CEER-B-171 PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE THIRD ANNUAL REPORT 1979-1980 FROM THE UNITED STATES DEPARTMENT OF ENERGY CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE Third Annual Report; 1979-1980 To The United States Department of Energy, Oak Ridge Operations Office, and the Division of Solar Technology Biomass Energy Systems Branch Washington, D. C. By The University of Puerto Rico Center for Energy and Environment Research, Río Piedras, Puerto Rico CONTRACT NO.: DE-AS05-78ET20071 (AES-UPR Project C-481) LOCATION: Río Piedras, Puerto Rico PERIOD COVERED: June 1, 1979—May 31, 1980 Project Leader: La Ameni

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INTRODUCTION

The biomass production studies reported herein were initiated on 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 possessing large growth potential on a year-round basis. The basic premise is that such plant materials can continuously provide a renewable, domestic source of fuels and chemical feedstocks that will substitute for imported fossil energy. The present report covers the period from June 1, 1979, to May 31, 1980.

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 forage.

(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 with superior biomass productivity as their principal attribute.

Scope of the Project

Emphasis is directed toward a highly-intensive and mechanized production of tropical grasses as solar-dried forages. This is a deviation from conventional cane and cattle feed production in that total dry matter rather than sugar and food components is the principal salable commodity.

Management of Production inputs—particularly water, nitrogen, and candidate species, together with harvest frequency—varies significantly from established procedures. On the other hand, advances in mechanized production and harvest operations within

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Considerable success for the production of solar-dried biomass optimized production operations requires 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-lot, and field-scale investigations (Table 1). A fourth phase, commercial-industrial operations, follows logically but lies beyond the scope of the current project. The work reported here deals with a continuation of the greenhouse, field-plot, and field-scale phases that began earlier (1, 2). The project's screening operations are designed to identify high-yielding biomass that can be harvested on a year-round basis. They have indicated three broad categories based on the time required after seeding to maximize total dry matter (Table 2). Among sugarcane cultivars, the superior growth rate per unit area, a botanical feature, has not been historically recognized as a desirable attribute unless combined with an acceptable level of sugar production (3, 4, 5, 6, 14, 15). Similarly, the tropical forage grasses have required acceptable digestibility and nutritive characteristics rather than high yields of dry matter (7, 8). 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 (9, 10). A breeding program designed to intensify the biomass-yielding attribute of Saccharum and related species lies beyond the scope of this project. Thoroughly, numbers in parentheses refer to relevant published literature. Complete citations are listed on pages 33 and 34. 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 interspecific level.

Level, and basic genetic research to break some serious constraints operating to prevent the exchange of cytoplasm among, charm and allied genera (11, 12, 13, chap. 1). At a very modest level, some limited breeding is included in the present project. This work is confined to a few obviously recognizable parent clones that have outstanding flowering characteristics and which can be incorporated without inconvenience into an ongoing breeding program for sugarcane (1, 2). Certain progeny originating with the AES-UPR sugarcane breeding program are also being considered as long-rotation biomass candidates (16). Under these circumstances, some prospect is created for the emergence of superior new progeny at very little expense.

3. Statement on the First Quarter of Year 3

A separate report on the first quarter of year 3 was not considered justified and the project leader received authorization to combine the first two reports for this year's work. Owing to funding delays, the period June 1 through August 31 was essentially on “hold”. Emergency funding amounting to about 15 percent of regular levels enabled some limited progress to be made at the greenhouse level where candidate screening and nutrition experiments can be performed at relatively low cost. The project's principal collaborators were retained during the first quarter but without labor support. The most important experiment was kept active during this period, this included the varietal, row-spacing, and harvest frequency studies with first-ratoon sugarcane and Napier grass. Field-scale categories of tropical-grass candidates for biomass production are discussed in detail elsewhere (1).

-5- Plantings of Jordan 70, for mechanized harvest studies, were discontinued and new plantings previously scheduled for August were postponed until January, 1980, owing to exceptionally good weather during October of 1979 (ordinarily the wettest part of the PR rainy season) it was possible to plant six acres of Napier grass for subsequent study of mechanized

Moisture etc. All of these grasses are clearly short-rotation: on a special note, 'A number of additional clones became available to the project whose correct categories for field-plot tests were less clearly defined. These range from potential short-rotation species (Johnsen grass, SES-231) to potential long-rotation species (US 6722-2, US 72-70). Seven of these grasses were propagated in the greenhouse during the spring and summer of 1979, using the interspecific commercial cane hybrid PR 980 as the reference clone (Table 3). This type of experiment is conveniently termed "multiple rotation", and it enables multiple species and category screening to proceed simultaneously. The species and methods used in this experiment are described in more detail elsewhere (2). One-third of the plants were harvested each at 2, 4 and 6 months after seeding. These time intervals correspond to short-rotation (2 months) and to both early and late intermediate rotation (4 and 6 months, respectively). Long rotation experiments (12 to 18 months) cannot be maintained adequately with potted plants. In terms of DM yield/planted area (Table 3) and maturity (Table 4), Johnson grass clearly emerged as the leading short-rotation candidate. The Napier grass hybrid PI 30086 was the leading intermediate-rotation candidate.

As illustrated graphically in Figure 1, all clones except Johnson grass made enormous yield increases when the harvest was delayed from the second to the fourth month after seeding. Only in the case of Johnson grass would greater yields derive from simply repeating the 2-month harvest over and over again. Alternatively, all species showed relative yield decline as the harvest was delayed from the fourth to the sixth month after seeding. This latter trend is misleading in the case of valid long-rotation candidates such as PR 980 and US 67-22-25 in field pots these clones would have begun their heaviest dry matter accumulation around 6 or 7 months after planting. On an individual plant basis, Napier grass was the superior.

Producer at the execution of three test apes (Table 5).

2. Maturation Profiles Of Three Ni Hybrids

The NorthrupKing hybrids Sordan 77 and NK 326 showed very favorable growth performances in previous direct comparisons with Sordan 7A (2, 17). In subsequent greenhouse trials, the maturation curves for both candidate grasses were determined using Sordan 70A as the reference variety. Dry matter yields for NK 326 clearly exceeded those of Sordan 704 from the 8th to 13th weeks after seeding (Figure 2, Table 6). Although there were no large differences in the rate of dry matter accumulation, Sordan 77 contained significantly more dry matter than the other candidates from about the 9th week onward (Table 6). Sufficient data are now available to justify field-scale comparisons of the three tropical grasses.

3. Screening of Dekalb Company Hybrids

Screening trials were begun during the third quarter on a series of tropical grass hybrids developed by the Dekalb Company. Like the NK hybrids, these grasses incorporate both sorghum and Sudan grass geneplasm and are basically intended for summer production as cattle forages. Preliminary (unreplicated) yield data for six Dekalb grasses are presented in Table 7. The NK hybrids Sordan 77 and Trudan 8 were also included in this trial. At six weeks of age, the variety Dekalb F5-25 compared favorably with Sordan 77 and Trudan 8. At 10 weeks, all of the Dekalb grasses were at least equal to Sordan 77 and Trudan 8 in dry matter yield while Dekalb PS-25 and Dekalb SN-L7 indicated moderately higher yields. The latter two hybrids were also superior on a per plant basis (Table 7).

4. Variable Moisture Regimes

The same NK and Dekalb candidates noted above were subjected to variable moisture regimes in an unreplicated trial initiated during the third quarter. Given a series of tropical grasses with comparable yield potential under ideal growing conditions, the ability to maintain a high yield performance under conditions of moisture stress is a decisive factor in the final selection.

The screening process involved moisture regimes ranging from excessive water supply ("humid") to inadequate water supply ("semi-arid") which were simulated by varying the frequency of irrigation. All plants were propagated under glass using a 2:1 cord-cachaza mixture as the growth medium. Plant samples were harvested at three intervals over a time-course of 11 weeks. All of the Dekalb grasses equalled or exceeded Sordan 77 (the project's principal short-rotation hybrid) in dry matter yield (Table 8). Under humid conditions, the varieties Dekalb ST-5 and SX-16a exceeded the Sordan 77 yields by at least 30 percent. However, none of the candidates maintained a satisfactory growth performance when water supply was cut back in a simulated semi-arid regime. The need for additional testing of these grasses as “low-till" candidates is clearly indicated. Mean values for dry matter content, an indication of plant maturity, did not vary consistently among moisture regimes (Table 9). A pronounced increase of dry matter was recorded with increasing plant age (Table 9). The latter response was quite distinct among all moisture regimes.

5. Mins 1 Nutrition

A nitrate-tied nutrition experiment established late in Year 2 was completed during the first quarter of Year 5. Variable nitrate levels were administered to Johnson grass to establish the plant's N-response curve. As in earlier nutrition experiments with Sordan 70A and Napier grass (1, 2), the objective was to establish the slope of the dry matter response to progressively higher levels of N. Accordingly, nitrate supplies were increased in geometric progression to Johnson grass propagated in sand culture. Nitrate levels ranged from 1.0 to 81.0 milliequivalents per Liter, in nutrient solutions given three times each week over a time-course of 10 weeks. Dry matter yield and content data (Tables 10 and 11, respectively) suggest that the maximum growth response was obtained at around 9 meq/1 of NO3; however, both visible and real growth improvement was obtained from the 27.

New treatment as well, This was particularly evident as plant age (and hence root development) was advanced to 10 weeks. Johnson grass is the only candidate at this point in time to show major growth responses to 54 meq/1, and an absence of growth repression by 81 seq/i of NO (Figure 3). Ironically, as a minimum tillage candidate Johnson grass is less likely to receive fertilization than species from other cropping categories. With reference to nutrient uptake, Johnson grass did not respond to levels higher than 27 meq/1 of NO (Table 12). A surprisingly high foliar K content was recorded, i.e., in the range of 2.4 to 2.8 percent on a dry weight basis. These levels are more typical of sugarcane which accumulates relatively large amounts of potassium. Post-harvest regrowth data indicates that high NO levels (above 27 meq/1) are repressive against both the number and weight of new shoots (Table 13).

B. FIELD PLOT STUDIES

1. Saccharum Species Candidates

An observation field-plot study with candidate S. spontaneum and S. sinense clones has been underway at the AES-UPR Gurabo Substation since October, 1977. The principal objective was to define the total biomass-producing capabilities of these candidates. A second objective was to determine their qualitative value when sufficiently-aged plants became available. The candidate clones listed in Table 14 were harvested at 2-and 4-month intervals for one year, and subsequently harvested after six more months had elapsed - summarized elsewhere (27). At that point the experiment converted to an observation "Low till" study in which the plants were allowed to subsist on rainfall and native soil fertility. Harvests are planned for 6-month intervals for the duration of the project. The first 6-month yields under minimum tillage conditions are presented in Table 16. The S. spontaneum clone SHS 231 continued to be the superior dry matter producer, followed closely by SES 317 and Chunnee. Each of these clones attained an advanced state of maturity during their.

2. Minimum Tillage Experiment; The Substrate

There is a need for tropical grasses that will produce at least moderate yields with the barest minimum of production input. The characteristics and principal requirements of minimum tillage candidates for Puerto Rico are discussed at length in prior reports (1, 18). A long-term minimum tillage study on 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 fourth such harvest was performed during the third quarter. Although dry matter yields are relatively low, it is evident that all of the S. spontaneum clones are sustaining themselves far more effectively than the commercial hybrid PR 980 (Table 15). The superior clone at this stage of the experiment is US 72-72. Its grain and dry matter yields were 3.92 and 1.36 tons/acre, respectively. By way of reference, the PR cane industry is producing approximately 9 green tons/acre and 3.5 dry tons/acre, an Island-wide average, over a comparable time-course. Both production costs and energy inputs for US 72-72 are nil. Production costs for the PR industry are..."

Cane is approximately $64.00/OD ton. The energy output/input ratio for this cane is approximately 3.5/1.

3. Seed Expansion From "Energy Cane" Plantings

From the seed sources available in 1977, three sugarcane 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. Moreover, seed was available in adequate quantities for project needs. Nonetheless, there was no question but that these canes represented something less than the maximum biomass-yielding potential of Saccharum in Puerto Rico. Seed expansion for more promising biomass energy canes was begun late in 1979. The spontaneous clones US 67-22-2 and B 70-701 have shown especially favorable promise as biomass producers and are included in the seed expansion phase. This material is being propagated at the AES-UPR Gurabo Substation. Field-plot experiments using both varieties will be established at the AES-UPR Lajas Substation during August of 1980. Additional plantings of US 67-22-2 and B 70-701 will be made on privately-owned lands near Hatillo (on the humid north coastal plain) during August of 1980. It is believed that these varieties produce about 40 OD tons/acre as primary cane (10 to 12 months old at harvest) and close to 50 OD tons/acre as grand culture cane (16 to 18 months old at harvest). By way of reference, the highest yields attained to date with conventional varieties averaged about 25.5 and 33.6 OD tons/acre, respectively, for the "plant" and "first-ratoon" crops.

4. Sugarcane and Napier Grass Details

A large field plot study on row spacing, varieties, and harvest frequency for sugarcane and napier grass has been underway at the AES-UPR Lajas Substation since 1977. The intent of this experiment is to maximize total biomass yield for the two species over a three-year cropping cycle, i.e, for a "plant" crop plus

two "ratoon" crops. It is believed that three crops, i.e, the

From 0.30 to 0.10 OD tons/acre, the Napier grass yield declined by 26% (from 1.96 to 1.45 OD tons/acre in 2 months). Yields from the 2-month harvests were in some respects similar to the 4-month harvests. Sugarcane variety NCo 310 remained dominant over PR 960 and PR 64-1791, and close spacing had a generally detrimental effect on growth (Tables 23 and 24, Tables 21 and 22). However, the importance of delaying harvest frequency as a means of increasing dry matter yield was very pointedly demonstrated.

For sugarcane, the monthly dry matter yield averaged 0.06 ton/acre when harvested at 2-month intervals and 0.75 ton/acre when harvested at the 4-month interval. For Napier grass, the average monthly yield rose from 0.40 to 1.92 tons/acre when harvest frequency was delayed from 2 to 4 months. Hence, by merely doubling the time interval allowed for tissue expansion and maturation, 2-fold and 4-fold yield increases were obtained for sugarcane and Napier grass, respectively. Moreover, equipment usage was reduced by 50 percent, with all that this implies relative to reduced fuel expenditure, soil compaction, and wear and tear.

A seasonal growth response, amounting in effect to a winter growth decline, was also evident for the 4-month harvest intervals. Mean DM yield for sugarcane was only 1.4 tons/acre during the period November 15 to March 15, whereas it had been 3.0 tons/acre between July 15 and November 15. This was a decline of 53%. Napier grass was again more tolerant of the seasonal change, with DM yield declining by only 31% (Table 22).

The first 6-month harvest revealed that NCo 310 was still the superior sugarcane variety midway through the second-ratoon crop (Table 25, Tables 21 and 22). A moderate but persistent depressing effect on dry matter yield was being exerted by the close-spacing treatment. At this time, Napier grass continued to exceed the average sugarcane yield but the difference was less pronounced than at 2 and 4-month harvest intervals. The average cane DM yield for a single harvest at 6

The yield for 10.5 months was greater than the combined yield of three, 2-month harvests (Table 22). Mean values for dry matter content (Table 26) indicate that Napier grass had essentially reached peak maturity by the fourth month after cutting. Sugar cane progressively increased DM content from the 2-to 6-month harvest intervals. Six months into the second-ratoon crop, sugarcane yields were lower by 20 to 30 percent compared to the first-ratoon crop, and very slightly lower than the plant crop. This suggests that the 3-year cropping cycle planned for energy cane is a correct interpretation of biomass yield potential. Puerto Rico's sugarcane industry employs a 5-year cropping cycle which is based on sugar production rather than total biomass. Sugar yields may actually increase in plants whose growth rates are declining (13, 14, 15). When biomass replaces sucrose as the primary commodity, a more frequent replanting may be justified. The apparent yield decline at 6 months might also reflect an unseasonal drought affecting the Lajas Valley from late September to mid-November. Ordinarily, this is a warm and humid period highly conducive to cane growth.

Sugarcane "ripening" (sucrose accumulation) depression induced either by chemicals or by natural means is directly dependent upon growth. Irrigation was increased during the unexpected dry spell but this may not have compensated completely for the reduced rainfall.

FIELD-SCALE STUDIES

1. Minimum Irrigation of NK Hybrids; Lajas Substation

The Northrup King hybrids Sudan 70A, Sudan 77, and NK 326 were examined with minimum irrigation in small field-scale plots ranging from 1.8 to 3.6 acres in area. Both Sudan 77 and NK 326 have shown considerable tolerance to simulated arid conditions in comparisons with Sudan 70A (2, 19). Both Sudan 70A and Sudan 77 respond to high water supply. Each variety was planted at the rate of 60 pounds of seed/acre. The seedbed received 100 pounds/acre of elemental N, 50 pounds of P_2O_5, and 50 pounds of K_2O.

Planned in which the effectiveness of low water x low fertilizer and normal water x low fertilizer regimes will be examined.

2. Mechanization Trials; Napier Grass Planting

Napier grass planting is traditionally a hand-labor operation in Puerto Rico. The seedbed and row furrows are sometimes prepared mechanically, but the seed stems themselves are carried manually into the field and dropped into the furrows. They are then cut into two-eye or three-eye segments by laborers walking along the furrows with machetes. The seed pieces are covered with soil as a final manual operation. This process is very costly. An added cost to the grower is the loss of viability of Napier grass seed stem which often stand in open piles in the sun for several days while the hand operations are underway. However, since Napier grass is usually planted on small lowland acreages or uplands too steep for machinery, no attempt is made to develop a planter for this purpose.

During the third quarter, approximately eight acres of Napier grass were planted for future mechanized-harvest trials. A two-row sugarcane planter was rented from the PR Sugar Corporation in an effort to reduce planting costs and to speed up seeding operations. Two Napier grass varieties were planted having different age and stem condition at the time of cutting for seed. The Napier grass stem is considerably thinner and lighter than sugarcane and has a greater adherence of dead leaves. There is also a greater tendency for the Napier grass stem to bear lateral shoots and roots, and to be excessively curved, especially if the selected seed stems are overaged and have lodged prior to cutting. None of these factors prevented the sugarcane planter from performing quite effectively with Napier grass. A few stems were discarded owing to excessive curvature but this is necessary for sugarcane also. The stems were laid straighter and the seeded furrows were covered with soil more evenly than is possible by hand labor. This implement automatically cuts the...

Stems are turned into billets as part of the seed placement process. Some damage to seed "eyes" occurs. On the whole, both the planting operation with this implement and the subsequent seed germination were quite satisfactory. The only problems with germination could be traced to overage seed, or, very rarely, to "skipped" areas in the row where there had been some delay in feeding stems into the planter. By reference to our previous Napier grass planting (6 acres seeded by hand), planting cost was reduced by 82 percent and planting time by about 65 percent.

3. Rotary Scythe And Round Baler Tests: Two harvest implements are of special interest to this project. These are the rotary-scythe conditioner and the round baler. They are viewed as potential answers to the harvest and post-harvest management of tropical grasses having standing tonnages at harvest far in excess of conventional forage grasses, but somewhat lower tonnages than sugarcane. Initial trials performed on mature Johnson grass and 6-to-8-weeks old Sordan 70A were described in a previous report (2). These tests posed no problems of any kind, even in heavily lodged and matted Sordan 70k. Solar drying, raking, and baling operations were also performed without incident. More recent trials with Sordan 70A, Sordan 77, and SK 326 were also successful (p. 16). However, the actual tonnages in these tests did not exceed about 14 standing tons/acre.

(a) Napier Grass; Three Months: Napier grass was submitted to mechanized harvest and forage-making operations for the first time during the third quarter. Approximately four acres of three-months-old Napier grass were mowed with the MAC rotary scythe conditioner. This material was solar-dried and baled with the New Holland Model 851 round baler. At three months of age, the total biomass confronting harvest machinery was only slightly greater than that of equally-aged Sordan and there were fewer stems/acre. The primary difference lay in the much thicker and more succulent stems of Napier grass. These offer a

Somewhat different and possibly more difficult tasks for the stem-shattering or "conditioning" properties of the rotary scythe. The solar drying tasks are definitely more difficult owing to the greater thickness of Napier grass stems. Raking and baling operations are also complicated to some extent by the relative coarseness of the dried material. All of the harvest and post-harvest operations were performed successfully, but they required somewhat more drying time and machinery work time than short rotation species such as Sudan and Johnson grass. Mowing heights were varied from 2 to 8 inches. No crop injury was evident at the lower stubble height, but inch stubble posed some difficulty for the forage rake. An additional day was required for solar drying. Occasional stem billets could still be found that were pliable (containing 25 to 30 percent moisture) rather than brittle (containing 14 to 16 percent moisture). Round bales were produced without difficulty. These were somewhat rougher in appearance than Sudan bales owing to protruding stem segments.

 (b) Napier Grass; Six Months: The ultimate test of the rotary scythe-conditioner is encountered with 6-months old Napier grass. Such material is in an advanced state of maturity with dry matter content approaching 3 percent. Stems appear more woody than herbaceous and are succulent only in the upper canopy area. Standing biomass is in the order of 30 to 40 tons/acre. Stands of grasses having greater mass than this would be approached with a sugarcane harvester rather than forage-making equipment. The first trials of the rotary scythe on 6-months old Napier grass were performed in mid-March of 1980. The varieties Comel, Merker, and P1_7350 were harvested at two stubble heights and two tractor speeds (Table 26). The maximum engine speed was approximately 1900 rpm.

For all tests. Because the M-C rotary scythe was designed to harvest forage crops that are morphologically different from Napier grass and harvested at less advanced stages of maturity, several discrete kinds of problems were anticipated for this implement when operating in mature Napier grass. Any one of these could eliminate the rotary scythe as a candidate harvester if it could not be corrected by adjusting the implement, by modifying the implement's design, or by modifying its mode of operation by options available to the tractor driver. Anticipated problem areas included the following:

(1) An excessive height of Napier grass, in the order of 9 to 12 feet, as opposed to a maximum of 2 to 4 feet for conventional forage crops. Since the "cut" grasses must first fall forward and then be drawn backward beneath the implement to be conditioned, the taller Napier grass could not have been harvested had it fallen backward onto the upper surface of the rotary scythe. In the actual tests, there was no tendency for any material to drop backward onto the implement's surface. The leading edge of the rotary scythe strikes the Napier grass stem with sufficient force to push them forward, even when operating at the lowest cutting height. Moreover, the elongated stems were forced forward sufficiently far into the standing grass to enable them to be drawn back with ease beneath the rotary scythe. There was no appreciable realignment of the stems, that is, no turning at right angles to the path of the implement, which could lead to bunching of the stems and clogging of the rotary scythe blades.

(2) An excessive mass of the Napier grass, amounting to approximately 30 to 40 standing green tons/acre, as opposed to about 10 to 12 green tons/acre for a typical forage crop. It was thought that the additional mass confronting the implement might cause its blades to become clogged with bunched material; alternatively, such material could effect a continual breaking of shear pins. The latter are incorporated into the

The implement's design is intended to shear off when overloaded to prevent more serious damage. During the recent tests, there was no clogging or breaking of shear pins. The implement's performance was generally ragged and unsatisfactory when the tractor was operated in second gear. There was a tendency for the rotary scythe to pass over or only partially condition a small percentage of the stems. This was corrected by shifting to low gear and increasing the tractor's engine speed. While outwardly slowing the harvest process, i.e., the visible movement of harvest machinery across the field, the decisive factor is the quantity of biomass being harvested per unit of time. In 6-months old napier grass, the rotary scythe was conditioning biomass at full capacity when operated in the tractor's low gear.

Under normal circumstances, the rotary scythe 'conditions' the conditioning of the relatively woody napier grass forage crops that are relatively immature, succulent, and easily disintegrated. The forage plant is shattered by repeated striking of the blades at distances of 4 to 6 inches along the stem. This greatly enhances the solar drying of such materials while aiding the windrowing and baling operations. Stems of 6-months old napier grass were quite effectively conditioned by the rotary scythe. Solar drying proceeded normally. Approximately one additional day was needed to attain 15% moisture (four days for napier grass as opposed to three days for Sudan). The increased drying time was mainly a function of the greater stem thickness and total mass of material per acre for napier grass.

Inadequate preparation for raking and baling operations was observed. Mature Napier grass plants are 3 to 4 meters long with stems up to 3 centimeters in diameter. In order to manage such material as solar-dried forages, it is necessary not only to shatter the stems but also to reduce them to shortened, pliable segments that can be raked into windrows and fed successfully into balers for compaction.

Grass erodes. This was especially true of high stubble (8 to 10 inches) but occurred in low stubble (1 to 2 inches) as well. The crown of a mature Napier grass plant offers considerable resistance, more like the stump of a sapling tree than a conventional forage grass. Although tines are easily replaced, the rate of breakage on Napier grass stubble was prohibitive. Moreover, a significant quantity of biomass lying flattened between the stubble remained unraked. It is believed that the problems of tine breakage and unraked material can be eliminated by the use of a different type of implement, one commonly described as a "wheel rake". This rake is not driven by a power take-off but rather operates through contact of its tines with the ground surface. The tines are mounted on a series of independent wheels which offer greater flexibility for penetration of a heavily-stubbled surface. Plans have been made to test a Farmhand model wheel rake with solar-dried Napier grass and sugarcane trash during the project's fourth year. Baling trials on the 6-month old Napier grass with a New Holland round baler proceeded normally. Although the Napier grass stems were far heavier than Sudan or conventional forage grasses, they were sufficiently broken up and weakened by the rotary scythe to be organized into round bales without difficulty. As was the case with the rotary scythe and rake, it was necessary to operate the baler in low gear owing to the very large mass of windrowed Napier grass.

5.4, Direct Firing Of Napier Grass

The first direct combustion tests for the solar-dried tropical grasses of this project were performed by PR Sugar Corporation engineers during late January of 1980. At the onset of a new campaign, sugar mill engineers need to ignite their furnaces to raise steam and process heat before the first harvested cane arrives at the mill. For this purpose almost any combustible material is used—old lumber, discarded railroad ties, wood scraps, and refuse of varying description. Mill workers at Central Gi

"Ica, located about 10 miles from the Project's Lajas Valley site, learned of the biomass bales accumulating there and received authorization to use some of these for start-up fuel. Some 50 bales of solar-dried Napier grass were obtained for this purpose. Although no formal data were gathered, the engineers were highly pleased with the combustion performance and handling properties of this material. No fuel oil was needed to assist in ignition as is the case with bagasse

2/. This was the first instance when the Project's experimental tropical grasses were actually used as fuel.

D. BREEDING

In Puerto Rico, sugarcane breeding is performed from mid-November to mid-December. Crosses completed during November of 1979 are summarized in Table 29. Each of the five tabulated crosses was performed by T. L. Chu in conjunction with the AES-UPR sugarcane breeding program. All were performed with biomass rather than sucrose as the primary objective. One cross, B 70-701 x ST-NG-54, has a high probability of producing offspring with a predominantly high-fiber attribute (16). The remaining crosses could produce seedlings with both high fiber and high fermentable solids attributes (Table 29).

J Central Guinica ordinarily adds 4 gallons of residual fuel oil to each ton of bagasse (about 512 moisture) to promote combustion.

Three subsequent crosses were made in December using an early-flowering Spontaneous hybrid as the male parent. This is an extremely vigorous clone found in the wild near Rio Piedras. Its early tasseling habit has been overcome to a limited degree by cutting back wild stands during the late spring. This forces the ratoon plants to pass their normal floral induction period in the juvenile state, and to enter the adult (reproductive) phase at a later time frame more consistent with potential crossing partners. Three commercial Puerto Rican sugarcanes served as the female parents, including PR 960, PR 67-1070, and PK 64-1618 (Table 30). Nearly 1000 seeds were obtained from the crosses."

With PR 980 and PR 67-1070, only about 20 seedlings were produced by the cross with PR 64-1618. At this writing, none of the progeny appear to resemble the male parent. Sufficient material is available to begin evaluating the transmission of a high-fiber attribute to hybrid progeny (16).

B. ECONOMIC STUDIES 1. Energy Cane Production

Preliminary cost analyses for energy cane production were performed on the basis of first-ratoon yields. A breakdown of production input charges is presented in Table 31. These figures pertain to a family-owned, 200-acre operation yielding 33 oven-dry tons of biomass per acre per year. The most expensive equipment items, a whole-cane harvester and low-bed truck, would be hired from the P.R. Sugar Corporation along with the equipment operators. In an energy cane industry, such investments would probably be family-owned, in which case the operation and maintenance costs would be appreciably lower. Both water and fertilizer charges are entered moderately higher than project data actually indicate, mainly owing to potentially large consumption differences as varietal and ecological life zone factors.

Total costs, including delivery to the milling site, amount to $25.46 per oven-dry ton, or about $1.70 per million BTUs. By way of reference, Puerto Rico is presently paying about $4.30 per million BTUs in the form of petroleum boiler fuels. In an energy cane scenario, about 68 percent of this dry matter would be burned as boiler fuel. The remainder would be extracted as fermentable solids during the cane dewatering process and later sold as constituents of high-test molasses. Neither raw sugar nor refined sugar sales are anticipated.

Cane milling costs in Puerto Rico today are presently about $5.00 per ton. The fermentable solids from one acre of energy cane (i.e., with yields of 33 oven-dry tons/acre), would be valued at $1,500 to $2,000 if marketed today as high-test molasses. The Puerto Rican emphasis on molasses rather than boiler fuel is quite real and probably justified.

Rum is one of Puerto Rico's leading sources of revenue, yet their molasses feedstocks are increasingly derived from foreign suppliers. Puerto Rico was one of the world's major molasses exporters in 1934 (21) but has declined to an 88% dependency on imported molasses in 1979 (22). Because of this, local interest in the energy cane herein described is directed mainly towards its molasses yield potential rather than its role as a renewable domestic boiler fuel. 2. Cost Comparisons: Energy Cane vs Conventional Sugarcane. Production cost estimates for conventional PR sugarcane were computed during the third quarter for direct comparison with energy cane estimates (Table 32). Sugarcane cost estimates are based on data obtained from Central Aguirre for the 1979 milling season. They probably constitute a "best case" for production operations in the PR sugar industry as a whole. As indicated in Table 32, production costs for energy cane are higher than sugarcane in five areas: seedbed preparation, feed, fertilizer, harvest operations, and delivery of harvested cane. Energy cane seed and fertilizer expenditures were double those of conventional sugarcane. Harvest operations and cane delivery expenses were 67 percent higher, and seedbed preparation costs were 50 percent higher. It should be noted also that the sugarcane cost estimates pertain to a private planter (or "Colono") for whom the major machinery items are rented rather than self-owned. The overall cost for producing a ton of energy cane was 46 percent higher than conventional sugarcane. However, the decisive difference between the two management scenarios lay in the total dry matter yield per acre year (Table 32). Energy cane yield exceeded sugarcane by a factor of about 3.7. Hence, the increased cost of "pushing" sugarcane, i.e., to maximize total biomass rather than sucrose, was more than compensated by even larger increases in dry matter yield. As a result of its relatively low productivity, the PR sugar industry cane cost in the order of $65.00/OD.

The ton of about $4.31/million BTUs. F. ENERGY BALANCES The final energy balance figures for energy cane will be based on cane production yields from a 3-year cropping cycle. Preliminary analyses were performed during the third quarter using the first-ratoon crop yields for varieties FR 980, NCo 310, and PR 64-1791. These varieties averaged 33 OD tons/acre year for the first-ratoon crop. Energy input estimates for this material are summarized in Table 33. Total energy inputs for energy cane production are in the order of 28 x 108 BTU/acre year. Energy output amounts to 279 x 106 BTU/acre year (Table 34). Estimates prepared by Dr. Levis Smith, Consulting Economist, CEER-UPR Biomass Energy Program.

The latter figure is computed on the assumption that most of the fermentable solids fraction of the total dry matter yield will be extracted at the sugar mill. The extracted fermentable solids amount to about 640 lbs/OD ton of energy cane. This figure is based on a recorded mean Brix value of 33.1" for energy cane juice and an assumed 80% extraction at the mill. In this instance, only 1360 pounds of dry matter/OD ton, or 22.4 tons/acre, will be used as boiler fuel. On a steam recovery basis, assuming 85% efficiency for a utility boiler, an energy output/input ratio of 9.95/1 is obtained (Table 34). Some authors have simply divided the total calorific value of their sample product by the total production energy input (23). By this method, energy cane would have an energy output/input ratio of about 7.7/1. It is instructive to note that nearly half of the total energy expenditure was for mineral N alone (Table 33). Hence, while the favorable energy balance obtained to date is mainly a reflection of high DM yield, future improvement of this balance can be gained both by increasing yields and by reducing the input of mineral N. One means of lowering N input is to apply the element as a soluble component of the irrigation water, particularly water applied via trickle irrigation (20). The increased

The efficiency of lower N supplies should compensate for the relatively inefficient plant use of dry fertilizer administered in larger amounts to the soil surface. Another potential means of lowering mineral expenditures is through increased usage of N-fixing legumes in conjunction with biomass energy crops. A large number of underutilized tropical legumes have been identified for possible use in this context (24, 25).

SUMMARY OF THIRD-YEAR STATUS

At the close of its third year, the project has progressed to the approximate point envisaged for year 3 in the original 5-year work plan. There have been a series of developments more favorable than expected, and one unforeseen development that has required some limited modification of the project's work plan.

Biomass researchers working with tropical grasses in a tropical climate have many factors working in their favor. Nonetheless, exceptionally favorable trends emerged for us in three distinct areas.

First, the botanical attributes of candidate tropical grasses conformed more favorably than expected with domestic energy resource requirements. It was possible to develop short-to-long rotation categories of grasses that would supply large quantities of biomass, on a year-round basis, in a solar-dried state that minimized dewatering and transportation costs.

Second, the project's agricultural engineering phases were enormously eased by prior developments in forage-making machinery. A very appreciable workload remains in our field evaluations of the rotary scythe, the bulk baler, and heavy-duty wheel rake; however, it is already evident these machines perform in the relatively massive biomass scenarios imposed by tropical grasses. If any one of them had failed to accommodate such materials, a large engineering gap would have remained in tropical grass fuels technology.

The third development favoring this project is a highly positive trend in production-cost and energy-balance data. The project's staff feels that considerably better data will be available in the future.

Variables plus 6 and 12-month harvest intervals will be retained. A "gran cultura" cropping interval (16 to 18 months between harvests) will be incorporated for the first time. A second-generation study on sugarcane for biomass (depicted as "energy cane" by the project staff) is being planted at the AES-UPR Laján Substation during the first quarter of year 4. Paper grove studies are being shifted to the field-scale phase. Special emphasis will be directed towards the mechanized harvest, storage, and transport of 6-month old material. Post-harvest handling and storage operations for bulk bales (1000 to 1500 lb. round bales) will be studied in a roofed storage facility presently being constructed for this purpose. This phase includes the evaluation of storage behavior for grasses baled at varying stages of solar drying.

2 - References

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DRY MATTER (g/Plant) by Sordan Ton and E396 (Oath short-rotation biomass mixture with adequate

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	Growth Interval 2/	ow Maximus 2/	Category	‘(onths)	(oaths)
Short Rotation	+6	a3			
Intermediate Rotation	8-18	6			
Long Rotation	36-60	12-18			
Minimum Tillage	Indeterminate	a vy			

2. Replanting frequency; at least two"

Ratoon crops are anticipated. Time required physiologically to maximize dry matter.

VOLUME 3. DRY MATTER PRODUCTION BY EIGHT CANDIDATE TROPICAL GRASSES HARVESTED 2, 4, AND 6 MONTHS AFTER PLANTING. Each species was propagated in a 1:1 soil-cachaza mixture with adequate water supply, approximately 30 square feet. Mean values in the same column bearing unlike letters differ significantly ($p<0.05$). Values bearing at least one letter in common are not significantly different.

TABLE 6. DRY MATTER CONTENT OF EIGHT CANDIDATE TROPICAL GRASSES HARVESTED AT 2, 4, AND 6 MONTHS AFTER PLANTING BY GENUS & SPECIES. Cultivated in a 1:1 soil-cachaza mixture with adequate water supply. Mean values bearing at least one letter in common do not differ significantly ($p<0.05$).

TABLE 5. DRY MATTER PRODUCTION, INDIVIDUAL PLOT BASIS, BY EIGHT TROPICAL GRASSES HARVESTED 2, 4, AND 6 MONTHS AFTER PLANTING BY GENUS & SPECIES. Cultivated in a 1:1 soil-cachaza mixture with adequate water supply. Mean values in the same column bearing unlike letters differ significantly ($p<0.05$). Values bearing at least one letter in common do not differ significantly.

Significantly.

Our needs.

TABLE 7. DRY MATTER PRODUCTION BY EIGHT CANDIDATE TROPICAL GRASSES OVER A TIME-COURSE OF 10 WEEKS (DM in g/Plot)

Each week —

Variety @ 10

Mean Sordan 77 0.32

Trudan 5 0.32

Dekalb F5-4 0.85

Dekalb F5-25 0.80

Dekalb st-6 0.54

Dekalb st-8 0.53

Dekalb st-16 0.52

Dekalb st-17 0.34

*Approximately 1/200 acre.

TABLE 8. DRY MATTER PRODUCTION BY EIGHT CANDIDATE TROPICAL GRASSES PROPAGATED WITH VARIABLE MOISTURE REGIMES OVER A TIME-COURSE OF 11 WEEKS

(g/kg/Plot)

Each week — Moisture regime, variety

Mean

Sordan 77

Trudan 5

Dekalb F5-4

Dekalb F5-25

Dekalb st-6

Dekalb st-8

Dekalb st-16

Dekalb st-17

*Approximately 1/200 acre.

TABLE 9. DRY MATTER CONTENT OF EIGHT CANDIDATE TROPICAL GRASSES PROPAGATED WITH VARIABLE MOISTURE REGIMES OVER A TIME-COURSE OF 11 WEEKS

Moisture (%)

Each Week = Regime Variety

Mean

Sordan 77 16.5

Trudan 5 2.6

Dekalb F5-4 8

Dekalb F5-25 12.13

Dekalb st-8 1

Dekalb st-16 23

Dekalb st-17 26

Mean 25.2

TABLE 10. DRY MATTER

The text seems to be a collection of data and notes, possibly from a scientific study. Due to the lack of contextual information, it's difficult to correct it accurately. However, I've tried to make it more readable below:

Production by Johnson Grass Propagated with Variable Nitrate Supply in Sand Culture

DM (g/Plant) AC week YM

0.99

3.00

1.90

2.78

0.68

1.92

5.68

2.03

3.38

2.20

3.38

4 Nutrient treatments were initiated. The initial harvests were four weeks of age. Seedlings were taken two weeks thereafter. Mean values in the same column bearing unlike letters differ significantly (P<0.03). Values bearing at least one letter in common do not differ significantly.

Dry Matter Content (DMC) of Johnson Grass Propagated with Variable Nitrate Supply in Sand Culture

DM (g/Plant) AC week YM

2.50

2.90

2.40

1.50

2.00

1.20

1.80

2.50

Mean values in the same column bearing unlike letters differ significantly (P<0.05). Values bearing at least one letter in common do not differ significantly.

Foliar Content (% Dry Weight) for Each Treatment

1.07

0.25

0.23

0.28

0.29

0.27

0.25

2.33

Active blades of leaf were harvested at week 10 of various treatments. Figures are the computed means of three replicates.

Post-Harvest Growth in Johnson Grass Plants Propagated with Variable Nitrate Supply in Sand Culture

s/Plant for — Telos Shots/plant__Green Wty Dry Weight

5.28

Measurements were taken four weeks after termination of the variable NO3 treatments. Figures are the computed means of three replicates.

Dry Matter Production by Candidate S. Spontaneum and S. Sinense (Clones) Given Minimum Tillage for Six Months

Matter/Plant (Kg) For — Species Clone Green Matter Dry Matter

S. Saccharum Hybrid PR 980

2.40

2.82

S. Sinense Aretha

1.50

2.00

Please note that this is a rough interpretation and may not accurately represent the original intention of the text.

The text provided appears to be a mix of alphanumeric characters that do not form coherent sentences or information. It seems like a corrupted version of a scientific document or paper, potentially dealing with biomass production and Saccharum (sugarcane) clones.

Due to its highly corrupted and incoherent state, it is impossible to accurately fix the text without additional context or a less corrupted version for comparison. I recommend trying to recover an original or less corrupted version of the document if possible.

The following text is a revision of the text provided. Please note that some information was hard to decipher and may need additional clarification.

Second Ratoon Crop of Three Sugarcane Varieties and One Napier Grass Variety Propagated with Variable Row Centers; Third 2-Month Harvest

Green Matter (Tons/A), At Row Center:
Cultivar 150 - Varieties:
Chasse PR 980: 0.28, Y 42.8
EO 310: Le 8, “03 PR
Perky: ~28'9
Napier Grass: tia = 3.8

Dry Matter (Tons/A):
PR 980: 0.08, 0.08, 30.9
EO 310: oh9, orb, iS
PR 6e-i791: 0105, 0105
Napier Grass: 1.48, aaa, -67, 1.0

Table 19, Biomass Production by the Second Ratoon Crop of Three Sugarcane Varieties and One Napier Grass Variety Propagated with Variable Row Centers; Fourth 2-Month Harvest

Green Matter (Tons/A), At Row Center:
PR 980: cage 0.32, 04, 654
EO 310: 265, 8, a, 9
Pe eei7e: 058, ee, oat
Napier Grass: 11.60, 9, 10.21, 9

Dry Matter (Tons/Acre):
PR 980: 0.02, 0.07, 250.0
EO 310: oi, on19, a4
PR e179: 0.08, 02, ote
Napier Grass: 1.29, 13s, aan

Table 20, Biomass Production of the Second Ratoon Crop of Three Sugarcane Varieties and One Napier Grass Variety Propagated with Variable Row Centers; Fifth 2-Month Harvest

Green Matter (Tons/A), At Row Center:
Cultivar: ioe Es, 1 change
PR 980: owe! ose = 38
EO 310: 20k, €, Tote, 263
Napier Grass: 15.258, 16.5

Dry Matter (Tons/Acre):
PR 980: 0.06, 0.07, 16.7
EO 310: 00, ona, 20
PR eei791: 08, bos, “es
Napier Grass: 23s, nae

Additional information is needed to correct the last part of the text provided.

The text appears to be corrupted and lacks coherence, making it impossible to correct in its entirety. However, I can attempt to fix some parts of it:

(This is not clear) 'transfer to oven etc. (something regarding stratane) see swing, or an occurrence, or something else. (Maybe something about Coorg, followed by unclear text) By (STVGNEINE TEVA BY GALSUNNWH SEVID LN may be a reference to an author or researcher, followed by unclear text) GO JOE WOOD-WINDERS BLL Wu EOTAIA GALIWN

TABLE 23, BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY. VARIABLE ROW CENTERS; FIRST MONTH HARVEST. Green Matter (Tons/A), At Row Center - cultivar 150 50 (unclear) change Px 980 (unclear) 1.9 6 13.0 (unclear) 310 (unclear) 20.9 3 (unclear). PR stel7a1 1513 be 35 (unclear) soem en Napier crane (unclear) zte = 6.3. PR 980 PR stet794 Napier grass Dry Matter Content (2) 7 980 18.6% (unclear) 310 (unclear) PR 6tei791 (unclear). Napier Grass (unclear) 4 29 AY. Mean values bearing unlike letters differ significantly (P <.08) those having at least one letter in common do not differ significantly.

(Note: The numbers and the unclear text need more context to be accurately fixed)

(Repeats similar structure as above with TABLE 24, again involving biomass production, sugarcane varieties, and Napier grass. The text includes measurements, possibly related to the biomass production or other agricultural data. However, without the correct context or uncorrupted text, it's impossible to accurately "fix" it.)

TABLE 25, BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY. VARIABLE ROW CENTERS; FIRST MONTH HARVEST. Green Matter (Tons/A), At Row Center - cultivar 150 = 50 (unclear) change 900 (unclear) as Meo 310 358s 33.6 (unclear) Pr elei791 (unclear) we sea Napier Grass 33.3 30.0 (unclear) Dry Matter (Tons/A) 2 980 (unclear) a9.6 (unclear) '310 (unclear) PE 6iet791 (unclear) Napier Grass 9.0.4 298 n2.2 PR 980 (unclear) 224.

(Corrections are limited due to the corrupted text, but the general structure seems to follow that of a scientific study or report, possibly related to agriculture and specifically sugarcane and Napier grass production).

1. Neo 310, 23 Ave 253. He is a part of 23% who are 2 years old. Kapier Grass AAA 26.2 AB 3A. AF Mena values bearing unlike letters differ significantly (P < .05). Those having at least one letter in common do not differ significantly.

Words sound (over agreement) - see serene room 21. See one agreement. Feel sent. We've so essent 008. 9 rag simulation. Eat and ranso sort. See 804, cover made. Worst, worst, worst. Seguaro Wear it WG. We see [Variant HWLVLEVA ZY GALSZNIN SOMO WELGWW GW WTAE AD GOED NOOK GRAS HAL won UD WaLGW AAO 9E RTO.

Table 27. Biomass production by three candidate tropical grasses over a course of 10 weeks with a minimum water supply. Average Yield (Tons/Acre) when planted with variety (here) Green Weight, Dry Weight. Sordan 70K 36 AAA 107, Sordan 77 AAA? A MW 326 9.36 139 AY. All plots received 2.0 acre-inches of water by overhead irrigation at planting. No additional irrigation was administered. Rainfall for the 10-week growth period totaled 2.75 inches. Solar dried to approximately 15% moisture.

Ore or or et "1 eo - 1 woe sor owe tai Coan time ME Ta only Matam ag aoe existing sentient dp pet.

Table 29. New sugarcane crosses for biomass, Nov. 1979. Female Parent, Male Parent, Objectives. B 70-701 x S7HNG-S4, Fiber only. Neo 310 x US 67-22-2 A, Fiber & Fermentable Solid. Neo 310 x B 70-701 2/, Fiber & Fermentable Solids. PR 62-195 x ST-NG-S4, Fiber & Fermentable Solids. PR 68-330 x 47-NG-54 A, Field cross.

Table 30. New sugarcane crosses for biomass, Dec. 1973. Estimated No. Crosses, No. Female Parent, Male Parent, No. of Seedlings. 1 R980 x S. spont. Hybrid, 400 to 300. PR OT-1010 x S. spont. Hybrid, 500. 3 PRGLISIE x S. spont. Hybrid, 20.

Table 31. Preliminary cost analysis for total dry matter production by first-rotation sugarcane managed as an energy crop. Dry matter yield: 33 OD Tons/Acre, Total 6600 Tons. Preliminary Cost Analysis: 1. Land Rental, at $50.00/Acre, $10,000. 2. Seedbed Preparation, at $15.00/Acre, $1,000. 3. Water.

(800 Acre Feet at $15.00/Acre Foot) $22,000
4. Water application, at $48.00/Acre Year $9,600
5. Sand for Plant crop Plus Two Rotation Crops, estimated at $15.00/ton $3,000
4. Fertilizer, at $160.00/Acre $36,000
7. Pesticides, at $26.50/Acre $3,300

8. Harvest, Including Equipment Charges, Equipment Depreciation, And Labor $20,000
3. Day Labor, 2 Man Year (2016 hours at $3.00/hour) $6,048
30. Cultivation, at $5.00/hour $2,000
31. Land Preparation & Maintenance (Pre Post-harvest) $600
32. Delivery, at $7.00/ton for 3 miles of Haul $46,200
33. Seeds $132,768
3. Management 10% of Subtotal $13,275
15. Total cost $368,025
Labor which is not included in other costs.
Total cost/Ton: ($368,023 + $600): $23.46
Total Cost/Million BTUs: ($23.46 + $15) = $1.70
One ton of this dry matter would contain approximately 600 pounds of fermentable solids, 600 pounds of fermentable solids, equal to about 61 gallons of high-test molasses.

TABLE 92. PRELIMINARY COST ANALYSIS FOR ENERGY CANE VS CONVENTIONAL SUGARCANE PRODUCTION
18. Puerto Rico (1979 Dollars) - Analysis For A Privately Owned 200 Acre Operation
Estimated Cost ($/Year) For -
1. Land cost, at $50.00/Acre $10,000
2. Water, at $15.00/Acre Foot $12,000
4. Water application, at $48.00/Acre Year $9,600
5. Seed (for Plant Crop Plus Two Rotation Crops) $3,000
6. Fertilizer $36,000
7. Pesticides, at $26.50/Acre $5,200
8. Harvest, including Equipment Charges, Equipment Depreciation, and Labor $20,000
9. Day Labor, at $3.00/hour $6,048
20. Cultivation, at $5.00/hour $1,000
21. Land Preparation & Maintenance (Pre Post-harvest) $600
22. Delivery, For 3 miles of haul $46,200
Yield (Tons/Acre Year): Sugarcane, 9.0; Energy Cane, 33.0.
Labor which is not included in other costs.
Total Cost/Ton: Sugarcane, $84.68; Energy Cane, $25.66
Total Cost/Million BTUs: Sugarcane, $4.32

I'm sorry, but the text you provided is too garbled and lacks context for me to accurately fix it. Could you please provide a clearer text or more information?