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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE

Second Quarterly Report for 1978-1979

MASTER

Work Performed Under Contract No. ET-78-S-05-5912

Agricultural Experiment Station
Puerto Rico University
Rio Piedras, Puerto Rico

U.S. Department of Energy

Solar Energy

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE

Second Quarterly Report; Year 2
1978-79

To

The United States Department of Energy
Oak Ridge Operations Office, and the Division of Solar Energy
Fuels From Biomass Systems Branch
Washington, D. C.

By

The University of Puerto Rico
Center for Energy and Environment Research

Through

The Office of the President
University of Puerto Rico

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Project Leader

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SECOND QUARTERLY REPORT; YEAR 2

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

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ABSTRACT

Research during the second quarter centered on greenhouse screening of candidate grasses coupled with field-plot studies on varieties, optimal nitrogen and seeding rates, variable row spacing, and frequency of harvest. Candidate grasses were identified for short-rotation crops having potentially greater versatility than Sordan 70A (earlier maturation greater tolerance to moisture stress). Field-plot studies were performed on the optimization of N-fertilization and seeding rates for Sordan 70A. Field-plot data were recorded on sugarcane and napier grass responses to harvest frequency and row spacing. These results underscore a superiority of first-ratoon yields over plant-crop yields, of napier grass over sugarcane (up to 4 months), and delayed harvests over frequent harvests. Breeding tests were successful in producing F_1 seedlings from crosses between an unknown and early-tasseling wild S. spontaneum hybrid and late-tasseling commercial sugarcane hybrids.

1/ Contract No. ET-78-S-05-5912 (AES-UPR project C-481).

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/

INTRODUCTION

The biomass production studies herein reported were performed between September 1 and November 30, 1978, as a contribution to the biomass energy program of the UPR Center for Energy and Environment Research (CEER). 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 as a renewable, domestic source of fuels and chemical feedstocks that will substitute for imported fossil energy sources. The present report covers the second quarter of the project's second year.

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 alternate 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.

1/ Contract No. ET-78-S-05-5912 (UPR-AES Project No. C-481).

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 plant densities and harvest frequency, will vary significantly from established procedures. On the other hand, advances in mechanized production and harvest operations within the sugar and cattle forage industries will be utilized to the maximum extent possible for dry biomass production.

The project's work plan during the first year developed along two planned dimensions: (a) Development of candidate species categories, and (b), development of optimized botanical, agricultural, and economic inputs for biomass production with superior candidates (1) ^{1/}. Species categories include short-, intermediate-, and long-rotation plants for co-production with food crops. A fourth category includes minimum tillage or "low till" candidates. The latter group would be produced on marginal lands too dry, too saline, or too steeply contoured to be competitive for conventional food production. Candidate species screening and the optimization of botanical and agricultural inputs is progressing well. Economic analyses will begin during the fourth quarter of year 2. All candidate species are herbaceous annuals (sugarcane is sometimes propagated as a perennial plant), as opposed to woody species.

^{1/} Numbers in parenthesis refer to relevant government reports or published literature. Complete citations are listed on page 21.

Statistical analyses that were incomplete in the previous report, ie, pertaining to experiments still in progress, are generally updated at this time. New experiments are now in progress and in some cases their finalized data will also need to appear in subsequent reports.

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. This is a continuous process and also the first major phase in a systematic conversion of wild or untested species to energy plantation crops whose management requirements are understood in depth (Table 1). Fewer candidates are being screened during year 2 but there is a much clearer picture now of the categories of species required and of the production capabilities which must be met by individual clones within each category.

Biomass studies at the greenhouse level are basically a time- and money-saving operation. They are designed to identify superior clones and management practices to be directed to the more costly field-plot and field-scale studies. Descriptions of the greenhouse methods for this project are given elsewhere (1, 2).

1. Candidate Screening; Total DM and Maturation Curves

The first clearly outstanding candidate to emerge during the project's first year was a sweet sorghum x sudan grass hybrid produced by the Northrup-King Company (3). Marketed under the trade name "Sordan 70A", this hybrid had

shown considerable growth potential as a cattle forage on Puerto Rico's arid south coast (4). For biomass production it is basically a short-rotation candidate, that is, it makes very rapid growth over a short time-course, and completes both a tissue-expansion and a maturation phase within about 9 or 10 weeks after seeding (Table 2).

While Sordan 70A is regarded as an extremely promising candidate for biomass production, a series of screening experiments have been initiated with the objective of identifying superior or more versatile candidates. The reasons for this are as follows: (a) There is a reasonable likelihood that the same breeding programs for commercial forage grasses that produced Sordan 70A could also yield superior biomass-yielding varieties; (b) candidates are needed with greater tolerance to heat and drouth conditions; (c) greater disease resistance is needed (Sordan 70A has shown downy mildew susceptibility in Puerto Rico); (d); there is a need for somewhat longer-maturing grasses to supplement napier grass and napier hybrids in the intermediate-rotation category; and (c) there is also need for shorter-maturing grasses to accommodate extremely short-rotation situations.

One screening experiment included seven forage grasses from the same breeding program (Northrup King Company) that produced Sordan 70A; in this instance Sordan 70A was retained as the standard or reference variety. Dry matter yield values were recorded from weeks 3 through 7 (Table 3). In essence, this covers the period of rapid tissue expansion for Sordan 70A. On an individual plant basis Sordan 70A appeared to outyield each of the other grasses by week 7; however, the difference was statistically significant only in the instance of Millex 23. Total productivity of varieties such as Sordan 77 and NK 300, when measured in terms of dry matter tonnage/acre year, could conceivably equal or exceed that Sordan 70A.

Evidence of an early maturation characteristic superior to Sordan 70A was found in the varieties Sordan 77 and Trudan 7 (Table 4). Both varieties revealed dry matter accumulations significantly higher than Sordan 70A by the fourth week after seeding, and these trends persisted throughout the experiment (Figure 1). Sordan 77 appeared to have largely completed its maturation phase by week 6. The maturation profiles for both Sordan 77 and Trudan 7 were continuing to develop at week 7, but they were advanced some one to two weeks over of Sordan 70A. The value of such varieties relates in part to their potential contributions as energy crops during extremely brief land vacancies in food crop rotations. Hence, Sordan 70A requires about 10 to 12 weeks to complete its maturation phase (1), while time intervals of only six weeks or less are quite certain to occur between the harvest of one food crop and the planting of another. They have added value to the extent that they increase the size of the varietal pool for accommodating variable soil, water, and climate regimes in different parts of Puerto Rico and other regions of the world.

2. Variable Moisture Regimes

The first variable-moisture study of the project utilized the same Northrup-King varieties discussed above. It was a non-replicated observation experiment in which humid, normal, and semi-arid conditions were simulated by varying the frequency of plant watering. All plants were propagated in the greenhouse in a 1:2 mixture of soil and cachaza, and Sordan 70A again served as the reference variety. In this instance the experiment's duration was extended to 11 weeks, thereby encompassing both the tissue-expansion and maturation phases of Sordan 70A.

Summary data for all varieties revealed the following trends: (a) The "humid" regime in which the propagation medium was kept constantly moist was repressive for total DM production (Table 5), while the "normal" regime was superior to both humid and semi-arid conditions; (b) mean values for dry matter content indicate that, as a group, the candidate grasses experienced a rapid maturation phase from week 6 to 10 (Figure 2); (c), individual varieties, in direct comparisons with Sordan 70A and propagated with normal water regimes, revealed a much superior maturation curve for Trudan 7 (both earlier and more extensive DM accumulation), and an inferior maturation curve for Millex 23 (Figure 3); (d), under semi-arid regimes, the varieties Trudan 7, Sordan 77, NK 300, and NK 326 gave growth performances which equaled or exceeded those of Sordan 70A (Table 6, Figure 4).

As unreplicated data these trends are not yet verified statistically, but they have important implications nonetheless. They suggest that a fairly large pool of "short-rotation" candidates exists having a productive capability comparable to Sordan 70A. Possibly more important, the tolerance of several candidates to low moisture regimes may enable them to serve as "minimum tillage" candidates, that is, within biomass production regimes receiving only the barest minimum of production inputs. Additional experiments are planned involving replicated treatments, fewer varieties, and more severe low-water regimes.

3. Mineral Nutrition

Nitrogen-response curve studies were extended to the intermediate-rotation category of tropical grasses during the second quarter. Initial N-curve results with Sordan 70A (short rotation) were reported previously (1, 2). The hybrid napier grass PI 300086 is the representative cultivar. It is being propagated by sand culture with controlled water and nutrient supplies. The primary

objective is to determine the slope of dry matter response to progressively higher input levels of N. Accordingly, N supplies are varied in an essentially geometric progression from 1.0 to 81.0 milequivalents per liter of NO_3 (Table 7). Other macronutrients and micronutrients are maintained in constant but adequate levels. The total ionic concentration of these nutrient solutions is adjusted to that of the highest N level with NaCl.

Nutritional information obtained by the sand culture technique is not directly applicable to field conditions; however, important relationships of nutrient supply to biomass-yielding potentials are obtained this way more rapidly, at lower cost, and with greater precision than is possible under field conditions. For example, the initial slope and overall shape of the N-response curve is a characteristic feature of the test species whether propagated in an open field or in soil or nutrient culture under glass.

A very favorable N-response curve was obtained previously for Sordan 70A (1, 2). A distinct plateau for dry matter yield was obtained beyond which higher N levels produce little added return. This lack of response by Sordan 70A to high N supplies was subsequently verified in field-plot tests (pp. 12-14). A less favorable response curve is anticipated for the hybrid napier grass. This is based on prior research in Puerto Rico with common napier grass produced as a cattle forage (5, 6). At least for that variety, green matter yields continue to rise with N-input levels far higher than a grower could wisely provide.

4. Importation and Quarantine of Candidate Tropical Grasses

During the late summer of 1978 two shipments of candidate tropical grasses totalling 37 clones were imported into Puerto Rico and placed in quarantine at the AES-UPR Gurabo Substation. These clones derived from USDA-World collections

at Beltsville, Maryland and at Canal Point, Florida. They include clones from the Saccharum species spontaneum, robustum, fusca, and narenga, and from the genera Ripidium, Miscanthus, and Erianthus.

These candidates were planted in soil-cachaza mixtures and all but one gave satisfactory germination. Growth has been adequate though unremarkable for most clones. Several clones produced tassels (flowers) late in November and December, 1978. Saccharum species very rarely flower under greenhouse conditions, but the late flowering trait could be a useful factor in its own right since it would enable these clones to be crossed with hybrid sugarcane which normally tassel at this time ^{1/}. The observed flowering could also be an artifact of the plants' greenhouse environment or their late-summer time of planting.

None of the imported species are thought to be suited for short-rotation cropping. They are regarded as candidates for long-rotation and minimum-tillage biomass crops, although certain of the Saccharum species may compare favorably with napier grass and napier hybrids as intermediate-rotation candidates. They might also expand the planting zones of intermediate- and long-rotation species into semi-arid and arid regions too dry to sustain napier grass and conventional sugarcane hybrids.

^{1/} The sugarcane of commerce tend to flower later than the more primitive Saccharum species. This is an unfortunate trait of considerable importance to sugarcane breeders concerned with utilizing the widest possible range of Saccharum germplasm in their hybridization programs.

B. FIELD PLOT STUDIES

1. Saccharum Species Candidates; Gurabo Substation

An observation field-plot trial with candidate S. spontaneum and S. sinense species has been underway since October, 1977. The final harvest completing one year of growth performance was taken during October of 1978 (Table 8). Cut repeatedly at 2-month intervals during the final eight months of year 1, the plants were subjected to a reharvest syndrome comparable to that of short-rotation cropping. Under this harvest regime the S. spontaneum clones SES 317 and SES 327 died out, as did the one Erianthus maximus clone tested to date, NG 132.

Yield values (Table 8), together with tillering and maturation characteristics (Table 9), indicate that three outstanding candidates emerged in two categories. The first group is dominated by the S. spontaneum clone SES 231, a wiry, thin-stemmed grass having no sugar potential at all but persistently high fiber production per acre year. It tillers abundantly and has a fairly high dry matter content for 2-month old material (Table 9). Similar traits were evident to a lesser degree in the S. sinense clones Chunnee and Tainan. The second category includes thick-stemmed S. spontaneum clones having a sugar-yielding capability in addition to high fiber production. The outstanding clone is US 67-22-2, followed closely by US 72-70 (Table 8). Their dry matter yields slightly exceed that of SES 231 while exceeding the commercial hybrid reference clone (PR 980) by roughly 50 percent. Neither US 67-22-2 nor US 72-70 tillered as profusely as SES-231, but nonetheless they produced more than double the number of stems recorded for PR 980.

Each of the three outstanding grasses is regarded as a potential minimum tillage candidate for field plot trials on the Island's semi-arid south coast. At this point in time, SES 231 is viewed as an intermediate-rotation candidate to be harvested as a solar-dried forage at intervals of 4 to 6 months. There is some possibility also that it can serve as a dryland short-rotation crop to be harvested at 2 to 3 month intervals. The thick-stemmed grasses, US 67-22-2 and US 72-70, should probably stand a year between harvests to obtain both sugar and fiber. In any case, these varieties would require milling as a de-watering step in their processing operations for fuels. They cannot be accommodated by any existing equipment for production of solar-dried forages.

The S. spontaneum and S. sinense crowns presently established at the Gurabo Substation are being retained for one additional year. This will provide the project with data on the long-term durability of such species without accruing the added time and expense of a new experiment. During the second year these clones will also be managed as minimum tillage crops receiving low water, fertilizer, and pesticide inputs. Harvest intervals will be extended from two months to four or six months.

2. Variable N and Seeding Rates, Sordan 70A; Lajas Substation

By the close of Year 1, Sordan 70A had been identified as the first authentic biomass source for short-rotation cropping (1). Initial trials had utilized a nitrogen level equivalent to 300 pounds of elemental N per acre year, and a seeding rate of 60 pounds per acre. The N level was roughly double that used by the local sugarcane industry and about half the amount used locally for producing napier grass. The seeding rate originally recommended by the Northrup King Company was only 30 pounds per acre, for propagation of Sordan 70A as a cattle forage, and this rate produced a perceptively sparse

stand of plants. When increased to 60 pounds per acre a much better stand was obtained, yet this also seemed sparse for optimal biomass production. It was considered likely that a seeding rate somewhere in the range of 60 to 120 pounds per acre would be optimal for total biomass production.

Accordingly, a major field-plot study was established at the semi-arid AES Lajas Substation during July, 1978, with the objective of clarifying optimal N fertilization and seeding rates for Sordan 70A. The experiment was planted on a Fraternidad Clay soil. This is a greyish-brown soil distributed widely throughout the Lajas Valley and characterized by a light, crumbly texture when dry and a heavy, plastic condition when wet. Controlled variables included nitrogen at 300, 600, 900 and 1200 pounds per acre, and seeding rates of 60, 80, 100, and 120 pounds per acre. Nitrogen was supplied in the form of ammonium sulfate. All seeding was performed by hand in rows spaced 9 inches apart. Plot size was 1/50 acre and there were six replications arranged in a randomized split plot design. Three harvests were performed at intervals of 10 weeks. One-third of the fertilizer was applied at the time of planting, 1/3 immediately after the first harvest, and the final 1/3 after the second harvest. Irrigation water, amounting to about two acre inches per application, was administered by overhead sprinklers at planting and by flooding as needed thereafter.

Whole plots were harvested for green-weight determinations at 10, 20, and 30 weeks following seeding. Sub-samples consisting of ten whole plants per plot were harvested and dried in a forced-air oven for dry matter determinations. Identical sub-samples were also harvested for foliar mineral analyses. The entire blades of leaf ranks ⁺¹ and ⁺² were oven-dried, ground to pass a

40-mesh screen, and submitted to the AES Central Analytical Laboratory for total N, P, and K analyses.

Although statistical analyses are still pending, neither increased N levels nor increased seeding rates appreciably raised the dry matter yields of Sordan 70A (Table 10). Similar results were obtained for total green matter (Table 11). While unexpected, these responses do have the effect of minimizing input costs for future planting of Sordan 70A.

(a) Responses to Variable N Supply: Mean values for increasing N supply indicate that the highest yields of the study were obtained from 600 lbs of N per acre (224 kg/ha), but that this constituted an increase of only four percent over the yields from 300 lbs N/acre (Table 10). Similarly, mean values for increased seeding rates reveal that the highest dry matter yields were produced by 100 lbs of seed per acre (112 kg/ha). This was an increase of only 10 percent over yields obtained from 60 lbs/acre. Yield gains of such low magnitude cannot justify the higher fertilizer and seed costs that would be incurred.

Foliar N analyses were consistent with the view that Sordan 70A made little or no response to N-fertilization levels higher than 300 lbs/acre (Table 12). It should be noted that the dry matter and foliar N data are at least consistent with earlier data obtained by sand culture during year 1 (1). At that time the N-response curve revealed an abrupt plateau for dry matter which could not be altered by large increases in nitrate-N supply.

It is now evident that the N-fertilization range established for this experiment was too high. The optimal level probably lies within the range of 100 to 300 lbs N/acre. This point can be verified rather easily with a small field plot experiment far less elaborate than the one presently described.

(b) Maturation Responses to Variable N and Seeding Rates: Data from the first harvest (at 10 weeks) indicate that neither the N-nor seeding-rate variables appreciably affected the plants' state of maturation. Mean values presented in Table 13 reflect only small decreases in dry matter content as a result of increased N supply and plant density, although fairly pronounced changes could have been expected, for example, on the basis of N effects upon sugarcane maturation processes (7, 8).

Tissue samples harvested weekly during the plants' growth and maturation phases similarly reveal little effect on maturation by the two controlled variables (Table 14). Plotted graphically (Figure 5), the maturation curves for low-N and high-N plants are seen to differ persistently from week 4 onward, with high N causing a moderate delay in maturation. However, this delay amounts only to a week or less in the maturation time-course. It is interesting to note that all plants experienced a minor increase in dry matter at about week 3 (Figure 5). This may have been caused by a temporary soil moisture stress.

(c) Plant Density, Lodging, and Downy Mildew: Increased seeding rates produced moderate increases in the number of harvestable stems (Table 15). However, these gains did not reflect the large amounts of seed involved. Mean values for main effects indicate that plant number was increased by only 24 percent in response to a 100 percent increase in seed. Somewhat larger gains in harvestable plants resulted when seeding rates were increased within the lowest two N regimes (300 and 600 lbs/acre). These gains were negated in the higher N regimes (Table 15).

Some evidence of downy mildew was detected at about the fifth week of the study. By week 10 the disease had spread in varying degrees to all plots.

The infection was not sufficiently severe to reduce yields among any of the treatments; however, the apparent severity of this disease was visually ranked on a numerical scale to determine whether it was directly related to the N-and seeding-rate variables. Some evidence of lodging was also visible in certain plots by week 10, and this was similarly rated on a numerical scale while the plots were being harvested. The numerical rankings indicate that downy mildew became moderately more severe with increasing levels of N fertilization (Table 16). Lodging was apparently unrelated to the variable N levels. In a similar vein, neither downy mildew nor lodging were related to variations in seeding rate (Table 17).

3. Sugarcane and Napier Grass Trials; Lajas Substation

A major study was conducted during Year 1 evaluating high-tonnage varieties (sugarcane and napier grass), row spacing (150 cm and 50 cm for sugarcane; 50 cm and 25 cm for napier grass), and harvest frequency (2-, 4-, 6-, and 12-month harvest intervals). Complete data for first-year results were presented in the first quarterly report of Year 2 (2). The study was continued during the project's second year with the following objectives: (a) to evaluate ratoon-crop responses, as opposed to "plant crop" responses; (b) to provide increased fertilization for plants receiving an apparently inadequate N supply during Year 1; and (c), to evaluate longer-term effects of narrow row centers and frequent recutting on plant crown productivity.

(a) Increased Fertilization and Crown Maturity: During Year 1, sugarcane received nitrogen at the rate of 300 lbs per acre applied in three increments (1/3 at planting, 1/3 at 4 months, and 1/3 at 8 months). Napier grass received 600 lbs of nitrogen per acre applied in three increments at the

same time intervals. For Year 2, these levels were increased to 600 and 1200 lbs. per acre for sugarcane and napier grass, respectively, by increasing the number of incremental applications from three to six (ie, to six applications at 2-month intervals).

Growth data for the plant crop had revealed major growth surges in the two months following the application of each fertilizer increment, followed by growth decline for the subsequent two months preceeding the next fertilizer increment (Figure 6). This response was more pronounced for napier grass than for sugarcane. One potential effect of applying fertilizer at two-month intervals rather than four months would be a persistent growth surge throughout the crop's second year. Added to this, the increased maturity of the plant crowns (particularly for sugarcane) might logically sustain greater yields throughout Year 2.

(b) Initial Growth Responses; Two Month Harvests: Results from the initial two-month harvests of Year 2 (the "first ratoon" crop) differed from those of the plant crop in two important features: (a) There were no pronounced yield increases from narrow rows in sugarcane, and (b), one of the three sugarcane varieties (NCo 310) increased productivity while the remaining varieties (PR 980 and PR 64-1791) showed reduced productivity. These trends were reflected both in dry matter (Table 18) and total green weight (Table 19). Napier grass did not respond to narrow rows but at this stage was far more productive than the sugarcane varieties. The dry matter content of sugarcane was slightly higher than that of napier grass (Table 20).

The second two-month harvest, performed in mid-November, revealed less growth by sugarcane than the first harvest performed in September, even though fertilizer had been applied following the first harvest (Tables 21 and 22). This may reflect an abnormally cool and rainy autumn for Puerto Rico's south coast; nonetheless, napier grass retained a high productivity throughout this period. The dry matter contents of both napier grass and sugarcane were appreciably higher for the autumn harvest (Table 23). Again, narrow rows persistently failed to increase yields in each of the three sugarcane varieties, and only a small (but statistically significant) increase was obtained from napier grass at close spacing.

These trends support our first-year conclusions relative to close spacing in sugarcane. Initial yield gains, although large, must relate to crown development rather than canopy closure. If canopy closure were the decisive factor, the closely-spaced plants should have outyielded the standard spacing as they did early in the plant crop; none of the standard crowns had appreciably filled in the interrow spaces. At this stage also it is evident even from visual inspection that the closely-spaced crowns have failed to develop with a vigor comparable to that of the widely-spaced crowns.

(c) Initial Four-Month Harvest: Sugarcane yields of dry matter (Table 24) and total green weight (Table 25) recorded four months into the first ratoon crop again failed to show any appreciable effect of close spacing. The variety NCo 310 remained slightly superior to PR 980 and PR 64-1791. Napier grass was again more productive than sugarcane; in this instance close

spacing resulted in a small but statistically significant decline in dry matter yield (Table 24). As anticipated, sugarcane maturity remained in the same order of magnitude recorded for two-months old plants (15-20% DM). On the other hand, napier grass was well into its maturation phase at this time. Its dry matter values were approaching 30 percent (Table 26), as opposed to 11 to 16 percent at two months.

(d) Total Yield Trends; First Four Months: Total yields for the first four months of the ratoon crop verified several important trends established by the plant crop (Table 27). These include the following: (a) Both green and dry biomass yields increased with decreasing frequency of harvest; (b) napier grass and sugarcane produced approximately the same amount of green matter when harvested at four months, but napier grass was far more productive of dry matter; and (c), napier grass easily out-produced sugarcane over a time-course of four months.

Summary data presented in Table 27 indicate that sugarcane's combined DM yields from two, 2-month harvests totaled less than a third of the dry matter obtained from a single harvest at four months. Similarly, napier grass nearly doubled its dry matter yields when harvested only once at four months rather than twice at two-month intervals. Equally important, the total dry matter productivity of napier grass exceeded that of sugarcane by about 190 percent with two-month harvest intervals, and by 75 percent with a single four-month harvest. The superior dry matter output for napier grass was a function of greater tissue expansion at the two-month intervals, that is tissue maturation was not yet operating in favor of napier grass. On the other hand, the superior dry matter production by napier grass at four months was a function of tissue maturation rather than expansion. At this time the dry matter

content of napier grass was nearly double that of sugarcane, ie, 29.0 percent for napier grass vs 16.5 percent for sugarcane (Table 27).

(e) Total Yields; Plant Crop vs First-Ratoon Crop: Summary yield values reveal that, by four months into the first-ratoon crop, the second-year yields were considerably greater than those from the same period of the plant crop (Table 28). This was true of both green and dry biomass, for sugarcane and napier grass, and for two-month and four-month harvest intervals.

The least effect of ratoon cropping was recorded for sugarcane harvested at two-month intervals (Table 29). There were no gains for either green matter or dry matter. When harvested once at four months, the ratoon-crop gains were in the order of 38 percent and 65 percent, respectively, for green matter and dry matter. For napier grass, the ratoon crop yields exceeded those of the plant crop at both harvest frequencies. The largest gain attributed to ratoon cropping was a 70 percent increase of dry matter from napier grass harvested at four months after seeding. It should be noted that, in the instance of four-month data, the higher yields can be a result of increased fertilization ^{1/} as well as the more favorable crown development of second-year plants.

C. BREEDING STUDIES

Limited breeding work was initiated during the project's first year and was continued during the autumn of 1978. Breeding studies are confined to

^{1/} The ratoon crop is receiving the same amount of fertilizer per increment as the plant crop; however, the ratoon plants receive twice the number of increments, ie, six increments at two-month intervals as opposed to three increments at four-month intervals.

the following areas: (a) Evaluation of local germplasm sources; (b) evaluation of conventional progeny from the AES-UPR sugarcane breeding program as possible biomass-producing candidates; and (c), crossing a local wild S. spontaneum hybrid with commercial canes.

Of particular interest to the project is an exceptionally vigorous S. spontaneum clone found in the wild in the vicinity of Río Piedras (Figure 7). It is tentatively identified as an S. spontaneum hybrid owing to the exceptional length and diameter of its internodes, an unusually rapid growth rate, and anatomical features of its leaf and flower tissues definitely characteristic of S. spontaneum (9). This cultivar, or its parents, may have escaped from AES-UPR species collections dating back to the 1930's. The plant is not regarded as a native Puerto Rican species.

Attempts to cross this hybrid with suitable male-sterile parents at first met with only limited success. Its natural flowering interval ranges from mid August to late September, a period when prospective female (commercial canes) are not yet tasseling in Puerto Rico. During the project's first year, samples of the hybrid's early tassels were frozen and later employed in crosses with the commercial hybrids F-146 and PR 63-227 (both male sterile). Only five seedlings were produced and these revealed none of the wild S. spontaneum traits when propagated in a field plot. There is some question now as to whether these progeny derive from viable frozen pollen or from a contaminant pollen source (9).

During 1978 attempts were made to delay flowering in the S. spontaneum hybrid sufficiently long to synchronize some of the tassels with those of local hybrid canes. Several stands of the wild plants were cut back during the month of May in an effort to force them to pass their normal floral

induction period as juveniles, and to enter their adult stage at about the time that commercial hybrids are forming flower primordia (early September). This approach presupposes that at least part of the flowering stimulus has accumulated in the plant crowns and will subsequently contribute to flower induction even though foliar tissues were absent at a decisive time in the normal flower induction period.

One of these groups failed to tassel at the usual time in August-September, but tasseled heavily in the period October 15-30. This constituted a major delay, but it fell short by about three weeks of the earliest tassels of prospective female parents. Fortunately, a small second set of tassels emerged from this group during the period December 1-15. A few of these were transferred immediately to the AES-Gurabo Substation where crosses were performed with the hybrid canes PR 69-2 and PR 67-245. Apparently normal seed developed from these crosses which was planted in greenhouse flats in mid-January of 1979. At the time of this writing, there appears to be a total of about 400 seedlings from these crosses.

Some of the crosses performed for the AES-UPR sugarcane breeding program are also of special interest to the biomass project. Most of these are polycrosses in which a given clone can serve either as a male or female parent. The variety US 67-22-2, bearing a large dosage of S. spontaneum germplasm, has shown excellent growth potential and figures prominently in the sugarcane crosses performed during October and November of 1978 (Table 29). The variety B 70701 is also an excellent high tonnage candidate, and in this instance a cross was performed directly in the field with US 67-22-2 serving as the male parent.

D. LITERATURE CITED

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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	Production Interval (Months)
Short Rotation	2-4
Intermediate Rotation	6-18
Long Rotation	30-60
Minimum Tillage	Indeterminate

TABLE 3. DRY MATTER YIELD OF SEVEN NORTHRUP-KING GRASSES

NK Variety	Dry Matter (g/Plant), At Week -					Mean
	3	4	5	6	7	
Sordan 70A	0.9 a	2.3 a	5.3 a	6.0 ab	10.5 a	5.1
Sordan 77	0.9 a	2.3 a	4.8 a	6.7 ab	8.2 ab	4.6
Trudan 5	0.8 ab	2.2 ab	4.3 ab	5.7 b	8.1 ab	4.2
Trudan 7	0.7 ab	1.9 b	4.2 ab	5.9 ab	8.8 ab	4.3
Millex 23	0.6 b	1.8 b	3.6 b	3.6 c	5.2 b	3.0
NK 300	0.8 ab	2.2 ab	4.2 ab	7.6 a	9.4 a	4.8
NK 326	0.8 ab	2.0 ab	4.3 ab	6.6 ab	7.5 ab	4.2

^{1/} Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Mean values bearing one or more letters in common do not differ significantly.

TABLE 4. DRY MATTER CONTENT OF SEVEN NORTHRUP-KING GRASSES

NK Variety	Dry Matter (%), At Week --					Mean
	3	4	5	6	7	
Sordan 70A	7.6 ab	7.7 b	9.3 b	11.3 b	15.4 b	10.3
Sordan 77	7.9 ab	8.5 a	12.1 a	18.4 a	18.4 a	13.1
Trudan 5	7.8 ab	8.1 ab	9.9 b	14.8 a	14.8 b	11.1
Trudan 7	8.3 ab	8.8 a	12.3 a	14.7 a	19.7 a	12.8
Millex 23	6.6 b	7.2 c	9.8 b	12.9 b	15.7 b	10.4
NK 300	8.5 a	8.3 ab	10.2 ab	12.1 b	15.2 b	10.9
NK 326	7.2 ab	8.2 ab	9.5 b	11.1 b	14.3 b	10.1

^{1/} Mean values in the same column bearing unlike letters differ significantly (P < .05). Mean values bearing one or more letters in common do not differ significantly.

TABLE 5 . DRY MATTER PRODUCTION BY SEVEN NORTHRUP-KING GRASSES PROPAGATED WITH VARIABLE WATER SUPPLY OVER A TIME-COURSE OF ELEVEN WEEKS ^{1/}

Simulated Moisture Regime	Variety	Dry Matter (g/Plant), At Indicated Week --										Mean
		2	3	4	5	6	7	8	9	10	11	
Humid	Sordan 70A	.06	0.3	1.2	2.6	4.1	6.2	9.0	12.5	16.9	17.9	7.1
	Sordan 77	.07	0.4	1.4	3.1	4.5	4.9	5.4	8.2	14.0	15.3	5.8
	Trudan 5	.04	0.2	1.0	2.9	4.2	6.9	9.1	9.9	10.4	10.5	5.6
	Trudan 7	.04	0.3	1.3	2.6	4.0	5.1	5.8	8.0	11.1	11.3	5.0
	Millex 23	.03	0.2	0.7	1.5	3.9	3.9	4.4	4.7	5.2	5.0	3.0
	NK 300	.06	0.3	1.0	2.1	3.2	5.6	8.1	8.8	8.4	8.8	4.7
	NK 326	.06	0.4	1.0	3.1	5.9	6.4	9.6	9.7	9.4	11.7	5.8
	Mean	.05	0.3	1.1	2.6	4.3	5.6	7.3	8.8	10.8	11.5	5.3
Normal	Sordan 70A	.08	0.4	1.9	3.9	6.9	12.3	12.7	13.5	13.0	14.8	8.0
	Sordan 77	.07	0.4	1.4	4.2	5.0	9.4	11.6	11.4	16.0	21.7	8.2
	Trudan 5	.05	0.4	1.4	3.4	5.0	4.4	7.3	7.2	12.5	20.7	6.3
	Trudan 7	.06	0.3	1.4	4.0	7.5	10.2	11.3	12.3	13.6	13.2	7.4
	Millex 23	.04	0.3	1.4	3.1	4.3	5.3	6.1	6.2	7.0	6.9	4.1
	NK 300	.06	0.4	1.1	3.3	5.1	9.1	9.5	10.6	13.6	11.5	6.5
	NK 326	.06	0.4	1.5	4.4	7.5	10.1	10.4	12.9	14.3	13.5	7.6
	Mean	.06	0.4	1.4	3.8	5.9	8.7	9.8	10.7	12.9	14.8	6.9
Semi-arid	Sordan 70A	.07	0.4	1.4	3.4	4.9	8.4	9.8	10.3	13.0	11.0	6.3
	Sordan 77	.06	0.4	1.3	4.1	5.3	6.1	6.8	8.8	12.4	20.5	6.6
	Trudan 5	.05	0.3	1.1	3.4	5.9	6.1	6.8	8.3	10.7	15.4	5.9
	Trudan 7	.05	0.3	1.5	4.0	6.5	9.1	9.9	12.9	12.2	15.0	7.2
	Millex 23	.03	0.3	1.3	3.7	4.5	6.6	6.7	5.0	7.5	8.6	4.5
	NK 300	.07	0.3	1.0	3.8	5.9	5.0	7.9	15.5	9.4	12.8	6.2
	NK 326	.06	0.4	1.6	3.8	5.5	12.3	12.7	14.7	13.1	10.3	7.5
	Mean	.05	0.3	1.3	3.7	5.5	7.7	8.7	11.1	10.9	13.4	6.3

^{1/} Unreplicated observation experiment.

TABLE 6 . DRY MATTER CONTENT OF SEVEN NORTHRUP-KING GRASSES PROPAGATED WITH VARIABLE WATER SUPPLY OVER A TIME-COURSE OF ELEVEN WEEKS ^{1/}

Simulated Moisture Regime	Variety	Dry Matter Content (%), At Indicated Week Number —										Mean
		2	3	4	5	6	7	8	9	10	11	
Humid	Sordan 70A	12.9	8.4	6.8	8.4	10.5	14.7	18.1	25.2	25.8	26.3	15.7
	Sordan 77	12.6	8.8	7.9	9.6	12.3	16.7	21.6	27.9	30.9	31.6	17.9
	Trudan 5	13.2	9.5	7.6	8.2	11.0	15.8	16.9	20.7	23.6	26.6	15.3
	Trudan 7	11.7	8.8	8.2	10.5	14.9	18.8	19.3	23.8	29.0	29.5	17.5
	Millex 23	11.3	7.5	7.2	8.7	14.3	17.7	18.8	21.2	22.1	22.3	15.1
	NK 300	12.7	9.6	9.0	9.9	12.6	18.0	18.0	27.3	27.0	28.8	17.3
	NK 326	11.8	9.0	7.4	8.9	12.2	14.3	16.7	21.1	22.0	24.2	14.8
	Mean	12.3	8.8	7.7	9.2	12.5	16.6	17.7	24.5	25.5	27.0	16.2
Normal	Sordan 70A	12.5	8.4	7.1	7.5	8.8	12.6	16.1	25.7	24.5	24.7	14.8
	Sordan 77	13.0	9.3	6.9	8.4	12.8	16.7	21.5	25.8	32.1	31.9	17.8
	Trudan 5	13.0	9.2	7.6	8.0	11.9	14.4	16.1	20.3	23.3	25.7	15.0
	Trudan 7	14.4	9.6	7.7	10.0	13.6	19.6	24.3	34.5	34.8	35.6	20.4
	Millex 23	10.0	7.0	5.8	6.9	8.6	13.7	14.6	14.8	16.7	17.3	11.5
	NK 300	12.6	8.9	7.4	8.6	11.1	16.1	19.1	28.1	28.7	27.5	16.8
	NK 326	11.6	8.7	7.4	7.9	9.5	13.2	14.9	13.7	23.0	22.5	13.2
	Mean	12.4	8.7	7.1	8.2	10.9	15.2	17.9	24.0	25.8	26.2	17.1
Semi-Arid	Sordan 70A	12.3	9.1	7.3	7.9	12.0	13.8	15.9	17.9	22.4	23.7	14.2
	Sordan 77	12.5	9.7	8.2	9.1	12.3	18.4	18.1	24.7	28.1	31.5	17.3
	Trudan 5	13.0	10.4	7.7	8.3	11.0	15.2	15.2	32.3	25.1	27.2	16.5
	Trudan 7	13.0	10.6	8.4	8.9	12.6	18.9	23.8	30.7	28.2	31.8	18.7
	Millex 23	9.7	8.0	6.2	8.0	12.0	16.5	17.5	18.8	20.2	22.2	13.9
	NK 300	12.0	9.7	8.6	8.9	12.0	14.6	16.6	27.7	24.4	26.7	16.1
	NK 326	11.5	9.0	7.5	7.9	9.8	13.6	15.3	27.7	20.7	21.8	14.5
	Mean	12.0	9.5	7.7	8.4	10.0	15.9	17.1	26.1	24.2	26.4	15.9

^{1/} Unreplicated observation experiment.

TABLE 7. VARIABLE NITRATE-N CONCENTRATIONS SUPPLIED
TO NAPIER HYBRID PI 300086 IN SAND CULTURE

NO ₃ Conc. (meq/l)	Simulated N Regime
1	Deficient
3	Deficient to Low
9	Low or "Hidden Hunger"
27	Adequate
54	Adequate to Excessive
81	Excessive

TABLE 8. DRY MATTER PRODUCTION BY CANDIDATE S. SPONTANEUM AND S. SINENSE CLONES IN SMALL FIELD PLOTS ^{1/}

Species	Clone	Dry Matter Yields (Kg/Plot) At Month —					Total Yields	
		4	6	8	10	12	Kg	% of PR 980
<u>Saccharum</u> Hybrid	PR 980	17.1	2.5	2.2	1.1	0.8	23.7	100
<u>S. sinense</u>	Saretha	11.3	2.7	3.3	1.4	0.8	19.5	82.2
	Chunnee	11.7	2.4	3.1	3.1	3.0	23.3	98.3
	Natal Uba	9.5	1.9	2.4	1.1	0.9	15.8	66.6
	Tainan	13.3	4.1	5.0	2.8	1.7	26.9	114.0
<u>S. spontaneum</u>	SES 231	8.8	5.2	7.2	5.8	6.7	33.7	142.1
	SES 317	10.9	- ^{2/}	-	-	-	-	-
	SES 327	10.9	3.1	3.0	0.9	- ^{3/}	17.9	78.1
	US 67-22-2	18.5	4.7	5.2	3.6	4.0	36.0	151.8
	US 67-34-24	12.4	3.2	2.9	1.5	1.6	21.6	91.1
	US 72-97	12.5	4.4	5.3	2.9	3.6	28.7	122.1
	US 72-70	19.9	4.6	5.1	2.8	2.7	35.1	148.1
	US 72-72	12.4	4.0	4.0	2.6	2.8	25.8	108.8
	US 72-144	15.8	4.5	4.7	2.3	2.9	30.2	127.4
<u>Erianthus maximus</u>	NG 132	7.5	- ^{2/}	-	-	-	-	-

^{1/} Plot size = 1/200 acre.

^{2/} Clones not harvested at months 6, 8, and 10.

^{3/} No plant growth following the 10-month harvest.

TABLE 9. TILLERING AND DRY MATTER CHARACTERISTICS OF CANDIDATE S. SPONTANEUM AND S. SINENSE CLONES IN SMALL FIELD PLOTS

Species	12 Month Harvest		Five Harvests Combined	
	No. Of Tillers	% DM	Total Tillers	Ave. % DM
<u>Saccharum Hybrid</u>				
PR 980	162	21.2	1,560	20.5
<u>S. Sinense</u>				
Saretha	242	20.6	2,415	19.4
Chunnee	603	17.9	3,414	18.9
Natal Uba	172	16.6	1,455	16.5
Tainan	651	18.0	4,257	20.6
<u>S. spontaneum</u>				
SES 231	1,551	20.3	7,104	20.0
SES 327	0	-	-	-
US 67-22-2	661	16.9	3,006	17.5
US 67-34-24	319	17.4	1,866	19.2
US 72-97	731	19.1	4,429	20.2
US 72-70	670	19.5	3,882	21.6
US 72-72	634	23.5	3,174	22.9
US 72-144	583	19.3	3,288	20.6

TABLE 10. DRY MATTER YIELDS BY JORDAN 70A PROPAGATED WITH VARIABLE N-FERTILIZATION AND SEEDING RATES OVER A TIME-COURSE OF TEN WEEKS

N Supply (Lbs/A)	Tons/Acre, At Seeding Rate (Lbs/A) -				Mean
	60	80	100	120	
100	5.4	4.1	5.0	4.8	4.8
200	4.2	4.9	5.6	5.3	5.0
300	4.6	4.8	5.7	4.6	4.9
400	5.0	4.2	4.9	5.5	4.9
Mean	4.8	4.5	5.3	5.1	

TABLE 11. GREEN MATTER YIELDS BY SORDAN 70A PROPAGATED WITH VARIABLE N-FERTILIZATION AND SEEDING RATES OVER A TIME-COURSE OF TEN WEEKS

N Supply (Lbs/A)	Tons/A, At Seeding Rate (Lbs/A) -				Mean
	60	80	100	120	
100	17.0	15.7	18.9	17.9	17.4
200	16.2	18.9	19.7	18.8	18.4
300	17.4	19.3	20.0	18.8	18.9
400	18.6	18.2	19.7	19.9	19.1
Mean	17.3	18.0	19.6	18.9	

TABLE 12. FOLIAR NITROGEN CONTENT OF SORDAN 70A PLANTS PROPAGATED WITH VARIABLE N FERTILIZATION AND SEEDING RATES ^{1/}

N Supply (Lbs/Acre)	% N, At Seeding Rate (Lbs/Acre) -				Mean
	60	90	100	120	
100	2.89	2.67	2.88	2.77	2.80
200	2.71	2.84	2.73	2.83	2.78
300	2.87	2.90	2.89	2.84	2.88
400	2.91	2.79	2.79	2.94	2.86
Mean	2.85	2.80	2.82	2.85	

^{1/} Leaf ranks +1 and +2, harvested 10 weeks after seeding.

TABLE 13. DRY MATTER CONTENT OF SORDAN 70A PROPAGATED WITH VARIABLE N-FERTILIZATION AND SEEDING RATES OVER A TIME-COURSE OF TEN WEEKS

N Supply (lbs/acre)	DM (%), At Seeding Rate (kg/ha) -				Mean
	67	90	112	135	
100	31.5	26.2	27.5	26.6	28.0
200	26.2	25.9	24.6	23.4	25.0
300	26.2	28.3	28.2	24.6	26.8
400	27.0	28.6	25.2	27.4	27.1
Mean	27.7	27.3	26.4	25.5	

TABLE 14. DRY MATTER CONTENT OF SORDAN 70A PLANTS PROPAGATED WITH VARIABLE N-FERTILIZATION AND SEEDING RATES OVER A TIME-COURSE OF TEN WEEKS.

Nitrogen (lbs/acre)	% Dry Matter, At Week -									Mean
	2	3	4	5	6	7	8	9	10	
100	12.6	14.4	13.0	11.1	13.3	15.7	18.5	24.6	27.7	16.8
200	9.2	13.1	11.8	10.6	13.2	14.6	17.3	20.5	27.3	15.3
300	13.1	15.0	12.7	10.5	11.1	14.0	16.3	20.5	26.4	15.5
400	13.2	14.8	12.3	9.6	11.8	12.3	15.8	20.8	25.5	15.1
Mean	12.0	14.3	12.5	10.5	12.4	14.2	17.0	21.7	26.8	

Seed (lbs/acre)	% Dry Matter, At Week -									Mean
	2	3	4	5	6	7	8	9	10	
60	12.0	13.6	12.7	10.6	12.1	13.8	17.0	25.7	28.3	16.2
80	13.2	14.3	12.4	9.9	12.2	14.3	16.9	20.3	25.0	15.4
100	10.5	14.4	12.4	11.7	13.2	15.3	17.1	20.2	26.8	15.7
120	12.5	15.0	12.4	9.6	11.8	13.8	17.0	20.4	27.0	15.5
Mean	12.1	14.3	12.5	10.5	12.3	14.3	17.0	21.7	26.8	

TABLE 15. EFFECTS OF VARIABLE N-FERTILIZATION AND SEEDING RATES ON THE NUMBER OF HARVESTABLE STEMS FOR SORDAN 70A TEN WEEKS AFTER PLANTING

N Supply (Lbs/Acre)	Stems/Acre (Thousands), At Seeding Rate (Lbs/Acre) —				Mean
	60	80	100	120	
100	118.0	96.8	157.2	161.6	133.4
200	95.2	114.0	120.0	148.8	119.5
300	91.6	88.0	110.4	116.8	101.7
400	123.2	102.4	110.0	101.6	109.3
Mean	107.0	100.3	124.4	132.2	

TABLE 16. EFFECTS OF VARIABLE NITROGEN SUPPLY ON THE INCIDENCE OF DOWNY MILDEW AND LODGING IN SORDAN 70A 1/

N Supply (Lbs/Acre)	Numerical Ranking For -	
	Downy Mildew	Lodging
100	3.04	2.25
200	3.75	2.46
300	4.75	3.04
400	5.08	2.83

1/ Disease and lodging incidence was ranked by visual inspection on a numerical scale of 1 to 10 (1 = no symptoms, 10 = severe symptoms). Each tabulated number is the arithmetic mean of 24 ranked plots. Data were recorded 10 weeks after seeding.

TABLE 17. EFFECTS OF VARIABLE PLANT DENSITY ON THE INCIDENCE OF DOWNY MILDEW AND LODGING IN SORDAN 70-A ^{1/}

Seeding Rate (Lbs/acre)	Numerical Ranking For -	
	Downy Mildew	Lodging
60	4.29	2.38
80	4.42	2.38
100	4.13	2.71
120	4.21	3.17

^{1/} Disease and lodging incidence was ranked by visual inspection on a numerical scale of 1 to 10 (1 = no symptoms, 10 = severe symptoms). Each tabulated number is the arithmetic mean of 24 ranked plots. Data were recorded 10 weeks after seeding.

TABLE 18. DRY MATTER PRODUCTION BY THE FIRST-RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; FIRST 2-MONTHS HARVEST

Cultivar	DM (Tons/A), At Row Center -		
	150 cm	50 cm	% Change
PR 980	0.69 c ^{1/}	0.66 c	-4.3
NCo 310	1.47 b	1.35 b	-8.1
PR 64-1791	0.85 c	0.93 c	9.4
	50 cm	25 cm	
Merker	2.25 a	2.50 a	11.1

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

TABLE 19. GREEN MATTER PRODUCTION BY THE FIRST RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; FIRST 2-MONTHS HARVEST

Cultivar	GM (Tons/A), At Row Center —		
	150 cm	50 cm	% Change
PR 980	4.22 c ^{1/}	4.45 c	5.4
NCo 310	8.19 b	7.97 b	-2.6
PR 64-1791	6.00 bc	6.42 bc	7.0
	50 cm	25 cm	
Merker	19.65 a	18.62 a	-5.2

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

TABLE 20. DRY MATTER CONTENT OF THE FIRST RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; FIRST 2-MONTHS HARVEST

Cultivar	Dry Matter (%), At Row Center —		
	150 cm	50 cm	% Change
PR 980	16.5 ab ^{1/}	15.0 ab	-9.0
NCo 310	17.3 a	16.7 ab	-3.4
PR 64-1791	14.3 bc	15.1 ab	5.5
	50 cm	25 cm	
Merker	11.4 c	13.5 bc	18.4

^{1/} Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Numerals bearing one or more letters in common do not differ significantly.

TABLE 21. DRY MATTER PRODUCTION BY THE FIRST-RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; SECOND 2-MONTHS HARVEST

Cultivar	DM (Tons/A), At Row Center -		
	150 cm	50 cm	% Change
PR 980	0.36 de ^{1/}	0.29 e	-19.4
NCo 310	1.19 c	0.92 c	-22.6
PR 64-1791	0.74 d	0.42 de	-43.2
	50 cm	25 cm	
Merker	2.36 b	2.78 a	17.7

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

TABLE 22. GREEN MATTER PRODUCTION BY THE FIRST-RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; SECOND 2-MONTHS HARVEST

Cultivar	GM (Tons/A), At Row Center —		
	150 cm	50 cm	% Change
PR 980	2.27 c ^{1/}	1.75 c	-22.9
NCo 310	5.75 b	4.66 b	-18.9
PR 64-1791	4.80 b	2.32 c	-51.6
	50 cm	25 cm	
Merker	14.91 a	17.27 a	15.8

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

TABLE 23. DRY MATTER CONTENT OF THE FIRST RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; SECOND 2-MONTHS HARVEST

Cultivar	Dry Matter (%), At Row Center -		
	150 cm	50 cm	% Change
PR 980	16.1 c ^{1/}	17.8 bc	10.5
NCo 310	20.5 a	19.6 b	-4.3
PR 64-1791	17.5 bc	18.1 bc	3.4
	50 cm	25 cm	
Merker	15.7 c	16.4 c	4.4

^{1/} Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Numerals bearing one or more letters in common do not differ significantly.

TABLE 24. DRY MATTER PRODUCTION BY THE FIRST RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; FIRST 4-MONTHS HARVEST

Cultivar	DM (Tons/A), At Row Center —		
	150 cm	50 cm	% Change
PR 980	4.8 d	5.9 c	22.9
NCo 310	6.1 c	6.2 c	1.6
PR 64-1791	5.2 cd	5.6 cd	7.6
	50 cm	25 cm	
Merker	10.4 a	9.0 b	-13.4

^{1/} Mean values in the same column bearing unlike letters differ significantly (P < .05). Numerals bearing one or more letters in common do not differ significantly.

TABLE 25. GREEN MATTER PRODUCTION BY THE FIRST RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; FIRST 4-MONTHS HARVEST

Cultivar	GM (Tons/A), At Row Center —		
	150 cm	50 cm	% Change
PR 980	29.4 c	35.5 b	20.8
NCo 310	35.1 b	38.0 a	8.2
PR 64-1791	32.4 bc	32.9 bc	1.5
	50 cm	25 cm	
Merker	33.8 b	33.0 bc	-2.3

^{1/} Mean values in the same column bearing unlike letters differ significantly ($P < .05$). Numerals bearing one or more letters in common do not differ significantly.

TABLE 26. DRY MATTER CONTENT OF THE FIRST RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY PROPAGATED WITH VARIABLE ROW SPACINGS; FIRST 4-MONTHS HARVEST

Cultivar	Dry Matter (%), At Row Center -		
	150 cm	50 cm	% Change
PR 980	16.3 ab	16.6 ab	1.8
NCo 310	17.4 a	16.4 ab	-5.7
PP 64-1791	16.1 bc	17.0 ab	5.5
	50 cm	25 cm	
Merker	30.7 a	27.3 bc	-11.0

^{1/} Mean values in the same column bearing unlike letters differ significantly (P<.05). Numerals bearing one or more letters in common, do not differ significantly.

TABLE 27. GREEN-AND DRY-MATTER YIELDS FOR THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY HARVESTED AT VARIABLE INTERVALS

Species	Tons/Acre At Indicated Harvest Interval —						Total Yields		Ave. % DM
	<u>First 2-Months Harvest</u>			<u>Second 2-Months Harvest</u>					
	Green	Oven-Dry	% DM	Green	Oven-Dry	% DM	Green	Oven-Dry	
Sugarcane <u>1/</u>	6.2	1.0	16.1	3.6	0.7	19.4	9.8	1.7	17.3
Napier Grass <u>2/</u>	19.1	2.4	12.5	16.1	2.6	16.1	35.2	5.0	14.2
	<u>First 4-Months Harvest</u>								
Sugarcane <u>1/</u>	33.9	5.6	16.5				33.9	5.6	16.5
Napier Grass <u>2/</u>	33.4	9.7	29.0				33.4	9.7	29.0

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

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

TABLE 28. GREEN-AND DRY-MATTER YIELDS FOR THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY HARVESTED AT TWO-AND FOUR-MONTH INTERVALS FROM PLANT-AND FIRST-RATOON CROPS

Tons/Acre At Indicated Harvest Interval -										
Species	Crop	First 2-Months Harvest			Second 2-Months Harvest			Total Yields		Ave. % DM
		Green	Oven-Dry	% DM	Green	Oven-Dry	% DM	Green	Oven-Dry	
Sugarcane ^{1/}	Plant Crop	2.5	0.4	16.0	7.6	1.3	17.1	10.1	1.7	16.6
	First Ratoon	6.2	1.0	16.1	3.6	0.7	19.4	9.8	1.7	17.3
Napier Grass ^{2/}	Plant Crop	16.0	2.2	13.7	8.8	1.6	18.1	24.8	3.8	15.9
	First Ratoon	19.1	2.4	12.5	16.1	2.6	16.1	35.2	5.0	14.2
First 4-Months Harvest										
Sugarcane	Plant Crop	24.5	3.4	13.8				24.5	3.4	13.8
	First Ratoon	33.9	5.6	16.5				33.9	5.6	16.5
Napier Grass	Plant Crop	21.6	5.7	26.3				21.6	5.7	26.3
	First Ratoon	33.4	9.7	29.2				33.4	9.7	29.0

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

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

TABLE 29. SECOND-YEAR YIELD INCREASES OF GREEN MATTER AND DRY MATTER FOR SUGARCANE AND NAPIER GRASS HARVESTED AT 2-AND 4-MONTH INTERVALS 1/

Species	Yield Increase (%) At Harvest Interval -			
	Two Months		Four Months	
	GM	DM	GM	DM
Sugarcane <u>2/</u>	-2.9	0	38.3	64.7
Napier Grass <u>3/</u>	41.9	31.5	54.6	70.1

1/ Yield increases of the "first-ratoon" crop (second year) as opposed to the "plant crop" (first year).

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

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

TABLE 30. SACCHARUM CROSSES PERFORMED DURING THE AUTUMN OF 1979 BY THE AES-UPR SUGARCANE BREEDING PROGRAM; AES-UPR GURABO SUBSTATION

Date Of Cross	Parental Clones		Type Of Cross	No. Of Tassels	Remarks
	Male	Female			
Oct. 20, 1978	US 67-22-2	x B 70701	BP	3	Performed in field
Nov. 13, 1978	F 160	x US 67-22-2	"	5	
	US 67-22-2	x PR 68-3041	"	3	
Nov. 17, 1978	PR 68-330	x US 67-22-2	"	5	
Nov. 21, 1978	PR 70-3391	x US 67-22-2	"	4	
Nov. 28, 1978	PR 70-3364	x US 67-22-2	"	3

Figure 1. Dry matter content of four Northrup-King grasses propagated over a time-course of seven weeks

Figure 2. The mean maturation curve (dry matter accumulation) for seven Northrup-King grasses propagated over a time-course of eleven weeks. Each plotted value is the computed mean of seven varieties and three moisture regimes.

Figure 3. Dry matter accumulation in five Northrup-King grasses propagated with a "normal" water regime over a time-course of eleven weeks.

Figure 4. Dry matter production by Sordan 70A, Trudan 7, and NK 326 propagated with variable moisture supplies simulating humid, normal, and semi-arid rainfall regimes. Each plotted value is the computed mean of ten plant samples harvested over a time-course of ten weeks.

Figure 5. Effects of variable nitrogen supply on dry matter accumulation in Sordan 70A. Low N = 100 lbs/acre; high N = 400 lbs/acre, applied in a single increment at the time of planting.

FIGURE 6. Variable dry matter production by sugarcane and napier grass as a function of incremental fertilizer supply. Both species received 1/3 of their annual fertilizer complement at planting, 1/3 following the 4-month harvest, and 1/3 following the 8-month harvest.

Figure 7. An unidentified S. spontaneum clone found in the wild near Río Piedras. Tentatively identified as a natural S. spontaneum hybrid, it is characterized by rapid growth, excessively elongated internodes, and solid fibrous stems attaining lengths of 15 to 17 feet in approximately six months. It is regarded as a potentially superior parent for breeding intermediate-rotation grasses for biomass production.