factorial analysis has the distinct advantage of delving into the nature and significance of the interaction of crop x variety. In total, 5 separate analyses were conducted, one for estimated yield, and one each for all variables which were directly measured: stalk population, mean stalk weight, mean stalk length, and mean stalk diameter.

The results of these five analyses are reproduced in the following source table, Table 3.

In all cases, that is, for yield and each of its components, the analysis of variance showed that highly significant differences existed among crops.

Differences between the parent varieties themselves were shown to be significant only between weight per stalk, length of stalk, and diameter of stalk. No significant differences in stalk population and estimated yield were shown to exist between the parents.

A most interesting finding of this analysis was that the interaction of crop x variety was nonsignificant, without exception, for each of the variables studied. This is lucidly shown by the data of Table 2 from which it is quickly noticed that the yield trends of both parents over the three crops studied were markedly similar. This nonsignificant interaction indicated that the parents reacted similarly and remained the same in rank relative to each other for all traits measured over the plant cane, first ratoon, and second ratoon
Table 3. Analysis of variance - mean squares for estimated yield and its components for the parents.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Estimated yield</th>
<th>Stalk population</th>
<th>Stalk weight</th>
<th>Stalk length</th>
<th>Stalk diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crops</td>
<td>2</td>
<td>5997.82 **</td>
<td>1610.63 **</td>
<td>0.580 **</td>
<td>1.120 **</td>
<td>16.58 **</td>
</tr>
<tr>
<td>Varieties</td>
<td>1</td>
<td>172.81</td>
<td>240.83</td>
<td>0.230 **</td>
<td>0.220 **</td>
<td>9.08 **</td>
</tr>
<tr>
<td>Crops x Varieties</td>
<td>2</td>
<td>36.86</td>
<td>8.23</td>
<td>0.010</td>
<td>0.020</td>
<td>0.20</td>
</tr>
<tr>
<td>Residual</td>
<td>24</td>
<td>80.51</td>
<td>60.03</td>
<td>0.007</td>
<td>0.024</td>
<td>1.12</td>
</tr>
</tbody>
</table>

** = significant at the 1% probability level; other mean squares non-significant.
crops.

For instance, Table 2 shows that in estimated yield both parents showed highest in plant cane - L 65-69 with 80.72 kg of cane per plot and CP 65-357 with 73.92 kg/plot. In first ratoon, the same data showed decreases in estimated yield for both varieties with L 65-69 yielding 68.24 kg/plot and CP 65-357 yielding 61.03 kg/plot. In second ratoon also, both check varieties reacted similarly. Both demonstrated drastically reduced yield with L 65-69 producing only 30.19 kg/plot and CP 65-357 yielding but 29.83 kg/plot.

In stalk population too, the parents again showed very similar trends in mean behavior as a function of crop age. From Table 2 it can be seen that both parents showed progressively lower stalk population with each successive crop.

Correspondently, the data of Table 2 also indicate that the parents showed like behavior of weight per stalk over the three crops. Like stalk population and estimated yield, mean weight per stalk decreased for both parents with the succession of crops.

The parents also showed similar trends over crops in the behavior of mean stalk length and mean stalk diameter.

Again from Table 2, it can be seen that both parents showed increases in first ratoon mean stalk length of the plant cane. In second ratoon however, mean stalk length declined for both parents. Mean stalk length was the only component of yield in the experiment which showed a first ratoon increase, but like all the other components studied did show a decline in second ratoon.
The mean stalk diameter of the parents declined steadily with crop age and both parents again showed good agreement in demonstrating this trend.

The intent of the discussion of the homology in yield trends between the two parental checks is to add weight to the finding in the analysis of variance of a nonsignificant interaction of crop x variety.

The main importance of this nonsignificant interaction is that it allowed the two parents to be combined for use in making comparisons between specific crops. Thus, a higher number of degrees of freedom became available for making these multiple comparisons of means, the standard error was effectively reduced, and greater precision was gained in studying yield and its components as a function of crop age.

The separation of the highly significant differences among crops shown in the analysis of variance, Table 3, was done using Tukey's w procedure for multiple comparison testing of mean differences (Tukey's HSD test). The results of these comparisons are presented in the following table, Table 4.

From Table 4 it can be seen that as an average of both varieties, significant differences in estimated yield were shown among all crops through the HSD test. These differences were the result of successively lower yields of the parents with increasing crop age and, although a possible contributory role of seasons to these significant decreases cannot be eliminated, the magnitude and consistency of the trend in
Table 4. Tukey's w procedure for testing mean differences in yield and its components among crops as an average of both parents combined.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Estimated yield (kg/plot)</th>
<th>Stalk population (stalk no.)</th>
<th>Mean stalk weight (kg)</th>
<th>Mean stalk length (m)</th>
<th>Mean stalk diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant cane</td>
<td>77.33 a</td>
<td>66.60 a</td>
<td>1.17 a</td>
<td>2.25 a</td>
<td>24.45 a</td>
</tr>
<tr>
<td>First ratoon</td>
<td>64.64 b</td>
<td>60.80 a</td>
<td>1.07 b</td>
<td>2.35 a</td>
<td>23.60 a</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>30.01 c</td>
<td>42.30 b</td>
<td>0.71 c</td>
<td>1.73 c</td>
<td>21.29 b</td>
</tr>
</tbody>
</table>

HSD = 10.02 9.21 0.09 0.17 1.18

Means followed by same letter are not significantly different at the 5 percent probability level.
yields of the parents are strongly indicative of ratoon yield decline not due solely to seasonal effects. In fact, as previously commented upon in the review of literature, the commonness of ratoon yield decline in Louisiana and elsewhere is widely recognized and accepted as a natural occurrence. The decline in the ratoon yields of the parents in this study was especially pronounced in second ratoon and was not unexpected.

Again from Table 4, stalk population is also shown to have decreased with crop age but the difference between plant cane stalk population and first ratoon stalk population was nonsignificant. However, the differences between stalk population in plant cane versus second ratoon, and first ratoon versus second ratoon were significant. This is a commonly observed phenomenon of commercial varieties grown in Louisiana. They often tend to show as high or sometimes a higher stalk population in first ratoon crops as that shown by the plant cane crop.

Also as shown in Table 4, mean stalk weight of the parents significantly decreased in each successive ratoon crop.

Mean stalk length of the parents was nonsignificantly higher in first ratoon than in the plant cane. By second ratoon, mean stalk length was significantly decreased in comparison to its measurements in plant cane and first ratoon alike.

Mean stalk diameter decreased for the parents in first ratoon but this decrease was nonsignificant. By second ratoon, however, mean stalk diameter was significantly lower than its average measurements.
In plant cane or first ratoon.

Length and diameter of stalk directly condition mean stalk weight, and as shown in Table 4, mean stalk weight significantly decreased as early as first ratoon. Since the differences in mean stalk length and mean stalk diameter between the plant crop and first ratoon crop were nonsignificant for the checks, it would seem that the change in mean stalk weight from plant cane to first ratoon would also be nonsignificant. Thus, the significant decrease of mean stalk weight in first ratoon could not be readily accounted for by the changes which occurred in mean stalk length and mean stalk diameter within the same period.

Stalk population and mean stalk weight directly condition yield of cane. The significant difference in estimated yield in plant cane versus first ratoon was accompanied by a significantly decreased first ratoon mean stalk weight and a nonsignificantly decreased stalk population. The first ratoon decrease in estimated yield of the parents was caused by both decreased mean stalk weight, and decreased stalk population. However, it appears, by virtue of its statistical significance, that decreased mean stalk weight was somewhat more contributory to the first ratoon decrease in yield of the parents than was stalk population.

The mean differences for yield and each of its separate components were statistically significant between plant cane versus second ratoon, and first ratoon versus second ratoon. This agrees well with the frequently observed ratoon performance of varieties under Louisiana
growing conditions wherein second ratoon yields are often quite poor in relation to those of the plant cane and first ratoon alike.

A prime objective from the beginning of this experiment was to determine, if possible, which component or components of yield are most important in contributing to ratoon yield decline. In studying this question, it is especially desirable to approach it from the standpoint of second ratoon yields since sugarcane researchers have long known that this is where ratoon declines are likely to become most pronounced.

The data of Table 4 bear on the question of which yield component(s) was most involved in second-ratoon yield decline. The data clearly indicate that the decline in second ratoon yield of the parents, CP 65-357 and L 65-69, was due not to one component of yield alone but to all of them together. The second ratoon decrease in stalk population appears to have been no more important to the second ratoon yield decline than was decreased second ratoon mean stalk weight. Furthermore, mean stalk length and diameter declines in second ratoon were certainly both involved in the second ratoon decrease of mean stalk weight.

Since all of the individual components of yield have been shown to be contributory to ratoon yield decline, any one might serve as a trait upon which to measure ratooning ability. Certainly, though, a component which shows little variability could possibly be used as a gauge of ratooning ability with more reliability than a component of high variability especially if such measures were made in clonal
plots of small size.

The coefficients of variation in yield and its components are presented for the parents in the next table, Table 5, and are useful in comparing the relative amount of variation among all of the components of yield for each parent within the same crop. Through the coefficients of variation, a good idea can be gotten of which components of yield, if any, showed the least amount of variation in any one crop, be it plant crop, first ratoon, or second ratoon. Further, it would be hoped that such a component show this tendency consistently across all crops in order that it might in some way prove useful as a selection criterion for ratooning ability.

From the data of Table 5, it can be seen that, within a given crop, yield and stalk population showed high coefficients of variation for both parents while mean stalk length, and mean stalk diameter had relatively low coefficients of variation. This was true in all three crops - plant crop, first ratoon, and second ratoon.

Fairly large variability in estimated yield among the five replications of each variety was expected considering the large influence of environment upon yield, the small size of plots used in the study, and the completely random design of the experiment.

In all three crops, stalk population showed higher coefficients of variation as an average of both parents than did the other individual components of yield - mean stalk weight, mean stalk
Table 5. Coefficients of variation in estimated yield and its components for both parents in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Estimated yield (kg/plot)</th>
<th>Stalk population (stalks/plot)</th>
<th>Mean stalk weight (kg)</th>
<th>Mean stalk length (m)</th>
<th>Mean stalk diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant cane</td>
<td>L 65-69</td>
<td>8.96</td>
<td>12.10</td>
<td>4.93</td>
<td>1.94</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td>CP 65-357</td>
<td>16.40</td>
<td>14.23</td>
<td>8.08</td>
<td>5.56</td>
<td>4.35</td>
</tr>
<tr>
<td>First ratoon</td>
<td>L 65-69</td>
<td>8.36</td>
<td>6.95</td>
<td>2.79</td>
<td>5.90</td>
<td>4.25</td>
</tr>
<tr>
<td></td>
<td>CP 65-357</td>
<td>18.42</td>
<td>16.14</td>
<td>7.95</td>
<td>7.34</td>
<td>2.38</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>L 65-69</td>
<td>30.79</td>
<td>26.88</td>
<td>9.85</td>
<td>8.33</td>
<td>2.40</td>
</tr>
</tbody>
</table>
length, and mean stalk diameter.

Mean stalk weight and stalk population determine yield of cane, and from the data of Table 5 it can be seen that, within a given crop, mean stalk weight generally showed lower coefficients of variation among the five samples of each parent than did stalk population or estimated yield. The only exception was for L 65-69 in second ratoon where mean stalk weight evidently showed higher variation than stalk population. As an average of both parents however, stalk population showed higher variability than mean stalk weight over all crops studied. This suggests that in small plots stalk population may contribute more to variation in yield than does mean stalk weight.

The two remaining components of estimated yield, mean stalk diameter and mean stalk length, are the direct components of stalk weight and are known to vary little on a per clone basis.

From Table 5, mean stalk length is shown to have reacted as expected in regard to its variability. Mean stalk length showed coefficients of variation which were relatively low in comparison to yield or its major components - mean stalk weight and stalk population.

Mean stalk diameter too showed relatively low coefficients of variation, in fact, the lowest of all the individual components of yield when compared by crops as an average of the parents.

Low variability in diameter of stalk and length of stalk is to be expected in clonal populations. Legendre et al. (53) have reported coefficients of variation in stalk diameter of commercially-grown
CP 52-68 plant cane as low as 3.5% from 10-stalk samples and 2.6% from 20-stalk samples. Length of stalk was shown to vary even less in the same experiment with coefficients of variation as low as 1.8% reported for 10-stalk samples and 1.3% for 20-stalk samples. They also found relatively low coefficients of variation in weight per stalk and concluded that small samples could be effectively used to estimate weight per stalk. In turn, yield of cane in large plots could be accurately estimated, they believed, by taking careful stand counts of millable stalks per plot and multiplying times the average weight per stalk as determined from 20-stalk samples. This method correlated well with the usual method of determining yield in large plots by direct weighing.

Yield determinations, however, are likely to be unreliable no matter how they are obtained when based on unreplicated small-plot data.

This is important because it indicates that retooning ability cannot be reliably determined in small plots (such as those of early line trials) based on yield, whether determined as actual yield, estimated yield, or rated yield (as rated against standard check varieties).

However, since much of the monetary return on sugarcane cropping is made through the growth of ratoon crops, perhaps more emphasis should be placed on specific selection for higher retooning ability in earlier stages of our sugarcane breeding programs where the greatest amount of genetic variability is to be found. It would remain only to find
an effective method for making such selections feasible.

In Louisiana, the currently used methods of clonal selection in early first and second line trials concentrate on selection of clones of good agronomic worth based on such criteria as visual appraisal of stalk size, degree of lodging, general appeal to the selector, estimates or direct counts of stalk population (stand counts) and sucrose analyses of 10-stalk samples. In essence, high yield of sugar and cane per acre is the eventual goal but unfortunately yield of cane, unlike sucrose content, cannot be directly selected for in small clonal plots but must instead be evaluated through the behavior of its individual components.

First-line-trial clonal plots are small (single row, 3 m) and are grown to begin the improvement of selection efficiency for such traits as sucrose content, and to gain additional planting material for the second line trial. The first line trial is grown to first ratoon only before destruction.

The second line trial is very similar to the first line trial. The two differ mainly in plot size (second-line-trial plot size = single row, 6 m) and in the number of clones grown as some are eliminated in first line trial and not advanced to second line trial. Like the first line trial, the second line trial is only grown to first ratoon.

Since neither early line trial is grown past first ratoon, the obtainment of data on second ratoon performance of the clones is delayed until the replicated infield testing stage.
Selection for ratooning ability in first and second line trial stages, where more genetic variability is expected than in advanced testing, may thus be rendered only partly effective since second ratoon performance is not examined, and since an indirect means is used for selecting good ratooning ability.

One approach toward optimizing the selection of good ratooning ability in first and second line trials might be to measure ratooning ability at this stage based on the percentage decline in stalk weight from the plant cane to the first ratoon crop. These measurements could be made by weighing the samples cut for sucrose analysis but could entail extra time and labor if a larger sample size was called for, as could be the case, since stalk weight is subject to greater variation in small plots than are, for instance, its individual components - diameter of stalk and length of stalk.

Perhaps a quicker measure of ratooning ability might be based on stalk diameter which could possibly be used as a gauge of stalk weight.

Since stalk diameter shows low variability within a clonal plot, measurements of stalk diameter based on small samples of perhaps as few as 10 stalks could be taken in plant cane and ratoon crops of early line trials and used to determine the percentage decline of stalk diameter from plant cane to the ratoon crops. The selection technique presently in use would not have to be altered in any way to include this selection criterion. Diameter measurements could be taken rapidly on samples to be brixed, or analyzed for sucrose, or on
standing cane through the use of a vernier caliper reading to the nearest 0.5 mm. This method could contribute additional information on the ratooning ability of varieties to the standard selection information normally taken in early line trials.

Ratooning ability of the selected clones could be determined more accurately later in replicated testing by basing the measurement of ratoon percent performance of the plant cane on yield itself.

Perhaps mean stalk length too could be used in early line trials in the same manner as mean stalk diameter in order to gain an idea of ratoon percentage decline since mean stalk length also shows fairly low variability in clonal plots. However, this does not seem as easily applicable as readings of mean stalk diameter.

Another possible method of selecting for better ratooning ability which represents a more radical departure from the present methods of sugarcane selection could be to eliminate first and second line infield trials as separate tests and instead plant one unreplicated clonal plot test to serve the purpose of both. Plot size in such a test could be comparable to that of the first line trials now in use (3 m) but increased selection pressure for ratooning ability could be applied by growing the test through second ratoon. This is because ratoon decline, as pointed out earlier, often becomes most serious in second ratoon and such second-ratoon declines are not selected against with the present methods of early-line selection.

In changing to a selection system of the type proposed it would be imperative that it fit well into the normal time schedule of variety
development. This would be possible if second line trials were bypassed and all early clonal selection was instead made in the new early-line trial so proposed. With the present system of sugarcane selection, clones are grown for a combined total of 3 years in first and second line trials. This time limit could still be met with the suggested new system but additional information on ratooning ability could be gained.

In selecting for ratooning ability in this manner it would be important, as always, to take into account certain associations among yield and its components. For example, the well-known correlation of diameter of stalk and number of stalk has been shown to be negative, highly significant, and low to moderate in strength (44, 65). This means that clones of large diameter are likely to have lower stalk population than clones of average diameter. Selection for ratooning ability could not therefore be based on finding large diameter clones which show minimal stalk diameter decrease in their ratoons because these clones will likely show worse than average stalk population and therefore inferior yield in all crops.

High yielding ability is always the main objective in sugarcane breeding and rightly so, but most varieties of commercial caliber, both past and present, experience approximately equal and serious ratoon declines in yield which are characterized by a general loss of vigor which affects all of the individual components of yield. In sum, it can be stated that sugarcane selection must continue to rely on obtaining a good balance of desirable characteristics. Good ratooning
ability is recognized as one of these characteristics but could perhaps be more effectively screened and selected for especially in early stages of variety development.

From the analysis of variance, it remains only to discuss differences due to varieties. As previously shown by the data of Table 3, significant differences between the parents were shown to exist only for mean weight per stalk, mean length per stalk, and mean diameter of stalk. No significant differences in stalk population or estimated yield were shown to exist between the parents.

Most importantly, however, it is of greatest concern to realize that as far as differences between the parents in any one specific crop are concerned it is sufficient to know only if differences existed as a combination of all crops for any variable studied because the nature and magnitude of the differences can be observed from the means of Table 2, and absolute differences in yield or its separate components between the two parents within any one crop are not important in assessing their separate ratooning abilities. This is because ratooning ability is measured over crops and not within crops. The fact that the interaction of crop x variety was consistently nonsignificant also lends substance to this reasoning.

It is important to remember that ratooning ability is related to many factors of growth, disease resistance, and interactions involving plant physiology and morphology with numerous and diverse plant environments. By the purest definition, ratooning ability refers not to high yields in the ratoon crops but to the ability of a clone to
show a minimal decline in yield of the ratoon crops, especially in second ratoon, when compared with the yield of the plant cane crop, irrespective of whether this initial plant cane yield was low or high.

In Table 6 data are presented on the mean ratoon percentage performance of plant cane for estimated yield of cane and its separate components for the parents. The data are subdivided into the first and second ratoon percentage performance of the plant cane crop and represent the average of 5 replications of each parent.

At first glance, the most outstanding feature of the data of Table 6 is the remarkably concordant behavior of the parents in regard to their ratooning abilities in both first and second ratoons.

Less superficially, the data of Table 6 also show good agreement with the finding that ratoon yield decline is equally contributed to by declining stalk population and stalk weight. As expected, those traits of least variability and simplest inheritance, diameter of stalk, and length of stalk, showed the highest second ratoon repeatability of the components of yield for both parents.

Of natural relevance in determining if the parents differed in ratooning ability is a statistical test of significance for differences between them in their ratoon percentage performance of yield and its components.

The F test was used for this purpose and in all instances failed to show significant differences between the ratooning ability of the parents within either first ratoon percentage performance of the plant
Table 6. Mean ratoon percentage performance of plant cane for estimated yield of cane and its components.

<table>
<thead>
<tr>
<th>Variety</th>
<th>% estimated yield</th>
<th>% population</th>
<th>% weight</th>
<th>% length</th>
<th>% diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 65-69</td>
<td>84.86</td>
<td>94.66</td>
<td>90.06</td>
<td>101.95</td>
<td>95.96</td>
</tr>
<tr>
<td>CP 65-357</td>
<td>83.44</td>
<td>89.26</td>
<td>93.10</td>
<td>107.83</td>
<td>97.35</td>
</tr>
</tbody>
</table>

Means for second ratoon percent of plant cane

<table>
<thead>
<tr>
<th>Variety</th>
<th>% estimated yield</th>
<th>% population</th>
<th>% weight</th>
<th>% length</th>
<th>% diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 65-69</td>
<td>37.49</td>
<td>63.79</td>
<td>58.88</td>
<td>74.18</td>
<td>90.36</td>
</tr>
<tr>
<td>CP 65-357</td>
<td>41.39</td>
<td>64.76</td>
<td>63.24</td>
<td>79.59</td>
<td>89.09</td>
</tr>
</tbody>
</table>
cane or second ratoon percentage performance of the plant cane. This was true for estimated yield and each of its individual components.

Not only were the analyses of variance for differences in ratooning ability based on the actual percentages-of-the-plant cane computations themselves but also on numbers produced through the arcsine transformation of these percentages, also known as an angular transformation.

By this method, as described by Snedecor and Cochran (75), a measurement of proportion is transformed to a corresponding angle taken as the sine of the square root of the percentage. The effect of the angular transformation is to spread out the values of small proportions in order to increase their variance.

Again, no significant differences in ratooning abilities of the checks were shown by the F test when performed on the angularly transformed data.

From the analysis of the data it could only be concluded that in this study, there were no significant differences in the ratooning abilities of the parental checks, L 65-69, and CP 65-357.

This may seem surprising at first, especially in light of earlier-referenced reports intimating the superiority in ratooning ability of CP 65-357 over that of L 65-69, but upon careful consideration of the techniques used in the selection of sugarcane varieties this finding becomes less surprising and perhaps is to be expected instead.

From the onset of selection, clones which show poor ratooning ability (those that yield poorly in ratoon crops of early-line trials)
are quickly discarded. In replicated infield trials also, clones not showing well in their ratoons are quickly discarded. Thus, by the replicated outfield-yield-trial stage of selection, it is reasonably safe to assume that those varieties remaining for testing are relatively close in their ratooning ability. This assumption becomes even more reasonable when it is considered that selection in sugarcane is pivotally oriented toward high yield and sucrose content and not toward ratooning ability per se.

As far as the reputation of L 65-69 for being a poor ratooning variety is concerned, it may have been more the result of its poor harvestability, and high susceptibility and low tolerance to RSD - two known serious disadvantages - and less the result of inherently poor ratooning ability. Admittedly, L 65-69 under poor management, high prevalence and/or poor control of RSD, and adverse mechanical harvesting conditions could absolutely appear to be a poor ratooner.

If transgressive segregation or a reasonable amount of variability in ratooning ability occurs in the progeny of interspecific crosses of the type studied; then early-stage selection for ratooning ability within such progenies could perhaps be optimized by employing more direct methods, such as those suggested, for screening and selecting for improved ratooning ability. More direct and intense selection for improved resistance or tolerance to RSD could also be valuable in improving the ratoon potential of sugarcane selections.

If variability in the expression of ratooning ability proves to be limited in varieties now used as parents in commercial crossing
then other sources of germplasm will have to be explored in search of high ratocing power.
Ratooning Behavior Of The Progeny

Mean behavior for all parameters:

Of the 210 experimental clones originally planted in the experiment, 18 failed to germinate or had less than 10 stalks per plot in the plant crop and were dropped, thus leaving 192 clones from which to obtain data. All 192 clones were measured in the plant cane and first ratoon crops, but by the second ratoon crop, some clones were so reduced in stalk population that adequate sample sizes were unobtainable for yield and some of the other components. Based on the variability of the components involved, and the available sample sizes, decisions were made to eliminate some second ratoon measurements from the statistical treatment of the data in order to avoid bias of the experiment. For this reason, estimated yield, stalk weight and stalk length of the progeny were measured in 183 clones in second ratoon, and stalk diameter was measured in 185 clones. Only stalk population was recorded in second ratoon for all 192 of the clones measured in the plant cane and first ratoon crops.

Table 7 shows the means for estimated yield and its components for the progeny by separate crops. A broad look at the data reveals that the behavior of the progeny across crops was in many ways similar to the behavior of the parents. This was especially true of the second ratoon behavior of the progeny wherein yield was greatly reduced as a result of declines in all of its separate components.

Unlike the parents, however, the progeny, as an average of all
Table 7. Progeny means for estimated yield and its components in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Estimated yield (kg/plot)</th>
<th>Stalk population (stalks/plot)</th>
<th>Stalk weight (kg/stalk)</th>
<th>Stalk length (m/stalk)</th>
<th>Stalk diameter (mm/stalk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant cane</td>
<td>49.24</td>
<td>54.07</td>
<td>0.92</td>
<td>2.03</td>
<td>22.50</td>
</tr>
<tr>
<td>First ratoon</td>
<td>50.06</td>
<td>59.74</td>
<td>0.85</td>
<td>2.27</td>
<td>21.57</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>22.52</td>
<td>35.14</td>
<td>0.61</td>
<td>1.66</td>
<td>20.06</td>
</tr>
</tbody>
</table>
clones, showed no first ratoon decrease in estimated yield. As previously shown (see Table 4), the parents showed significantly decreased yield between the plant cane and first ratoon crops. Like the parents, though, estimated yield of the progeny was greatly reduced in second ratoon.

Stalk population was shown earlier to have decreased for the parents in both ratoon crops but was significantly decreased only in second ratoon. For the progeny, Table 7 shows a small average increase in first ratoon stalk population and a large decrease in second ratoon stalk population.

There were decreases in mean stalk weight of the progeny in each successive ratoon crop. The data show that this decrease was greatest for the second ratoon crop.

Similar to its reaction in the parents, mean stalk length of the progeny showed an increase in first ratoon and a pronounced second ratoon decrease.

Mean stalk diameter of the progeny also followed true to the behavior of the parents by showing steady decreases across the ratoon crops.

In summary, the data of Table 7 show that the progeny behaved quite like the parents with the exception that estimated yield, and one of its major components, stalk population, showed no first ratoon decreases as an average of all clones. The data show that ratoon decline of the progeny was far more serious in second ratoon than in first ratoon.
Progeny behavior of estimated yield:

The frequency distributions of estimated yield of the progeny in the plant cane and ratoon crops are shown in Table 8. The plant cane data of the table show a continuous, normal distribution of estimated yield among the clones in this crop across 9 yield classes. The class marks of the table are the midpoints in the range of each 10-kg class. A total of 9 clones, 4.6% of the progeny, are shown in classes 85 and 95 kg/plot in the plant crop frequency distribution. These were the only clones which showed estimated yields as high as those of L 65-69 in the plant crop. There was a combined total of 19 clones, or approximately 9.8% of the progeny, in the 75 kg/plot and higher yield classes which were therefore as high as CP 65-357, the lower-yielding parent. Whether these clones with yields as high as those of the parents', were inherently equal to them in yield of the plant cane crop cannot, however, be determined from the data due to the low heritability of yield and the unreplicated design and small plot size of the experiment.

The remaining 173 clones, or 90.1% of the progeny, beneath the mean yield of CP 65-357 in the plant crop (classes 65 kg/plot and below), point out the genetically complex, quantitative inheritance of yield in sugarcane hybrids and the high frequency of distinctly inferior clones from crosses between high yielding parents. It is for this reason that selection for new varieties is begun in segregating F₁ seedling populations numbering in the tens of thousands.
Table 8. Frequency distributions of estimated yield of the progeny in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th></th>
<th>No. and relative frequency of clones in following yield classes (kg/plot)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Plant cane</td>
<td></td>
</tr>
<tr>
<td>No. clones</td>
<td>4</td>
</tr>
<tr>
<td>Rel freq (%)</td>
<td>2.1</td>
</tr>
<tr>
<td>First ratoon</td>
<td></td>
</tr>
<tr>
<td>No. clones</td>
<td>2</td>
</tr>
<tr>
<td>Rel freq (%)</td>
<td>1.0</td>
</tr>
<tr>
<td>Second ratoon</td>
<td></td>
</tr>
<tr>
<td>No. clones</td>
<td>23</td>
</tr>
<tr>
<td>Rel freq (%)</td>
<td>12.6</td>
</tr>
</tbody>
</table>

Mean estimated yield of parents in: 'Plant cane'  First ratoon  Second ratoon

<table>
<thead>
<tr>
<th></th>
<th>Plant cane</th>
<th>First ratoon</th>
<th>Second ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 65-69</td>
<td>80.7</td>
<td>68.2</td>
<td>30.2</td>
</tr>
<tr>
<td>CP 65-357</td>
<td>73.9</td>
<td>61.0</td>
<td>29.8</td>
</tr>
</tbody>
</table>
The distribution of estimated yield of the progeny in the first ratoon crop, as seen in the table, looks much like that of the plant crop in that it is continuous and appears to have the normal shape. There were 52 clones, 27.1% of the progeny, (classes 65 kg/plot and above) which showed estimated yields as high or higher than those of CP 65-357 in the first ratoon crop. Most of the progeny, 140 clones, or 72.8% of the group, fell beneath the performance of CP 65-357 in estimated yield of the first ratoon crop. This includes the clones of classes 55 kg/plot and below of the first ratoon frequency distribution.

The similarity of the first ratoon distribution to the plant crop distribution and the tendency for there to be a higher frequency of high yielding clones in the first ratoon over that of the plant crop as indicated by increased frequencies of clones in 4 out of the 6 highest classes (classes 65 kg/plot and above) suggests that few clones declined in estimated yield from the plant crop to the first ratoon. This was evident in the progeny means (Table 7). The only sure evidence of decline within the frequency table lies in the 5 and 15 kg/plot yield classes where increased first ratoon frequencies over those of the plant crop show that some clones did decrease in estimated yield in the first ratoon.

In the second ratoon crop, no clones yielded higher than 60 kg/plot. All clones in classes 35 kg/plot and above, or 42 clones, 22.9% of the progeny, were, however, as high as or higher than the 30.0 kg/plot average yield of the parents in second ratoon, and it
Is interesting that so many of the experimental clones were on par with the parents with respect to second ratoon yields. The mean yield of the progeny, 22.52 kg/plot (Table 7), was still below the mean of the parents as it was in the plant cane and first ratoon crops. Although a few of the clones in class 25 kg/plot may have equalled the second ratoon yield of CP 65-357, most probably did not, and counting this class and the two below, 141 clones, or about 77.0% of the progeny, showed less than the parents in yield.

The absence of clones yielding over 60 kg/plot (classes 65 kg/plot and above) in the second ratoon frequency distribution as opposed to 45 and 55 clones in those classes in the plant cane and first ratoon crops shows a severe amount of second ratoon yield decline to have occurred in the progeny. Similar to the parents, no clones with relatively high yield in the plant cane and first ratoon crops retained those high yields in the second ratoon crop.

It can be shown by subtraction of the parents' second ratoon yields from their plant crop yields that L 65-69 declined 50.5 kg/plot in second ratoon over its yield in the plant crop, and CP 65-357 declined 44.1 kg/plot. These are percentage declines in second ratoon of 62.6% and 59.7% of the plant crop yields of L 65-69 and CP 65-357, respectively. These results indicate that the parents behaved similarly in percentage decline and that this decline was severe, approximating 60%. It was of interest to see how these second ratoon yield declines compared with those of the experimental clones of the progeny which had relatively high plant crop yields.
The 19 clones which were equal to or greater than CP 65-357 in yield of the plant cane were taken as a sample group, and it was found that their average decline from plant cane to second ratoon was 49.4 kg/plot (range = 31.2 - 76.8 kg/plot). This mean decline of the group approximates the amount shown by the parents. This amount of decline in the clones also approximates the parents' reaction when expressed as the mean percent decline from the plant crop, 61.3%. However, the range in percentage decline of these 19 clones was large - 41.9 to 83.9%.

There were 2 clones in the group which showed second ratoon percentage declines about the same as those of the parents, or in the range of 55 to 65%. Another 9 clones, or roughly half the sample group, may have actually shown somewhat less second ratoon yield decline than the parents; these clones showed less than 55% loss of their plant cane yields in second ratoon, and 2 of these clones showed less than 50% decline. The data are not, however, sufficiently reliable to justify the conclusion that these 9 clones were superior to the parents in ratooning ability. It is probably safer to conclude that some clones appeared to be equal to the parents in ratooning ability. It should be stressed, however, that all 19 clones of the group showed marked declines in yield of the second ratoon crop, declines which exceeded 40% of the plant cane yields in all cases.

The remaining 8 of the 19 highest-yielding clones in the plant crop showed percent yield declines of over 65% in the second ratoon and may have therefore shown poorer ratooning abilities than the
parents although the nature of the data again did not permit an exact interpretation.

Perhaps a basic overall conclusion is that few if any of the clones with high initial yield in the plant crop showed much greater ratooning ability than the parents although some were probably about equal. In view of the fact that the parents are the result of intensive, rigid selection for high yield in both plant and ratoon crops, it may be surprising that such a large number of the relatively small progeny included in this experiment appeared to be equal to the parents in ratooning ability.
Progeny behavior of stalk population:

Stalk population is a major component of yield in sugarcane (64), is typically high in our best commercial varieties, and is an important selection objective in variety development. Since ratoon decline in stalk population was found to be an important cause of reduced ratooning ability of the parents in this study (Tables 3 and 4), a thorough examination of the behavior of stalk population within the progeny is in order.

The plant crop distribution of stalk population in Table 9 denotes quantitative gene action in the inheritance of this trait by virtue of the normal shape of the distribution about the plant crop mean of 54.07 stalks/plot (Table 7), and by the continuous spread of the progeny within a range starting in the 15 stalks/plot class and ending in the 95 stalks/plot class. This is the type of behavior normally expected with polygenically inherited traits of diploid plant species and is notable in light of the extreme chromosomal complexity of progenies, such as this one, derived from interspecific hybrid parents which are themselves descended from crosses among 2 or more distinctly different polyploid species of Saccharum.

The high end of the plant crop distribution shows that there were 62 clones, 32.3% of the progeny, in the same or higher class as the parents (class 65 or higher) in regard to stalk population. This number includes 9 clones, 4.7% of the progeny, which had stalk numbers of 81 to 90 stalks/plot (class 85) and 3 clones, 1.6% of the progeny, which had stalk numbers of 91 to 100 stalks/plot (class 95). These
Table 9. Frequency distributions of stalk population of the progeny in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th>No. and relative frequency of clones in following stalk population classes (stalks/plot)</th>
<th>5</th>
<th>15</th>
<th>25</th>
<th>35</th>
<th>45</th>
<th>55</th>
<th>65</th>
<th>75</th>
<th>85</th>
<th>95</th>
<th>105</th>
<th>115</th>
<th>125</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant cane</strong></td>
<td>No. clones</td>
<td>2</td>
<td>10</td>
<td>27</td>
<td>44</td>
<td>47</td>
<td>34</td>
<td>16</td>
<td>9</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rel freq (%)</td>
<td>1.0</td>
<td>5.2</td>
<td>14.1</td>
<td>22.9</td>
<td>24.5</td>
<td>17.7</td>
<td>8.3</td>
<td>4.7</td>
<td>1.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>First ratoon</strong></td>
<td>No. clones</td>
<td>1</td>
<td>3</td>
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<td>16</td>
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<td>5</td>
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<tr>
<td></td>
<td>Rel freq (%)</td>
<td>0.5</td>
<td>1.6</td>
<td>3.6</td>
<td>8.3</td>
<td>20.8</td>
<td>18.2</td>
<td>20.8</td>
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<td>6.8</td>
<td>3.6</td>
<td>1.0</td>
<td>2.6</td>
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<td><strong>Second ratoon</strong></td>
<td>No. clones</td>
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<td>37</td>
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<td>34</td>
<td>33</td>
<td>21</td>
<td>10</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rel freq (%)</td>
<td>3.6</td>
<td>19.3</td>
<td>22.4</td>
<td>17.7</td>
<td>17.2</td>
<td>10.9</td>
<td>5.2</td>
<td>2.6</td>
<td>0.5</td>
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Stalk population of parents in:

<table>
<thead>
<tr>
<th>Plant cane</th>
<th>First ratoon</th>
<th>Second ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 65-69</td>
<td>63</td>
<td>59</td>
</tr>
<tr>
<td>CP 65-357</td>
<td>70</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>40</td>
</tr>
<tr>
<td></td>
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</table>
are stalk numbers considerably greater than the mean stalk numbers of either parent in the plant crop, and in fact are above the upper limits of the 5-plot range in stalk numbers of either parent (L 65-69 range = 56 - 72 stalks/plot; CP 65-357 range = 54 - 80 stalks/plot). These 12 highest clones in classes 85 and 95 stalks/plot are suggestive of transgressive segregation for stalk number in that they showed a more extreme expression of the trait than did the parents.

There was a large number of clones with lower stalk numbers than the parents. This included all clones in classes 55 or below for a total of 130 clones, or 67.7% of the progeny. The clones of classes 15, 25, 35 and 45 stalks/plot showed stalk numbers ranging from no less than 11 to no greater than 50 and were therefore below the lowest recorded stalk number of either parent in plant cane. This is again evidence of transgressive segregation for stalk population within the cross. Such a large number of low-population clones from parents of superior stalk population is not, however, a typical characteristic of quantitative inheritance.

In the first ratoon, the distribution of stalk population remained within an approximately normal curve as in the plant crop; however, there was a widening in its range (6 to 123 stalks/plot). This is perhaps partly reflective of the strong influence of environment and season on the individual genetics of the clones.

In the first ratoon crop, there were 125 clones, or about 65.0% of the progeny, in classes 55 stalks/plot and above which were thus equal to or greater in stalk population than the lower-population
parent, L 65-69, which had an average of 59 stalks/plot in first ratoon (5-plot range of L 65-69 = 53 - 64 stalks/plot). The number of clones equalling or exceeding the mean of CP 65-357 was not as great, but still quite large, 90 clones, or 46.8% of the progeny, including all individuals in classes 65 stalks/plot and above. The 5-plot range of stalk population of CP 65-357 in first ratoon (50 - 76 stalks/plot) suggests that as many as 28 of the clones, 14.5% of the progeny, behaved as transgressive segregates for high stalk population in the first ratoon. This includes 13 clones in class 85 stalks/plot, 7 clones in class 95, 2 clones in class 105, 5 clones in class 115 and 1 clone in class 125 in the first ratoon distribution. Only 12 clones appeared as transgressive segregates in the plant crop. Notice also that the 8 clones of classes 105 and above in the first ratoon distribution were higher in stalk population than any clones were in the plant crop thus indicating greater realization of genetic potential for high stalk population for some clones in the first ratoon as opposed to their phenotypic expression in the plant crop.

There were 67 clones, or 34.8% of the progeny, below the mean stalk population of L 65-69 in first ratoon. The slightly higher first ratoon stalk population of CP 65-357 over that of L 65-69 placed it in a higher class in respect to the frequency distribution; thus, a total of 102 clones, or 53.0% of the progeny including all clones in classes 55 stalks/plot and below, appeared lower in first ratoon stalk population than CP 65-357. In addition, the clones of classes 35 stalks/plot and below were beneath the lowest recorded stalk
population of either parent in first ratoon for a total of 27 transgressive segregates for low stalk number in the first ratoon.

As shown earlier in Table 7, there was a tendency toward first ratoon increase in stalk numbers of the clones. This is verified in Table 9 by increased first ratoon frequencies of clones in the 65, 75, 85 and 95 stalks/plot population classes over the relative frequencies of clones in those classes in the plant cane crop, and by the occurrence of 8 clones in classes 105 through 125 where no clones were present in the plant crop. Coincident with these increased class frequencies were decreased first ratoon frequencies of clones in classes 25, 35, 45 and 55 stalks/plot. All this is indicative of overall first ratoon increase in stalk population of many of the clones and in fact the presence of an additional clone in the 15 stalks/plot class in first ratoon over the frequency of clones in that class in the plant crop, and a clone in the previously unoccupied 5 stalks/plot class provide what little obvious evidence exists that some clones did show first ratoon decline in stalk population.

The second ratoon distribution of stalk population shows 105 clones (classes 35 stalks/plot and higher) to have performed at a level equal to or better than the mean stalk population of L 65-69 in that crop, 40 stalks/plot (5-plot range of L 65-69 = 25 - 54 stalks/plot). As in the plant cane and first ratoon crops, CP 65-357 again showed somewhat higher mean stalk population than L 65-69 in the second ratoon crop (CP 65-357 mean stalk population =
45 stalks/plot; 5-plot range = 41 - 50 stalks/plot). A total of 71 clones including those in classes 45 stalks/plot and above were equal to or greater than CP 65-357 in stalk population in the second ratoon crop. This represents 36.9% of the progeny.

The 17 highest clones in this distribution, or those in classes 65 stalks/plot and higher, showed transgressive segregation in that they were above the largest recorded measurement in stalk number for any plot of the parents in second ratoon. Notice also that the clone in class 95 stalks/plot was equal in stalk population in second ratoon to the highest-population clones of the plant cane crop.

Only 87 clones, or less than half the progeny (45.3%) showed lower stalk population in second ratoon than L 65-69. This includes all clones in classes 25 stalks/plot and under. With respect to CP 65-357, there were an additional 34 clones (class 35) to add to this number, for a total of 121 clones, 63.0% of the progeny, with lower second ratoon stalk numbers than that parent. This shows that about half of the progeny was lower in ratooning ability of stalk population in the second ratoon than the parents, or low or only mediocre in stalk population in the plant cane and first ratoon crops.

The somewhat skewed shape of the second ratoon frequency distribution in relation to that of the plant crop and first ratoon crops resulting from decreased relative frequencies of clones in the high-population classes and increased relative frequencies of clones in the low-population classes indicate that many clones showed serious losses in stalk number in second ratoon over those in the plant crop.
and first ratoon. A similar reaction was shown for the parents which showed significantly reduced second ratoon stalk population.

Nevertheless, the evidence that 28 and 62 clones were equal to or greater than CP 65-357 and L 65-69, respectively, in the plant crop as opposed to even larger numbers equalling them in the ratoon crops suggests that some high-population clones may also have been equal to or higher than the parents in ratooning ability of stalk population. To test this assumption, a sample of the 30 highest clones with respect to stalk population in the plant crop were examined in regard to their ratooning behavior of stalk population. These clones had plant cane stalk populations ranging from 70 to 99 stalks/plot and include all the clones of classes 75 stalks/plot and above of the plant crop frequency distribution in Table 9.

The mean decline in stalk population of the sample group expressed as percentage of the plant crop stalk numbers of the clones was 31.6\% (range = 3.1 - 71.4\%). The decline in second ratoon stalk population of the parents expressed in similar terms was: L 65-69 mean percentage decline = 36.9\% (5-plot range in mean decline = 3.6 - 56.1\%) and CP 65-357 mean percentage decline = 36.1\% (5-plot range = 22.2 - 46.1\%).

Nearly two thirds of the sample group, 19 clones, showed percentage declines in stalk population no greater than those of the parents. Furthermore, these clones were evenly dispersed within the range from lowest to highest stalk populations within the group, and 5 of the clones showed percentage declines of less than 15.0\%. These data suggest a tendency for higher ratooning ability of stalk population.
within some of the experimental clones than that shown by the parents.

The data therefore indicate that selecting clones of high ratooning ability of stalk population from progenies similar to this one should pose no problem in itself to sugarcane breeders. The bearing of this statement upon the selection for high ratooning ability of yield is, however, uncertain, as it is well known, for instance, that clones of exceptionally high stalk population are often deficient in stalk diameter and therefore high in fiber percent cane.

In summation, the data on stalk population in the progeny showed that the majority of the clones increased in stalk population in the first ratoon, and decreased in stalk population in the second ratoon when compared to the plant crop. Not barring the fact that seasonal effects could have played a strong role in influencing this behavioral pattern, this is the usual reaction of many clones under Louisiana growing conditions for yield also, which may be due in part to the behavior of stalk population. This places great emphasis on the importance of adequate stalk population to high yield and ratooning ability although the earlier data on the parents' behavior and the overall progeny means within separate crops (Table 7) tend to indicate that decline in stalk population is not the only serious factor in declining ratoon yields.
Progeny behavior of stalk weight:

Like stalk population, weight per stalk is a basic component of yield of cane per hectare. From Table 10, the distribution of mean weight per stalk in the plant crop shows a continuous distribution and a close approximation of the normal curve thereby indicating quantitative inheritance of weight per stalk. The plant crop distribution is centered about the overall progeny mean of 0.92 kg/stalk (Table 7) and ranges from class 0.35 kg/stalk to class 1.55 kg/stalk. The plant crop mean stalk weight of CP 65-357, the lower-weight parent, was equalled or exceeded by 64 clones, the cumulative frequency of classes 1.05 kg/stalk and above. This represents 33.3%, exactly one third, of the 192 clones measured in the plant crop. Only 20 clones, or 10.3% of the progeny, equalled or exceeded L 65-69, the higher-weight parent, in mean weight per stalk in the plant crop. These 20 clones are distributed as 11 clones, 5.7% of the progeny, in class 1.25 kg/stalk, 5 clones, 2.6% of the progeny, in class 1.35 kg/stalk and 2 clones each in classes 1.45 and 1.55 kg/stalk. The upper limit of the range in mean weight per stalk among the 5 plots of L 65-69 in the plant crop (1.21 - 1.36 kg/stalk) was exceeded by only the 4 clones in classes 1.45 and 1.55 kg/stalk; thus, these clones are the only evidence of transgressive segregation for high mean weight per stalk in the plant crop.

Two thirds of the progeny, or 128 of the clones including those of classes 0.95 kg/stalk and below, were lower than CP 65-357 in mean weight per stalk in the plant cane. A total of 172 clones, or 89.6%
Table 10. Frequency distributions of mean stalk weight of the progeny in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th>No. and relative frequency of clones in following mean stalk weight classes (kg/stalk)</th>
<th>.25</th>
<th>.35</th>
<th>.45</th>
<th>.55</th>
<th>.65</th>
<th>.75</th>
<th>.85</th>
<th>.95</th>
<th>1.05</th>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>No. clones</td>
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<td>11</td>
<td>17</td>
<td>31</td>
<td>33</td>
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<td>2</td>
<td>2</td>
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<td></td>
</tr>
<tr>
<td>Rel freq (%)</td>
<td>0.5</td>
<td>5.7</td>
<td>8.9</td>
<td>16.1</td>
<td>17.2</td>
<td>18.2</td>
<td>16.7</td>
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<td>5.7</td>
<td>2.6</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>First ratoon</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rel freq (%)</td>
<td>0.5</td>
<td>1.0</td>
<td>5.7</td>
<td>13.5</td>
<td>20.3</td>
<td>24.5</td>
<td>17.2</td>
<td>10.4</td>
<td>3.6</td>
<td>1.6</td>
<td>1.0</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second ratoon</td>
<td></td>
<td></td>
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<td></td>
</tr>
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<td>51</td>
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<td>1</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rel freq (%)</td>
<td>1.6</td>
<td>4.9</td>
<td>21.9</td>
<td>18.6</td>
<td>27.9</td>
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<td>4.9</td>
<td>1.0</td>
<td>1.0</td>
<td>0.5</td>
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Mean stalk weight of parents in:

<table>
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<tr>
<th>Plant cane</th>
<th>First ratoon</th>
<th>Second ratoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>L 65-69</td>
<td>1.29</td>
<td>1.16</td>
</tr>
<tr>
<td>CP 65-357</td>
<td>1.05</td>
<td>0.97</td>
</tr>
</tbody>
</table>
of the progeny were lower in mean weight per stalk than L 65-69. This includes the clones of classes 1.15 kg/stalk and below. Although the clones of classes 1.05 and 1.15 kg/stalk were below the mean weight of L 65-69, they would still have been acceptable in a breeding program in that they were at least equal to CP 65-357. The existence of a variety like CP 65-357 demonstrates that clones below the highest attainable extremes of mean weight per stalk can still be highly vigorous, superior yielders. Furthermore, the plant crop data in relation to the mean weight per stalk of CP 65-357 may indicate that finding clones of acceptable mean weight per stalk should not present a serious problem in selection programs. However, a high percentage of most progenies will probably prove to be unacceptably low in weight per stalk.

The first ratoon distribution of mean weight per stalk of the progeny showed the same range as in the plant crop, class 0.35 to class 1.55 kg/stalk. The mean of the progeny was somewhat lower, however, 0.85 kg/stalk as opposed to 0.92 kg/stalk in the plant crop.

Sixty-six clones, 34.3% of the progeny, were in classes 0.95 through 1.55 kg/stalk and thus equalled or exceeded the mean weight per stalk of CP 65-357 in the first ratoon crop. Only 13 clones, 6.7% of the progeny, had this standing with respect to mean weight per stalk of L 65-69. This includes the clones of classes 1.15 kg/stalk and above. The 6 highest of these clones, or those in classes 1.25 kg/stalk and above, showed transgressive inheritance of stalk weight in that they exceeded the upper limit of the 5-plot range of L 65-69
In first ratoon (1.11 - 1.20 kg/stalk).

There was a larger number of transgressive segregates for low mean weight per stalk than for high mean weight per stalk in first ratoon. Of the 126 clones, 65.5% of the progeny, below the mean of CP 65-357 in first ratoon (those in classes 0.85 and below), 79 clones, or 41.0% of the progeny (those in classes 0.75 and below), were lower than any recorded measurement of mean stalk weight of the parents in first ratoon (5-plot range of CP 65-357 = 0.89 - 1.07 kg/stalk) and are thus transgressive segregates.

The decreased relative frequencies of clones in classes 0.95 and above, and increased frequencies in classes 0.65, 0.75 and 0.85 in the first ratoon distribution in contrast to the frequencies of clones in those classes in the plant crop distribution reflect a tendency toward some decline in stalk weight of the progeny in the first ratoon crop. That the decline was not severe can be shown by the means of stalk weight of the progeny in Table 7 and by the fact that there was no large increase in the frequency of clones in the four lowest classes of the first ratoon distribution in comparison to their frequencies in the plant crop.

In overview, the first ratoon distribution of mean weight per stalk shows only a mild reduction in stalk weight of the progeny with the total range of expression having remained essentially the same as that of the plant cane crop.

The distribution of mean weight per stalk of the progeny in second ratoon in relation to the mean weight of the parents shows
97 clones in classes 0.65 and above, or 52.8% of the progeny, with mean weights per stalk equal to or greater than the average weight of CP 65-357 in second ratoon, and 46 clones, in classes 0.75 and above, or 24.9% of the progeny, with mean weights equal to or greater than that of L 65-69.

The 5-plot second ratoon range in stalk weights of L 65-69 (0.67 - 0.85 kg/stalk) shows, again, that as in the plant cane and first ratoon crops, only a small proportion of the progeny appeared to show transgressive segregation for high stalk weight. There were but 5 such clones in second ratoon - those of classes 0.95 and above.

There were 86 clones, 47.0% of the progeny, in classes 0.55 and below, which fell beneath the mean performance of CP 65-357. A total of 137 clones, 74.9% of the progeny in classes 0.65 kg/stalk and below were beneath the performance of the higher-weight parent, L 65-69.

The reduced relative frequencies in classes 0.75 and above in the second ratoon distribution, and increased frequencies in all classes below class 0.75 kg/stalk relative to the plant cane and first ratoon distributions are the result of sharp reductions in mean weights per stalk of the experimental clones. However, the distributions of mean weight per stalk of the progeny in relation to the mean weights of the parents shows a higher frequency of clones which equalled or exceeded the parents in second ratoon than in the plant cane and first ratoon crops. There were 46 clones equal to or greater than the average weight of L 65-69 in second ratoon as opposed to 20 such clones
in the plant crop, and 13 such clones in the first ratoon. A similar comparison for CP 65-357 shows 97 clones to have equalled or exceeded the mean of that parent in second ratoon in comparison to 64 such clones in the plant crop and 66 in the first ratoon. These data suggest that the rate of decline in weight per stalk in second ratoon was not as great in the progeny as a whole as in the parents.

The second ratoon decline in mean weight per stalk of the progeny was examined in greater detail by the same procedure used in examining the second ratoon decline in estimated yield and stalk population.

The 30 clones with highest mean weight per stalk in the plant crop were taken as a sample, and their amount of second ratoon decline was examined in relation to the parental declines. These clones were in classes 1.15 through 1.55 kg/stalk.

The decline of L 65-69 from 1.29 kg/stalk in the plant crop to 0.76 kg/stalk in second ratoon computes to a percentage decline of 41.1% (5-plot range in % decline of L 65-69 = 29.8 - 46.8%). The second ratoon percentage decline of CP 65-357 was similar - 36.2% (range = 26.9 - 54.2%).

Two of the 30 clones examined in detail with respect to second ratoon decline in stalk weight had no recorded second ratoon mean weights per stalk because of inadequate sample size (stalk population) in second ratoon. The decline behavior among the 28 clones which were measured revealed second ratoon percentage declines in weight per stalk in all of them which ranged from 4.1% to 62.3%. The average percentage decline in second ratoon stalk weight of the clones was
40.4%, a figure essentially the same as those for the parents. This is a severe amount of second ratoon decline in mean weight of the parents and progeny alike.

Ten of the 28 clones showed percentage declines within a range of 35 - 45%; 9 other clones showed declines of less than 35%; however, only 1 of these 9 clones showed a second ratoon percentage decline in mean weight (4.1%) which was beneath the lowest recorded percentage decline of any plot of the parents. Thus, as many as 19 of the 28 clones examined were probably equal to the parents in ratooning ability of mean weight per stalk and 1 of these 19 clones may have shown higher ratooning ability in this trait.

The remaining 9 of the 28 clones showed second ratoon percentage declines in mean weight per stalk of greater than 45.0% and were thus lower than the parents in ratooning ability of stalk weight.

It should be stressed again, as it was in discussing estimated yield and stalk population, that the nature of the data is such that exact interpretations of the number of clones with greater, equal or lower ratooning abilities than those of the parents might be unreliable to a degree. Thus, the foregoing discussion should be interpreted in general terms.

In conclusion, the data on weight per stalk indicate that the parents and most of the clones showed similar ratoon decline over the entire crop cycle. The data suggest, however, that there were some clones which showed ratooning abilities of weight per stalk which were inherently equal to those of the parents. In addition, there may have
been some clones with higher ratooning ability in weight per stalk than that shown by the parents although the data do not strongly support this.
Progeny behavior of stalk length:

The behavior of mean stalk length of the progeny is of direct interest in light of the relationships of this character to mean weight per stalk and to yield of cane.

The frequency distribution of mean stalk length is shown in Table 11 from which the yearly trends in the reaction of stalk length of the progeny show: 1) a first ratoon increase in stalk length of the progeny over its length in the plant crop, and 2) a pronounced second ratoon decrease in mean stalk length in comparison to the first ratoon and plant crop alike. This was also the pattern of behavior of mean stalk length shown by the parents.

The overall mean length of the progeny in plant cane was shown in Table 7 as 2.03 m/stalk. From Table 11, the plant crop distribution of the clones about this mean appears approximately normal within a range starting at class 1.45 m/stalk and ending in class 2.65 m/stalk.

There were 44 clones, 22.9% of the progeny, equal in length or longer than the taller parent, L 65-69, in the plant crop. This includes the clones of classes 2.35, 2.50 and 2.65 m/stalk of the plant crop frequency distribution. Only the 8 longest clones of the plant crop including the 3 of class 2.65 m/stalk and 5 of 7 in class 2.50 m/stalk of the plant cane frequency distribution showed transgressive segregation for long length of stalk in that they showed longer length of stalk than the uppermost reading among the 5 plots of the longer-stalked parent, L 65-69, in the plant crop (L 65-69 range = 2.33 - 2.45 m/stalk). The lower plant crop mean length of CP 65-357, 2.12
Table 11. Frequency distributions of mean stalk length of the progeny in plant cane, first ratoon and second ratoon crops.

<table>
<thead>
<tr>
<th>Mean stalk length classes (m/stalk)</th>
<th>Plant cane</th>
<th>First ratoon</th>
<th>Second ratoon</th>
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<tr>
<td></td>
<td>No. clones</td>
<td>No. clones</td>
<td>No. clones</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rel freq (%)</td>
<td>Rel freq (%)</td>
</tr>
<tr>
<td>1.15-1.30</td>
<td>6</td>
<td>3.1</td>
<td>0.5</td>
</tr>
<tr>
<td>1.45-1.60</td>
<td>15</td>
<td>7.8</td>
<td>0.5</td>
</tr>
<tr>
<td>1.75-1.90</td>
<td>25</td>
<td>13.0</td>
<td>2.6</td>
</tr>
<tr>
<td>2.05-2.20</td>
<td>38</td>
<td>19.8</td>
<td>10.4</td>
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<tr>
<td>2.35-2.50</td>
<td>37</td>
<td>19.3</td>
<td>10.9</td>
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<tr>
<td>2.65-2.80</td>
<td>27</td>
<td>14.1</td>
<td>22.4</td>
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<td></td>
<td>34</td>
<td>17.7</td>
<td>24.0</td>
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<td>3.6</td>
<td>19.8</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.6</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Mean stalk length of parents in:

- **L 65-69**: 2.39, 2.43, 1.77
- **CP 65-357**: 2.12, 2.27, 1.69
m/stalk, was equalled by another 27 clones in class 2.20 m/stalk for a total of 71 clones, 37.0% of the progeny, with stalk lengths as long or longer as those of that parent in the plant cane crop. This high frequency of clones with acceptable stalk length indicates that obtaining clones of adequate length of stalk from this cross or similar crosses should pose no particular problem in itself to selection.

All clones in classes 2.20 m/stalk and below, or 148 clones, showed lower mean length of stalk than L 65-69 in the plant crop. This is 77.1% of the progeny. CP 65-357 was 0.27 m shorter (11.3% shorter) than L 65-69 in the plant crop; the 121 clones of classes 2.05 m/stalk and below, or 63.0% of the progeny, were below its performance in mean length of the plant crop. The range in stalk length of CP 65-357 in the plant crop (1.94 - 2.24 m/stalk) shows that a large number of these 121 clones may have been transgressive segregates for shortness of stalk. Many of these clones would be passed over in selection, as short clones do not lend well to mechanical harvesting as practiced in Louisiana.

The first ratoon frequency distribution of stalk length shows a one-class increase in range at each end. The distribution appeared somewhat skewed toward the upper tail but still approximately normal.

There were 55 clones, or 28.6% of the progeny, with equal or greater mean length of stalk than the taller parent, L 65-69, in the first ratoon. This number includes the clones of classes 2.50 m/stalk and above. All clones in classes 2.35 m/stalk and above, or 101 clones, 52.6% of the progeny, were equal to or greater than the mean length of
CP 65-357 in the first ratoon.

Again, a large number of clones were below the performance of the parents in mean length per stalk. In relation to L 65-69 this includes 71.3% of the progeny in classes 2.35 m/stalk and below. For CP 65-357 the figure is 47.3% of the progeny in classes 2.20 m/stalk and below.

There was a tendency for many clones to show increased length of stalk in first ratoon compared to the plant crop. The mean of the progeny increased to 2.27 m/stalk in first ratoon from 2.03 m/stalk in the plant cane crop, and the parents showed similar behavior. The first ratoon increase in mean weight of the progeny is numerically shown in Table 11 by the occurrence of increased relative frequencies of clones in classes 2.20 m/stalk and above in the first ratoon distribution versus the plant crop distribution, and by the reciprocal decrease in classes below class 2.20 m/stalk. Most clones either gained length or remained about the same in first ratoon. The only positive indication of any first ratoon decline in mean stalk length is the occurrence of 1 clone in class 1.20 m/stalk, a class previously unoccupied in the plant crop frequency distribution.

The second ratoon frequency distribution of mean stalk length of the progeny is continuous, normal and centered on a mean of 1.66 m/stalk. A surprisingly large number of clones, 82, or 44.8% of the progeny, showed equal or greater length of stalk than did the parents in second ratoon. This includes all clones of classes 1.75 m/stalk and above (note; parents ranked equal in second ratoon i.e., both in class 1.75
104 m/stalk). The highest recorded measure of stalk length of either parent in second ratoon was for L 65-69 (range = 1.60 - 1.95 m/stalk), and this suggests the presence of as many as 15 transgressive segregates for long length of stalk in the second ratoon including the 11 clones of class 2.05 m/stalk and 4 clones in higher classes.

A comparison of the data of the second ratoon distribution to that of the plant cane and first ratoon distributions shows a pronounced loss in stalk length by most of the clones in second ratoon. Only the 4 highest transgressive segregates in second ratoon, 2.1% of the progeny, had stalk lengths falling in classes 2.20 m/stalk or above as compared to 37.0% of the progeny in those classes in plant cane and 75.0% in first ratoon. There were no clones in second ratoon with stalk lengths equal to those of the longest clones of the plant crop or first ratoon although the 4 highest transgressive segregates of the second ratoon crop were equal in stalk length to what the parents were in the plant cane.

The severe reduction in mean length of stalk within the second ratoon crop of the progeny can best be seen by a cross comparison of the relative frequencies of clones in classes of the frequency distributions of the separate crops. Even though the second ratoon reductions in stalk length of the progeny appeared severe, the high proportion of the progeny which remained equal to or longer in length of stalk than the parents in second ratoon suggests that some clones showed ratooning abilities for length per stalk which were comparable to those of the parents or perhaps greater in some cases.
The 30 longest clones of the plant cane crop were examined to assess this hypothesis. One of the 30 clones had missing data in the second ratoon crop; the remaining 29 clones ranged in length of stalk from 2.33 to 2.63 m/stalk. Thus, all of them appeared in classes 2.35 - 2.65 m/stalk in the plant crop - a ranking equal to or greater than that of the longer-stalked parent, L 65-69.

The second ratoon decline of L 65-69 expressed as the percentage decline in relation to the plant crop yield of that parent was 25.9% (5-plot range = 16.3 - 33.3%). CP 65-357 may have shown somewhat less decline than L 65-69 as its second ratoon percentage decline was 20.3%, but its range in percentage decline (11.2 - 32.0%) suggests that they were about equal in this respect.

In comparison to the parental declines, the mean second ratoon percentage decline of the 29 longest clones was 26.8%, a figure within the range of the parents. The range in percent decline of the sample group was 13.8 - 41.4%.

Fifteen clones, 51.7% of the group, showed declines about the same as those of the parents, that is, in the range of 20.0 - 30.0%. Only 4 clones, 13.8% of the group, showed declines of less than 20.0%. This is a fairly large portion of the group (many of which were transgressive segregates for long stalk length) which appeared to be as good as the parents in ratooning ability for stalk length.

Ten of the 29 clones of the test group, 34.5%, showed percentage declines of over 30.0%, and may have been lower in ratooning power for length per stalk than the parents.
In summation, the data on length of stalk suggest that other than seasonal effects alone were involved in the marked tendency toward second ratoon decline in mean length of stalk within the progeny and parents alike. The genetic behavior of the progeny in relation to that of the parents' suggests that although not many clones with high initial stalk length appeared to show higher ratooning ability for this trait than the parents, about half may have been equal. On the other hand, about half or somewhat less may have shown lower ratooning ability of this trait than the parents.
Progeny behavior of stalk diameter:

The frequency distributions of mean stalk diameter are shown for separate crops of the progeny in Table 12. Polygenic inheritance is indicated by the wide and continuous range in stalk diameters of the clones and in the normal shapes of the distribution curves. Like the other components studied, this trait is probably conditioned by a number of genes with heterozygous alleles at many loci on several separate chromosome pairs.

In the plant crop, diameter of the clones as shown in the table ranged from class 14.5 mm/stalk to class 32.5 mm/stalk. There were 27 clones in the plant crop, 14.1% of the progeny, with diameters larger than that of the larger-diameter parent, L 65-69, 25.0 mm/stalk. This includes 14 clones, 7.3% of the progeny, in class 25.5 mm/stalk, 6 clones, 3.1% of the progeny, in class 26.5 mm/stalk, 3 clones, 1.6%, in class 27.5 mm/stalk, 2 clones, 1.0%, in class 28.5 mm/stalk and 1 clone, 0.5% of the progeny, each in classes 29.5 and 32.5 mm/stalk. These 27 clones, having exceeded the plant crop diameter of L 65-69, are indicative of transgressive inheritance for large stalk diameter within the progeny. In this cross, transgressive segregation was involved in the inheritance of each component of yield as separately considered. It was not shown for the inheritance of estimated yield, however.

Another 22 clones, 11.5% of the progeny, appear in the 24.5 mm/stalk class in the plant crop. These clones equalled L 65-69 in mean diameter of stalk. The next lower class, 23.5 mm/stalk, contains 19 clones.
Table 12. Frequency distributions of mean stalk diameter of the progeny in plant cane, first ratoon and second ratoon crops.

|                      | No. and relative frequency of clones in following mean stalk diameter classes (mm/stalk) |              | 15.5* | 16.5 | 17.5 | 18.5 | 19.5 | 20.5 | 21.5 | 22.5 | 23.5 | 24.5 | 25.5 | 26.5 | 27.5 | 28.5* |
|----------------------|----------------------------------------------------------------------------------------|--------------|-------|------|------|------|------|------|------|------|------|------|------|------|-------|
| Plant cane           | No. clones 2                                                                           | 1            | 6     | 20   | 24   | 29   | 42   | 19   | 22   | 14   | 6    | 3    | 4    |      |       |
|                      | Rel freq (%) 1.0                                                                       | 0.5          | 3.1   | 10.4 | 12.5 | 15.1 | 21.9 | 9.9  | 11.5 | 7.3  | 3.1  | 1.6  | 2.1  |      |       |
| First ratoon         | No. clones 2                                                                           | 3            | 14    | 31   | 34   | 36   | 29   | 21   | 7    | 9    | 1    | 4    | 1    |      |       |
|                      | Rel freq (%) 1.0                                                                       | 1.6          | 7.3   | 16.1 | 17.7 | 18.8 | 15.1 | 10.9 | 3.6  | 4.7  | 0.5  | 2.1  | 0.5  |      |       |
| Second ratoon        | No. clones 2                                                                           | 11           | 17    | 33   | 30   | 42   | 18   | 13   | 9    | 6    | 3    | 1    |      |      | 0.5   |
|                      | Rel freq (%) 1.0                                                                       | 5.9          | 9.2   | 17.8 | 16.2 | 22.7 | 9.7  | 7.0  | 4.9  | 3.2  | 1.6  | 0.5  |      |      |       |

Mean stalk diameter of parents in: Plant cane First ratoon Second ratoon

| L 65-69 | 25.0   | 24.0   | 22.6   |
| CP 65-357 | 23.9  | 23.2  | 21.2  |

* (Lowermost and uppermost classes of this frequency distribution are compressed. Lowermost class actually includes clones in classes 13.5, and 14.5 mm/stalk. Uppermost class includes clones in classes 28.5, 29.5, 30.5, 31.5 and 32.5 mm/stalk).
which equalled the plant cane stalk diameter of CP 65-357, 23.6 mm/stalk. In all, there were 68 clones, 35.4\% of the progeny, equal to or larger than CP 65-357 in diameter of stalk in the plant crop.

Directly below the performance of CP 65-357 was a large group of 42 clones, 21.9\% of the progeny, in class 22.5 mm/stalk. The plant crop average for stalk diameter of the progeny, 22.5 mm/stalk, fell within this class. Counting this class and all those below, a total of 124 clones, or 64.5\% of the progeny, were smaller in stalk diameter in the plant crop than the smaller-diameter parent, CP 65-357. Thus, more than half of the progeny were too small in diameter to be acceptable in a breeding program. Such large proportions of so-called trashy clones occur regularly within the highly heterogeneous, diverse progenies of interspecific sugarcane hybrid x hybrid crosses.

The first ratoon frequency distribution shows 22 clones, 11.4\% of the progeny, which exceeded the first ratoon mean stalk diameter of the parents. This includes 7 clones in class 24.5 mm/stalk, 9 clones in class 25.5 mm/stalk, 1 clone in class 26.5 mm/stalk, 4 clones in class 27.5 mm/stalk and 1 clone in class 29.5 mm/stalk.

Another 21 clones, 10.9\% of the progeny, had first ratoon stalk diameters of 23.2 to 24.0 mm/stalk (class 23.5) and were therefore equal to the parents in first ratoon mean stalk diameter. Thus, a total of 43 clones, 22.3\% of the progeny, were equal to or greater than the parents in mean stalk diameter of the first ratoon crop. This is somewhat lower than the 35.4\% found in the plant cane crop.
All clones in the first ratoon frequency distribution below class 23.5 mm/stalk were inferior in diameter of stalk to the parents. This includes 149 clones, or 77.6% of the progeny, which ranged from class 14.5 mm/stalk to class 22.5 mm/stalk in diameter in the first ratoon crop. Most of these clones were too small in diameter of stalk to be acceptable in the plant crop and remained that way in the first ratoon. This is a very high frequency of the progeny that would have been unacceptable on the basis of a single trait.

There was evidence of ratoon decline in stalk diameter of the progeny as early as first ratoon. This is indicated in Table 12 by reduced frequencies of clones in the higher mean stalk diameter classes and increased frequencies in lower classes in the first ratoon distribution as compared to the plant crop distribution. Note that of the 7 mean stalk diameter classes of 22.5 mm/stalk and above, all except one class (class 23.5 mm/stalk) contained fewer clones in the first ratoon than in the plant cane crop. Furthermore, this is analogous to the parents' behavior. As previously pointed out, both had somewhat lower means in the first ratoon crop.

Of the 68 highest clones in the plant crop (those in classes 23.5 mm/stalk and above) only 8 did not show lower stalk diameter in the first ratoon crop. Two of these 8 clones showed no change in stalk diameter and the other 6 had slightly higher diameters in the ratoon crop (range of increase = 0.1 to 1.2 mm/stalk - data not shown). The range in decline of the 68 clones was from 0.0 to 3.8 mm/stalk and the
mean decline was 1.7 mm/stalk. Interestingly, 2 apparent transgressive segregates for large stalk diameter were among the 8 clones that showed no decline in stalk diameter - one in class 25.5 mm/stalk and 1 in class 27.5 mm/stalk.

Nearly half of the 68 clones which appeared to be acceptable in plant cane declined seriously enough in first ratoon to render them inferior, based on the behavior of CP 65-357. The evidence for overall first ratoon decline in stalk diameter of the progeny is obvious, and this, in light of the facts that mean stalk length showed an average increase in first ratoon while mean weight per stalk showed overall first ratoon decrease, suggests an important influence of declining mean diameter of stalk on the decline in weight per stalk as early as first ratoon. Unfortunately, the causes of early ratoon decline in stalk diameter in Louisiana are probably myriad and some can only be theorized.

The second ratoon frequency distribution of stalk diameter is centered on the overall progeny mean of 20.06 mm/stalk (Table 7), and shows 19 clones, or 10.2% of the progeny, with larger second ratoon mean stalk diameters than L 65-69, the larger diameter parent of the cross. This includes those clones in classes 23.5 mm/stalk and above. The 4 highest of these clones, including the 3 in class 25.5 mm/stalk and 1 in class 28.5 mm/stalk, had larger second ratoon mean stalk diameters than that of L 65-69 in the plant crop. Although these 4 clones did not in any crop exceed the estimated yield of L 65-69, they are especially strong evidence of transgressive
segregation for large stalk diameter.

In addition to the 19 clones with larger mean diameter of stalk than L 65-69 in second ratoon, there were 13 clones, 7.0% of the progeny, in class 22.5 mm/stalk which equalled the second ratoon performance of L 65-69 in stalk diameter. The 18 clones in the next lower class, 21.5 mm/stalk, were not equal to L 65-69 but did equal the second ratoon diameter of CP 65-357, 21.2 mm/stalk, and in total there were 50 clones, 26.9% of the progeny, equal to or larger than CP 65-357 in diameter in the second ratoon crop.

There were more clones near the lower extreme of small stalk diameter in the second ratoon crop than in the other 2 crops. In fact, 135 of the 185 remaining clones in the second ratoon crop, 72.9% were below CP 65-357 and hence would be considered inferior and probably unacceptable in respect to stalk diameter alone. This includes all clones in classes 20.5 mm/stalk and below in the second ratoon frequency distribution. It is possible that some of these clones equalled the parents in yield of the second ratoon crop due to sheer numbers of stalks; however, their small diameters are a serious defect which is associated with other undesirable characteristics. Nearly all of these clones would be rejected early in a selection program for failing to meet minimum diameter standards.

A progression toward severe second ratoon decline in mean stalk diameter of the progeny is clearly shown in the second ratoon frequency distribution of this trait. Notice the strong tendency toward reduced frequencies of clones in classes 21.5 mm/stalk
and above, and increased frequencies of clones in lower classes in the second ratoon frequency distribution in comparison to the plant crop and first ratoon frequency distributions. Further, it would appear that the reduction in diameter of the clones was more severe from first ratoon to second ratoon than the amount of reduction from plant cane to first ratoon. This can also be noted for the parents.

Reference was made earlier to the behavior in first ratoon of the 68 clones which were in classes 23.5 mm/stalk and above (equal to or larger in diameter of stalk than CP 65-357) in the plant cane crop. These clones were examined in detail in regard to their amount of second ratoon decline in stalk diameter with respect to the amount of second ratoon decline in stalk diameter of the parents. Five of the 68 clones had too few stalks by second ratoon to provide adequate samples and their data were not used. Of the 63 remaining clones, all were found to have declined in diameter of stalk in second ratoon in comparison to their performance in plant cane. The amount of this decline ranged from 0.2 to 8.3 mm/stalk and the mean decline of the group was 3.3 mm/stalk. The mean decline of the group expressed in terms of second ratoon percentage decline of the plant crop was 13.2% (range = 0.8 - 32.8%). This amount of decline in stalk diameter was somewhat larger than those of the parents. L 65-69 declined an average of 2.4 mm/stalk from plant cane to second ratoon. This calculated to an average 9.6% loss in stalk diameter in second ratoon for that parent (range of % second ratoon decline = 7.3 - 10.8%). CP 65-357 showed a similar amount of second ratoon decline; an average
loss in stalk diameter of 2.7 mm/stalk. This was an 11.3% decline in stalk diameter in second ratoon (range of % second ratoon decline = 0.0 - 24.9%).

Only 15 of the 63 clones, or approximately 23.8% of the sample group, showed similar second ratoon percentage declines in stalk diameter to those of the parents - within a range of 8.0 - 12.0%. Most of the group, 34 clones or 54.0%, showed declines greater than those of the parents (greater than 12.0%). Just how much loss in estimated yield such large declines in stalk diameter may account for was undetermined in this study. It is probably a safe assumption, however, that the losses were appreciable. A 10 to 20% loss in stalk diameter could possibly account for an equally large loss in estimated yield.

This brings up those clones which showed less decline in stalk diameter than the parents. In all there were 14 such clones, 22.2% of the sample group, which showed less than 8.0% decline in stalk diameter from plant cane to second ratoon. There was no readily discernible specific pattern in regard to where these clones ranked in the sample. Some of them were clones which only equalled the plant crop diameter of the lower-diameter parent, CP 65-357, and some were transgressive segregates for large stalk diameter.

Clones such as these might be of interest in a breeding program. Any means of reducing the amount of second ratoon yield loss through selection could be valuable, and the possibility that clones exist which decline less in diameter than others (and even less than
established varieties) suggests an approach to selection for improved ratooning ability of mean stalk weight through this component.

Of course, other parameters are involved such as the ratoon behavior of the other individual components of yield within a clone. For instance, a large amount of decline in stalk population can have a devastating effect on a clone's yield even when its mean stalk weight of the plant crop remains nearly constant over the ratoons. Such complicating relationships deserve careful consideration.
Between-Crops Correlations For Estimated Yield And Its Components Within The Progeny

Phenotypic correlation coefficients were calculated between separate crops of the progeny to examine the association of clonal yield characteristics in one crop to those of succeeding crops. Table 13 shows these coefficients for estimated yield and each of its components.

Relatively strong association of estimated yield and its components is indicated by the correlations between traits in the plant crop with traits in the first ratoon crop of the progeny. Estimated yield of the progeny in first ratoon correlated well with estimated yield in the plant cane crop \( (r = 0.67**) \), and similar, relatively strong, highly significant correlation coefficients were computed for each of the separate components of estimated yield in this crop comparison. For stalk population, the correlation coefficient was \( r = 0.80** \), thus indicating that clones of high standing in the plant crop with respect to this trait were generally high in standing within the first ratoon crop.

The correlation coefficients between the plant crop and first ratoon crop for stalk weight \( (r = 0.73**) \) and its components, stalk length \( (r = 0.60**) \) and stalk diameter \( (r = 0.84***) \), also indicate good agreement (i.e., high repeatability) between the relative ranking of clones in the plant crop and their relative ranking in the first ratoon crop with respect to these characteristics.
Table 13. Phenotypic correlation coefficients (r) between same traits in different crops of the progeny.

<table>
<thead>
<tr>
<th>Trait</th>
<th>Crop comparisons</th>
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<tr>
<td></td>
<td>Plant cane and</td>
<td>First ratoon</td>
<td>First ratoon</td>
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<td>first ratoon</td>
<td>and second</td>
<td>and second</td>
<td>second ratoon</td>
</tr>
<tr>
<td>Estimated yield</td>
<td>0.67**</td>
<td>0.64**</td>
<td>0.46**</td>
<td></td>
</tr>
<tr>
<td>Stalk population</td>
<td>0.80**</td>
<td>0.75**</td>
<td>0.62**</td>
<td></td>
</tr>
<tr>
<td>Stalk weight</td>
<td>0.73**</td>
<td>0.72**</td>
<td>0.67**</td>
<td></td>
</tr>
<tr>
<td>Stalk length</td>
<td>0.60**</td>
<td>0.45**</td>
<td>0.44**</td>
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<tr>
<td>Stalk diameter</td>
<td>0.84**</td>
<td>0.84**</td>
<td>0.78**</td>
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</table>

** = Significant at the 1 percent level of probability.
Hebert (35), in a previous experiment showed similar associations of certain characters between the plant crop and first ratoon crop of clones established from single stool progenies. He obtained a highly significant correlation coefficient ($r = 0.64$) between stalk diameter in the plant crop and stalk diameter in the first ratoon which indicated relatively high repeatability of this trait, but noted that some clones apparently did not "give the same relative stalk diameter in the 2 seasons."

Since it has already been shown in this experiment that there was little or no decline for yield or its components in the first ratoon crop, it is felt that the high correlation coefficients between the plant cane and first ratoon crops do not have an important bearing on the subject of ratoon decline.

The correlations of the next comparison, that of the first and second ratoon crops, are very similar to those for the comparison of the plant crop to first ratoon crop. Even the correlation for estimated yield between the first and second ratoon crops ($r = 0.64^{**}$) is nearly the same as its correlation between the plant crop and first ratoon. This again tends to indicate high repeatability and fair reliability in using a clone's behavior in a preceding crop to predict its performance in a succeeding one. Furthermore, with the exception of the correlation coefficient for stalk length, the correlations of all yield components between first and second ratoon crops closely parallel their correlation coefficients computed for the comparison of the plant cane to first ratoon crops.
Perhaps the most fundamentally important correlations of Table 13 in connection with this study are those between the plant crop and second ratoon crop because of their bearing on the key question of how useful and precise plant crop data are when used as predictors of second ratoon behavior of clones in a breeding population. An answer to this question has application to sugarcane breeding in Louisiana in that when clones are given number assignments (names) within the breeding programs, and thus advanced as potential varieties, very limited information exists in regard to their second ratoon yielding ability. The assignments are made mostly on the basis of plant crop data and some first ratoon data. Furthermore, it is well known that many of these assigned clones are discarded at replicated testing stages because of failure to show acceptable second ratoon yields. It would be desirable to eliminate such clones at the earliest possible stages of the breeding programs where enough variability still exists to make other selections which might have otherwise been passed over because of limited available land and labor.

With the weight of these factors in mind, the correlations in Table 13 between the plant crop and second ratoon crop gain added significance. In general, the correlations of yield and its components were lower in this comparison than in the other two, thus indicating a weakening of association or repeatability between traits separated by one crop as opposed to immediate succession. Yet, the correlation coefficients remained at least moderately
strong and highly significant in all cases. Especially notable in this respect was the correlation of stalk diameter ($r = 0.78^{**}$). It would appear that even estimated yield was moderately repeatable between the plant cane and second ratoon crops ($r = 0.46^{**}$).

Thus, the correlation coefficients between the plant cane and second ratoon crops for yield and each of its components suggest that behavior of the clones in the second ratoon crop could have been predicted from the plant cane data with sufficient reliability as to cast doubt on the need for second ratoon data in the selection of clones with relatively satisfactory second ratoon performance.

The correlation coefficients do not tell the whole story, however. For example, as brought out in an earlier section, there was little decline in the first ratoon crop when compared with plant cane but severe decline occurred in the second ratoon for all traits, with marked differences between clones in degree of this second ratoon decline. Despite this, the correlation coefficients between the first ratoon and second ratoon crops were essentially as high as between the plant cane and first ratoon crops.

The question of the value of plant cane performance in predicting behavior of clones in second ratoon, consequently the need for second ratoon data of experimental clones in an early stage of the breeding programs is not only relevant in the current study but has great practical significance. Because of doubt concerning the proper interpretation of the correlation coefficients between the plant cane and second ratoon crops for each of the yield traits, a more
detailed evaluation of the performance of the clones in plant cane and second ratoon was undertaken for each of the four yield components in the study.

In respect to stalk population, the parents, L 65-69 and CP 65-357, had means in the plant cane crop of 63 and 70 stalks per plot, respectively, and each underwent a decline of approximately 35% in the second ratoon crop. A total of 49 experimental clones from the cross had 63 or more stalks per plot in plant cane and would have been of potential interest for selection at this stage. Using plant cane and second ratoon data, the percentage decline in stalk population was computed for each of these 49 clones. Then, based on admittedly but necessarily rough estimates, it was concluded that approximately 50% of the 49 clones showed a degree of decline similar to that of the parents (about 35%) while the other half of these clones appeared to differ from the parents appreciably in percent decline, some showing more decline and others less decline than the parents. Some clones declined as much as 70% in stalk population while for a few clones the decline was less than 10%.

It appears from the results summarized in the preceding paragraph that performance of the clones in second ratoon could not have been predicted as reliably from plant cane data as might have been concluded from the correlation coefficient of $r = 0.62^{**}$ found for stalk population between the plant cane and second ratoon crops. Only by use of second ratoon data could the clones which appeared
to be inferior or superior to the parents be identified and selected at this early stage.

The above analysis was repeated for each of the other yield components. For stalk weight, a pattern of second ratoon decline similar to that of stalk population was found. Again, roughly one half of the selected group showed second ratoon declines within the range of those of the parents. For the rest, about one fourth of the group showed somewhat less second ratoon decline than the parents, and the remaining one fourth showed somewhat more.

There were 72 experimental clones with mean stalk lengths equal to or greater than that of the shorter-stalked parent, CP 65-357, in the plant crop. Approximately two thirds of these 72 clones showed second ratoon percentage reductions in stalk length of about the same magnitude as those of the parents (about 15 to 30% reduction). The rest of the clones were divided equally in two directions; about 15 to 20% of them showed somewhat less decline than the parents, and about the same proportion showed somewhat greater second ratoon decline in mean length than did the parents.

Perhaps the exceptional characteristic with respect to percentage decline in second ratoon was mean stalk diameter. The selected group of clones for this trait consisted of 55 clones with plant cane stalk diameters equal to or larger than those of CP 65-357 (23.9 mm). Unlike the other components of yield, for which about one-half of all selected clones tended to show declines similar to those of the parents, only about 20% or one-fifth of the selected group for stalk diameter reacted
the largest proportion (about 60%) of the clones showed more decline in stalk diameter than the parents (more than approximately 10% second ratoon decline). The remaining clones, about 20% of the group, showed somewhat less decline than the parents.

These results for the second ratoon behavior of stalk diameter belie what might have been concluded from the strong correlation of $r = 0.78^{**}$ between stalk diameter of clones in the plant crop with stalk diameter in the second ratoon. Despite this high correlation coefficient, it would appear that the majority of clones with acceptable stalk diameter in the plant crop underwent more second ratoon decline than the parents, and thus many fell below an acceptable level of second ratoon performance in this trait. This is a serious defect which could lead to reduced yield in second ratoon, and it would appear that this decline could not be predicted on the basis of plant cane data alone. Clones which were inferior or superior to the parents with respect to the amount of second ratoon decline in stalk diameter could only be identified and selected by growing the second ratoon crop, and it would thus appear that second ratoon data on stalk diameter taken at early stages of selection could have been a valuable supplement to plant cane and first ratoon data in the prediction of second ratoon behavior of stalk diameter of clones in later testing.

It is well known that stalk population and stalk diameter are negatively correlated. For this experiment, this correlation was found to be $r = -0.33^{**}$ as an average of the three crops. This
correlation indicates a tendency for large diameter clones to show lower stalk population than most smaller-diameter clones, and the data bore this out. However, it was wondered how this correlation related to the amount of second ratoon decline in stalk population between large diameter clones versus small diameter clones. To study this, the percentage second ratoon decline in stalk population was computed for the larger-diameter clones of the selected group and for the smaller-diameter clones of the selected group. No great differences could be found. The percentage decline in stalk population was approximately the same for clones with stalk diameters equaling those of the parents as for those with stalk diameters greater than those of the parents. It did appear, however, that clones of appreciably smaller diameter than the parents underwent less second ratoon decline in stalk population than the parents did, but such clones are usually of little worth because of their small diameter and unacceptable millability.

To summarize, it appeared that most of the clones in a group selected on the basis of plant cane behavior in comparison to that of the parents for a specific trait showed about the same amount of second ratoon percentage decline in that trait as the parents showed. Generally speaking, the percentage of such clones was about 50% for all traits with the highly notable exception of stalk diameter where it was found that the majority of selected clones (approximately 60%) underwent more severe second ratoon percentage decline than the parents.
Perhaps the most important concept arising from this treatment of the data, however, is that there always appeared to be some clones which showed more and some which showed less second ratoon percentage decline in each trait than the parents. Although the application of this information to selection for improved ratooning ability is not entirely clear-cut, the data do suggest that early-obtained second ratoon data might be useful in eliminating obviously poor performers. This could be particularly true in the case of stalk diameter where it was found that an especially large number of the selected group of clones showed more decline than the parents.

Whether or not data for estimated yield itself could be treated in this manner is unknown. There were only 14 clones in the plant crop of the progeny which yielded as well as the parents, and none of these showed appreciably less second ratoon percentage decline in yield than the parents. However, some apparently showed more.
Yield Component Interrelationships And Their Bearing On Ratooning Behavior In The Progeny

In separately analyzing the ratoon behaviors of yield and each of its major components within the progeny, there came to light a discrepancy between the number of clones with superior ratooning ability in individual yield components and the number of clones with superior ratooning ability of yield itself. The intent of this section of the discussion is to further investigate this discrepancy.

To begin, all possible correlations within each crop - plant crop, first ratoon crop, and second ratoon crop - were computed between estimated yield and its individual components in an effort to observe firsthand which yield components most strongly conditioned high yield within the progeny, and to study the changes which occurred in these relationships as a function of crop age.

Table 14 shows these phenotypic correlation coefficients between yield and its components as calculated within each crop and as an average of all crops combined.

The correlation of stalk population to estimated yield was, as anticipated, very strong (average $r = 0.79$) and highly significant in all crops. This is due to the fact that stalk population is, in conjunction with mean stalk weight, a major component of cane yield. It should perhaps be pointed out again that clonal yield in this study was estimated as stalk population $\times$ mean stalk weight, and it is realized that this computation in itself might have artificially strengthened, to some degree, the associations of yield
Table 14. Phenotypic correlation coefficients for estimated yield and its components within plant cane, first ratoon and second ratoon crops, and as an average of all crops combined for the progeny.

<table>
<thead>
<tr>
<th>Estimated yield of cane per plot and</th>
<th>Phenotypic correlation coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stalk population</strong></td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.70 **</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.80 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.87 **</td>
</tr>
<tr>
<td>Average</td>
<td>0.80</td>
</tr>
<tr>
<td><strong>Mean stalk weight</strong></td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.56 **</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.42 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.39 **</td>
</tr>
<tr>
<td>Average</td>
<td>0.46</td>
</tr>
<tr>
<td><strong>Mean stalk length</strong></td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.60 **</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.57 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.45 **</td>
</tr>
<tr>
<td>Average</td>
<td>0.54</td>
</tr>
<tr>
<td><strong>Mean stalk diameter</strong></td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.22 *</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.05</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.10</td>
</tr>
<tr>
<td>Average</td>
<td>0.12</td>
</tr>
</tbody>
</table>

*, ** = significant at the 5 percent and 1 percent probability levels, respectively; other correlation coefficients nonsignificant.
to stalk population and mean stalk weight. However, upon review of some past literature, such as that of Hebert (33), concerning the estimation of cane yields in sugarcane, it can be stated that estimated yields and yields determined through actual weighing are found in general to be in good agreement.

The correlation of mean stalk weight to estimated yield within the progeny is shown in Table 14 to have been moderately strong and highly significant across all crops (three-crop average $r = 0.46$). Mean stalk weight, like stalk population, was expected to correlate strongly with estimated yield.

The correlation coefficients for stalk population to estimated yield were higher, and remained so over all crops, than the correlation coefficients of mean stalk weight to estimated yield, and thus a higher importance of adequate stalk population over the importance of high stalk weight in the obtainment of adequate yield within the progeny would seem to be indicated by the data.

Selection for good ratooning ability cannot, however, be based strictly upon selection for high stalk population alone as good weight per stalk is also of considerable importance.

It is also interesting that the correlation of stalk population to estimated yield increased steadily with crop age while the correlation of mean stalk weight to estimated yield decreased with crop age. This may indicate a somewhat greater importance of selecting for better than average stalk population in procuring high ratooning ability than the selection of clones with greater
than average weight per stalk. Surely, though, both adequate stalk population and weight per stalk should be given due consideration in selecting for high ratooning ability.

The correlations of mean stalk length to estimated yield are also presented in Table 14. These correlations were all moderately strong, highly significant, and averaged $r = 0.54$ over all crops. It would appear that clones of higher yield tended to be associated with adequate length of stalk.

The last set of correlations in the table, those of mean stalk diameter to estimated yield, were much weaker than those of estimated yield with any of its other individual components. Only within the plant cane crop did this correlation reach statistical significance and even here it was weak, indicating little association. From these data there would appear to have been no restrictions on obtaining clones of good yielding ability from among clones of various diameter sizes within the progeny. Clones of very small stalk diameter are, however, usually unacceptable for other reasons.

The next table, Table 15, shows the phenotypic correlation coefficients between the separate components of yield within the progeny calculated by crops and as an average of crops.

Taking them in order of appearance, stalk population is first correlated to mean stalk weight and this relationship is shown to have been negative, low in magnitude, and significant only within the plant crop and first ratoon. This implies the presence of an inverse relationship, although not very strong, of stalk population
Table 15. Phenotypic correlation coefficients between the individual components of yield within plant cane, first ratoon and second ratoon crops, and as an average of all crops combined for the progeny.

<table>
<thead>
<tr>
<th>Yield component comparisons</th>
<th>Phenotypic correlation coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stalk population and</td>
<td></td>
</tr>
<tr>
<td>Mean stalk weight</td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.17 *</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.16 *</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.06</td>
</tr>
<tr>
<td>Average</td>
<td>0.13</td>
</tr>
<tr>
<td>Mean stalk length</td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.20 *</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.29 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.19 *</td>
</tr>
<tr>
<td>Average</td>
<td>0.23</td>
</tr>
<tr>
<td>Mean stalk diameter</td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.32 **</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.42 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.25 **</td>
</tr>
<tr>
<td>Average</td>
<td>0.33</td>
</tr>
<tr>
<td>Mean stalk weight and</td>
<td></td>
</tr>
<tr>
<td>Mean stalk length</td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.59 **</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.52 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.58 **</td>
</tr>
<tr>
<td>Average</td>
<td>0.56</td>
</tr>
<tr>
<td>Mean stalk diameter</td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.73 **</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.78 **</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.74 **</td>
</tr>
<tr>
<td>Average</td>
<td>0.75</td>
</tr>
<tr>
<td>Mean stalk length and</td>
<td></td>
</tr>
<tr>
<td>Mean stalk diameter</td>
<td></td>
</tr>
<tr>
<td>Plant cane</td>
<td>0.01</td>
</tr>
<tr>
<td>First ratoon</td>
<td>0.02</td>
</tr>
<tr>
<td>Second ratoon</td>
<td>0.09</td>
</tr>
<tr>
<td>Average</td>
<td>0.03</td>
</tr>
</tbody>
</table>

*, ** = significant at the 5 percent and 1 percent levels of probability, respectively; other correlation coefficients non-significant.
The correlations of stalk population to mean stalk length were positive, significant within all three crops, but also low in magnitude (average $r = 0.23$). This indicates a weak but positive and significant tendency for clones of high stalk population to be relatively taller than clones of low stalk population.

It is well known in sugarcane research that stalk population and stalk diameter are negatively associated. The genotypic correlation coefficient for this association was recently reported by Khairwal and Babu (45) as $r = -0.60$ with high statistical significance. James (43) found a negative phenotypic correlation of $r = -0.36$ between stalk population and stalk diameter in a random population of first ratoon clones.

The correlation coefficients for stalk population and mean stalk diameter were calculated to be negative, low to moderate in strength (average $r = -0.33$) and highly significant in all three crops, thus indicating an important adverse relationship between these two traits. The negative direction of this correlation signifies that clones with high stalk population tended to show low diameter of stalk and vice versa. This adverse relationship effectively reduces the chances of obtaining clones with both large diameter per stalk and high stalk population.

In order to more fully explore the bearing of the correlations between stalk population and the other components of yield on the discrepancy between the number of clones showing good ratooning
ability of individual yield components and the number of clones showing good ratooning ability of yield itself, it was decided to return to the data on individual clones to possibly discern the direct effects of these relationships on ratooning ability.

Recall from the previous section that there were 49 clones in the progeny with acceptable stalk population in the plant crop, and that some of these clones appeared to have shown less second ratoon decline in stalk population than the parents - it is this last portion of the group which was restudied. This roughly one-third of the group actually equated to 18 clones which appeared to have shown better ratooning ability of stalk population than the parents. These clones were listed, and beside each one were written its mean weight per stalk, mean length, and mean diameter in the plant cane and second ratoon crops.

It was found that only 5 of these 18 clones with superior ratooning ability of stalk population had acceptable mean stalk weight in the plant cane crop. In addition, only 1 of these 5 showed appreciably less second ratoon decline in mean weight per stalk than the parents. These data concur with the average negative correlation of \( r = -0.13 \) between stalk population and stalk weight found in the progeny (Table 15). Thus, the data appear to indicate that there would have been some difficulty in selecting clones with high ratooning ability of both stalk population and stalk weight.
With respect to stalk length, 9 of the 18 clones were acceptable in the plant crop and showed no greater second ratoon decline in length than the parents did. These facts together with the average correlation of $r = 0.23$ for stalk population to stalk length would tend to indicate that clones with acceptable ratooning ability of stalk population and stalk length could be found in the progeny.

The situation was different for stalk diameter. Among the 18 highest ratooning clones for stalk population there was but one clone which showed acceptable stalk diameter in the plant cane crop when compared to the parents. Furthermore, this single clone showed approximately the same amount of second ratoon decline in stalk diameter as did the parents. As a group, the 18 clones showed plant crop stalk diameters ranging from 19.1 to 26.3 mm and averaged 21.7 mm, or 2.2 mm under the average plant cane stalk diameter of CP 65-357, 21.2 mm, and although about half the clones appeared to have shown somewhat less second ratoon percentage decline in stalk diameter than the parents did, the effect of their smaller diameters on mean weight per stalk appeared to severely limit their yield and thus only 2 of the 18 clones were high in ratooning ability when assessed on the basis of yield itself. One of these two clones was the only one in the group with acceptable initial stalk diameter, and the other clone was 1 mm larger in plant cane diameter than the group average. These data thus point to a relatively serious impediment to the selection of clones with a combination of high ratooning ability of stalk population and
stalk weight. In addition, it would seem that this problem was largely the result of the negative association between stalk diameter and stalk population.

In looking at this negative association from another angle, the clones which showed superior ratooning ability of stalk diameter within the progeny were examined in detail with regard to their ratooning behavior in the other yield components. There were 9 progeny clones which appeared to have superior ratooning ability of stalk diameter, and upon examination, it was revealed that about half of them had adequate stalk weight in the plant crop and second ratoon percentage declines in stalk weight which were no worse than those of the parents. These clones did not fare so well in stalk population, however. None of them showed adequate stalk population in the plant crop (the group average was 50 stalks/plot), and all of them showed some degree of second ratoon decline in stalk population.

Thus, the negative association of stalk population to stalk diameter was again supported by the data on individual clones. It appeared that clones with high ratooning ability of stalk diameter within the progeny were generally not found to have high ratooning ability of stalk population.

The next set of correlation coefficients in Table 15 are those between mean stalk weight and its components, stalk length and stalk diameter.

The correlations of mean weight to mean length were fairly consistent over crops, moderately strong, and in all cases positive
and highly significant (average $r = 0.56$) thus indicating the importance of selection for adequate length per stalk to the procurement of good weight per stalk.

Similarly, the correlations of mean stalk weight to mean stalk diameter were positive, strong (average $r = 0.75$) and highly significant in all crops. The strength of these correlations shows the importance of adequate stalk diameter to good weight of stalk.

In accord with these correlation data, it was found that clones with high ratooning ability of stalk weight in the progeny were generally associated with good ratooning ability of stalk length and stalk diameter. Again, however, the negative associations of stalk diameter and stalk weight to stalk population tended to limit the ratooning power of such clones, and thus, none of the clones with the highest ratooning ability of stalk weight within the progeny appeared in the list of clones with good ratooning ability of estimated yield.

The last correlations of Table 15 are those between mean stalk length and mean stalk diameter of the progeny. These correlations indicated essentially no association between these two characters, and therefore denoted essentially no problem in combining high ratooning abilities of both traits within the progeny. In addition, this was found to be true when the clones with high ratooning ability of stalk length were examined with respect to ratooning ability of stalk diameter and vice versa.
To summarize, the correlations of stalk population to mean stalk weight and the individual components of stalk weight, mean stalk length and mean stalk diameter, are highly interrelated. The negative association of stalk population to mean stalk weight indicates that clones which showed the highest stalk populations were more often than not lower than the population average in mean weight per stalk. This is likely due to the negative association of stalk population to mean stalk diameter. Those clones of highest stalk population were often associated with stalks of small diameter and thus reduced stalk weight. Only if such clones tillered very well and/or showed greater than average stalk length could they be expected to show high yield in any crop, and especially in the ratoons. This is sound evidence against overstressing the selection of clones with exceptionally large stalk diameter in an effort to select for high yielding ability as these clones usually could be expected to show lower than average stalk population.

The correlations of mean stalk weight to mean stalk length and mean stalk diameter point to the necessity of selecting for satisfactory stalk length and diameter in obtaining clones of acceptable stalk weight, however, clones of exceptionally large diameter can often be expected to be associated with unacceptable stalk population and ratooning ability.

Among the slightly more than 50 clones with good ratooning ability in individual components examined in the progeny, only 5 appeared to have been relatively high in ratooning ability of yield
Itself. Thus, a main problem in selecting for high ratooning ability would appear to have been that of combining high ratooning ability of several traits in one clone.

Again, the importance of getting a good balance of characteristics is emphasized in obtaining clones of good yielding ability from among which clones of superior ratooning ability might be selected. All of the components of yield have been shown to have been contributory to ratoon yield decline in the progeny, and highly interrelated in the final phenotypic expression of yield and the ability to maintain that yield over the ratoon crops.
SUMMARY

Data from the three harvests showed the inheritance of ratooning ability in sugarcane hybrids to be complex and quantitative in nature. Ratooning ability in the progeny ranged from clones which did not ratoon at all to clones whose ratoon yields were similar to those of the parents. None of the clones in the progeny which yielded well in the plant cane crop appeared to be superior to the parents in ratooning ability.

The progeny, when examined on the basis of individual yield components, was found to contain clones which equalled the plant cane performance of the parents in those components. For instance, about 30% of the progeny had plant cane stalk populations equal to or greater than those of L 65-69, the lower-population parent of the cross. In addition, approximately 6% of the progeny showed transgressive segregation for high stalk population in having exceeded CP 65-357 in stalk population. Similar behavior was found for weight per stalk and its components, stalk length and stalk diameter. The percentages of clones equal to or higher than the parent of lower expression for mean weight, mean length and mean diameter of stalk were 33%, 37% and 35%, respectively. There appeared to be some transgressive segregates for these traits also (about 2% of the progeny for stalk weight, 4% for stalk length and 14% for stalk diameter). On the other hand, only about 10% of the progeny showed plant cane yields which were equal to those of the parents,
and there was no strong evidence of transgressive segregation of estimated yield.

Furthermore, it was concurrently found that although clones existed within the progeny which showed higher ratooning power in separate yield components than did the parents—none appeared to be superior to the parents in ratooning ability for yield. Only about 5% of the progeny appeared to be about equal in ratooning ability of yield to the parents.

The data showed that neither the parents nor progeny underwent serious first ratoon decline in yield. The decline in second ratoon yield was, however, generally quite severe (approximately 50 to 60% less than in the plant crop) for the parents and progeny alike, and could not be attributed more to decline in any one particular yield component over declines in the others.

The apparent discrepancy between high ratooning ability in individual yield components and low ratooning ability of yield itself was strongly conditioned by negative associations of traits. Especially notable in this regard is the negative correlation between stalk population and stalk diameter ($r = -0.33$).

It appeared that high incidence of good ratooning ability was strongly suppressed by a limited number of clones with desirable combinations of high-ratooning yield components, and by the presence of a large number of low-yielding clones to begin with.

It is concluded that the genetic behavior of ratooning ability is highly conditioned by environment, and that selection for high
ratooning varieties of sugarcane must be practiced under the specific environmental conditions in which they will be grown. It seems that second ratoon data taken at early stages of selection could be valuable in detection of clones with acceptable ratooning ability, and perhaps even more valuable in the early detection and elimination of obviously inferior-ratooning clones.

Possible approaches for increased early selection pressure for high ratooning ability were suggested, including the growing of second ratoon crops in early line trials.

As found, only about 10% of the progeny showed acceptable plant cane yields, but among these clones there was an apparent differential in ratooning ability. Although the nature of the data did not permit an exact interpretation of their genetic behavior with respect to these differences in ratooning ability, it seemed that approximately half these clones were about equal to the parents in ratooning ability and about half were probably inferior. A similar differential in ratooning behavior could be found for other clones within the progeny, and these data collectively revealed that the high repeatabilities of yield and its components between the planted and ratoon crops did not necessarily denote high reliability in selecting for good ratooning ability (especially for good second ratoon yielding ability) on the basis of information largely composed of plant cane data.

For these reasons it seems that the growing of second ratoon crops in small-plot stages of selection would perhaps be a reliable means of estimating the ratooning potential of clones in a breeding program.
and increasing the number of clones with acceptable ratooning ability in later testing stages. The value of this procedure would depend, however, on the efficiency and practical applicability of the selection techniques used and the amount of genetic advance possible within the available germplasm base.
REFERENCES


VITA

John Walter Dunckelman, the second of five children of Preston H. and Rose L. Dunckelman, was born February 17, 1954 in Baton Rouge, Louisiana.

He attended elementary school in Pahokee, Florida, and middle and high school in Houma, Louisiana where he graduated from Terrebonne High School in May, 1972.

He enrolled at Nicholls State University in Thibodaux, Louisiana and graduated in May, 1976 with a B. S. in Animal Science. He married the former Leslie Lynne Regan of Houma in December of that year.

He entered the graduate school at Louisiana State University in 1976 on a research assistantship to the Agronomy Department, and obtained his M. S. in Agronomy in May, 1978.

He was hired as research agronomist by the United States Department of Agriculture in January, 1981, at the U. S. Sugarcane Field Laboratory at Houma, Louisiana after completing all requirements for the Ph. D. degree except the dissertation. He is now a candidate for that degree.