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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE

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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 dry matter yield increases with delay of harvest interval;
(c) A superiority of variety NCo 310;
(d) A superiority of first-ratoon dry matter yields over those of the plant and second ratoon crops.

As a 3-year average, dry matter yields for cane and napier grass were 9.0 and 27.5 dry 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 Farrand wheel rake gave superior performance in dense, wetted material, including high stubble. Diesel fuel...

Consumption by a category III tractor operating the rotary scythe in 6-month-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 lb total 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 50-50 tons/acre, and millable stem weights ranged from 33 to 37

tons/acre, at the 6-month harvest. Dry matter yields ranged from 8 to 11 tons/acre. Juice quality values indicated minimal sugar content at this stage of maturity. Fiber values ranged from 7 to 142. A field-scale demonstration study was also established near Hatillo on the semi-humid north coast. 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 towards 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 sellable 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). 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 our cane cultivars, the superior growth rate per se, a botanical feature, has not been historically recognized 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 deals with long-established cultivars, but in a 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 cane 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 (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 ON GREENHOUSE STUDIES

The project's greenhouse phase is concerned with the screening of candidate tropical grasses and the response of superior

Puerto Rico and all produce moderate to heavy nodulation over short periods. The first experiment dealt with species of Leucaena, Phaseolus, Albizia, and Sesbania (Table 3). Direct growth comparisons were made with one of the fastest-growing tropical grasses available, i.e., Sordan 70k, a short-rotation species attaining maximum height and tissue saturation within 12 weeks after seeding. Due to 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 ft2/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 an individual plant.

Two roles are perceived for tropical legumes as supplemental N for tropical grass energy crops: (a) as a precursor 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 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 W 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 exalts 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; Espania was again the most productive of the four legume species tested. (b) Sordan 704 produced more green weight but less dry matter when planted in autumn (i.e., it was relatively less mature at each of the winter harvest intervals). (c) Maturation trends in legume species were essentially equal for spring and autumn planting. (d) The legume Phaseolus Lathyroides was as productive in winter as in summer when dry matter was measured on an individual plant basis (Table 5). Winter thus appears to have affected germination and seedling establishment rather than growth per se. (e) Plant height was restricted in all species by autumn planting. (f) 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 daylight in the tropics have effects on plant growth, they 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 also relate to the island's reduced rainfall during winter months. Vegetable crops are enormously sensitive to weather in Puerto Rico and this is recognized by the local and national growers alike. It now appears that the indigenous tropical legumes will have to be examined closely in this respect whether they are planted as nitrogen-sources for tropical grasses or 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 nitrogen-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 levels were increased in a geometric progression ranging from 1.0 to 81.0 milliequivalents 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 NO3). Two harvests were performed after 5 and 10 weeks of variable treatment, i.e., when the plants were 11 and 16 weeks of age.

-30- For both harvests, the green and dry matter yield data indicate a maximum growth response at around 9.0 meq/l of NO3 (Table 6: Figure 4). On an individual plant basis, there was little difference among variable N levels at 9 weeks; however, the second harvest indicated a broad range of DM responses with high N (61.0 meq/1 NO3) being clearly repressive. Maturation values (DM content) varied but little either among 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.

FIELD-PLOT STUDIES 2, 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...

The performance was conducted 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 6.71 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). 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 6-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 can increase yields, and (c) major yield increases can be achieved 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 XCo 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 26.8 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).

(®) 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. Page Break

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 from 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, 26.0 dry tons).

tons). This is indicated by summary data presented in Tables 16 and 15. Napier grass continued to attain a higher level of maturity than sugar-cane during Year 3 (Table 16). The maximum average DM content for sugar-cane was 26.7% at twelve months; Napier grass achieved a comparable maturity (25.82) 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 crops, 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).

The 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 16 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 use. 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 PR rum industry as a somewhat lower quality "high-test” molasses.

Plant Densities: The number of stems produced by the cane and rapier grass crops was a function of species, harvest frequency, and row spacing (Table 19). Even though close spacing failed to increase yields for sugarcane and rapier 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

The 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+ and 6-month harvest intervals. Napier grass produced more stems than sugarcane, irrespective of the harvest interval. The 6-month harvest period yielded the highest stem counts of the project to date, i.e., 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 199,000 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 longevity 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.

L2-month harvest interval (Table 22). 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, i.e., leaf and leaf-sheath tissues that had detached from the stem and fallen to the ground, such 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. 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 are clear from these results. Under tropical conditions, sugarcane will fill in the available growing space through crown expansion from standard row centers spaced 150 cm apart. Narrowing row centers to 50 cm makes no sense unless the planter intends to harvest only a single crop about 6 to 8 months after seeding. Such management for sugarcane in Puerto Rico would result in gross underutilization of the island's year-round growing season. This would also ignore the plant's botanical need for at least two years to maximize its growth capability.

The vegetative tissue of sugarcane, which includes parts like the leaf sheath known as trash, may not always detach and accumulate on the ground even if they are long dead. The adherence of trash to the stem is probably a varietal characteristic.

2. Napier Grass; 3-Year Trends

(a) Maximum Yields: Three years of cropping show two distinct trends for dry matter (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 22 months; and (b) the first-ratoon crop was the most productive while the plant and second-ratoon crops were about equal.

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. 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. The highest average DM yield for the three crops was 27.5 dry tons/acre per year, which was derived from the combined yield of two, 6-month harvests. This compares quite favorably with the highest 3-year average for sugarcane, that is, 29.0 dry tons/acre per year.

(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.

There were about 20 crops, but these subsequently disappeared and there were no consistent differences noted thereafter. Like sugarcane, it appeared that there were 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: Per acre, approximately three times more than sugarcane, as a main effect, Napier grass produced an enormous number of stems (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.

Sugar-oriented commercial cane industries and (c) new progeny to be bred specifically for the high MM 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 Rican sugar industry. However, without question, these varieties fail to represent the maximum yield potential 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.

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 sub-treatments (varieties PR 960, US 67-22-2, and B 70-701), and three sub-sub-treatments (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 per 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 current varieties, US 67-22-2 and B 70-701 are “second generation” canes having enormous growth potential under PR conditions. PR 960 is a reference variety typifying the island's commercial sugarcane.

"First-generation" canes, managed as biomass crops, require about 400 lbs of elemental N per acre each year. The new N variables will indicate the extent to which this quantity could be reduced (or profitably increased) in varieties specially selected for dry matter and molasses production. The N source is ammonium sulfate in a 6-4-8 fertilizer formulation 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 per year (26). 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 intermittent between those of the first two crops, and subsequent crop years are expected to be 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). 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

Total green weight values at 6 months were surprisingly high for all treatments, 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 treatments.

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 A/ 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).

The key 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 67-222 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 regimens. 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 IM content, was

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 with 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 Casuy River. The predominant soil series is a fertile 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 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 grass. During the first quarter, approximately 25 acres were mowed with a rotary scythe, plowed, rotavated, land-leveled, lined, 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

The energy cane treatment is double-seeded at standard (150 ca) row centers. Un-germinated 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 kept 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 cane 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 sugar cane. It consists of a heavy-duty tool bar and two vertical steel shanks having a maximum submergible 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 the time of planting, or immediately following germination when plant rows are clearly visible to the driver. A Category III.

A tractor is required. Pre-emergence weed control with Atrazine and Anytrine was generally quite effective at the Hatillo site. One weed, a species of Ipomea, survived the pre-emergence 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 size (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 at 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 even though 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 gpa 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 a 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 process.

Preparation operations started in 1980. Water is provided to approximately 2/3 of the planted area, with the remainder being divided into control plots of unirrigated energy cane and unirrigated conventional sugar areas. 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 Hatille dry season.

Initial Yields At 6 Months; Hatillo Site

The principal harvest interval for this study is 18 months. The aim is to demonstrate the disproportionately larger yields to be gained through the delay of energy cane harvest by 6 months, i.e., by use of the "gran custura" 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-month data are included in this report.

Green Matter and Mix

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 960. 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

The variety, which accounted for its superior yields, was due to the 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, but somewhat lower tonnage 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 seem 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 crop injury with the MC 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 58). 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 2/, operates as a single unit. When any portion of the rake is lifted by a QyBLaRe crown, much of the entire rake is lifted and passes over waves 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 sowing. 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 4 sufficient clusters 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.

Fuel Consumption And Estimated Horsepower: Fuel consumption was measured for the new 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 an 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 sugar cane 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 sowing utilizes moderately more fuel than high-stubble mowing (Tables 60 and 61). This relates to the greater resistance offered by Napier grass stems close 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. Moreover, 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-month-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 22-month-old Napier grass, could likely place the rotary scythe workload 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 Mathes Company; (b) a New Holland Company Round Baler;

and (c) a Farmhand Company wheel rake. The rotary scythe-conditioner is of decisive importance in the handling of large tropical grasses as solar-dried energy crops. Successful...

Tox, 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, i.e., as designed for operation on 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 chrome 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 weighs 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 farmer: particularly Sorghum 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;
(d) As a source of cellulose for enzymatic conversion to glucose in a local fermentation project.

Early 1980, the New York-based firm...

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

F. Breeding Studies:

1. Seedling Trials at 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, 5ft x 20ft 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 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 is used for seed expansion purposes. Approximately 2.0 acres were planted with this variety. At intervals of 8 to 10 months, the cane will be cut and planted in a larger seed expansion area. This will in turn 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 with 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 genetic chromosome number). These include PR 68-335, PR 67-1070, the S. robustum clones S7-NoS4, and a wild S. spontaneus hybrid from Rio Piedras (S. sp. RF). The use of S7-NOS4 represents a long-desired entry of S. robustum germplasm into the ARS-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 S 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 (lines 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

The probability of obtaining new progeny with interesting biomass attributes is good.

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DRY WT (kg/PLANTED Area) 36. 400 | Volume 1. Relative dry matter production by Sordan 704 and four legumes propagated in the research growth

PLANT HEIGHT (cm) FIGURE 2. Vertical growth by Sordan 70K and four tropical legumes propagated in the greenhouse with an active research growth series. Seed area = 60 ft2/species/harvest.

WT (Kg/Plant) 0. Figure 3. Individual plant weights for Sordan TOA and four tropical species propagated in the greenhouse with a soil/research growth series

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

Cropping	Growth Interval	Maximum	Category (Months)
Short Rotation	46	23	
Intermediate Rotation	18	46	
Long Rotation	36-60	12-18	
Minimum Tillage	Indeterminate	0	

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Mean	37	122	4.9	21.2	10	1	446	107	6.8	23.9	3	658	Ma	ma	22
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Table 7: Biomass Production by Five Saccharum Clones Under Minimum-Tillage Conditions, Feb. 11 - Aug. 5, 1980

Clone	Months	Yield (Tons/Acre)	Green Matter	Dry Matter
PR 980	173	0.52	30.0	
US 67-22-2	31	0.98		
US 72-72		0.38	30.9	
US 72-93	4	1.88	39.9	

Spont. Hybrid		0.86	0.26	30.0

* 4 months harvest. Originally planted during February, 1977.

Table 8: Biomass Production by Five Saccharum Clones Propagated with Minimum Cultural Inputs, Harvested at Intervals of Six Months

Clone	Yield (Tons/Acre, 6 Month)	Feb. 5, 1978 - Aug. 5, 1978	Aug. 5, 1978 - Feb. 5, 1979	Feb. 5, 1979 - Aug. 5, 1979	Aug. 12, 1979 - Feb. 11, 1980	Feb. 11, 1980 - July 27, 1980
PR 980	16.0			0.22		
Green-2						
US 67-22-2	16.7					
US 72-72						
US 72-93						
Spont. Hybrid	3.33			0.6		

*Originally planted during February, 1977.

Approximately 50% 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 - 2 Month Harvest

Cultivar	Row Center	Green Matter (Tons/Acre)	Dry Matter (Tons/Acre)
PR 980	180.0		300.0
PR 791			
Napier Grass			16.2

Dry Matter (%)	PR 980	20.28	47
Neo 310	19.56		
PR 791			
Napier Grass	12.8		

*Mean values in the same column bearing unlike letters differ significantly (@.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 6 Month Harvest

Cultivar	Row Center	Green Matter (Tons/Acre)
PR 980		23.9

Neo 310 | 18.9 | 13.2
PR 791 | |
Napier Grass | |

Table 11. Biomass production by the second ratoon crop of three sugarcane varieties and one Napier grass variety from allocated variable row centers; second 6-month harvest.

Green Matter (Tons/Acre), at Row Center:
Cultivar 130: 980 tons, 18.2 tons
Cultivar 310: Not available
Cultivar PR 64-1791: Not available
Napier Grass: Not available

Dry Matter (Tons/Acre):
Cultivar 980: 3.2 tons
Cultivar 310: Not available
Cultivar PR 64-1791: Not available
Napier Grass: 15.64 tons

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 12. Biomass production by the second ratoon crop of three sugarcane varieties and one Napier grass variety from allocated variable row centers; 12-month harvest.

Green Matter (Tons/Acre), at Row Center:
Cultivar 150: 980 tons, 56.0 tons
Cultivar 310: 32.0 tons
Cultivar PR 64-1791: Not available
Napier Grass: Not available

Dry Matter (Tons/Acre):
Cultivar 980: 26.3 tons
Cultivar 310: Not available
Cultivar PR 64-1791: Not available
Napier Grass: Not available

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.

Dry Matter (Tons/Acre) at Row Center:
Cultivar 150: PR 980 - 26.7 tons, No 310 - 31.3 tons, PR 64-1791 - 25.4 tons
Cultivar 50: Napier Grass - 19.9 tons

Trash included.

This text appears to be highly corrupted and unclear. It may contain complex abbreviations and codes that are not widely recognized or understood. Without a clearer context or a more specific guideline, I'm sorry but it's difficult for me to correct it. Could you please provide more details or context?

The provided text seems to be highly disorganized and contains many non-English terms. It could possibly be because of a faulty OCR (Optical Character Recognition) scan or a typing error. It's not possible to correct the text without knowing the correct context or the original text. It would be best to rescan the document or check the original source.

Of Crop's Total Yield, For Crop — Plant Period 1st Ratoon 2nd Ratoon Mean July 15—Sept. 15 16.50 21.0 19.2 Sept. 15—Nov. 15 13.6 15.5 Nov. 15—Jan. 15 23.6 15.9 16.7 Jan. 15—Mar. 15 2.0 25 13.6 9.3 Mar. 15—May 15 21.8 25.2 26.1 May 15—July 15 10.2 12.6

Table 36. Seasonal Influence on Dry Matter Yields by Three Crops of Sugarcane and Napier Grass; 4-Month Harvests

Sugarcane

Of Crop's Total Yield, For Crop Period Plant 1st Ratoon 2nd Ratoon Mean

July 15—Nov. 15 30.6 46.8 Nov. 15—Mar. 15 32.8 16.2 Mar. 15—July 15 36.9 38.6

Napier Grass

July 15—Nov. 15 25.2 36.3 32.7 Nov. 15—Mar. 15 37 23.6 27.8 Mar. 15—July 15 37.6 39.4 39.6

Table 25. Treatments and Harvest Dates for the “Second Generation" Energy Cane Study at AES-UPR Lajas Substation

Harvest Date, At Interval Variety lbs/Acre Yr) 6 Months 12 Months 18 Months 24 Months

PR 980 200 Feb. 1, 1981 Aug. 2, 1981 Feb. 1, 1982

US 67-22-2 200

B 70-701 200

* For plant crop only.

Table 36. Projected DM Yields for Second Generation Energy Canes Propagated in Puerto Rico's Lajas Valley

Projected DM (Tons/A), For Crop Variety Category

PR 980 1st Generation 27-29 36-40

US 67-22-2 2nd Generation 38-42 48-52

B 70-701 2nd Generation 38-42

* Year included.

Table 37. Total Green Weight for Three Sugarcane Varieties Under Variable N and Harvest Regimes

GY (Tons/A), At Month Variety (Lbs/Acre Yr) 6 12 18 Mean

PR 960 200 49.9 400 33.8 600 51.0 Mean 51.6

US 67-22-2 200 60.2 400 60.9 600 61.5 Mean 60.8

B 70-701 200 52.3 400 52.9 600 56.3 Mean 53.8

* 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

TCA, At Month — Variety (Lbs/Acre Yr) 6 12 18

Corrected text:

18 Mean PR 980 200 31 400 35.0 600 36.6 Mean 34.9 US 67-22-2200 33.7 400 36.4 600 31.3 Mean 33.8 SR B 70-701, 200 31.6 400 600 Mean 33.0 A/ Each figure is the mean of four replicates.

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

Percent x Plant Mass (Lbs), At Month — Variety (lbs/Acre Yr) 6 12 18 Mean, PK 980 200 2.97 400 2.96 600 2.55 Mean 2.83 US 67-22-2200 2.45 400 2.56 600, 2.51 Mean 2.51 B 70-701, 200, 2.80 400 2.98 600 2.97 Mean 2.92 A/ 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

Percent x Stalk Weight (Lbs), At Month Variety (Lbs/Acre Yr) 6 12 18 Mean PR 980 200 1.97 400 1.93 600 1.83 Mean 1.92 US 67-22-2200 200 1.37 400 1.53 600 1.36 Mean 1.36 B 70-701 200 1.69 400 1.77 600 1.96 Mean 1.81 A/ 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 S AND HARVEST REGIMES

Stem Length (Ft), At Month Variety (Lbs/Acre Yr) 6 12 18 Mean PR 980 200 4.63 400 4.56 600 4.45 Mean 4.55 US 67-22-2200 4.29 400 4.00 600 4.01 Mean 4.10 B 70-701 200 6.60 400 6.27 600 6.29 Mean 6.39 A/ Each figure is the mean of four replicates. Six stems were harvested per replicate.

TABLE 42, STEM COUNTS FOR THREE SUGARCANE VARIETIES UNDER VARIABLE S AND HARVEST REGIMES

Stem/acre (Thousands) At Month Variety (lbs/acre Yr) 6 12 18 Mean PR 980 200 29.4 400 31.5 600 38.1 Mean 33.0 US 67-22-2200 46.3 400 63.0 600 49.1 Mean 52.8 B 70-701 200 46.0 400 50.0 600 56.0 Mean 50.7 A/ Each figure is the mean of two replicates.

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

Metric Tons/Acre (Tons/A), At Month Variety (Lbs/Acre Yr) 6 12 18 Mean PR 980 200 8.7 400 8.8 600 8.9

Mean 8.5 US 67-22-2200, 400 9.6, 600 9.6, Mean 10.1 B 70-701, 200 9.6, 400 9.6, 600 9.3, Mean 2.5 A. Each figure is the mean of four replicates.

TABLE 44. DRY MATTER CONTENT OF THREE SUGARCANE VARIETIES UNDER VARIABLE WATER HARVEST REGIMES (Experimental x PAGE) At Month Variety (Lbs/Acre Yr), 6 2 18 Mean PR 980, 200 17.5, 400 16.4, 600 15.7, Mean 16.5 US 67-22-2200, 200 18.4, 400 35.8, 600 15.6, Mean 16.6 AJ. Each figure is the mean of four replicates.

TABLE 45. BRIX VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE NITROGEN AND HARVEST REGIMES Elemental Variety (Lbs/Acre Yr), 6 R 18 Mean, PR 980, 200 6.16, 400 5.80, 600 5.58, Mean 5.85 US 67-22-2, 200 6.14, 400 3.27, 600 5.57, Mean 5.66 B 70-701, 200 4.40, 400 4.193, 600 4.30, Mean 4.50. Each figure is the mean of four replicates.

TABLE 46. POL VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE NITROGEN AND HARVEST REGIMES Elemental POL Reading, At Month Variety (Lbs/Acre Yr), 2 18 Mean PR 980, 200 2.3, 400 1.8, 600 1.68, Mean 1.87 US 6722-2, 200 2.90, 400 1.40, 600 1.0, Mean 1.48 B 70-701, 200 0.88, 400 0.93, 600 0.80, Mean 0.87. Each figure is the mean of four replicates.

TABLE 47. YIELD VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE WATER AND HARVEST REGIMES Elemental N At Month Variety (Lbs/Acre Yr), 6 2 18 Mean PR 960, 200 0.05, 400 0.17, 600 0.34, Mean 0.19 US 67 22-2, 200 0.33, 400 0.166, 600 0.70, Mean 0.70 B 70-701, 200 -0.99, 400 0.135, 600 -1.05, Mean -1.05. Each figure is the mean of four replicates.

TABLE 48. FIBER VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE WATER AND HARVEST REGIMES Elemental Fiber (%), At Month Variety (Lbs/Acre Yr), 6 2 18 Mean PR 980, 200 -, 400 -, 600 -, Mean - US 67-22-2, 200 20.21, 400 10.01, 600 9.6, Mean 9.79 B 70-701, 200 -, 400 13.102, 600 8.75, Mean 10.56. Each figure is the mean of four replicates.

TABLE 49. TRASH YIELDS FOR THREE SUGARCANE VARIETIES UNDER VARIABLE WATER AND HARVEST REGIMES. Elemental Tons.

The text appears to be a compilation of several tables related to some kind of agricultural study or report, possibly related to cane harvesting. It's difficult to correct the text without additional context or understanding of the original intention and layout of the tables. It seems the text has been distorted and the correct values or labels for some fields might be missing.

However, I can still correct the obvious spelling and grammar errors, and organize the text in a more readable format:

'Trash/Acre, At Month variety (per acre) 6 2 18 Mean FR 980 200 0.84. 00 ras 600 099 Mean LoL vs 67-222 200 0.96 00 or 00 ms a Mean 1.03 a B 70-701 200 0.74 00 oe 600 0.73 ee Mean 0.72 s+. 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 Exergy Cane Demonstration on a Humid Alluvial Plain Matiulo, PR. Seedbed prep: Standard. Seeding rate: Double-seeded. Row spacing: Standard (150 cm). Variety: 7 980 PR 960 PR 980. Herbicides: Pre-k Post-emergence. Nitrogen: 600 lbs/acre/18 months. Water fertilization: Irrigation plus rainfall. Harvest: 18 months, grain culture. Planting completed August 27, 1980.

Table 51. Total Green Weight Yields for Energy Cane Harvested at Variable Intervals; Hatillo Project. Tot. Green Wt. (Tons/A), At Month - Treatment 6 2 18 Mean. Control (Low Till): 36.7. Control (Sugar Corp.): 30.8. Energy Cane: 36.0. US 67-22-2: 50.2.

Table 52. Millable Cane Yields for Energy Cane Harvested at Variable Intervals; Hatillo Project. Millable Cane (Tons/A), At Month - Treatment 6 2 18 Mean. Control (Low Till): 23.2. Control (Sugar Corp.): 19.3. Energy Cane: 24.0. US 67-22-2: 34.7.

Table 53. Top Weights for Energy Cane Harvested at Variable Intervals; Hatillo Project. Top Weight (Tons/A), At Month - Treatment 6 2 18 Mean. Control (Low Till): 9.9. Control (Sugar Corp.): 6.4. Energy Cane: 6.6. US 67-22-2: 12.3.

Table 54. Trash Yields for Energy Cane Harvested at Variable Intervals; Hatillo Project. Trash Weight (Tons/A), At Month - Treatment 6 2 18 Mean. Control (Low Till): 5.8. Control (Sugar Corp.): 5.2. Energy Cane: 6.1. US 67-22-2: [Value is missing]'

Please note that the tables might not represent the correct labels or values as it is difficult to interpret the original text.

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

Dry Matter (Tons/AC), At Harvest 2 — Treatment

Control (Low 2611)

Control (Sugar Corp.) 5.7

Energy cane 5.9

Variety US 67-222

Note: Oven-dry, approximately 62% moisture.

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

Dry Matter Content (%), At Month — Treatment 6 12 18 Mean

Control (Low Ts11)

Control (Sugar Corp.) 18.4

Energy Cane 16.5

Variety US 67-222

Mean 17.5

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

Plant Height (Ft), At Month — Treatment 6 12 18 Mean

Control (Low Tii1) 5.4

Control (Sugar Corp.) 4.7

Energy Cane 4

Variety US 67-22-2

Mean 4.8

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

Stems/A (Thousands), At Month — Treatment 6 12 18 Mean

Control (Low 1411)

Control (Sugar Corp.) 28.4

Energy Cane 32.5

Variety 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.

Rotary Scythe Area or Yield Per Crown

Plot No. Mowing Height (in.) (Acres) (Tons/Acre) Damage

1 8-10 0.69 7.98 Minimal

2 0.69 8.77 None

3 0.68 1.67 Minimal

4 0.69 8.80 Minimal

Note 1: Excluding approximately 20% of the total dry matter in the form of unraked residues. This material could not be windrowed with the available forage rake.

Note 2: Observations based on subsequent production of new shoots.

[Unreadable text]

TABLE 61: PERCENTAGE INCREASE IN FUEL EXPENDITURE AND HORSEPOWER FOR LOW CUTTING AS OPPOSED TO REGULAR CUTTING

TO HIGH CUTTING: ROTARY SCYTHE TEST ON SIX-MONTH-OLD NAPIER GRASS.
Fuel Expenditure Calculations: 29.8 Gallons/Hour, 15.9 Gallons/Acre, 30.2 BTUs/Acre, 30.2 Horsepower 15.9

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

Number of Seedlings — Crosses:

US 67-22.2 x PR 68-330: 966, 7, 5
US 67-2202 x PR 67-1070: 2, 6
US 67-22-2 x PR 68-2061: 1200, 2, 6
US 67-22-2 x F160: 270, 5
PR 68-3061 x US 67-2202

Note:
1. Planted during 1979 at the AES-UPR Gurabo Substation for initial seedling evaluation.
2. Planted on August 14, 1990, 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.

(48-3) (BED) Ux Cae yy bog 1 s ews sox ote eon ru sx ore con 900-69 a oxtt-a9 ta wero we 9