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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE

FOURTH ANNUAL REPORT

1980—1981

TO

THE UNITED STATES DEPARTMENT OF ENERGY

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO - - U.S. DEPARTMENT OF ENERGY

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Fourth Annual Report; 1980—1981

To

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Oak Ridge Operations Office, and the Division of Solar Technology
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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE 1/

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ABSTRACT

Research continued on tropical grasses from Saccharum and related genera as sources of intensively- propagated fiber and fermentable solids. Yield trends for sugarcane and napier grass over the first three years were compiled during year 4. Four trends were evident: (a) A general failure of narrow row spacing to increase yields; (b), major DM yield increases with delay of harvest interval; (c) a superiority of variety NCo 310; and (d), a superiority of first-ratoon DM yields over those of the plant and second-ratoon crops. As a 3-year average, DM yields for cane and napier grass were 29.0 and 27.5 OD tons/acre year, respectively. Optimal harvest interval was 12 months for cane and 6 months for napier grass.

Harvest machinery trials for mature napier grass continued during Year 4. The M-C rotary scythe and New Holland round baler continued to perform well with 6-month old grass, representing 40 to 45 tons/acre of standing green biomass when mowed. A Farmhand wheel rake gave superior performance in dense, matted material, including high stubble. Diesel fuel consumption by a category III tractor operating the rotary scythe in 6-months old napier grass ranged from 2.38 to 2.95 gallons/hour, or 1.92 to 2.69 gallons/acre. There was moderately greater fuel consumption at low mowing heights. Horsepower usage ranged from 41.4 hp at low stubble to 35.7 hp at high stubble.

A major field-plot study was established to evaluate yield potentials of two "second generation" energy cane varieties specifically selected for high biomass yield. In addition to varieties, controlled variables include harvest frequency (6-,12-, and 18-month intervals), and nitrogen supply (200, 400, and 600 lbs elemental N/acre year). This study is maintained under border irrigation in the semi-arid Lajas Valley. Yield data at 6 months indicate high but essentially equal growth rates among all varieties and N-variables. This is attributed to the use of a land rotavator during seedbed preparation—the first such application of this implement on Lajas Valley soils. Total green weights were in the order of 50-60 tons/acre, and millable stem weights ranged from 33 to 37 tons/acre, at the 6-months harvest. Dry matter yields ranged from 8 to 11 tons/acre. Juice quality values indicated a minimal sugar content at this stage of maturity. Fiber values ranged from 7 to 14%. A field-scale demonstration study was also established near Hatillo on the semi-humid north coast.

1/ Contract No. DE-AS05-78ET20071

INTRODUCTION

The biomass production studies herein reported were initiated June 1, 1977 as a contribution to the Biomass Energy Program of the UPR Center for Energy and Environment Research (CEER-UPR). This research deals with sugarcane, tropical grasses related to sugarcane, and other tropical grasses having large growth potentials on a year-round basis. Its basic premise is that such plant materials can be produced continuously as a renewable, domestic source of fuels and chemical feedstocks that will substitute for imported fossil energy. The present report covers the period June 1, 1980 to May 31, 1981.

1. Project Objectives

Primary objectives include: (a) Determining the agronomic and economic feasibility of mechanized, year-round production of solar-dried biomass, through the intensive management of sugarcane and napier grass as tropical forages, and (b), examination of alternative tropical grasses as potential sources for intensive biomass production. A secondary objective concerns the selection and breeding of new sugarcane progeny having superior biomass productivity as their principal attribute.

2. Scope of the Project

Emphasis is directed toward a highly-intensive and mechanized production of tropical grasses as solar-dried forages. This is a deviation from conventional cane and cattle feed production in that total dry matter rather than sugar and food components is the principal salable commodity. Management of production inputs—particularly water, nitrogen, and candidate species, together with harvest frequency—varies significantly from established procedures. On the other hand, advances in mechanized production and harvest operations within the sugar and cattle forage industries are being utilized with considerable success for production of solar-dried biomass.

Optimized production operations require the identification of a few select clones and the conditions required for their management in an economically-realistic operation. This is being accomplished in the continued development of three project phases, including greenhouse, field-plot, and field-scale investigations (Table 1). A fourth phase, commercial-industrial operations, follows logically but lies beyond the scope of the present project. The work herein reported deals with a continuation of the greenhouse, field-plot, and field-scale phases begun earlier (1,2,3) [1/].

The project's screening operations are designed to identify high-yielding grasses that can be harvested on a year-round basis. They have indicated three broad categories based on the time required after seeding to maximize total dry matter (Table 2). Among sugarcane cultivars the superior growth rate *per se*, a botanical feature, has not been recognized historically as a desirable attribute unless combined with an acceptable level of sugar production (4,5,6,7,8,9,10). Similarly, the tropical forage grasses have required acceptable digestibility and nutritive characteristics rather than high yields of dry matter (11,12). Accordingly, our screening program often

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1/ Numbers in parentheses refer to relevant published literature. Complete citations are listed on pages 42-44.

deals with long—established cultivars, but in manner that would have astonished their original developers. In some respects this is a tropical application of the herbaceous species screening program formulated by the DOE Biomass Systems Program (13,14).

A breeding program designed to intensify the biomass-yielding attribute of Saccharum and related species lies beyond the scope of this project. Thorough breeding studies would require and justify a separate project. This would include the screening of candidate parental types, a physiological phase to synchronize flowering periods at the intergeneric level, and basic genetic research to break some serious constraints operating to prevent the exchange of germplasm among Saccharum and allied genera (15,16,17, chap. 1). At a very modest level some limited breeding is included in the present project. This work is confined to a few obviously desirable parent clones that have suitable flowering characteristics and which can be incorporated without inconvenience into an ongoing breeding program for sugarcane (1,2). Certain progeny originating with the AES-UPR sugarcane breeding program are also being considered as long-rotation biomass candidates (3,18). Under these circumstances some prospect is created for the emergence of superior new progeny at very little expense.

TECHNICAL REPORT

A. GREENHOUSE STUDIES

The project's greenhouse phase is concerned with the screening of candidate tropical grasses and the response of superior cultivars to growth input and management variables. Much information of this nature is obtained more rapidly and cheaply than is possible under field conditions. Greenhouse data are not definitive in the sense that direct field responses and cultural recommendations can be stated, but perhaps two-thirds or more of the total data package needed for a herbaceous candidate can be gathered in this way. For Saccharum and related species ordinarily propagated in populations of 30,000 to 300,000 plants per acre, the greenhouse offers a level of precision for control of the individual plant that is not possible in the field. This method is currently used in Puerto Rico for its economy of project resources; under temperate-climate conditions it offers an economy of time where field work is seasonally limited to four or five farorable months per year.

Both replicated and non-replicated "observation" experiments are conducted in the greenhouse (1). The latter usually concern preliminary growth-potential measurements involving only a few hundred plants in an area covering roughly 1/200 acre. Replicated experiments deal with specific growth characteristics in previously-identified candidates. Ordinarily these have involved 3 to 5 replications of each treatment arranged in an incomplete randomized block design (1, 2).

1. Legume Screening

Preliminary analyses of the energy expenditures for intensive sugarcane production (3) have indicated a disproportionately large energy input for nutrients, particularly for the elemental nitrogen provided in the form of chemical fertilizers. Nearly half of the total energy inputs are accountable to elemental N alone (3, p. 70). There is considerable evidence that herbaceous crop plants can obtain at least part of their N requirements through intercropping or co-production with legume species (19,20,21).

Greenhouse trials during the second quarter included four legume species regarded as potential N sources for tropical grasses managed as energy crops. Each species is widely distributed in the wild in Puerto Rico and all produce moderate-to-heavy nodulation over short periods of time. The first experiment delt with species of Leucaena, Phaseolus, Albizia, and Sesbania (Table 3). Direct growth comparisons were made with one of the fastest-growing tropical grasses available, ie, Sordan 70A, a short-rotation species attaining maximum height and tissue maturation within 12 weeks after seeding.

Because of the rapid germination, elongation, and canopy closure of short-rotation grasses, candidate legumes for co-production with these plants would also require an early rapid growth habit, both to avoid shading out and to contribute a meaningful amount of dry matter at the time of harvest. Growth measurements were recorded for Sordan 70A and the four legumes at six, 12, and 18 weeks after seeding (Table 3). Growth parameters included green and dry matter produced/planted area (approximately 60 ft^2/species/harvest), plant height, and DM yield on an individual plant basis. Plant maturation, as indicated by percent dry matter, was also recorded.

None of the legume species attained the early elongation and dry matter yield characteristic of Sordan 70A (Table 3). The species Sesbania exaltata (Colorado River Hemp) most nearly matched the tropical grass in dry matter yield (Figure 1) and vertical growth (Figure 2). Sesbania also performed relatively well on an individual plant basis (Figure 3), although none of the candidate legumes produced more than about 40 percent of the DM attained by Sordan 70A as individual plants.

Two roles are perceived for tropical legumes as supplemental N sources for tropical grass energy crops: (a) As "intercrops" propagated on a given site between planting of energy cane or other tropical grasses, and (b) as biomass energy crops co-produced (grown simultaneously) with the tropical grass energy crop. Candidate legumes for the first role would be incorporated into the seedbed prior to seeding the energy crop, and presumably any of the test species described above might fulfill this purpose. Over 100 legume species have been identified as candidates for intercropping with tropical grasses (22). Such evaluations lie beyond the scope of the present project. The second role is a more demanding one in the sense that legume candidates must themselves produce an appreciable quantity of biomass while contributing an immediate supply of fixed N to its companion crop. The task is particularly difficult when intercropping with short-rotation grasses where rapid vertical growth and canopy closure occurs within three weeks after seeding, and harvest is performed within 12 weeks after seeding. Growth data from the initial four test legumes indicate that Sesbania exaltata can probably give a satisfactory performance in this role.

For intermediate-rotation crops, such as napier grass, the initial growth surge is somewhat delayed and a legume species will have a better chance to establish itself with only limited shading from the tropical grass. The age at harvest will vary from about 18 to 30 weeks. During this interval the vertical growth of napier grass will reach 9 or 10 feet. There is little prospect of finding an upright legume that can equal this growth; however, Sesbania exaltata appears to be the best candidate tested to date (Figure 2). Given sufficient time, some woody legume species (Leucaena and Albizia) might attain this height but they could not do so in the growth interval of intermediate-rotation grasses. Certain of the tropical legumes have a trailing, indeterminate growth habit and will cling to upright objects as climbing vines.

A subsequent experiment was performed to verify the legume growth potential and to determine whether the season of planting was a significant factor in their growth performance; none of these species have ever been planted as agricultural crops or experimental entities in Puerto Rico. Growth data for the first experiment, planted during the spring (May), and the second experiment, planted 6 months later in the autumn (November), are combined in Tables 4 and 5.

Several trends are evident for both green and dry biomass production (Table 4): (a) The legume species were far less productive when planted in autumn. Each species is quite clearly sensitive to Puerto Rico's "winter"; (b) Sesbania again was the most productive of the four legume species tested; (c) Sordan 70A produced more green weight but less dry matter when planted in autumn (ie, it was relatively less mature at each of the winter harvest intervals); (d), Maturation trends in legume species were essentially equal for spring and autumn planting; (e) The legume Phaseolus lathyroides was as productive in winter as in summer when DM was measured on an individual plant basis (Table 5). Winter thus appears to have affected germination and seedling establishment rather than growth per se; (f), Plant height was restricted in all species by autumn planting; (g), Sesbania was the tallest of the legume species in both spring and autumn plantings, attaining about 73% of the corresponding Sordan heights as main effects (Table 5).

Although seasonal changes in temperature and daylength seem small in the tropics their effects on plant growth are probably underestimated. For example, Puerto Rico is often depicted as having a "year-round growing season". Yet, sugarcane experiences a major growth decline during Puerto Rico's winter while a lesser growth restraint is exerted on napier grass. Some of the growth decline might relate also to the Island's reduced rainfall during winter months. Vegetable crops are enormously sensitive to planting season in Puerto Rico and this is recognized by the layman and professional growers alike. It now appears that the indigenous tropical legumes will have to be examined closely in this respect whether they are planted as N-sources for tropical grasses or as biomass crops in their own right.

2. Mineral Nutrition

A nitrate-N nutrition experiment with sugarcane variety PR 980 was established during the autumn of 1980. Variable nitrate levels were administered in sand culture to evaluate the variety's N-response curve. As in earlier nutrition experiments with short-rotation and intermediate-rotation species (1, 2), the objective with sugarcane was to establish the slope of the dry matter yield response to progressively larger amounts of N. Accordingly, nitrate-N levels were increased in a geometric progression ranging from 1.0 to 81.0 milequivalents per liter, in nutrient solutions given three times per week over a time-course of 16 weeks.

All plants were maintained for 6 weeks with a standard nutrient solution containing low N (1.0 meq/1 of NO_3). Two harvests were performed after 5 and 10 weeks of variable treatment, ie, when the plants were 11 and 16 weeks of age.

For both harvests, the green and dry matter yield data indicate a maximum growth response at around 9.0 meq/l of NO_3 (Table 6; Figure 4). On an individual plant basis there was little difference among variable N levels at 5 weeks; however, the second harvest indicated a broad range of DM responses with high N (81.0 meq/l NO_3) being cleary repressive. Maturation values (DM content) varied but little either among N treatments or harvest interval (Table 6). These data suggest that the sugarcane was much too immature to express a valid Saccharum species response to N variables of this magnitude. Alternatively, it is very difficult to propagate sugarcane to maturity via sand culture under glass.

B. FIELD-PLOT STUDIES

1. Minimum Tillage Experiment; Lajas Substation

There is a need for tropical grasses that will produce at least moderate yields with the barest minimum of production inputs. The characteristics and principal requirements of minimum tillage candidates for Puerto Rico are discussed at length in prior reports (1, 2).

A long-term minimum tillage study on Saccharum species was initiated at the AES-UPR Lajas Substation during mid-February of 1977. There are four S. spontaneum clones and an interspecific commercial hybrid (PR 980) serving as the control. Receiving no production inputs since the original planting, harvests have been taken at 6-month intervals. The fifth such harvest was performed during the first quarter. Dry matter yields are relatively low for all clones; however, it is evident that two of the S. spontaneum clones, US 67-22-2 and US 72-93, are sustaining themselves more effectively than the commercial hybrid PR 980 (Table 7).

The superior clone at this stage of the experiment is US 72-93. Its green and dry matter yields were 4.71 and 1.88 tons/acre, respectively. Energy inputs for US 72-93 under these circumstances are nil since neither irrigation nor machinery-use practices are involved. Cost inputs are confined to land rentals ($50.00/acre year) and labor for harvest operations (approximately ($45.00/acre year). Assuming an annual yield of 3.76 OD tons/acre for US 72-93 (two 6-month harvests), its production cost at $25.26/ton would be almost identical to that of "energy cane" at $25.46/ton (3).

The yields herein reported are from the fifth 6-month harvest of a planting seeded early in February of 1977. They constitute the fourth consecutive harvest performed under minimum tillage conditions, that is, where no production inputs have been given other than harvest operations. All clones indicate that they can survive and produce some biomass under these conditions. The average dry matter yield for the group appears to have become fairly constant at slightly less than one OD ton/acre/6 months of growth (Table 8).

2. Sugarcane And Napier Grass; Third Year Results

(a) Final Growth Data of Year 3: Because this study was planted 1.5 months into Year 1, the final growth data for each year is obtained during the first quarter of the following year. Hence, the Third Annual Report covering activities for Year 3 was lacking data for the sixth 2-month harvest, the third 4-month harvest, the second 6-month harvest, and the 12-month harvest.

Final data for Year 3 (Tables 9-13) are consistent with yield trends reported previously for years 1 and 2 (3, 1). These trends include:

(a) Lack of major yield differences between sugarcane varieties, with NCo 310 being moderately superior to PR 980 and PR 64-1791; (b) a general failure of narrow row spacing to increase yields; and (c), major yield increases by delaying the napier grass harvest interval from 2 to 4 or 6 months, and by delaying the sugarcane harvest until 12 months.

The 2-month harvest interval had virtually destroyed sugarcane varieties PR 980 and PR 64-1791 by the end of the third year of cropping (Table 9). Napier grass was far more tolerant of frequent recutting than sugarcane. On the other hand, the 12-month interval which favored sugarcane was repressive for napier grass (Table 12).

Sugarcane trash yields were higher for variety PR 980 than NCo 310 and PR 64-1791 (Table 12). Napier grass generally produced less trash than sugarcane, but the percentage of its biomass comprised of trash was higher than for cane. Hence, 28.4 percent of the total napier grass DM consisted of trash, while sugarcane trash ranged from 14.1 to 28.8 percent of the total. Among the cane varieties NCo 310 produced the least trash (Table 12). Nonetheless, total dry matter yields (oven-dry millable cane plus trash) indicate that NCo 310 was still the superior biomass producer for Year 3 (Table 13).

(b) Maximum Biomass Yields; Year 3: As noted above, the 12-month harvest was by far the most important for sugarcane while the 6-month harvest gave maximum yields for napier grass. The highest green matter yield (exclusive of trash) for Year 3 was 92.0 tons/acre year (Table 12, variety NCo 310); the highest dry matter yield was 31.3 tons/acre year, including trash (Table 13, variety NCo 310). As a point of reference the PR sugar industry currently produces 26 to 28 green tons and 9 to 10 dry tons per acre year as an Island-wide average. Trash is not credited to total cane yield by the PR Sugar Corporation.

The maximum napier grass yield at 12 months was 67.8 green tons and 19.9 dry tons/acre year (Tables 12 and 13). A much greater yield was obtained as the combined output of three, 4-month harvests (88.9 green tons, 22.4 dry tons) or two, 6-month harvests (88.7 green tons, 24.0 dry tons). This is indicated by summary data presented in Tables 14 and 15.

Napier grass continued to attain a higher level of maturity than sugarcane during Year 3 (Table 16). The maximum average DM content for sugarcane was 26.7% at twelve months; napier grass achieved a comparable maturity (25.8%) within four months. By the twelfth month the napier grass DM content exceeded 32% (Table 16).

Although annual napier grass yields were roughly equal for combined 4-month and 6-month harvests, appreciably less cost would be incurred when only two harvests are performed (at 6-month intervals). There would be less damage to plant crowns, less soil compaction, and less destruction of irrigation borders by heavy machinery when one of the three harvests is eliminated. A decisive factor here is the work capacity of available harvest equipment. There is little point in attempting to harvest 6-months old biomass with harvest equipment designed to accommodate only 2-months old material. Machinery studies during Year 3 have shown quite decisively that 6-months old napier grass can be harvested with existing equipment (see pages 33 to 36).

(c) Sugarcane Quality: The sugarcane management practices for this project are designed to maximize growth rather than quality of the cane. Relatively poor juice quality was obtained for the plant crop and first-ratoon crop. The second ratoon plants showed moderately improved quality but nonetheless would be regarded as substandard in most cane sugar industries. Sucrose content averaged 7.2% for all varieties and row spacings (Table 17).

Variety PR 64-1791, at standard row spacing, produced 8.4% sucrose. Fiber content averaged 16.4 percent, a value which is not exceptionally high.

While the quality of the cane herein described as "energy cane" was low, it is nonetheless equal to or better than that of Puerto Rico's commercial sugar industry. Commercial sugarcane in Puerto Rico today rarely produces more than 8% sucrose. This is a consequence of a whole series of field and factory problems which lie beyond the scope of our discussion. However, it must be noted that cane grown for biomass cannot be faulted for low yields of sucrose or fermentable solids when these are computed on a per acre basis. For the Year 3 crop the three test varieties averaged 5.18 tons sugar/acre (TSA) at standard row spacing and 5.71 TSA for narrow row spacing (Table 18). By contrast the PR sugar industry produced less than 2.2 TSA in 1980 (22). The Government's long-term goal of 3.0 TSA (24) appears virtually unattainable under present conditions in the Island's sugar industry.

In the management of "energy cane", fermentable solids have been depicted as a major byproduct rather than the primary objective of sugarcane production (25, 26, 27). In Puerto Rico, especially when world prices for raw sugar are low, sucrose would be sold to the Island's rum industry as a component of high-test molasses. As recently as the autumn of 1979 sucrose values appeared constant at around 14 cents/pound, and high-test molasses was priced at approximately 95 cents/gallon.

During periods of high sucrose values it could be profitable to recover part of the sucrose for local or foreign sales. One means of doing this would be to retain the "first strike" (containing perhaps 60% of the recoverable sucrose in cane juice) for raw sugar sales. The balance of the sucrose would remain in the molasses. This would be sold to the UP rum industry as a somewhat lower quality "high-test" molasses.

(d) Plant Densities: The number of stems produced by the cane and napier grass crowns was a function of species, harvest frequency, and row spacing (Table 19). Eventhough close spacing failed to increase yields for sugarcane and napier grass, the number of stems harvested from the second-ratoon crop continued to reflect the increased seeding rates of three years earlier. The highest plant density attained by sugarcane was 183,896 stems per acre (variety NCo 310 at close spacing and the 6-month harvest interval). The highest tonnage of the second ratoon crop was achieved with about 93,000 stems/acre, from variety NCo 310 at standard row spacing (Table 19, 12-month harvest). Variety NCo 310 also produced the highest number of stems for 2-, 4-, and 6-month harvest intervals.

Napier grass produced more stems than sugarcane irrespective of harvest interval. The 4-month harvest period yielded the highest stem counts of the project to date, ie, 511,975 stems/acre for close-spaced napier grass (Table 19). However, like sugarcane, napier grass yield was not a function of stem numbers but of harvest interval. The maximum DM yield for napier grass (19.9 OD tons/acre year) was attained with 193,000 stems/acre, at standard row spacing and the 6-month harvest interval.

The lack of yield increases from plots having very appreciably larger numbers of stems suggests that there were too many plants occupying the available space for individual stems to attain maximum development. Under some circumstances the dispersal of a given biomass tonnage among a greater number of stems is seen as an important factor, particularly during harvest and solar-drying operations in which thin-stemmed plants are clearly favored over thick-stemmed plants.

C. FIELD-PLOT STUDIES; 3-YEAR TRENDS

With the completion of the second-ratoon harvest it is possible to begin evaluating some long-term trends in sugarcane and napier grass production as perennial sources of biomass. As a sugar crop, sugarcane can be grown for many years without replanting, but significant yield decline is usually evident after the fourth or fifth crop. The PR sugar industry ordinarily harvests five crops (the plant crop plus four ratoon crops) but a plant crop plus two ratoons might be justified under some circumstances.

The longivity of napier grass when managed as an energy crop remained an open question. Napier grass will prosper both as a cultivated crop and as a wild specimen. The author is aware of napier grass plantings in Puerto Rico that are over 30 years old. Very little is needed by such plants in the way of production inputs; alternatively, neither wild napier grass nor conventional plantings for pasture and forage purposes have been managed as energy crops in the past. In particular, the longivity of napier grass crowns under harvest regimes maximizing dry matter (recut at 4-to 6-month harvest intervals) rather than digestible green material (recut at 5 to 7 week intervals) is a critically important question. Equally important is the survival of napier grass crowns when exposed to the harvest, solar drying, baling, and transport operations that will characterize energy plantation cropping.

1. Sugarcane; 3-Year Trends

(a) Maximum Yields: Summary yield values for three years of sugarcane growth indicate the following trends: (a) The first ratoon crop (Year 2) gave the superior yields of both green matter and dry matter (Tables 20 and 21);

(b), the second ratoon crop was more productive than the plant crop but less productive than the first ratoon (12-month data); and (c), for all crops, yields increased progressively with lengthening time interval between harvests. The highest average cane yield for the 3-year study was 33.6 dry tons/acre year, including trash, produced by the first-ratoon crop (Table 21).

These results support the view that three crops will maximize the yield of a given sugarcane planting when managed for total biomass. The implication is that the land area should be replanted following harvest of the second ratoon crop. However, the 12-month plots have been retained for an additional year for confirmation of the apparent yield decline.

(b) Maturation Trends: Data for dry matter accumulation indicate that the second ratoon crop was the least mature of the three crops (Table 22). The first-ratoon crop was the most mature. For all crops there was a marked lack of maturity when cane was harvested at intervals of less than 12 months duration. The highest average value for dry matter content of sugarcane was 31.0 percent, recorded for the first-ratoon crop at the 12-month harvest interval (Table 22).

(c) Varietal Trends: Three-year growth performances for each variety are summarized in Table 23 (2-and 4-month harvest intervals) and Table 24 (6-and 12-month harvest intervals). Dry matter yield differences were not extensive among the three varieties; however, NCo 310 gradually emerged as the superior variety. Like the other varieties it was unable to produce very effectively at the 2-to 6-month harvest intervals. It was appreciably more successful in resisting a third-year yield decline which drastically affected PR 980 and PR 64-1791 at these intervals. For the 12-month harvest (the only harvest of practical importance), NCo 310 produced the highest yield of millable cane for each of the three crops. It was a relatively poor producer of trash, however (Table 25). The total DM yields, in which trash was included, revealed only small differences among the three varieties. NCo 310 was the superior producer for the plant crop and second ratoon crop, while PR 980 slightly exceeded NCo 310 (by 0.5 tons/acre year) for the first-ratoon crop (Table 24).

Trash yields were clearly a varietal factor. Since only free trash was measured, ie, leaf and leaf-sheath tissues that had detached from the stem and fallen to the ground, 1/ these differences could reflect a genetic control of cane "cleanliness" long recognized by sugarcane breeders (16). Variety PR 980 produced appreciably more trash than NCo 310 and PR 64-1791 for each of the three crops (Table 25). Moreover, each crop's yield for PR 980 exceeded that of the previous crop. Narrow row spacing appeared to increase trash yields for varieties NCo 310 and PR 64-1791. This was especially true of the plant crop (Table 25), and to some degree might simply reflect the greater number of plants available to shed leaves at that time.

(d) Row Spacing Trends: Close spacing failed to increase yields of 12-month sugarcane for each of the three crop years (Table 26). Only for the 2-and 4-month harvests of the study's plant crop were any appreciable yield increases obtained from narrow row spacing. The very clear message from these results is that, under tropical conditions, sugarcane will fill in

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1/ The leaf and leaf-sheath tissues which comprise trash, eventhough they may be long dead, do not always detach and accumulate on the ground. Trash adherence to the stem is probably a varietal characteristic.

the availalle growing space through crown expansion from standard row centers spaced 150 cm apart. Narrowing row centers to 50 cm makes no sense at all unless the energy planter intends to harvest only a single crop within about 6 to 8 months after seeding. Such management for sugarcane in Puerto Rico would be a gross underutilization of the Island's year-round growing season. Such management would also ignore the plant's botanical need for at least two years to maximize its growth capability (9, 17).

2. Napier Grass; 3-Year Trends

(a) Maximum Yields: Three years of cropping show two distinct trends for DM production by napier grass: (a) Yields increase as harvest interval is delayed from two to six months, and decrease as the interval is extended to 12 months; and (b), the first-ratoon crop was the most productive while the plant and second-ratoon crops were about equal (Table 27). Unlike sugarcane, the general decline of DM evidenced by the third-year data was not expected.

Green matter yields were virtually equal for the 4-and 6-month harvest intervals (Table 28). Moreover, the second-ratoon yields were equal to those of the first-ratoon crop. In essence, the third year's napier grass appeared to be less mature at harvest than the previous year's crop (Table 29).

The highest average DM yield for the three crops was 27.5 OD tons/acre year, which derived from the combined yield of two, 6-month harvests (Table 27). This compares quite favorably with the highest 3-year average for sugarcane, ie, 29.0 OD tons/acre year (Table 21).

(b) Row Spacing Trends: Narrow row spacing had virtually no effect on DM yields by napier grass over a time-course of three years (Table 30). Very small yield increases were recorded at the 2-and 4-month harvests of the plant crop, but these subsequently disappeared and there were no consistent differences noted thereafter. Like sugarcane, there appeared to be sufficient plants at standard row spacing (50 cm) to take complete control of the area when sufficient time was allowed for them to do so. Narrow row spacing similarly had no effect on trash yields by napier grass (Table 25).

3. Plant Density; 3-Year Trends

(a) Sugarcane: As a main effect the number of sugarcane stems per acre was highest for the first ratoon crop and declined moderately thereafter (Table 31). However, for the critical 12-month interval the number of stems increased each year. The highest absolute number was approximately 115,000 stems/acre, produced by the 4-month harvest interval of the first-ratoon crop. The lowest number, slightly less than 8,000 stems/acre, was obtained from the 2-month harvest interval of the second ratoon crop.

(b) Napier Grass: Napier grass produced an enormous number of stems per acre, approximately three times more than sugarcane as a main effect (Table 31). Mean values indicate that stem density was highest for the second-ratoon crop. In terms of harvest interval, the greater number of stems was produced by the 4-month harvest and the fewest by the 12-month harvest. For both napier grass and sugarcane there was no apparent relationship between the treatments producing the highest number of stems and the highest tonnages of biomass.

4. Seasonal Influences On Cane And Napier Grass

The project's experiments are being performed at sea level at approximately 18° north latitude. This is a tropical setting widely recognized for its year-round growing season. Nonetheless there were definite seasonal variations in the growth rates of both sugarcane and napier grass.

The 2-month interval from January 15 to March 15 was the least productive for both sugarcane (Table 32) and napier grass (Table 33). This is attributed to the relatively cool nights in Puerto Rico during this period. Because this interval also falls within the Island's dry season, some claim can be made that the growth reduction was a result of reduced water supply. This could be a contributing factor, for eventhough the experiments were irrigated it is impractical to simulate the region's natural rainy season by this means.

The 4-month harvest intervals correspond roughly with three seasons in Puerto Rico: Late humid summer (July 15 to November 15), semi-arid "winter" (November 15 to March 15), and early humid summer (March 15 to July 15).

For both sugarcane and napier grass the season least suitable for growth was the semi-arid winter (Table 34). This was clearly evident for the two ratoon crops of each species. In the case of sugarcane nearly half of the ratoon crops' total annual yield was produced in a 4-month period from July 15 to November 15. The importance of the warm, humid, late summer months to sugarcane growth has been recognized for many years by sugar planters seeking to maximize tonnage. Hence, the Island's "gran cultura" crop was always planted by early August, thereby enabling the cane to pass through two late summer growing seasons before being harvested at 16 to 18 months of age.

D. FIELD PLOTS; SECOND GENERATION ENERGY CANE

A "second generation" study on energy cane 1/ was established at the AES-UPR Lajas Substation during August and September, 1980. This is the

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1/ "Energy cane" is sugarcane managed for maximum growth rather than sucrose.

project's last major experiment designed to demonstrate the upper yield potentials of tropical grasses.

Essentially three "generations" of energy cane were envisioned at the project's onset in 1977: (a) Existing sugarcane varieties, developed for sugar, whose biomass yields could be improved by management practices oriented to growth rather than sugar; (b), existing varieties having superior biomass yield potentials but otherwise unplanted in the sugar-oriented commercial cane industries; and (c) new progeny to be bred specifically for the high DM yield attribute, with fermentable solids (molasses) as a major by-product.

From the seed sources available in 1977 three "first generation" varieties were selected for the project's initial studies on cane biomass. Each variety has a history of high yields for both sugar and bagasse over a range of PR soil and rainfall conditions. Equally important was the immediate availability of seed from Puerto Rico's sugar industry. However, without question, these varieties fail to represent the maximum yield potentials of Saccharum. A search has been underway since 1977 to identify superior biomass canes already extant in Puerto Rican and Federal collections. Seed expansion for a series of promising candidates was begun late in 1979.

1. Treatments And Harvest Intervals

The newly-established energy cane experiment has 27 treatments with four replications arranged in a randomized split-plot design (Table 35). There are three primary treatments (harvest frequencies at 6-, 12- and 18-month intervals), three subtreatments (varieties PR 980, US 67-22-2, and B 70-701), and three sub-subtreatments (variable nitrogen at 200, 400, and 600 lbs/acre year of elemental N). Row spacing is constant among all treatments at standard 60-inches. Irrigation is also constant at approximately 54 acre inches/year administered as needed via border irrigation in 2-inch increments.

Variable harvest intervals underscore the need for more than one year to optimize Saccharum biomass. An important shortcoming of our previous energy cane work was a 12-month maximum interval between harvests, a reflection of commercial sugarcane management in Puerto Rico. At least 18 months are needed to maximize total dry matter in sugarcane. Of the three test varieties, US 67-22-2 and B 70-701 are "second generation" canes having enormous growth potential under PR conditions. PR 980 is a reference variety typifying the Island's commercial sugarcane. For "first generation" canes managed as biomass crops, about 400 lbs of elemental N are required per acre year. The new N variables will indicate the degree to which this quantity might be reduced (or profitably increased) in varieties specifically selected for dry matter and molasses. The N source is ammonium sulfate in 16-4-8 fertilizer formualtion administered incrementally at 3-month intervals.

2. Projected Yields

The first-generation studies completed to date indicate an average yield of 29.0 OD tons/acre year (28). This figure is the average of three crop years (the plant crop plus two ratoon crops). Annual yields varied from 25.6 OD tons/acre for the plant crop to 33.6 OD tons/acre for the first ratoon crop. The second ratoon crop yield was intermittant between those of the first two crops and subsequent crop years are expected to be still lower (Figure 5). The yield value of 29.0 OD tons probably represents the highest average yield attainable for first-generation energy cane intensively propagated under PR conditions in a 3-year cropping cycle.

With intensive management the second-generation canes US 67-22-2 and B 70-701 should exceed these yields by a significant margin. Projected DM yields for both varieties are in the order of 40 OD tons/acre as a 12-month crop and 50 OD tons/acre as an 18 month crop (Table 36)[1/]. Third-generation canes, that is, hybrid varieties developed specifically for high yields of dry matter and molasses, could conceivably exceed the second generation yields by up to 20 OD tons/acre

3. Yields; First 6-Months Harvest

(a) Green Matter: Total green weight values at 6 months were surprisingly high for all treatments while indicating a relatively superior growth performance by variety US 67-22-2. However, also quite surprisingly, there were no appreciable differences among the variable N treatments (Table 37). Millable cane yields were also high at 6 months (Table 38), averaging nearly 34 tons/acre for all treatments. There were no appreciable differences among varieties and N variables. It is noteworthy that Puerto Rico's commercial cane industry averaged only 26.6 tons cane per acre (TCA) for the 12-month crop in 1980.

On an individual plant basis, total green weight values again showed little variation among varietal and N treatments (Table 39). Millable stem weights were moderately lower for variety US 67-22-2 (Table 40). The latter variety displayed a notably massive green canopy at this period, with the green-leaf area extending down to the soil surface. The principal varietal

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1/ In Puerto Rico conventional sugarcane is managed as two categories of crops, the "primavera" (10 to 12 months between harvests) and the "gran cultura" (16-18 months between harvests).

difference at this time was a perceptively greater height of B 70-701. The stem length for this variety averaged 41 and 57 percent greater than for PR 980 and US 67-22-2, respectively (Table 41). Stem length was not affected appreciably by variable N.

Varietal differences were also evident in the number of harvested stems per acre (Table 42). Stubble counts indicated a moderately greater density of plants for the two "second generation" varieties (US 67-22-2 and B 70-701) which averaged over 45,000 stems/acre, as opposed to about 38,000 stems/acre for PR 980. The latter figure is also relatively high for 6-months old cane in a "plant" crop.

(b) Dry Matter And Plant Maturity: Dry matter yields were slightly higher for varieties US 67-22-2 and B 70-701 than for PR 980 (Table 43). The highest yield was 11.1 short tons/acre, produced by US 67-22-2 under a "low" N regime of 200 lbs elemental N/acre year. The lowest yield was 8.0 short tons/acre year, from PR 980 under "high" N (600 lbs elemental N/acre year). For the most part there was little difference in yields among the variable N regimes. By way of reference the PR sugar industry produced about 9.0 dry tons/acre in 1980 as an Island-wide average for 12-month cane.

The maturity of all of the cane harvested at this period, as evidenced by DM content, was quite low (Table 44). DM content averaged 16.9% for all treatments at 6 months, whereas approximately 25% DM would be expected at 12 months and 30% or more for an 18-month gran cultura crop. Maturity was slightly higher for variety B 70-701, and within the "low" N regime of each variety (Table 44). These maturity values suggest that all plants were responding to an abundance of water and available N irrespective of varietal and N-fertilization regimes.

(c) Juice Quality: Further evidence of the plants' total commitment to growth at this time was the very low qualitative values obtained for raw juice. For all treatments, Brix and Pol values averaged 5.4 and 1.4, respectively (Tables 45 and 46). The values from variety B 70-701 were lowest for both parameters; however, varietal differences at these levels of magnitude have little meaning since there was very little in the way of extractable fermentable solids contained in this cane. Rendiment levels were near zero for PR 980 (Table 47), and negative values were recorded for the varieties US 67-22-2 and B 70-701. The poor quality of this cane was anticipated. Similarly, quite respectable yields of fermentable solids and sucrose should accrue at the 12-and 18-month harvest intervals, at least on a per-acre basis, even if the quality of individual plants remains low.

(d) Fiber And Trash: 1/ Fiber content was generally quite low, ranging from 7.1 to 13.8% (Table 48). There were no consistent differences among variable N regimes. Fiber was moderately higher in the two second generation varieties than in PR 980.

Trash yields averaged slightly less than 1.0 ton/acre for all treatments (Table 49). This amounted to roughly 10% of the total dry matter yield at 6 months. Trash values should increase to about 20-30% of total DM yield for the 12-and 18-month harvests. Variety B 70-701 produced slightly less trash than US 67-22-2 and PR 980. There were no consistent yield responses to the variable N regimes.

1/ "Trash" in this instance includes only leaf and leaf-sheath tissues that had detached from the stem and fallen to the ground. It does not include materials still adhering to the stem.

(e) Lack of N-Fertilization Response: The minimal response to increasing N fertilization is attributed to two factors: (a) The incorporation of organic matter into the soil (old bales of Sordan 70A, approximately 2 tons/acre) at the time of seedbed preparation, and (b), conditioning of the upper root zone with a land rotavator prior to seeding. The organic matter was added to help maintain soil structure during the subsequent 3-year period of intensive production operations. Up to 80 pounds of N/acre could become available from this source within one to three months via N mineralization. Perhaps more important was the thorough rotavation of the seedbeds' upper 6 to 8 inches. The Fraternidad soil series of this region are notably heavy and plastic and excessive compaction of new seedbeds is a common occurrence. The rotavation of this site was the first use of such an implement in the Lajas Valley. It provided a light, freeable structure at the time of planting. Recompaction of the soil occurs gradually through the effects of rainfall plus the traffic of labor and machinery. It is believed, however, that the soil's native fertility contributed more effectively to the plants' establishment and early growth performance than was formerly possible. Unfortunately, no control plots were retained as a check against rotavator effects. A subsequent cane planting (seed expansion for variety US 67-22-2) planned for mid 1981 will include soil rotavation as a controlled variable.

E. FIELD-SCALE STUDIES

1. Energy Cane Demonstration Study; Hatillo

Through the project's third year a majority of field-plot and field-scale experiments have been confined to the AES-UPR Lajas Substation on Puerto Rico's semi-arid southwest coast. This is a major agricultural region having important potential as a future zone for biomass energy cropping. There is an abundance of rain-free days suitable for solar drying operations. Irrigation is required for approximately 8 to 10 months annually.

The project's original work plan called for at least one major study with sugarcane somewhere on the Island's humid north coast. A site more closely integrated with private farms than is possible with Experiment Station lands was also desired. A favorable opportunity arose for establishing such a study during the spring of 1980. Mr. José B. De Castro, an elderly landowner having a strong personal interest in biomass energy cropping, offered CEER-UPR the use of 30 acres near the northwest coastal town of Hatillo. The offer was accepted and an energy cane demonstration study was established there during July and August of 1980.

The land itself is situated on a deep alluvial plain bordered by the Camuy River. The predominate soil series is a feeable Coloso clay loam, much less plastic than the Fraternidad clay series at Lajas. The soil appears to be at least four to six feet deep and is well drained; in fact, this farm is an "all weather" site insofar as most agricultural production operations are concerned. The De Castro farm had not been cultivated for seven years and was occupied by a mixture of volunteer sugarcane and wild grasses.

During the first quarter approximately 25 acres were mowed with a rotary scythe, plowed, rotavated, land-planned, limed, and planted into three field-scale treatments: (a) An energy cane planting, of approximately 17 acres, in which intensive production operations will be demonstrated; (b), a control plot of about 2.5 acres managed as conventional sugarcane; and (c), a second control plot, about 6 acres, simulating the unmanaged wild sugarcane that had been occupying the site until the summer of 1980. In addition, about 2 acres were planted in the "second generation" energy cane US 67-22-2, as part of the seed expansion program for this variety.

Production inputs for the three treatments are summarized in Table 50. A single cane variety, PR 980, is being used for all treatments. The energy cane treatment is double-seeded at standard (150 cm) row centers. Ungerminated spaces in the row were replanted, and the area was watered by overhead irrigation from the Camuy River. This cane received 200 lbs of elemental N/acre applied as a band beneath the seed in the furrow. An additional 400 lbs of elemental N/acre are being administered as side-dressed increments at months 4 and 8. A single "gran cultura" harvest will be performed 18 months after planting. Planned production input costs will be held under $900.00/acre/18 months. Our primary objective is to demonstrate yields of at least 90 tons/acre of millable cane, plus about 15 tons/acre of trash, at costs commensurate with an attractive margin of profit for north-coast planters.

Additional work was performed at the Hatillo site during the second quarter. This included: (a) Subsoiling of all treatments four weeks after germination of the cane; (b) post-emergence weed control operations; and (c), overhead irrigation of the plants about six weeks after germination

The subsoiling operation is designed to improve root-zone development in a fertile but relatively compacted soil. The same concept can be applied with profit to most of Puerto Rico's best agricultural lands where soil compaction in one form or another has been underway for over four centuries. The implement used in this study was originally constructed by the UPR Department of Agricultural Engineering for demonstration use on conventional sugarcane. If consists of a heavy-duty tool bar and two vertical steel shanks having a maximum submergeable depth of about 30 inches. These are bolted to the tool bar and can be adjusted laterally to accommodate variable row spacing. A horizontal blade is attached to the bottom of each shank; these provide lateral shattering of the soil directly beneath the row center. This implement can be used with maximum effect at time of planting, or immediately following germination when plant rows are clearly visible to the driver. A Category III tractor is required.

Preemergence weed control with Atrazine and Amytrine was generally quite effective at the Hatillo site. One weed, a species of Ipomea, survived the preemergence treatments and its population increased markedly as a result of the subsoiling operations. It produces a long, trailing vine which overruns sugarcane and other upright plants within a few weeks. This weed was effectively controlled with 2,4-D.

Overhead irrigation was needed to offset an unseasonal dry period during September and October. A very adequate water source is provided by the Camuy River which adjoins the experimental site. The seedbed itself was leveled, land-planned, and bordered for eventual water application by flood irrigation. The necessary pumping capacity for border irrigation of this site (about 1400 gallons/minute) was not immediately available. Alternatively, a portable overhead unit was rented at nominal cost from the PR Sugar Corporation. This is a "big gun" system delivering in the order of 600 gallons of water/minute. With this system the Hatillo site was provided with approximately four acre inches of water in less than three days.

2. Supplemental Irrigation; Hatillo Site

Although the Hatillo site is situated in a semi-humid region, a need develops for supplemental irrigation each January at the onset of the area's dry season. Irrigation can be performed to great advantage during four or five months of the year eventhough private planters there have rarely done so. To sustain maximum growth of the energy cane study, flood irrigation was initiated in February of 1981, using a 2000 gpm Rainbow Company pump to obtain water from the Camuy River which adjoins the experimental farm. The pump is portable, diesel powered, and equipped with a 30 ft. intake tube with screened foot-valve. A 30 ft. discharge tube is also transported with the unit for convenient placement of the pumped water.

The Hatillo site was leveled, land-planned, and bordered to receive the seasonal irrigation water as part of the land preparation operations in 1980. Water is provided to approximately 2/3 of the planted area, the remainder being divided into control plots of unirrigated energy cane and unirrigated conventional sugarcane. It is calculated that roughly one additional ton per acre of energy cane will eventually be harvested for every acre inch of water provided during the Hatillo dry season.

3. Initial Yields At 6 Months; Hatillo Site

The principal harvest interval for this study is 18 months. It is intended to demonstrate the disproportionately larger yields to be gained through delay of energy cane harvest by 6 months, ie, by use of the "gran cultura" cropping system rather than the 12 month "primavera" system employed for most of the sugar industry's cane. In the meantime, as an indicator of crop development, cane samples from each of the study's four experimental fields are being harvested at 6 months and 12 months after planting. The 6-months data are included in this report.

(a) Green Matter And Millable Cane: The field demonstration plots at Hatillo include three management variables using the project's standard high biomass variety, PR 980: (a) A low-tillage control in which cane is essentially allowed to grow wild after being assisted in its establishment;

(b) a "Sugar Corporation" control in which the cane is managed according to procedures used by Puerto Rico's cane sugar industry; and (c), energy cane management in which the same variety is encouraged to produce maximum biomass rather than sugar. There is one additional plot consisting of about two acres of variety US 67-22-2, a "second generation" energy cane receiving the same energy cane production inputs as PR 980. This is a varietal expansion planting designed to increase seed for the eventual replacement of variety PR 980. For the initial growth measurements, 1000 square feet of each PR 980 treatment and 400 square feet of US 67-22-2 were harvested at 6 months of age.

Total green weight yields varied but little among the three PR 980 treatments which averaged 34.5 tons/acre (Table 51). Variety US 67-22-2 produced about 45% more green matter at 50.2 tons/acre. Millable cane yields were slightly higher for energy cane (24.0 tons/acre), but for this parameter also the three PR 980 treatments were essentially equal (Table 52). Again, US 67-22-2 produced the highest yield at 34.7 tons/acre, about 56% higher than the PR 980 average. Top weights (representing the non-millable green canopy and immature internodes) averaged 7.6 tons/acre for PR 980 and 12.3 tons/acre for US 67-22-2 (Table 53).

Trash yields similarly varied but little among treatments (Table 54). In this study, "trash" refers to leaf and leaf-sheath tissues, both green and partially desiccated, which were still adhering to the stem at time of harvest. These were stripped off by hand in order to obtain millable stem weights. Under mechanized harvest conditions (with a Klass whole cane harvester), these tissues would be largely removed in the field by a powerful air blast.

The "tops" (Table 53) would be removed by a vertically-adjustable set of circular discs, or "topper", which is also a component of the Klass harvester. The topper's cutting level is under direct control of the machine operator; hence, the precise point of topping is a matter of judgment and considerable skill of the man operating this machine.

(b) Dry Matter Yield: Dry matter yields were unremarkable and essentially equal for the three PR 980 treatments, averaging 6.0 tons/acre (Table 55). Variety US 67-22-2 produced 8.8 tons/acre, or 47% more than the PR 980 average. The unspectacular DM yields were lartely a function of the low maturity of all cane at this point in the study. Dry matter content, averaging 17.5%, was nearly equal for each of the four cane plots (Table 56).

(c) Plant Height And Density: There were some small variations in plant height among the three PR 980 treatments, ranging from 4.7 to 5.4 feet (Table 57). The average height of US 67-22-2 was perceptibly lower at 4.1 feet. The principal feature of this variety which accounted for its superior yields was an ability to produce a greater number of stems per planted area. Hence, within six months after seeding, US 67-22-2 had produced 46,000 stems/acre, some 50% more than PR 980 which averaged 30,700 stems/acre (Table 58).

4. Mechanization Trials

Mechanization studies continued during the first quarter with two implements of special interest to this project. These are the rotary scythe-conditioner and the round baler. They are viewed as potential answers to the harvest and post-harvest management of tropical grasses having standing tonnages at harvest far in excess of conventional forage grasses, but somewhat lower tonnages than sugarcane. Initial trials on Johnson grass and Sordan were very successful (1, 2). Considerably more demanding tests were begun on 6-months old napier grass late in Year 3. The results have already been described in detail (3). They seen to indicate that, with limited modification and correct training of the equipment operators, such implements can deal successfully with the high-density biomass offered by mature stands of napier grass.

(a) Yield Data; 6 Months: A 2.75 acre stand of 6-months old napier grass was evaluated for yield and crown injury with the M-C rotary scythe operated at two mowing heights. The latter were "low stubble" (1 to 2 inches) and "high stubble" (8 to 10 inches). Four subplots of 0.69 acres each were mowed on June 20 and were solar-dried and baled over a 4-day interval. Drying operations included two days exposure to the sun as the material lay behind the rotary scythe, followed by windrowing with a conventional forage rake, and turning the windrows over twice with the same rake. The solar-dried material was baled on June 24, at which time the moisture content was approximately 15 percent.

Overall dry matter yields averaged 9.3 tons/acre, with high stubble and low stubble plots averaging 8.4 and 10.2 tons/acre, respectively (Table 59). Because of a large variation in low stubble yields these data are taken only as a very preliminary indication of mowing height effect. Moreover, a significant amount of conditioned biomass lay flattened between the stubble and could not be recovered with the available forage rake 1/.

1/ This implement, like most standard forage rakes, operates as a single unit driven from the tractor's PTO system. When any portion of the rake is lifted by a plant crown, much of the entire rake is lifted and passes over a layer of biomass untouched by the implement's tines.

Upon visual inspection some of the stubble appeared broken and crushed by the tractor and rotary scythe. However, the same crowns generally produced an abundance of new shoots within a few days after mowing. It is believed that (a) either the latent buds (located at or slightly below the soil surface) were not injured by the machinery passing above, or (b), more than a sufficient number of buds survive these operations to reestablish a normal plant stand even when some of the buds are destroyed. It is also possible that some level of crown injury is stimulatory to shoot production.

(b) Fuel Consumption And Estimated Horsepower: Fuel consumption was measured for the napier grass harvests described above (Table 59). These measurements refer to the total diesel fuel consumed by a model 8700 Ford tractor (a category III, 120 hp unit), operating a M-C model 9-E rotary scythe (9 foot mowing swath), both idling and in actual movement on the measured test plot areas. They do not include movement of the tractor and implement to and from the fields themselves. Estimates of the horsepower utilized by the tractor were calculated from the fuel consumption figures in accordance with published Nebraska Tractor Test Data for the model 8700 Ford tractor (Table 60).

Diesel fuel consumption was somewhat lower than expected, ranging from 2.38 to 2.95 gallons/hour, or 1.92 to 2.69 gallons/acre. A fuel consumption level in the order of magnitude of sugarcane harvesters had been anticipated (roughly 4 to 6 gallons of diesel fuel/hour). It should be noted that the standing green biomass confronting the rotary scythe (about 40 tons/acre) exceeded the sugarcane tonnages confronting cane harvesters in Puerto Rico today (approximately 27 tons/acre as an Island-wide average).

Low-stubble mowing utilized moderately more fuel than high-stubble mowing (Tables 60 and 61). This relates to the greater resistance offered by napier grass stems cose to the soil surface, and to the greater tonnage of biomass to be conditioned with low-stubble harvesting. Alternatively, low stubble mowing does a much cleaner job. It minimizes the tendency of high mowing to leave long, ragged stubbles which in turn complicate raking and baling operations, in addition to leaving unharvested a significant fraction of the standing green napier grass.

Horsepower usage by the 8700 Ford tractor ranged from 35.7 hp at high-stubble mowing to 41.4 hp at low-stubble mowing (Table 60). Performance data provided by the Ford Company indicate that this tractor can supply about 95 gross hp at the power take off with an operating engine revolution range of 1500 to 1800 rpm (29). Hence, less than half of the tractor's work potential was being utilized in conditioning the 6-months old napier grass. On the other hand, it is estimated that the rotary scythe itself, although an extremely rugged implement, can utilize a maximum input of only about 60 hp without sustaining major damage (30). Exceptionally heavy stands of biomass, such as mature sugarcane or 12-months old napier grass, could likely place the rotary scythe work load in the 60 hp range. There would be no purpose in attempting this since there are cane harvesters available to deal with such materials.

5. Rotary Scythe Modifications

Mechanized harvest studies for short-and intermediate-rotation grasses have centered on three machinery units: (a) A rotary scythe-conditioner, manufactured by the Mathews Company; (b), a New Holland Company Round Baler;

and (c), a Farmhand Company wheel rake. The rotary scythe-condtioner is of decisive importance in the handling of large tropical grasses as solar-dried energy crops. Successful implementation of this unit would virtually assure an adequate performance of successive machines needed to deliver a solar-dried feedstock to the biomass processing or utilization center.

Rotary scythe trials on Sordan 70A and Johnson Grass delt with a maximum mass of about 20 tons/acre of standing green material. No problems were encountered and the machine completed the work it was designed to perform. With napier grass, representing 40 to 45 standing green tons/acre, the interior edge of the rotary scythe tended to lift from the ground when passing over exceptionally heavy or lodged clumps of grass. It was felt that this problem could be overcome by increasing the implement's weight. A second and more serious problem lay in its tendency to drag sections of uncut grass along its interior edge. This occurred in lodged and heavily matted materials that were interwoven in a contiguous mass. Such materials extended inward into uncut grass up to several yards beyond the cutting swath edge. In upright stands or where only partial lodging had occurred the rotary scythe easily sectioned off the biomass in normal swath segments.

The rotary scythe's problem in sectioning the heavy and matted napier grass was solved by fitting its interior cutting edge with a parting knife taken from a Klass Model 1400 sugarcane harvester. The parting knife consists of a single 12-inch blade which rotates counter-clockwise against a heavy metal plate and shears off impeding stems in a scissors-like action. It is normally driven by a hydraulic motor with a force of about 5 horsepower. Fortunately, the heavy-duty construction of the rotary scythe offered a 0.25 inch metal plate to which the parting knife frame and supports could be welded directly.

It was necessary to adapt the parting knife's hydraulic lines to the smaller dual remote outlets of the project's tractor (a Category III Model 8700 Ford). The lines themselves extend directly backward from the tractor, over the top of the rotary scythe's drive shaft and gear box, and then across the implement's backside where they remain free of entanglement with the conditioning grass stems. As described in earlier reports, the tall grasses being conditioned with this unit invariably drop forward of its leading edge and never backward over the machine itself. Otherwise neither the rotary scythe nor its affixed parting knife could perform their tasks in heavy tropical grasses.

In the limited tests made to date with this system it does not appear that we have developed the full cutting force of the parting knife, ie, as designed for operation on a sugarcane harvester. Nonetheless, its performance in 6-months old napier grass has been very good. It clearly sections through dense matter and lodged materials where formerly a rather ragged division was made, coupled with uprooted and dragged crowns of napier grass. Moreover, the rotary scythe ceased elevating above the ground in dense materials once the parting knife became operational. No supplemental weighting of the implement was necessary. The parting knife unit weights nearly 100 pounds so this in itself may contribute materially to the performance of the rotary scythe.

6. Napier Grass Processing

Formal utilization studies on tropical grasses lie beyond the scope of this project. However, project personnel have cooperated with others wishing to utilize or examine some of the harvested grasses that have no further use to the project. During 1979-1980, tropical grasses that had been solar-dried, baled, weighed, and then discarded, were donated locally for the following purposes: (a) As cattle feed by Lajas farmers, particularly Sordan 70A, but also mature napier grass (presumably mixed with more digestible forages); (b) as test additives to processed municipal refuse, by a firm developing alternative biomass products at Ponce, P.R.; (c) as a start-up boiler fuel by sugar mill engineers; and (d), as a source of cellulose for enzymic conversion to glucose in a local fermentation project.

Early in 1980, the New York-based firm Combustion Equipment Associates, Inc., became interested in solar-dried tropical grasses as potential feedstocks for a patented fuel product derived from agricultural residues. Termed AGRI-FUEL, the material is a fine powder that can be burned directly in existing oil-fueled furnaces. Such a product, if shown to be technically and economically feasible, would be of immense interest to Puerto Rico. During June of 1980 a SEA-LAND van was loaded with baled napier grass plus stored bagasse and shipped to CEA's processing plant at Bridgeport, Connecticut. CEA requested the materials for feedstock evaluation purposes and paid all transportation charges.

F. BREEDING STUDIES

1. Seedling Trials; Lajas Substation

The project's breeding phase aimed at producing new sugarcane progeny with superior biomass attributes was confined to the AES-UPR Gurabo Substation during the first three years. Recently, 92 seedlings showing some preliminary evidence of high tonnage capability were transferred to the Lajas Substation for second-phase evaluation. They were planted in unreplicated, 5' x 20' plots, with standard seedbed preparation, row spacing, fertilization, and weed control measures.

A total of six crosses are represented (Table 62). All were made by Mr. T. L. Chu during the autumn of 1979. All crosses were part of the AES-UPR Sugarcane Breeding Program, but in these instances there were parental types involved having important biomass attributes. Of special interest is the S. spontaneum hybrid US 67-22-2 which served as both female and male parent. Under Gurabo conditions this clone has shown very superior potential for the production of both sucrose and total biomass.

2. Seed Expansion For US 67-22-2

Early in 1980 the clone US 67-22-2 was planted in field plots at the AES-UPR Gurabo Substation for the purpose of producing seed for a second generation energy cane study. This study was planted at Lajas Substation late in July, 1980. The remaining seed of US 67-22-2 was shipped to Hatillo in August and planted on the De Castro farm for seed expansion purposes. Approximately 2.0 acres were planted in this variety. At intervals of 8 to 10 months the cane will be cut and planted in a larger seed expansion area. This in turn will be used for additional seed expansion. Within about three years there will be sufficient seed of US 67-22-2 to replace all older varieties in the Island's energy cane programs, including commercial-scale plantings of 50 acres or more.

3. New Crosses; 1980-1981 Breeding Season

Eight new crosses were performed in 1980 having the high biomass attribute as the principal objective for hybrid progeny. All crosses were performed by Mr. T. L. Chu at the AES Gurabo Substation.

Eleven parental clones were used in five breeding lines (Table 63). Four of the clones served both as female parents (contributing the somatic chromosome number) and as male parents (contributing the gametic chromosome number). These include PR 68-335, PR 67-1070, the S. robustum clones 57-NG54, and a wild S. spontaneum hybrid from Río Piedras (S. sp. RP). The use of 57-NG54 represents a long-desired entry of S. robustum germplasm into the AES-UPR cane breeding program.

An approximate total of 5,000 seedlings were produced by these crosses (Table 63). Of special interest is the contribution of both US 67-22-2 and B 70-701 as male parents in crosses with NCo 310. These are the two "second generation" clones already selected for seed expansion as energy canes in their own right. About 1150 seedlings were obtained from these crosses (items 7 and 8, Table 63). The most prolific progeny yield was obtained from the crossing of PR 68-1220 (female parent) with the hybrid PR 67-1070 x S. sp. RP (male parent). Some 2000 seedlings were obtained from this cross.

The total number of seedlings produced by these crosses is small by reference to major sugarcane breeding programs throughout the world. However, the quality of parental stock and breeding line selection for the intended purpose is very high. For this reason the probability of obtaining new progeny with interesting biomass attributes is good.

REFERENCES

1. Alexander, A. G., González-Molina, C., and J. Ortiz-Vélez. Production of Sugarcane and Tropical Grasses as a Renewable Energy Source. First Annual Report (1977-1978). DOE contract no. EG-77-G-05-5422. August, 1978.

2. Alexander, A. G., Allison, W., Ortiz-Vélez, J., Ramírez, G., Vélez, A., Vélez-Santiago, J., García, M., and T. L. Chu. Production of Sugarcane and Tropical Grasses as a Renewable Energy Source. Second Annual Report (1978-1979). DOE contract no. ET-78-S-05-5912. July, 1979.

3. Alexander, A. G., Allison, W., García, M., Ramírez, G., Chu, T. L., Vélez-Santiago, J., and L. Smith. Production of Sugarcane and Tropical Grasses as a Renewable Energy Source. Third Annual Report (1979-1980). DOE Contract No. DE-AS05-78ET20071. September, 1980.

4. Artschwager, E., and Brandes, E. W. Sugarcane. Agricultural Handbook No. 122. U.S. Govt. Printing Office, Washington, D. C., 1958.

5. Brandes, E. W., and Sartoris, G. B. Sugarcane: Its Origin and Improvement. USDA Yearbook of Agriculture. U.S. Govt. Printing Office, Washington, D. C. pp. 561-611. 1936.

6. Stevenson, G. C. Commentary on paper by S. Price and J. N. Warner. Proc. ISSCT 10: 791, 1959.

7. Chu, T. L. Breeding potentials for <u>Saccharum</u> biomass. Proc. Symposium on Alternate Uses of Sugarcane for Development. San Juan, P.R. March 26 and 27, 1979.

8. Alexander, A. G. Sugar and energy attributes of the genus <u>Saccharum</u>. Proceedings of the conference Alternative Uses of Sugarcane for Development, Caribe Hilton Hotel, San Juan, P.R., March 26 and 27, 1979.

9. Van Dillewijn, C. Botany of Sugarcane. The Chronica Botanica Co., Waltham, Mass., 1952.

10. Alexander, A. G. The energy cane concept for molasses and boiler fuel. Proc. Symp. "Fuels And Feedstocks From Tropical Biomass". Caribe Hilton Hotel, San Juan, P.R., Nov. 24 & 25, 1980.

11. Vicente-Chandler, J., Silva, S., and J. Figarella. Effects of nitrogen fertilization and frequency of cutting on the yield and composition of napier grass in Puerto Rico. J. Agr. Univ. P.R. 43(4): 215-227, 1959.

12. Sotomayor-Ríos, A., Vélez-Santiago, J. Torres-Rivera, S., and S. Silva. Effect of three harvest intervals on yield and composition of nineteen forage grasses in the humid mountain region of Puerto Rico. J. Agr. Univ. P.R 60(3): 294-309, 1976.

13. Saterson, K. Herbaceous species screening program. Third Annual Biomass Energy Systems Conference. Colorado School of Mines. Golden, Colorado. June 4-7, 1979.

14. Saterson, K. A., et al. Herbaceous species screening program. Phase I. Final Report. DOE Contract No. ET-78-C-02-5035, 1979.

15. Irvine, J. E. Genetic potentials and constraints in the genus Saccharum Proc. Symposium on Alternate Uses of Sugarcane for Development. San Juan, P.R. March 26 and 27, 1979.

16. Stevenson, G. C. Genetics and Breeding of Sugarcane. Longmans, Green and Company, London, 1965.

17. Alexander, A. G. Sugarcane Physiology: A Study of the Saccharum Source-to-Sink System. Elsevier Scientific Publishing Company, Amsterdam, 1973.

18. Personal communications with Mr. T. L. Chu, Plant Breeder and Sugarcane Commodity leader, AES-UPR Gurabo Substation.

19. Talleyrand, H., Pérez-Escolar, R., Lugo-López, M. A., and T. W. Scott, Utioization of N from crop residues in Oxisols and Ultisols. J. Agr. Univ. P.R. 61(4): 450-455, 1977.

20. Pérez-Escolar, R., Scott, T. W., and M. A. Lugo-López, Legume and Nonlegume Crop Residues as Sources of N in Oxisols and Ultisols. J. Agr. Univ. P.R 62(3): 361-366, 1978.

21. Warmke, H. E., Freye, R. H., and J. García. Evaluation of some Tropical Grass Legume Associations. Tropical Agriculture 29: 115-121, 1952.

22. Alexander, A. G., Co-Production of Tropical Legumes and Tropical Grasses as a Renewable Energy Source. Research Project Proposal Submitted to the US Agency for International Development. September, 1980.

23. Anon. Informe Número 24, 16 al 20 de junio (FINAL). Progreso de Molienda, Zafra 1980. Junta Azucarera de Puerto Rico, San Juan, P.R.; June, 1980.

24. Vicente-Chandler, J. Concepts, plan, and program for a modern agriculture in Puerto Rico. Commonwealth of Puerto Rico, Department of Agriculture, Santurce, P.R., 1978.

25. Alexander, A. G., Allison, W., García, M., Ramírez, G., Chu, T. L., and Vélez-Santiago, J. Production of Sugarcane and Tropical Grasses as a Renewable Energy Source. First and Second Quarterly Reports (1979-1980). DOE Contract No. DE-AS05-78ET20071. December, 1979.

26. Alexander, A. G. Biomass as a source of boiler fuel and molasses for Puerto Rico. Tec-nical Congress for the Investigation and Conservation of Energy Resources. El San Juan Hotel, San Juan, P.R., Nov. 7-9, 1979.

27. Energy Cane Management for Molasses and Boiler Fuel. Research project proposal, CEER-UPR to the Office of the Governor, Commonwealth of Puerto Rico, Dec., 1979.

28. Alexander, A. G., Allison, W., García, M., Ramírez, G., Chu, T. L., Vêlez-Santiago, J., and L. Smith. Production of Sugarcane and Tropical Grasses as a Renewable Energy Source. First Quarterly Report, 1980-1981. DOE Contract No. DE-AS05-78ET2007. November, 1980.

29. Anon. Ford 8700 and 9700 Specifications; p. 4 of Ford Company flier no. M-2537-E, entitled "FORD 8700-9700". FORD Tractor Operations, Troy, Michigan 48084. Received June, 1977.

30. Personal communications with Mr. William Allison, Agricultural Engineer, UPR Mayaguez Campus, June, 1980.

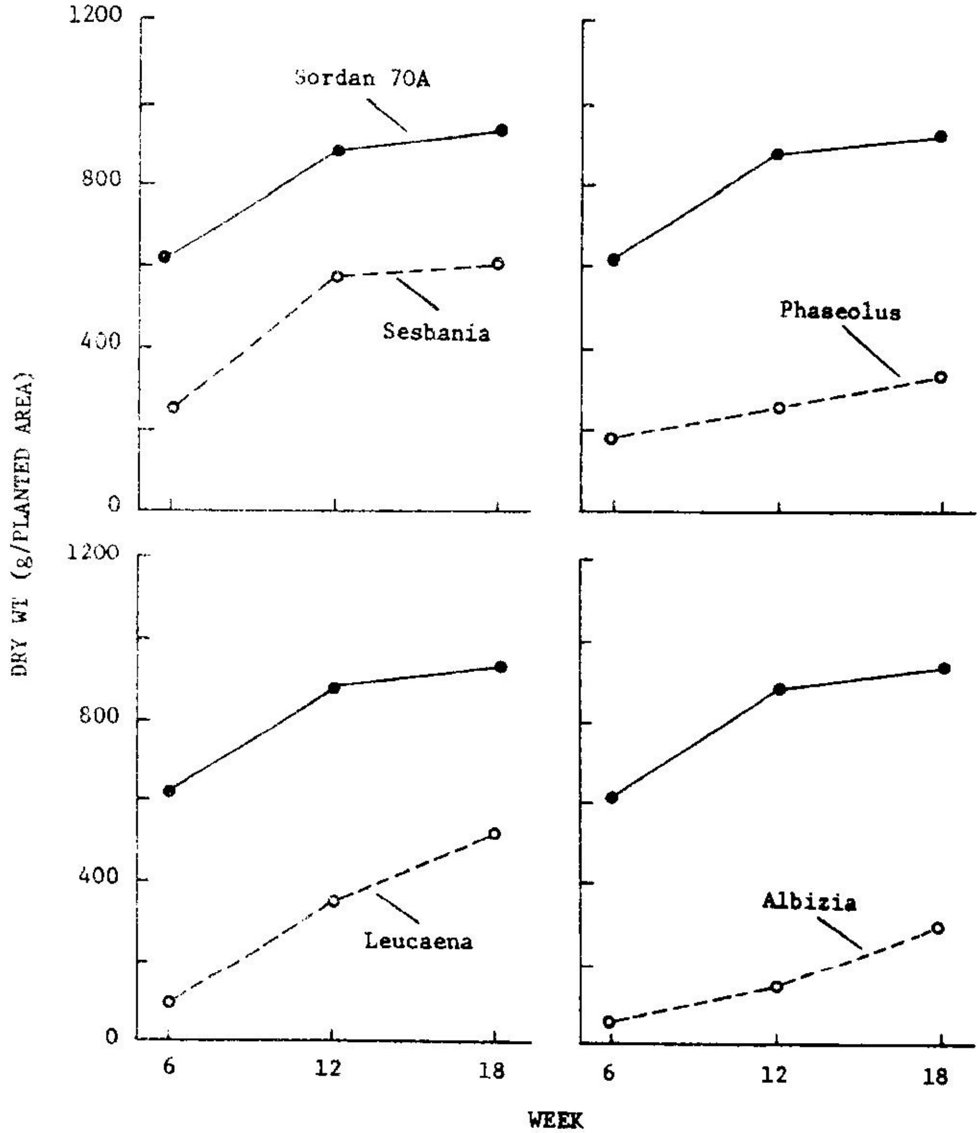

FIGURE 1. Relative dry matter production by Sordan 70A and four tropical legumes propagated in the greenhouse with a soil/cachaza growth medium. Planted area = 60 ft^2/species/harvest.

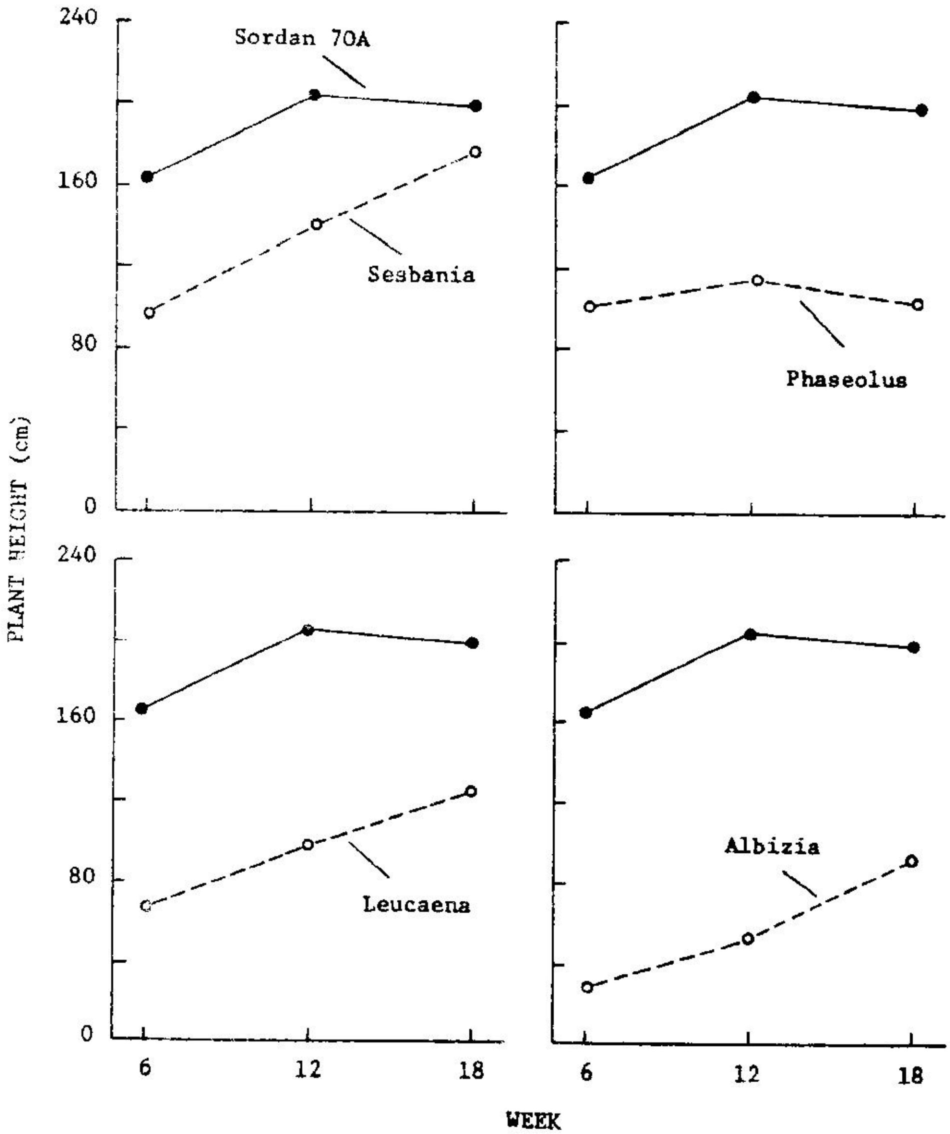

FIGURE 2. Vertical growth by Sordan 70A and four tropical legumes propagated in the greenhouse with a soil/cachaza growth medium. Planted area = 60 ft^2/species/harvest.

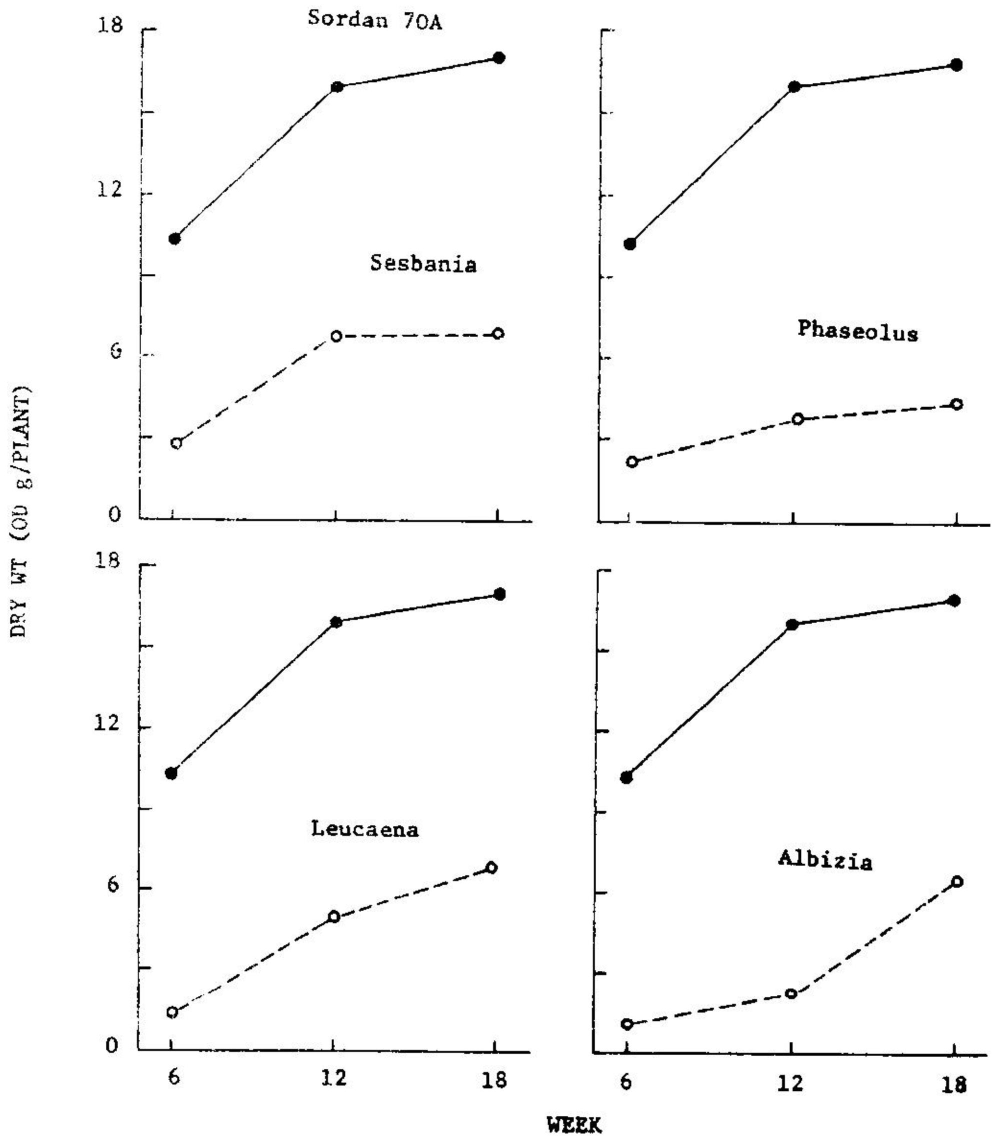

FIGURE 3. Individual plant weights for Sordan 70A and four tropical legumes propagated in the greenhouse with a soil/cachaza growth medium.

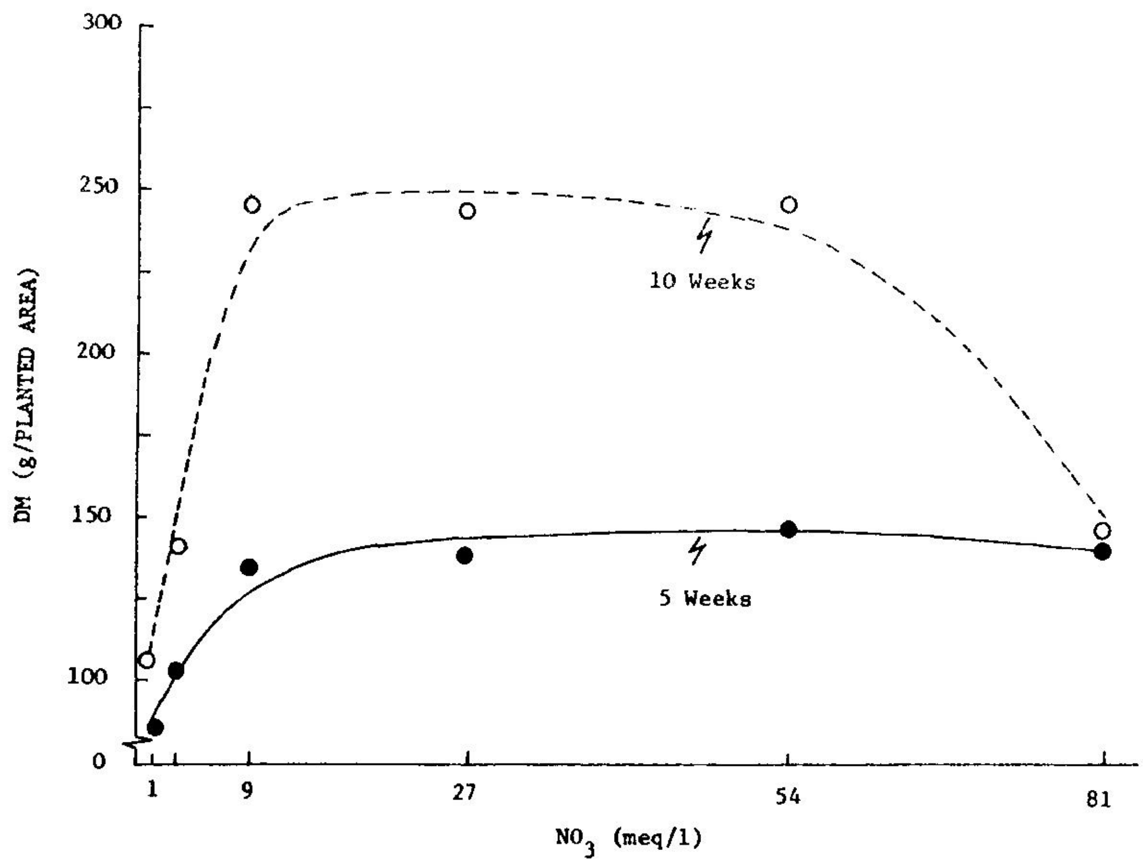

FIGURE 4. DRY MATTER YIELD OF SUGARCANE SUPPLIED WITH VARIABLE NO_3 IN SAND CULTURE AND HARVESTED AT 5 AND 10 WEEK INTERVALS

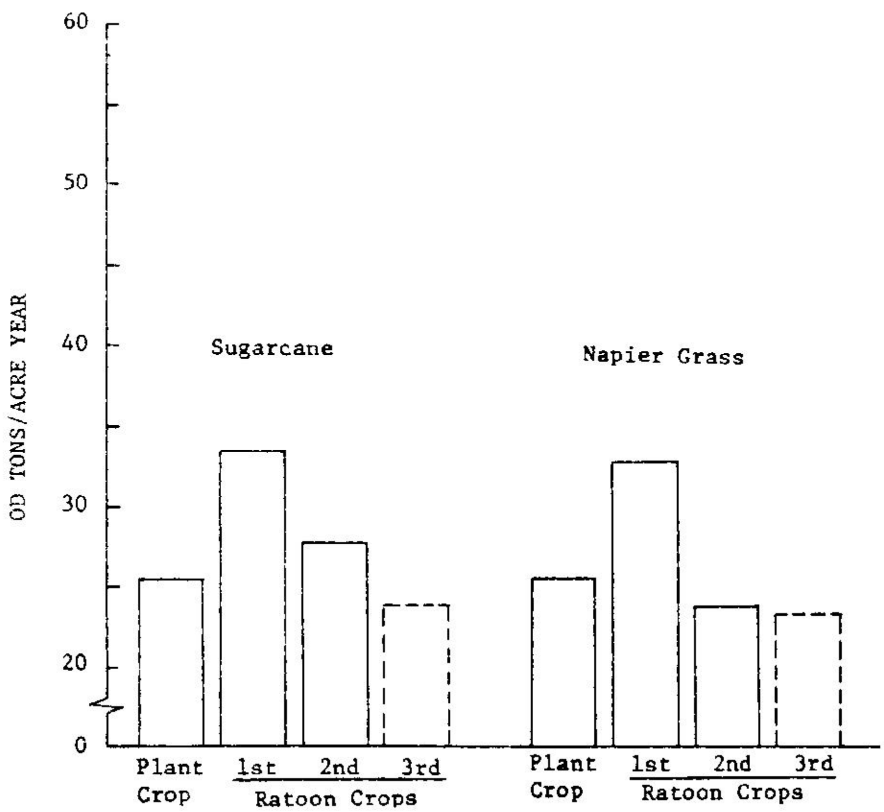

FIGURE 5. Total dry matter yields by sugarcane and napier grass over three successive crop years. Estimates for fourth-year yields (3rd ratoon crops) are also indicated. Sugarcane values are the computed mean of three varieties and two row spacings; napier grass values are the mean of two row spacings. Sugarcane yields represent a single 12-month growth interval per crop year, and napier grass the combined yields of two 6-month growth intervals per crop year.

TABLE 1. RESEARCH PHASES FOR BIOMASS PRODUCTION STUDIES WITH TROPICAL GRASSES

Research Phase	Class Of Objectives
Greenhouse	Physiological-Botanical
Field Plot	Botanical-Agronomic
Field Scale	Agronomic-Economic
Commercial-Industrial	Economic

TABLE 2. CATEGORIES OF CANDIDATE TROPICAL GRASSES

Cropping Category	Growth Interval 1/ (Months)	DM Maximum 2/ (Months)
Short Rotation	4-6	2-3
Intermediate Rotation	8-18	4-6
Long Rotation	36-60	12-18
Minimum Tillage	Indeterminate	(?)

1/ Replanting frequency; at least two ratoon crops are anticipated.

2/ Time required physiologically to maximize dry matter.

TABLE 3. RELATIVE GROWTH RATES OF SORDAN 70A AND FOUR LEGUME SPECIES INDIGENOUS TO PUERTO RICO 1/

Species	Green Wt (g), At Week - 6	12	18	Mean
Sordan 70A	2,970	2,745	2,175	2,630
Leucaena leucocephala	425	792	1,370	862
Phaseolus lathyroides	1,005	1,277	1,745	1,342
Albizia lebbek	215	510	1,132	619
Sesbania sp.	1,237	1,842	2,729	1,936
Mean	1,170	1,433	1,830	
		Dry Wt (g)		
Sordan 70A	633	882	933	816
Leucaena leucocephala	93	344	515	317
Phaseolus lathyroides	188	261	347	265
Albizia lebbek	51	137	297	162
Sesbania sp.	256	565	599	473
Mean	244	438	538	
		OD g/Plant		
Sordan 70A	10.4	16.1	17.0	14.5
Leucaena leucocephala	1.3	5.0	6.9	4.4
Phaseolus lathyroides	2.2	3.8	4.3	3.4
Albizia lebbek	1.0	2.2	6.5	3.2
Sesbania sp.	2.8	6.8	6.9	5.5
Mean	3.5	6.8	8.3	
		Plant Height (cm)		
Sordan 70A	165	208	198	190
Leucaena leucocephala	66	98	126	97
Phaseolus lathyroides	102	114	103	106
Albizia lebbek	29	53	93	58
Sesbania sp.	98	140	177	138
Mean	92	123	139	
		Percent Dry Matter		
Sordan 70A	21.2	32.1	42.8	32.0
Leucaena leucocephala	21.9	33.3	37.6	30.9
Phaseolus lathyroides	18.8	20.3	19.8	19.6
Albizia lebbek	23.9	26.8	26.2	25.6
Sesbania sp.	20.6	24.6	25.9	23.7
Mean	21.3	27.4	30.5	

1/ Growth data per planted area, approximately 60 ft.^{2}/species/harvest.

TABLE 4. RELATIVE GROWTH RATES OF SORDAN 70A AND FOUR LEGUME SPECIES PLANTED IN SPRING (MAY) AND AUTUMN (NOVEMBER)

Species	Week 6		Week 12		Week 18		Mean	
	May	November	May	November	May	November	May	November
	Green Wt (g), At Harvest Week And Month Of Planting 1/							
Sordan 70A	2,970	2,682	2,745	3,103	2,175	3,048	2,630	2,944
Leucaena leucocephala	425	109	792	310	1,370	467	862	295
Phaseolus lathyroides	1,005	483	1,277	693	1,745	248	1,342	475
Albizia lebbeck	215	44	510	103	1,132	178	619	108
Sesbania sp.	1,237	814	1,842	1,155	2,729	1,408	1,936	1,126
Mean	1,170	826	1,433	1,073	1,830	1,070	1,478	990
	Dry Wt (g)							
Sordan 70A	633	303	882	705	933	930	816	646
Leucaena leucocephala	93	20	344	72	515	165	317	86
Phaseolus lathyroides	188	58	261	129	347	93	265	93
Albizia lebbeck	51	11	137	26	297	50	162	29
Sesbania sp.	256	115	565	245	599	391	473	250
Mean	244	101	438	235	538	326	407	221
	Percent Dry Matter							
Sordan 70A	21.2	11.3	32.1	22.7	42.8	30.5	32.0	21.5
Leucaena leucocephala	21.9	18.1	33.3	23.4	37.6	35.3	30.9	25.6
Phaseolus lathyroides	18.8	12.0	20.3	18.7	19.8	37.4	19.6	22.7
Albizia lebbeck	23.9	25.2	26.8	25.2	26.2	27.9	25.6	26.1
Sesbania sp.	20.6	14.1	24.6	21.2	25.9	27.7	23.7	21.0
Mean	21.3	16.1	27.4	22.2	30.5	31.8	26.4	23.4

1/ Growth data per planted area, approximately 60 $ft.^2$/species/harvest.

TABLE 5. RELATIVE GROWTH OF SORDAN 70A AND FOUR LEGUME SPECIES PLANTED IN SPRING (MAY) AND AUTUMN (NOVEMBER)

Species	Week 6		Week 12		Week 18		Mean	
	May	November	May	November	May	November	May	November
	Oven-Dry Wt (g/Plant), At Harvest Week And Month of Planting [1/]							
Sordan 70A	10.4	4.6	16.1	12.2	17.0	17.6	14.5	11.5
Leucaena leucocephala	1.3	0.2	5.0	1.1	6.9	1.8	4.4	1.0
Phaseolus lathyroides	2.2	1.5	3.8	4.2	4.3	5.0	3.4	3.6
Albizia lebbeck	1.0	0.3	2.2	0.6	6.5	1.0	3.2	0.6
Sesbania sp.	2.8	1.4	6.8	3.3	6.9	5.6	5.5	3.4
Mean	3.5	1.6	6.8	4.3	8.3	6.2	6.2	4.0
	Plant Height (cm)							
Sordan 70A	165	120	208	172	198	181	190	158
Leucaena leucocephala	66	24	98	66	126	77	97	56
Phaseolus lathyroides	102	75	114	108	103	107	106	97
Albizia lebbeck	29	16	53	17	93	26	58	20
Sesbania sp.	98	78	140	128	177	140	138	115
Mean	92	63	123	98	139	106	118	89

TABLE 6. GROWTH PERFORMANCE OF IMMATURE SUGARCANE SUPPLIED WITH VARIABLE NO_3 IN SAND CULTURE, AND HARVESTED AFTER 5 AND 10 WEEKS OF TREATMENT

Week	NO_3 (meq/1)	g/Planted Area 1/ Green	g/Planted Area 1/ Oven-Dry	OD g/Plant	% DM
5	1	339	80	4.2	23.6
	3	483	103	4.7	21.4
	9	667	135	4.9	20.1
	27	623	128	5.2	19.8
	54	688	146	5.6	21.2
	81	642	141	4.6	21.9
	Mean	574	122	4.9	21.2
10	1	446	107	6.8	23.9
	3	659	141	7.1	21.2
	9	1153	246	11.0	21.3
	27	1140	242	10.6	21.4
	54	1145	245	10.4	21.3
	81	703	147	5.7	20.9
	Mean	874	188	8.6	21.5

1/ Approximately 60 ft^2.

TABLE 7. BIOMASS PRODUCTION BY FIVE SACCHARUM CLONES UNDER MINIMUM-TILLAGE CONDITIONS; FEB. 11—AUG. 5, 1980 1/

Clone	6-Months Yield (Tons/Acre) For —		% DM
	Green Matter	Dry Matter	
PR 980	1.73	0.52	30.0
US 67-22-2	3.14	0.98	31.1
US 72-72	1.11	0.34	30.9
US 72-93	4.71	1.88	39.9
S. spont. Hybrid	0.86	0.26	30.0

1/ Fifth 6-month harvest. Originally planted during February, 1977.

TABLE 8. BIOMASS PRODUCTION BY FIVE SACCHARUM CLONES PROPAGATED WITH MINIMUM CULTURAL INPUTS AND HARVESTED AT INTERVALS OF SIX MONTHS

		Tons/Acre (6 Months) 1/		
Growth Period	Clone	Green	Dry	% DM
Feb. 5, 1978—Aug. 5, 1978	PR 980	16.5	6.4	38.8
	US 67-22-2	15.9	6.0	37.8
	US 72-72	14.7	5.5	37.4
	US 72-93	6.0	2.6	43.3
	S. spont. Hybrid 2/	13.3	4.3	32.3
	Mean	13.3	4.9	37.9
Aug. 5, 1978—Feb. 5, 1979	PR 980	1.04	0.22	20.7
	US 67-22-2	1.70	0.37	21.8
	US 72-72	1.02	0.20	19.9
	US 72-93	0.60	0.11	18.9
	S. spont. Hybrid 2/	2.54	0.64	25.0
	Mean	1.38	0.31	21.3
Feb. 5, 1979—Aug. 5, 1979	PR980	2.08	0.48	23.2
	US 67-22-2	4.24	1.08	25.4
	US 72-72	4.15	1.12	27.0
	US 72-93	2.46	0.74	30.2
	S. spont. Hybrid 2/	3.96	1.37	34.5
	Mean	3.38	0.96	28.1
Aug. 11, 1979—Feb. 11, 1980	PR 980	1.32	0.49	34.0
	US 67-22-2	2.47	0.89	34.8
	US 72-72	3.92	1.36	34.7
	US 72-93	1.66	0.79	47.6
	S. spont. Hybrid 2/	3.18	0.96	30.1
	Mean	2.51	0.89	36.2
Feb. 11, 1980—July 27, 1980	PR 980	1.73	0.52	30.0
	US 67-22-2	3.14	0.98	31.1
	US 72-72	1.11	0.34	30.9
	US 72-93	4.71	1.88	39.9
	S. spont. Hybrid 2/	3.86	1.15	30.0
	Mean	2.97	0.97	32.4

1/ Originally planted during February, 1977.

2/ Approximately 40% germination was obtained at the time of planting.

TABLE 9. BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW CENTERS; SIXTH 2-MONTH HARVEST

Cultivar	Green Matter (Tons/A), At Row Center —		
	150 cm	50 cm	% Change
PR 980	0.06 b [1/]	0.15 b	150.0
NCo 310	0.61 b	0.71 b	16.3
PR 64-1791	0.19 b	0.04 b	-78.9
	50 cm	25 cm	
Napier Grass	8.65 a	7.67 a	-11.3
	Dry Matter (Tons/Acre)		
PR 980	0.01 c	0.03 c	300.0
NCo 310	0.11 c	0.13 c	18.1
PR 64-1791	0.04 c	0.01 c	-75.0
Napier Grass	1.17 a	0.98 b	-16.2
	Dry Matter (%)		
PR 980	21.2 b	20.2 b	- 4.7
NCo 310	19.5 b	19.4 b	- 0.5
PR 64-1791	18.4 ab	20.5 b	11.4
Napier Grass	13.5 b	12.8 b	- 5.1

1/ Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Mean values bearing at least one letter in common do not differ significantly.

TABLE 10. BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW CENTERS; THIRD 4-MONTH HARVEST

Cultivar	Green Matter (Tons/A), At Row Center –		
	150 cm	50 cm	% Change
PR 980	9.6 cd 1/	7.3 cd	-23.9
NCo 310	18.0 b	13.2 bc	-26.6
PR 64-1791	12.1 bcd	5.2 d	-57.0
	50 cm	25 cm	
Napier Grass	34.9 a	37.7 a	8.0
	Dry Matter (Tons/Acre)		
PR 980	1.7 b	1.4 bc	-17.6
NCo 310	3.3 b	2.4 bc	-27.2
PR 64-1791	2.2 bc	0.9 c	-59.0
Napier Grass	9.2 a	9.6 a	4.3
	Dry Matter (%)		
PR 980	18.2 bc	19.7 b	8.2
NCo 310	18.4 bc	18.0 bc	-2.1
PR 64-1791	18.4 bc	16.6 c	-9.7
Napier Grass	26.0 a	25.8 a	-0.7

1/ Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Mean values bearing at least one letter in common do not differ significantly.

TABLE 11. BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW CENTERS; SECOND 6-MONTH HARVEST

Cultivar	Green Matter (Tons/A), At Row Center — 150 cm	25 cm	% Change
PR 980	34.4 a 1/	28.8 bc	-16.2
NCo 310	36.0 b	34.4 b	- 4.4
PR 64-1791	20.3 c	18.7 c	- 7.8
	50 cm	25 cm	
Napier Grass	55.7 a	58.3 a	4.6
	Dry Matter (Tons/Acre)		
PR 980	5.6 b	5.2 bc	- 7.1
NCo 310	6.2 b	6.4 b	3.1
PR 64-1791	3.8 c	3.6 c	- 5.2
Napier Grass	15.6 a	15.3 a	- 1.9
	Dry Matter (%)		
PR 980	15.9 c	18.1 bc	13.8
NCo 310	17.7 bc	18.8 b	5.0
PR 64-1791	19.3 b	19.8 b	2.5
Napier Grass	26.3 a	26.2 a	- 0.3

1/ Mean values in the same column bearing unlikeletters differ significantly ($P < .05$). Mean values bearing at least one letter in common do not differ significantly.

TABLE 12. BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW CENTERS; 12-MONTH HARVEST

	Green Matter (Tons/A),[1] At Row Center —		
Cultivar	150 cm	50 cm	% Change
PR 980	75.8 bc [2]	71.5 c	- 5.6
NCo 310	92.0 a	90.2 a	- 1.9
PR 64-1791	84.0 b	84.3 b	0.3
	50 cm	25 cm	
Napier Grass	67.8 c	67.1 c	- 1.0
	Dry Matter (Tons/Acre) [1]		
PR 980	19.0 cde	18.6 def	- 2.0
NCo 310	26.9 a	25.1 ab	- 6.6
PR 64-1791	20.3 cd	22.8 bc	12.3
Napier Grass	15.5 ef	15.0 f	- 3.2
	Trash (Tons/Acre)		
PR 980	7.7 a	7.5 a	- 2.5
NCo 310	4.4 b	4.6 b	4.5
PR 64-1791	5.1 b	5.0 b	- 1.9
Napier Grass	4.4 b	3.9 b	-11.3
	Dry Matter (%)		
PR 980	25.1 bcd	26.3 abc	4.7
NCo 310	29.1 a	27.7 ab	5.1
PR 64-1791	25.0 bcd	27.1 ab	8.4
Napier Grass	22.9 cd	22.3 d	- 2.6

1/ Trash excluded.

2/ Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Mean values bearing at least one letter in common do not differ significantly.

TABLE 13. TOTAL DRY MATTER PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW CENTERS; 12-MONTH HARVEST 1/

Cultivar	DM (Tons/Acre) At Row Center —		
	150 cm	50 cm	% Change
PR 980	26.7	26.1	- 2.2
NCo 310	31.3	29.7	- 5.1
PR 64-1791	25.4	27.8	9.4
	50 cm	25 cm	- 5.0
Napier Grass	19.9	18.9	- 5.0

1/ Trash included.

TABLE 14. GREEN MATTER YIELDS FOR THE SECOND-RATOON CROP OF SUGARCANE AND NAPIER GRASS HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Species	Green Matter (Tons/Acre), At Indicated Month [1/]						Total Yield
		2	4	6	8	10	11	
2 Months	Sugarcane [2/]	2.1	1.3	0.7	0.7	0.9	0.3	6.0
	Napier Grass [3/]	12.4	8.3	11.5	10.9	15.9	8.2	67.2
4 Months	Sugarcane		15.5		7.6		10.9	34.0
	Napier Grass		22.9		29.7		36.3	88.9
6 Months	Sugarcane			26.1			28.8	54.9
	Napier Grass			31.7			57.0	88.7
12 Months	Sugarcane						83.0	83.0
	Napier Grass						67.5	67.5

1/ Trash excluded.

2/ Mean values for three varieties and two row spacings.

3/ Mean values for one variety and two row spacings.

TABLE 15. DRY MATTER YIELDS FOR THE SECOND-RATOON CROP OF SUGARCANE AND NAPIER GRASS HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Species	Dry Matter (Tons/Acre), At Indicated Month [1/]						Total Yield
		2	4	6	8	10	12	
2 Months	Sugarcane [2/]	0.3	0.2	0.1	0.1	0.2	0.1	1.0
	Napier Grass [3/]	2.0	1.3	1.4	1.3	2.4	1.1	9.5
4 Months	Sugarcane		3.0		1.4		2.0	6.4
	Napier Grass		7.7		5.3		9.4	22.4
6 Months	Sugarcane			6.3			5.1	11.4
	Napier Grass			8.5			15.5	24.0
12 Months	Sugarcane						22.1	22.1
	Napier Grass						15.3	15.3

1/ Trash excluded.

2/ Mean values for three varieties and two row spacings.

3/ Mean values for one variety and two row spacings.

TABLE 16. DRY MATTER CONTENT FOR THE SECOND RATOON CROP OF SUGARCANE AND NAPIER GRASS HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Species	Dry Matter Content (%), At Indicated Month –						
		2	4	6	8	10	12	Mean
2 Months	Sugarcane 1/	14.4	14.1	14.0	13.4	19.8	19.9	15.9
	Napier Grass 2/	15.8	15.9	12.6	10.8	14.6	13.2	13.8
4 Months	Sugarcane		19.2		16.7		18.2	18.0
	Napier Grass		33.7		17.8		25.9	25.8
6 Months	Sugarcane			23.4			18.3	20.9
	Napier Grass			26.7			26.2	26.5
12 Months	Sugarcane						26.7	26.7
	Napier Grass						32.6	32.6

1/ Each figure is the computed mean for three varieties and two row spacings.

2/ Each figure is the computed mean for one variety planted at two row spacings.

TABLE 17. JUICE QUALITY VALUES FOR THREE SUGARCANE VARIETIES PROPAGATED WITH STANDARD AND NARROW ROW SPACING; SECOND RATOON CROP

	Brix Values, At Row Center —		
Variety	150 cm	50 cm	% Change
PR 980	10.92	10.60	- 2.9
NCo 310	11.64	11.92	2.4
PR 64-1791	10.34	11.20	8.3
		Polarization	
PR 980	8.81	9.35	6.1
NCo 310	8.90	8.75	- 2.0
PR 64-1791	9.73	8.83	9.2
		Fiber	
PR 980	17.07	16.94	- 0.7
NCo 310	16.30	15.68	- 3.8
PR 64-1791	16.42	16.05	-2.2
		Purity	
PR 980	79.94	87.45	9.3
NCo 310	76.15	72.62	- 4.6
PR 64-1791	93.28	78.06	-16.3
		Rendement (% Sucrose)	
PR 980	6.89	7.77	12.7
NCo 310	6.75	6.42	- 4.8
PR 64-1791	8.45	6.86	-18.8
		Tons Sucrose/Acre (TSA)	
PR 980	5.22	5.56	6.5
NCo 310	6.21	5.79	- 6.7
PR 64-1791	7.10	5.78	-18.5

TABLE 18. TONS SUCROSE PER ACRE (TSA) FOR THREE SUGARCANE VARIETIES PROPAGATED AT STANDARD AND NARROW ROW SPACING; SECOND RATOON CROP; 12-MONTH HARVEST

Variety	TSA, At Row Spacing —		
	150 cm	50 cm	% Change
PR 980	5.22	5.56	6.5
NCo 310	6.21	5.79	- 6.7
PR 64-1791	7.10	5.78	-18.5
Mean	6.18	5.71	- 7.6

TABLE 19. PLANT DENSITIES FOR THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACING AND HARVEST FREQUENCY; SECOND RATOON CROP (1979-1980).

	Stems/Acre, At Indicated Harvest Interval And Row Spacing 1/					
	2-Month Interval			4-Month Interval		
Variety	150 cm	50 cm	% Change	150 cm	50 cm	% Change
PR 980	3,485	726	-79.1	36,409	64,469	77.0
NCo 310	25,483	12,306	-51.7	92,783	165,310	78.1
PR 64-1791	2,831	2,977	5.1	53,071	40,257	-24.1
	50 cm	25 cm		50 cm	25 cm	
Merker	124,691	318,061	155.0	175,002	511,975	192.3

	6-Month Interval			12-Month Interval		
	150 cm	50 cm	% Change	150 cm	50 cm	% Change
PR 980	64,759	128,720	98.7	92,347	139,973	51.5
NCo 310	97,429	183,896	88.7	93,218	97,538	4.6
PR 64-1791	53,506	105,887	97.8	89,225	121,569	36.2
	50 cm	25 cm		50 cm	25 cm	
Merker	193,406	360,096	86.1	138,230	278,675	101.6

1/ Mean values from two replicates.

TABLE 20. GREEN MATTER YIELDS FOR THE PLANT CROP AND TWO RATOON CROPS OF SUGARCANE HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Crop 2/	Green Matter (Tons/Acre) At Indicated Month 1/						Total Yield
		2	4	6	8	10	12	
2 Months	Plant	2.5	7.6	6.5	4.3	8.0	4.5	33.4
	First Ratoon	6.2	3.6	2.7	1.2	3.5	1.4	18.6
	Second Ratoon	2.1	1.3	0.7	0.7	0.9	0.3	6.0
	Mean	3.6	4.2	3.3	2.1	4.1	2.1	19.3
4 Months	Plant		24.5		20.0		18.2	62.7
	First Ratoon		33.9		7.7		22.3	63.9
	Second Ratoon		15.5		7.6		10.9	34.0
	Mean		24.6		11.8		17.1	53.5
6 Months	Plant			43.2			31.3	74.8
	First Ratoon			46.2			34.3	88.6
	Second Ratoon			26.1			28.8	83.0
	Mean			38.5			31.5	70.0
12 Months	Plant						74.8	74.8
	First Ratoon						88.6	88.6
	Second Ratoon						83.0	83.0
	Mean						82.1	82.1

1/ Trash excluded.

2/ Mean values for three varieties and two row spacings.

TABLE 21. DRY MATTER YIELDS FOR THE PLANT CROP AND TWO RATOON CROPS OF SUGARCANE HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Crop 1/	Dry Matter (Tons/Acre) At Indicated Month 1/						Total Yield
		2	4	6	8	10	12	
2 Months	Plant	0.4	1.2	1.2	0.8	1.7	1.2	6.5
	First Ratoon	1.0	0.7	0.6	0.2	0.5	0.3	3.3
	Second Ratoon	0.3	0.2	0.1	0.1	0.2	0.1	1.0
	Mean	0.6	0.7	0.6	0.4	0.8	0.5	3.6
4 Months	Plant		3.4		3.6		4.1	11.1
	First Ratoon		5.6		1.7		4.6	11.9
	Second Ratoon		3.0		1.4		2.0	6.4
	Mean		4.0		2.2		3.6	9.8
6 Months	Plant			8.6			8.0	16.6
	First Ratoon			12.8			9.2	21.8
	Second Ratoon			6.3			5.1	11.4
	Mean			9.2			7.4	16.6
12 Months	Plant						25.5 2/	25.5 2/
	First Ratoon						33.6 2/	33.6 2/
	Second Ratoon						27.8 2/	27.8 2/
	Mean						29.0	29.0

1/ Mean values for three varieties and two row spacings.

2/ Trash included.

TABLE 22. DRY MATTER CONTENT FOR THE PLANT CROP AND TWO RATOON CROPS OF SUGARCANE HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Crop	Dry Matter Content (%) At Indicated Month 1/						Mean
		2	4	6	8	10	12	
2 Months	Plant	16.3	16.2	18.8	18.3	21.7	25.1	19.4
	First Ratoon	15.8	18.3	18.9	21.6	19.1	19.2	18.8
	Second Ratoon	14.4	14.1	14.0	13.4	19.8	19.9	15.9
	Mean	16.5	16.2	17.2	17.8	20.2	21.4	18.0
4 Months	Plant		13.7		18.0		22.5	18.1
	First Ratoon		16.6		21.6		20.5	19.6
	Second Ratoon		19.2		16.7		18.2	18.0
	Mean		16.5		18.8		20.4	18.6
6 Months	Plant			19.9			22.7	21.3
	First Ratoon			21.5			24.1	22.8
	Second Ratoon			23.4			18.3	20.9
	Mean			21.6			21.7	21.7
12 Months	Plant						28.3	28.3
	First Ratoon						31.0	31.0
	Second Ratoon						26.7	26.7
	Mean						28.7	28.7

1/ Mean values for three varieties and two row spacings.

TABLE 23. DRY MATTER YIELDS FOR THE PLANT CROP AND TWO RATOON CROPS OF THREE SUGARCANE VARIETIES HARVESTED AT 2-AND 4-MONTH INTERVALS

Harvest Interval	Variety	Crop	Dry Matter Yield (Tons/Acre) At Indicated Month 1/						Total Yield
			2	4	6	8	10	12	
2 Months	PR 980	Plant	0.5	1.4	1.2	0.7	1.5	1.0	6.3
		First Ratoon	0.7	0.4	0.3	0.2	0.5	0.1	2.2
		Second Ratoon	0.1	0.1	0.1	0.1	0.1	0.0	0.5
		Mean	0.4	0.6	0.5	0.3	0.7	0.4	3.0
	NCo 310	Plant	0.4	1.2	1.4	0.8	2.1	1.4	7.3
		First Ratoon	1.4	1.1	1.0	0.4	1.1	0.6	5.6
		Second Ratoon	0.6	0.4	0.2	0.2	0.4	0.1	1.9
			0.8	0.9	0.9	0.5	1.2	0.7	4.9
	PR 64-1791	Plant	0.4	1.1	1.2	0.8	1.6	1.1	6.2
		First Ratoon	0.9	0.6	0.4	0.2	0.5	0.2	2.8
		Second Ratoon	0.2	0.1	0.1	0.1	0.1	0.0	0.6
		Mean	0.5	0.6	0.6	0.4	0.7	0.4	3.2
4 Months	PR 980	Plant		4.0		3.8		3.9	11.7
		First Ratoon		5.4		1.6		3.7	10.7
		Second Ratoon		2.4		1.3		2.0	5.7
		Mean		3.9		2.2		3.2	9.4
	NCo 310	Plant		3.2		3.6		4.6	11.4
		First Ratoon		6.2		2.1		5.8	14.1
		Second Ratoon		4.2		1.8		3.0	9.0
		Mean		4.5		2.5		4.5	11.5
	PR 64-1791	Plant		3.0		3.5		3.7	10.2
		First Ratoon		5.4		1.4		4.2	11.0
		Second Ratoon		2.4		1.1		1.6	5.1
				3.6		2.0		3.2	8.8

1/ Based on mean values from replicated 1/50 acre plots. Each figure is the computed mean of two row spacings.

TABLE 24. DRY MATTER YIELDS FOR THE PLANT CROP AND TWO RATOON CROPS OF THREE SUGARCANE VARIETIES HARVESTED AT 6-AND 12-MONTH INTERVALS

Harvest Interval	Variety	Crop	Dry Matter Yield (Tons/Acre) At Indicated Month 1/ 2	4	6	8	10	12	Total Yield
6 Months	PR 980	Plant			9.2			8.4	17.6 2/
		First Ratoon			11.3			9.1	20.4
		Second Ratoon			5.5			5.4	10.9
		Mean			8.7			7.6	16.3
	NCo 310	Plant			8.4			7.9	16.3 2/
		First Ratoon			12.6			10.3	22.9
		Second Ratoon			8.6			6.3	14.9
		Mean			9.9			8.2	18.0
	PR 64-1791	Plant			8.3			7.4	15.7 2/
		First Ratoon			10.5			8.3	18.5
		Second Ratoon			4.8			3.7	8.5
		Mean			7.9			6.5	14.2
12 Months	PR 980	Plant						24.7	24.7 2/
		First Ratoon						34.1	34.1
		Second Ratoon						26.1	26.4
		Mean						28.4	28.4
	NCo 310	Plant						26.4	26.4 2/
		First Ratoon						33.6	33.6
		Second Ratoon						30.5	30.5
		Mean						30.2	30.2
	PR 64-1791	Plant						25.4	25.4 2/
		First Ratoon						33.1	33.1
		Second Ratoon						26.6	26.6
		Mean						28.4	28.4

1/ Based on mean values from replicated 1/50 acre plots. Each figure is the computed mean of two row spacings.

2/ Trash included.

TABLE 25. TRASH YIELDS BY THREE CROPS OF SUGARCANE AND NAPIER GRASS PROPAGATED WITH VARIABLE ROW SPACING 1/

Species	Variety	Crop	Trash (Tons/Acre) At Row Spacing – 150 cm	50 cm	% Change
Sugarcane	PR 980	Plant	5.45	5.97	9.5
		First Ratoon	7.56	6.60	-13.7
		Second Ratoon	7.71	7.49	- 2.8
		Mean	6.91	6.69	- 3.1
	NCo 310	Plant	3.16	4.57	44.6
		First Ratoon	5.20	6.36	22.3
		Second Ratoon	4.40	4.59	4.3
		Mean	4.25	5.17	21.6
	PR 64-1791	Plant	3.07	4.13	34.5
		First Ratoon	5.27	5.95	12.9
		Second Ratoon	5.11	5.00	- 2.1
		Mean	4.48	5.03	12.2
Napier Grass 2/	Merker	Plant	2.73	2.67	- 2.1
		First Ratoon	2.57	2.87	11.6
		Second Ratoon	4.42	3.92	-11.3
		Mean	3.24	3.15	- 2.7

1/ Twelve-months harvest.

2/ Standard and narrow row spacings for napier grass were 50 cm and 25 cm, respectively.

TABLE 26. DRY MATTER PRODUCTION FOR THREE CROPS OF SUGARCANE PROPAGATED WITH VARIABLE ROW SPACING AND HARVESTED AT VARIABLE TIME INTERVALS

Harvest Interval	Crop	Total DM (Tons/Acre) At Row Center 1/ 150 cm	50 cm	% Change
2 Months	Plant	5.8	7.3	25.8
	First Ratoon	3.5	3.4	- 2.8
	Second Ratoon	1.0	0.8	-20.0
	Mean	3.4	3.8	11.7
4 Months	Plant	9.8	12.2	24.4
	First Ratoon	11.6	12.1	4.3
	Second Ratoon	7.2	5.5	-23.6
	Mean	9.5	9.9	4.2
6 Months	Plant	14.5	17.0	17.2
	First Ratoon	21.7	19.6	- 9.6
	Second Ratoon	11.9	10.9	- 8.4
	Mean	16.0	15.8	- 1.2
12 Months 2/	Plant	25.4	25.6	0.7
	First Ratoon	35.5	31.7	-10.7
	Second Ratoon	27.8	27.9	0.3
	Mean	29.6	28.4	- 4.0

1/ Each figure is the computed mean of three varieties.

2/ Trash included.

TABLE 27. DRY MATTER YIELDS FOR THE PLANT CROP AND TWO RATOON CROPS OF NAPIER GRASS HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Crop [1]	Dry Matter (Tons/Acre) At Indicated Month – 2	4	6	8	10	12	Total Yield
2 Months	Plant	2.1	1.4	3.0	0.9	4.0	1.3	12.7
	First Ratoon	2.4	2.6	1.9	0.9	2.6	1.5	11.9
	Second Ratoon	2.0	1.3	1.4	1.3	2.4	1.1	9.5
	Mean	2.2	1.8	2.1	1.0	3.0	1.3	11.4
4 Months	Plant		5.7		8.4		8.5	22.6
	First Ratoon		9.7		5.5		9.9	25.1
	Second Ratoon		7.7		5.3		9.4	22.4
	Mean		7.7		6.4		9.3	23.4
6 Months	Plant			13.1			12.4	25.5
	First Ratoon			13.6			19.4	33.0
	Second Ratoon			8.5			15.5	24.0
	Mean			11.7			15.8	27.5
12 Months	Plant						19.3 [2]	19.3 [2]
	First Ratoon						25.8 [2]	25.8 [2]
	Second Ratoon						19.4 [2]	19.4 [2]
	Mean						21.5	21.5

1/ Mean values for one variety and two row spacings.

2/ Trash included.

TABLE 28. GREEN MATTER YIELDS FOR THE PLANT CROP AND TWO RATOON CROPS OF NAPIER GRASS HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Crop 2/	Green Matter (Tons/Acre) At Indicated Month 1/						Total Yield
		2	4	6	8	10	12	
2 Months	Plant	16.0	8.8	19.4	5.8	21.5	6.2	77.7
	First Ratoon	19.1	16.1	12.8	5.2	17.6	9.7	80.5
	Second Ratoon	12.4	8.3	11.5	10.9	15.9	8.2	67.2
	Mean	15.8	11.1	14.6	7.3	18.3	8.0	75.1
4 Months	Plant		21.6		25.7		26.5	73.8
	First Ratoon		33.4		22.3		35.2	90.9
	Second Ratoon		22.9		29.7		36.3	88.9
	Mean		26.0		25.9		32.7	84.5
6 Months	Plant			40.7			33.6	74.3
	First Ratoon			39.2			51.6	90.8
	Second Ratoon			31.7			57.0	88.7
	Mean			37.2			47.4	84.6
12 Months	Plant						55.1	55.1
	First Ratoon						63.4	63.4
	Second Ratoon						67.5	67.5
	Mean						62.0	62.0

1/ Trash excluded.

2/ Mean values for one variety and two row spacings.

TABLE 29. DRY MATTER CONTENT FOR THE PLANT CROP AND TWO RATOON CROPS OF NAPIER GRASS HARVESTED AT VARIABLE INTERVALS

Harvest Interval	Crop 1/	Dry Matter Content (%) At Indicated Month – 2	4	6	8	10	12	Mean
2 Months	Plant	13.4	18.2	15.4	15.5	18.6	21.5	17.1
	First Ratoon	12.4	16.1	14.8	16.3	14.8	15.8	15.0
	Second Ratoon	15.8	15.9	12.6	10.8	14.6	13.2	13.8
	Mean	13.9	16.7	14.3	14.2	16.0	16.8	15.3
4 Months	Plant		26.3		32.8		32.5	30.5
	First Ratoon		29.0		24.9		28.0	27.3
	Second Ratoon		33.7		17.8		25.9	25.8
	Mean		29.7		25.2		28.8	27.9
6 Months	Plant			32.2			33.7	33.0
	First Ratoon			32.0			35.9	34.0
	Second Ratoon			26.7			26.2	26.5
	Mean			30.3			31.9	31.2
12 Months	Plant						30.1	30.1
	First Ratoon						36.2	36.2
	Second Ratoon						32.6	32.6
	Mean						33.0	33.0

1/ Mean values for one variety and two row spacings.

TABLE 30. DRY MATTER PRODUCTION FOR THREE CROPS OF NAPIER GRASS PROPAGATED WITH VARIABLE ROW SPACING AND HARVESTED AT VARIABLE TIME INTERVALS 1/

Harvest Interval	Crop	Total DM (Tons/Acre) At Row Center – 150 cm	50 cm	% Change
2 Months	Plant	12.7	13.2	3.9
	First Ratoon	11.8	12.0	1.6
	Second Ratoon	9.4	9.2	-2.1
	Mean	11.3	11.5	1.7
4 Months	Plant	21.5	23.7	10.2
	First Ratoon	26.2	24.0	-8.3
	Second Ratoon	22.4	22.4	0
	Mean	23.4	23.4	0
6 Months	Plant	25.4	23.3	-8.2
	First Ratoon	33.5	32.5	-2.9
	Second Ratoon	24.6	23.2	-5.6
	Mean	27.8	26.9	-5.3
12 Months	Plant	19.3	19.2	-0.5
	First Ratoon	25.3	26.3	3.9
	Second Ratoon	19.9	18.9	-5.0
	Mean	21.5	21.5	0

1/ Variety Common Merker.

2/ Trash included.

TABLE 31. STEM DENSITIES FOR THE PLANT CROP AND TWO RATOON CROPS OF SUGARCANE AND NAPIER GRASS HARVESTED AT INTERVALS OF TWO TO TWELVE MONTHS

Species	Crop	Stems/Acre (Thousands) For Month — 2	4	6	12	Mean
Sugarcane 1/	Plant	92.8	122.5	80.7	65.5	90.4
	First Ratoon	71.5	115.6	83.9	98.6	92.4
	Second Ratoon	7.9	75.4	105.7	105.2	73.6
	Mean	57.4	104.5	90.1	89.8	85.5
Napier Grass 2/	Plant	136.9	123.3	157.6	118.7	134.1
	First Ratoon	203.9	303.5	281.2	175.0	240.9
	Second Ratoon	221.4	343.5	276.8	208.5	262.6
	Mean	187.4	256.8	238.5	164.1	212.0

1/ Mean values for three varieties and two row spacings.

2/ Mean values for one variety and two row spacings.

TABLE 32. SEASONAL INFLUENCE ON DRY MATTER YIELD BY THREE CROPS OF SUGARCANE; 2-MONTH HARVESTS

	% Of Crop's Total Yield, For Crop —			
Period	Plant	1st Ratoon	2nd Ratoon	Mean
July 15—Sept. 15	6.1	30.3	29.8	22.1
Sept. 15—Nov. 15	18.4	21.2	20.2	19.9
Nov. 15—Jan. 15	18.4	18.1	10.0	15.5
Jan. 15—Mar. 15	12.3	6.0	9.9	9.4
Mar. 15—May 15	26.1	15.1	20.0	20.4
May 15—July 15	18.4	10.0	10.0	12.8

TABLE 33. SEASONAL INFLUENCE ON DRY MATTER YIELD BY THREE CROPS OF NAPIER GRASS; 2-MONTH HARVESTS

Period	% Of Crop's Total Yield, For Crop —			Mean
	Plant	1st Ratoon	2nd Ratoon	
July 15—Sept. 15	16.5	20.1	21.0	19.2
Sept. 15—Nov. 15	11.0	21.8	13.6	15.5
Nov. 15—Jan. 15	23.6	15.9	14.7	18.1
Jan. 15—Mar. 15	7.0	7.5	13.6	9.3
Mar. 15—May 15	31.4	21.8	25.2	26.1
May 15—July 15	10.2	12.6	11.5	11.4

TABLE 34. SEASONAL INFLUENCE ON DRY MATTER YIELDS BY THREE CROPS OF SUGARCANE AND NAPIER GRASS; 4-MONTH HARVESTS

Period	Plant	1st Ratoon	2nd Ratoon	Mean
	Sugarcane % Of Crop's Total Yield, For Crop —			
July 15—Nov. 15	30.6	47.1	46.8	41.5
Nov. 15—Mar. 15	32.4	14.2	21.8	22.8
Mar. 15—July 15	36.9	38.6	31.2	35.6
	Napier Grass			
July 15—Nov. 15	25.2	38.6	34.3	32.7
Nov. 15—Mar. 15	37.1	21.9	23.6	27.5
Mar. 15—July 15	37.6	39.4	41.9	39.6

TABLE 35. TREATMENTS AND HARVEST DATES FOR THE "SECOND GENERATION" ENERGY CANE STUDY AT AES-UPR LAJAS SUBSTATION

Variety	Elemental N (lbs/Acre Yr)	Harvest Date, At Interval 1/		
		6 Months	12 Months	18 Months
PR 980	200	Feb. 1, 1981	Aug. 1, 1981	Feb. 1, 1982
	400	"	"	"
	600	"	"	"
US 67-22-2	200	"	"	"
	400	"	"	"
	600	"	"	"
B 70-701	200	"	"	"
	400	"	"	"
	600	"	"	"

1/ For plant crop only.

TABLE 36. PROJECTED DM YIELDS FOR SECOND GENERATION ENERGY CANES PROPAGATED IN PUERTO RICO'S LAJAS VALLEY

Variety	Category	Projected DM (Tons/A), For Crop 1/	
		Primavera	Gran Cultura
PR 980	1st Generation 2/	27-29	36-40
US 67-22-2	2nd Generation	38-42	48-52
B 70-701	2nd Generation	38-42	48-52

1/ Trash included.

2/ Reference variety.

TABLE 37. TOTAL GREEN WEIGHT FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	GM (Tons/A), At Month 1/ 6	12	18	Mean
PR 980	200	49.9			
	400	53.8			
	600	51.0			
	Mean	51.6			
US 67-22-2	200	60.1			
	400	60.9			
	600	61.5			
	Mean	60.8			
B 70-701	200	52.1			
	400	52.9			
	600	56.3			
	Mean	53.8			

1/ Each figure is the mean of four replicates.

TABLE 38. TONS MILLABLE CANE PER ACRE (TCA) FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	TCA, At Month 1/ 6	12	18	Mean
PR 980	200	33.1			
	400	35.0			
	600	36.6			
	Mean	34.9			
US 67-22-2	200	33.7			
	400	36.4			
	600	31.3			
	Mean	33.8			
B 70-701	200	31.6			
	400	31.4			
	600	37.1			
	Mean	33.4			

1/ Each figure is the mean of four replicates.

TABLE 39. GREEN WEIGHT OF WHOLE PLANTS FOR THREE CANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Plant Wt (Lbs), At Month — 6	12	18	Mean
PR 980	200	2.97			
	400	2.96			
	600	2.55			
	Mean	2.83			
US 67-22-2	200	2.45			
	400	2.56			
	600	2.31			
	Mean	2.44			
B 70-701	200	2.80			
	400	2.98			
	600	2.97			
	Mean	2.92			

1/ Each figure is the mean of four replicates. Six plants were harvested per replicate.

TABLE 40. WEIGHT OF MILLABLE STEMS FOR THREE CANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Stem Wt (Lbs), At Month 1/ 6	12	18	Mean
PR 980	200	1.97			
	400	1.93			
	600	1.83			
	Mean	1.91			
US 67-22-2	200	1.37			
	400	1.53			
	600	1.17			
	Mean	1.36			
B 70-701	200	1.69			
	400	1.77			
	600	1.96			
	Mean	1.81			

1/ Each figure is the mean of four replicates. Six plants were harvested per replicate.

TABLE 41. LENGTH OF MILLABLE STEMS FOR THREE CANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Stem Length (Ft), At Month 1/ 6	12	18	Mean
PR 980	200	4.63			
	400	4.56			
	600	4.17			
	Mean	4.45			
US 67-27-2	200	4.29			
	400	4.14			
	600	3.62			
	Mean	4.01			
B 70-701	200	6.16			
	400	6.27			
	600	6.44			
	Mean	6.29			

1/ Each figure is the mean of four replicates. Six stems were harvested per replicate.

TABLE 42. STEM COUNTS FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Stems/A (Thousands) At Month 1/			
		6	12	18	Mean
PR 980	200	39.4			
	400	40.1			
	600	35.8			
	Mean	38.4			
US 67-22-2	200	46.3			
	400	46.3			
	600	44.4			
	Mean	45.7			
B 70-701	200	46.0			
	400	43.7			
	600	45.7			
	Mean	45.1			

1/ Each figure is the mean of two replicates.

TABLE 43. DRY MATTER PRODUCTION BY THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	DM (Tons/A), At Month — 1/ 6	12	18	Mean
PR 980	200	8.7			
	400	8.8			
	600	8.0			
	Mean	8.5			
US 67-22-2	200	11.1			
	400	9.6			
	600	9.6			
	Mean	10.1			
B 70-701	200	9.6			
	400	9.6			
	600	9.3			
	Mean	9.5			

1/ Each figure is the mean of four replicates.

TABLE 44. DRY MATTER CONTENT OF THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	DM (%), At Month – 1/ 6	12	18	Mean
PR 980	200	17.5			
	400	16.4			
	600	15.7			
	Mean	16.5			
US 67-22-2	200	18.4			
	400	15.8			
	600	15.6			
	Mean	16.6			
B 70-701	200	18.4			
	400	18.2			
	600	16.6			
	Mean	17.7			

1/ Each figure is the mean of four replicates.

TABLE 45. BRIX VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	°Brix, At Month 1/ 6	12	18	Mean
PR 980	200	6.16			
	400	5.80			
	600	5.58			
	Mean	5.85			
US 67-22-2	200	6.14			
	400	5.27			
	600	5.57			
	Mean	5.66			
B 70-701	200	4.40			
	400	4.93			
	600	4.30			
	Mean	4.54			

1/ Each figure is the mean of four replicates.

TABLE 46. POL VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Pol Reading, At Month 1/ 6	12	18	Mean
PR 980	200	2.13			
	400	1.80			
	600	1.68			
	Mean	1.87			
US 67-22-2	200	1.90			
	400	1.40			
	600	1.15			
	Mean	1.48			
B 70-701	200	0.88			
	400	0.93			
	600	0.80			
	Mean	0.87			

1/ Each figure is the mean of four replicates.

TABLE 47. RENDIMENT VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Rendiment, At Month 1/			
		6	12	18	Mean
PR 980	200	0.05			
	400	0.17			
	600	0.34			
	Mean	0.19			
US 67 22-2	200	-0.33			
	400	-0.66			
	600	-1.10			
	Mean	-0.70			
B 70-701	200	-0.99			
	400	-1.35			
	600	-1.05			
	Mean	-1.05			

1/ Each figure is the mean of four replicates.

TABLE 48. FIBER VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Fiber (%), At Month 1/			
		6	12	18	Mean
PR 980	200	9.02			
	400	7.13			
	600	8.81			
	Mean	8.32			
US 67-22-2	200	10.21			
	400	10.01			
	600	9.16			
	Mean	9.79			
B 70-701	200	9.11			
	400	13.82			
	600	8.75			
	Mean	10.56			

1/ Each figure is the mean of four replicates.

TABLE 49. TRASH YIELDS FOR THREE SUGARCANE VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

Variety	Elemental N (Lbs/Acre Yr)	Tons Trash/Acre, At Month 1/ - 6	12	18	Mean
PR 980	200	0.84			
	400	1.19			
	600	0.99			
	Mean	1.01			
US 67-22-2	200	0.96			
	400	1.01			
	600	1.13			
	Mean	1.03			
B 70-701	200	0.74			
	400	0.62			
	600	0.79			
	Mean	0.72			

1/ Trash that had detached and fallen to the ground. This does not include trash adhering to the stems and requiring removal by the cane harvest machine or by hand stripping.

TABLE 50. PRODUCTION INPUTS FOR AN ENERGY CANE DEMONSTRATION ON A HUMID ALLUVIAL PLAIN; HATILLO, PR 1/.

	Treatment –		
Input	Energy Cane	Standard Control	Low-Till Control
Seedbed prep.	Standard	Standard	Standard
Seeding rate	Double-seeded	Single-seeded	Single-seeded
Row spacing	Standard (150 cm)	Standard (150 cm)	Standard (150 cm)
Variety	PR 980	PR 980	PR 980
Herbicides	Pre-& Post-emergence	Pre-& Post-emergence	Pre-& Post-emergence
Nitrogen	600 lbs/acre/18 mo., in three increments	150 lbs/acre/18 mo., applied at planting	No fertilization
Water	Irrigation plus rainfull	Rainfall only	Rainfall only
Harvest	18 mo. gran cultura	18 mo. gran cultura	18 mo. gran cultura

1/ Planting completed August 27, 1980.

TABLE 51. TOTAL GREEN WEIGHT YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO PROJECT

Treatment	Tot. Green Wt. (Tons/A), At Month —			Mean
	6	12	18	
Control (Low Till)	36.7			
Control (Sugar Corp.)	30.8			
Energy Cane	36.0			
Var. US 67-22-2	50.2			
Mean	38.4			

TABLE 52. MILLABLE STEM YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO PROJECT

Treatment	Millable Cane (Tons/A), At Month —			Mean
	6	12	18	
Control (Low Till)	23.2			
Control (Sugar Crop.)	19.3			
Energy Cane	24.0			
Var. US 67-22-2	34.7			
Mean	25.3			

TABLE 53. TOP WEIGHTS FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO PROJECT

Treatment	Top Wt. (Tons/A, At Month —			
	6	12	18	Mean
Control (Low Till)	9.9			
Control (Sugar Corp.)	6.4			
Energy Cane	6.6			
Var. US 67-22-2	12.3			
Mean	8.8			

TABLE 54. TRASH YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO PROJECT

Treatment	Trash Wt. (Tons/A), At Month —			
	6	12	18	Mean
Control (low Till)	5.8			
Control (Sugar Corp.)	5.1			
Energy Cane	6.1			
Var. US 67-22-2	6.2			
Mean	5.8			

TABLE 55. DRY MATTER YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO STUDY

Treatment	DM (Tons/A), At Month 1/			Mean
	6	12	18	
Control (Low Till)	6.4			
Control (Sugar Corp.)	5.7			
Energy Cane	5.9			
Var. US 67-22-2	8.8			
Mean	6.7			

1/ Oven-dry, approximately 6% moisture.

TABLE 56. DRY MATTER CONTENT OF ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO STUDY

	DM Content (%), At Month —			
Treatment	6	12	18	Mean
Control (Low Till)	17.4			
Control (Sugar Corp.)	18.4			
Energy Cane	16.5			
Var. US 67-22-2	17.5			
Mean	17.5			

TABLE 57. PLANT HEIGHT FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO PROJECT

Treatment	Plant Height (Ft), At Month —			Mean
	6	12	18	
Control (Low Till)	5.4			
Control (Sugar Corp.)	4.7			
Energy Cane	4.9			
Var. US 67-22-2	4.1			
Mean	4.8			

TABLE 58. NUMBER OF STEMS PER ACRE FOR ENERGY CANE HARVESTED AT VARIABLE INTERVALS; HATILLO PROJECT

Treatment	Stems/A (Thousands), At Month –			Mean
	6	12	18	
Control (Low Till)	31.4			
Control (Sugar Corp.)	28.4			
Energy Cane	32.5			
Var. US 67-22-2	46.0			
Mean	34.6			

TABLE 59. DRY MATTER YIELD FROM NAPIER GRASS FIELD PLOTS MECHANICALLY-HARVESTED AT 6 MONTHS OF AGE; FIRST-RATOON CROP.

Plot No.	Rotary Scythe Mowing Height (in.)	Area (Acres)	DM Yield 1/ (Tons/Acre)	Crown 2/ Damage
1	8-10	0.69	7.98	Nil
2	8-10	0.69	8.77	Nil
3	1-2	0.69	11.67	Nil
4	1-2	0.69	8.80	Nil

1/ Excluding approximately 20% of the total DM in the form of unraked residues. This material could not be windrowed with the available forage rake.

2/ Observations based on subsequent production of new shoots.

TABLE 60. PRELIMINARY PERFORMANCE EVALUATIONS FOR THE M-C ROTARY SCYTHE-CONDITIONER OPERATING AT TWO CUTTING HEIGHTS IN NAPIER GRASS AGED SIX MONTHS

Cutting Parameter –			Fuel Expenditure –					Estimated
Height (in.)	Area (acres)	Time (min.)	Liters	Gallons	Gal/Hour	Gal/Acre	BTUs/acre 1/	Horsepower 2/
8-10	1.38	66.75	10.0	2.65	2.38	1.92	268,940	35.72
1-2	0.69	42.47	7.0	1.85	2.62	2.69	376,460	39.30
1-2	0.69	32.33	6.0	1.59	2.95	2.31	322,700	44.24
1-2 in. Combined	1.38	74.80	13.0	3.44	2.76	2.50	349,580	41.43
Combined Total	2.76	141.55	23.0	6.09	2.58	2.21	309,260	38.74

1/ Diesel fuel having a weight of 7.0 pounds/gallon and a heat value of 20,000 BTUs/pound.

2/ Taken from Nebraska Tractor Test Data for the project tractor (a Model 8700 Ford) using 0.06658 gallons/horsepower hour.

TABLE 61. PERCENTAGE INCREASE IN FUEL EXPENDITURE AND HORSEPOWER FOR LOW CUTTING AS OPPOSED TO HIGH CUTTING; ROTARY SCYTHE TEST ON SIX MONTHS OLD NAPIER GRASS.

Fuel Expenditure	% Increase
Gallons	29.8
Gallons/Hour	15.9
Gallons/Acre	30.2
BTUs/Acre	30.2
Horsepower	15.9

TABLE 62. SUGARCANE SEEDLINGS SELECTED FOR BIOMASS YIELD EVALUATION; AES-UPR LAJAS SUBSTATION, AUGUST, 1980.

Cross	Percentage			Number Of Seedlings —	
	Female		Male	Planted 1/	Selected 2/
3	F 160	x	US 67-22-2	966	7
5	PR 68-330	x	US 67-22-2	371	12
6	PR 67-1070	x	US 67-22-2	160	7
12	US 67-22-2	x	PR 68-3041	1240	36
16	US 67-22-2	x	F 160	270	5
17	PR 68-3041	x	US 67-22-2	741	25
			Total Seedlings	3,748	92

1/ Planted during 1979 at the AES-UPR Gurabo Substation for initial seedling evaluation.

2/ Planted August 14, 1980, at the AES-UPR Lajas Substation for second-stage evaluation. Plots are 5' x 20' and unreplicated. Superior selections from this group will be planted in 1981 in 20' x 20' plots.

TABLE 63. CROSSES FOR BIOMASS PERFORMED DURING THE 1980-1981 SUGARCANE BREEDING SEASON

No.	Cross			Breeding Line	Number Of Seedlings (Estimated)
1.	PR 68-355 x 57-NG54	X	S. sp. (RP)	F_1 (S. rob.) x S. sp.	250
2.	PR 68-355 x 57-NG54	X	PR 67-1070 x S. sp. (RP)	F_1 (S. rob.) x F_1 (S. sp.)	250
3.	PR 67-1070 x S. sp. (RP)	X	PR 68-355 x 57-NG54	F_1 (S. sp.) x F_1 (S. rob.)	500
4.	PR 68-1220	X	PR 67-1070 x S. sp. (RP)	BC_1 (S. sp.)	2,000
5.	PR 70-3364	X	PR 980 x S. sp. (RP)	BC_1 (S. sp.)	700
6.	PR 69-3061	X	PR 980 x S. sp. (RP)	BC_1 (S. sp.)	260
7.	NCo 310	X	B 70-701	BC_1 (S. sp.)	800
8.	NCo 310	X	US 67-22-2	BC_2 (S. sp.)	350
				Total	5,000