# CEER-B-172

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PRODUCTION OF SUGARCANE AND TROPICAL

GRASSES AS A RENEWABLE

ENERGY SOURCE

FOURTH ANNUAL REPORT

1980-1981

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?THE UNITED STATES DEPARTIGNT OF ENERGY

ENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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# PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE ENERGY SOURCE

Fourth Annual Report; 1980-1981

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?The United States Departaent of Energy

Oak Ridge Operations Office, and the Division of Solar Technology

Biomass Encrgy Systene Branch

Washington, D.C

By

The University of Puerto Rico

Center for Energy and Environment Research

Rio Piedras, Puerto Rico

(CONTRACT NO. DE-ASOS-762720071 (AES-UPR Project C-481)

LATION: Rio Piedras, Puerto Rico

PERIOD COVERED: June 1, 1980-May 31, 196

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?Alex 6. Alexander

Project Leader

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[PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE

[ENERGY SOURCE 1/

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ABSTRACT

Research continued on tropical grasses from Saccharum and related

neta as sources of intensively- propagated fiber and fermentable solids.

Yield trends for sugarcane and napier grass over the first three years vere compiled during year 4. Four trends were evident: (a) A general failure of narrow row spacing to increase yields; (b), major DM yield increases vith delay of harvest interval; (c) a superiority of variety NCo 310; and (4), @ superiority of first-ratoon DM yields over those of the plant and second: Fatoon crops. As a 3-year average, DM yields for cane and napier grass were 9.0 and 27.5 0D tons/acre year, respectively. Optinal harvest. interval vas 12?months for cane and 6 months for napier grass.

Harvest sachinery trials for mature napier grass continued during Year 4. ?The M-C rotary scythe and Nev Holland round baler continued to perfor well with 6-month old grass, representing 40 to 45 tons/acre of standing green biomass when moved. A?Farahand wheel rake gave superior performance in dense,

feted saterial, including high stubble. Diesel fuel consumption by a cate gory III tractor operating the rotary scythe in 6~onths old napier grass Fanged fron 2.38 to 2.95 gallons/hour, ot 1.92 to 2.69 gallons/acre. There was woderately greater fuel consumption at low moving heights. Horsepower Usage ranged from 41.4 hp at low etubble to 35.7 hp at high stubble.

A najor fLeld-plot study vas established to evaluate yield potentials

of two "second generation? energy cane varieties specifically selected for

high biomass yield. In addition to varieties, controlled variables include

harvest frequency (6-,12-, and 18-month intervals), and nitrogen supply:

(200, 400, and 600 1b tal N/acre year). This study is naintained

under torder irrigation in the semi-arid Lajas Valley. Yield data at 6 onthe

indicate high but essentially equal grovch rates anong all varieties and N-

variables. This is attributed co the use of a land rotavator during seedbed

Preparation?the first such application of this implement on Lajas Valley

soils. Total green weights were in the order of 50-50 tons/acre, and willable

stea weights ranged fron 33 to 37 tons/acre, at the 6-monthe harvest. Dry

hatter yields ranged from 8 to 11 tons/acre. Juice quality values indicated

?4 mininal sugar content at this stage of maturity. Fiber values ranged from

7 to 142. A field-scale denonstration study vas also established near Hatillo

fon the seni-humid noreh coast.

U/ Contract No. DE-ASOS-78ET20071

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INTRODUCTION

The biomass production studies herein reported vere initiated June 1, 1977 as a contribution to the Bionass Energy Progran of the UPR Center for Energy and Environment Research (CEER-UPR). This research deals with sugar-cane, tropical grasses related to sugarcane, and other tropical grasses having large growth potentials on a yea round basis. Its basic prenise is that such plant saterials can be produced contimiously as a renewable, donestic source of fuels and chenical feedstocks that will substitute for imported fossil energy. The present report covers the period June 1, 1980 to May 31, 1981.

1. Project objectives

Primary objectives include: (a) Determining the agrononic and econonie feasibility of mechanized, year-round production of solar-dried bionase, through the intensive managenent of sugarcane and napier grass as tropical forages, and (b), examination of alternative tropical grasses as potential sources for intensive bionass production. A secondary objective concerns the selection and breeding of nev sugarcane progeny having superior bionast

productivity as their principal attribute.

2, Scope of the Project

Bophasis is directed tovard « highly-intensive and mechanized product

tion of troy

ical grasses as solar-dried forages. This is a deviation from

conventional cane and cattle feed production in chat total dry matter rather

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than sugar and food components is the principal salable comodity. Manage ent of production inputs?particularly water, nitrogen, and candidate species, together with harvest frequency?varies significantly from estab- Lished procedures. On the other hand, advances in mechanized production ?and harvest operations within the sugar and cattle forage industries are being utilized with considerable success for production of solar-dried

bionas:

Optimized production operations require the identification of a few

select clones and the conditions required for their managenent in an

?econonically-ri

istic operation. This is being accomplished in the con

Cinued development of three project phases, including greenhouse, field-plot,

and fielé-scale investigations (Table 1). A fourth phase, comercial-

industrial operations, follovs logically but Lies beyond the scope of the

Present project. The work herein reported deals with a continuation of the

Breenhowse, Field-plot, and field-ecale phases begun earlier (1,2,3) 2/.

The project's screening operations are designed to identify high

yielding grasses that can be harvested on @ year-round basi

They have

indicated three broad categories based on the tine required after seeding to maximize total dry matter (Table 2). Among ous

wreane cultivars the superior

Growth rate per se, a botanical feature, has not been recognized historically

a5 a desirable attribute unless conbined vith an acceptable level of augar

Production (4,5,6,7,8,9,10). Similarly, the tropical forage grasses have

required acceptable digestibility and nutritive characteristics rather than

high yields of dry matter (11,12). Accordingly, our screening program often

B/ Numbers in parentheses refer to relevant published literature. Couplete

Citations are Listed on pages 42-44.

---Page Break---

deals vith long?establiabed cultivars, but in manner chat would have

astonished their original developers. In sone reapects this is « tropical

application of the herbaceous species screening program formulati by the

DOE Biomass Systens Program (13,14).

A breeding progran designed to intensify the bionass-yielding attribute

of

charm and related species Lies beyond the scope of this project.

?Thorough breeding studies would require and justify a separate project.

This vould include the ser

ing of candidate parental types, a physiological

Phase to synchronize flovering periods at the intergeneric level, and basic

genetic research to break sone serious constraints operating to prevent the

exchange of geruplasn anong Saccharua and allied genera (15,16,17, chap. 1).

At a very modest level some Limited breeding is included in the present

project. This work is confined to a few obviously desirable parent clones that have suitable flowering characteristice and which can be incotporated

Without inconvenience into an ongoing breeding program for eugarca

a2).

Certain progeny originating with the AES-UPR sugarcane breeding program ara

also being considered as long-rotation biowase candidates (3,18). Under

these circunstances some prospect is created for the energence of superior

new progeny at very Little axpens

?TECMUICAL REPORT

?Ay GREEMUOUSE STUDIES

?The project's greenhouse phat

ie concerned with the screening of

candidate tropical gras

18 and the response of superior cultivars to grovth

input and managenent variables. Much information of this nature is obtained

ty than is possible under field conditions. Greenhouses

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data are not definitive in the sense that direct field responses and

cultural recomendations can be stated, but perhaps two-thirds or more of

the coral data package needed for a herbaceous candidate can be gathere.

in

this vay. For Saccharum and related species ordinarily propagated in Populations of 30,000 to 300,000 plants per acre, the greenhouse offers a level of precision for control of the individual plant that is not possible in the field. This method is currently used in Puerto Rico for its econoay

of project resourc

under tenperate-clinate conditions it offers an econony of time where field work is seasonally limited to four or five faror~ able months per year.

Both replicated and non-replicated ?observation? experiments are conducted in the greenhouse (1). The latter usually concern prelisinary srovth-potential neasurenents involving only a fev hundred plants in an area covering roughly 1/200 acre. Replicated experiments deal with specific groveh characteristics in previously-identified candidates. Ordinarily these have

involv

3 to 5 replications of each treatment arranged in an incomplete

randoaized block 4

gn (1, 2).

- Legune Screening

Preliminary analyses of the energy expenditures for intensive sugarcane

Production (3) have indicated a disproportionately large energy input for

nutrients, particularly for the elmental nitrogen provided in the form of

henical fertilizers. Nearly half of the total energy inputs are account

able to elemental N alone (3, p. 70), There is considerable evidence that

herbaceous crop plant

can obtain at least part of their N requirements

through intercropping or co-production vith Legume species (19,20,21).

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during the second quarter included four legume

species regarded as potential N sources for tropical grasses managed ay

energy crops. Each species is widely distributed in the wild in Puerto

Rico and all produce moderai

torheavy nodulation over short periods of

?The first experinent dolt vith species of Leucaena, Phaseolus,

Albizia, and Sesbania (Table 3). Direct groveh comparisons were made

with one of the fastest-growing tropical grasses available, ie, Sordan 70k,

4 short-rotation species attaining maxinum height and tissue saturation

within 12 weeks after

ding.

Because of the rapid germination, elongation, and canopy closure of short-rotation grasses, candidate legumes for co-production with these Plants would also require an early rapid grovth habit, both to avoid shading out and to contribute @ meaningful anount of dry matter at the tine of harvest. Grovth measurements were recorded for Sordan 70A and the four Legumes at six, 12, and 18 veeks after seeding (Table 3). Growth paraneters included green and dry matter produced/planted area (approxizately 60 £t2/ species/narvest), plant height, and DM yield on an individual plant basis.

so recotded.

Plant maturation, as indicated by percent dry matter, wa

None of the legune specis

attained the early elongation and dry

matter yield characteristic of Sordan 70A (Table 3), The species Sesbania

@altata (Colorado River Heap) most nearly matched the tropical gra:

in dry

fatter yield (Figure 1) and vertical growth (Figure 2). Seshania al

performed relatively well on an individual plant basis (Figure 3), although

none of the candidate Legum

Pre

lueced more than about 40 percent of the

DM attained by Sordan 70A as individual plant

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Jo roles are perceived for tropical legumes as supplemental N

for tropical grass energy crops: (a) As

on a given site between planting of energy cane or other tropical grasses,

?and (b) as bionass energy crops co-produced (grown simultaneously) with the

tropical grass energy crop. Candidate legunes for the first role vould be incorporated into the

sdbed prior to seeding the energy crop, and presua-

ably any of the test species described above might fulfill this purpose.

Over 100 legume species have been identified

candidates for intercropping

with tropical gr

es (22). Such evaluations Iie beyond the scope of the

present project. The second role is a more denanding one in the sense that

Jeguae candidates must thenselves produce an appreciable quantity of bionass

while contributing an immediate supply of fixed W to its companion crop.

?The task is particularly difticule vhen intercropping vith shore-rotation

Brasses where rapid vertical grovth and canopy closure occurs vithin three

weeks after seeding, and harvest is performed within 12 weeks after seeding.

Growth data frou the initial four test legumes indicate that Se

exaltata can probably give a satisfactory performance in this role.

For intermediate-rotation crops, such as napier grass, the initial Browth surge fs somevhat delayed and a legune species vill have a better chance to establish itself with only Limited shading from the tropical grass. The age at harvest vill vary from about 18 to 30 weeks. During this interval the vertical growth of napier grass will reach 9 or 10 feet. There ia little Prospect of finding an upright Legume that can equal this growth; hovever,

Sesbania exalts years to be the best candi

ee tested to date (Figure 2).

Given sufficient time, some woody legune cies (Leucaena and Albizia) might

attain this height but they could not do go in the growth interval of

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intermediate-rotation grasses. Certain of the tropical legunes have a trailing, indeterminate grovth habit and will cling to upright objects as cliabing vines.

A subsequent experinent vas performed to verify the legume grovth poten

tial and to determine whether the season of planting wat a significant factor

in their grovth performance; none of these spi

es have ever been planted

agricultural crops or experinental entities in Puerto Rico. Growth data for the first experiment, planted during the spring (May), and the second exper~ iment, planted 6 months later in the autuan (Novenber), are combined in Tables 4 and 5.

Several trends are evident for both green and dry biomass production (Tabie 4): (a) The Legume species vere far less productive when planted in autuan. Each species is quite clearly sensitive to Puerto Rico's "inter"; oy

esbania again was the most productive of the four legune species tested; (©) Sordan 704 produced sore green veight but less dry matter vhen planted in autumn (ie, it vas relatively less mature at each of the vinter harvest intervals); (4), Maturation trends in legume species vere essentially equal for spring and autuan planting: (c) The legume Phascolus Isthyroides vas as

productive in winter a2 in summer vhen DM w:

seasured on an individual plant

basis (Table 5). Winter thus appears to have affected germination and seed-

Ling establishment rather than growth per se: (f), Plant height vas restricted

in all species by autuan planting; (g), Se

snia vas the tallest of the

Jegune species in toth spring and autumn plantings, attaining about 73% of

{the corresponding Sordan heights as main effects (Table 5).

Although seasonal changes in tenperature and daylength

tropics their effects on plant grovth are probably underestimated. For

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example, Puerto Rico is often depicted as having @ "year-round groving

Season". Yet, sugarcane experiences a major growth decline during Puerto

Rico's winter while a Lesser grouth restraint is exerted on napier gra:

Some of the grovth decline might relate also to the Island's reduced rain-

fall during winter months. Vegetable crops are enormously sensitive to

on in Puerto Rico and this is recognized by the layean and

ional grovers alike. It now appears that the indigenous tropical

Legumes will have to be examined closely in this respect whether they are

Planted as N-sources for tropical grasses or

biomass crops in their ovm

right.

2. Mineral Nutrition

A nitrate-N nutrition experiment with sugarcane variety PR 980 was established during the autunn of 1980. Variable nitrate levels were adain-

istered in sand culture to evaluate the variety's N-response curve. As in

earlier nutrition experinents with short-rotation and intermediate-rotation species (1, 2), the objective with sugarcane vas to establish the slope of the dry matter yield response to progressively larger amounts of N. Accord ingly, nitrate-¥ levels were increased in a geometric progression ranging from 1.0 to 81.0 milequivalents per liter, in nutrient solutions given chree

times per week over @ time-course of 16 veek

ALL plants were maintained for 6 weeks vith # standard nutrient soluti

containing lov W (1.0 meq/1 of N0,). Two harvests vere performed after 5 ?and 10 weeks of variable treatment, ie, vhen the plants vere 11 and 16 veeks

of

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For both harvests, the green and dry matter yield data indicate a

aaxinun grovth response at around 9.0 meq/t of NO, (Table 6: Figure 4). On

sn individual plant bs

fs there vas Little difference anong variable W levels

St 9 weeks; however, the second harvest indicated a broad range of DM re~

sponses with high W (61.0 meq/1 N03) being cleary repressive, Maturation

values (DM content) varied but Little either among i! treatnents or harvest

interval (Table 6). These data suggest that the sugarcane ves auch too

immature to express a valid Saccharun species response to M variables of

this magnitude, Alternatively, it is very difficult to propagate sugarcane

to maturity via sand culture under glass.

FIELD-PLOT sTuDIES

2, Minimum Tillage Experinent; Lajas Substation

There is a need for tropical grasses that will produce at least aoderate yields with che barest sinimun of production inputs. The characteristics and principal requirenents of miniaun t{llage candidates for Puerto Rico are discussed at length in prior reports (1, 2).

A Long-term minimum ¢illage study on Saccharum species was initiated

at the AES-UPR Lajas Substation during mid-February of 1977. There are four

s

spontaneum clones and an interspecific coumercial hybrid (PR 980) serving

?a8 the control. Receiving no production inputs since the original planting, harvests have been taken at 6-nonth intervals. The fifth such harvest was Performed during the first quarter. Dry matter yields are relatively low for ail clones; however, it is evident that two of the S. spontaneum clones,

US 67-22-2 and US 72-93, are sustaining thenselves more effectively than the

commercial hybrid PR 980 (Table 7).

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The superior clone at this stage of the experiment is US 72-93. tes green and dry matter yields were 6.71 and 1.88 tons/acre, respectively. Energy inputs for US 72-93 under these circumstances are nil since neither serigation nor aachinery-use practices are involved. Cost inputs are confined to land rentals ($50.00/acre year) and labor for harvest operations (approxinately ($45.00/aere year). Assuming an annual yield of 3.76 OD tons/ acre for US 72-93 (two 6-nonth harvests), its production cost at $25.26/ton would be alnost identical to that of ?energy cane? at $25.46/ton (3).

The yields herein reported are fron the fifth 6-nonth harvest of a Planting seeded early in February of 1977. They constitute the fourth consecutive harvest perforned under minimum tillage conditions, that is, where no production inputs have been given other than harvest operations.

ALL clones indicate that they can survive and produce sone biomass under

these conditions. The average dry matter yield for the group appears to have becone fairly constant at slightly less than one 0D ton/acre/6 onthe

of grovth (Table 8).

cause this study vas planted 1.5

onths into Year 1, the final growth data for each year is obtained during

the firet quarter of the following year.

Hence, che Third Annual Report

covering activities for Year 3 vas lacking data for the aixth 2-aonth harvest,

the third G-onth harvest, the second 6-onth harvest, and the 12-aonth

harvest.

Final data for Year 3 (Tables 9-13) are consistent with yield trends

reported previously for years 1 and 2 (3, 1). These trends includi

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

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

Sugarcane trash yields were higher for variety PR 980 than XCo 310 and PR 64-1791 (Table 12). Napier grass generally produced less trash than suger~ cane, but the percentage of its biomass comprised of trash was higher than for cane. Hence, 28.4 percent of the total napier grass DM consisted of trash, while sugarcane trash ranged fron 14.1 to 26.8 percent of the rotal. Among the cane varieties NCo 310 produced the least trath (Table 12). None- theless, total dry matter yields (oven-dry millable cane plus trash) indicate that NCo 310 was still the superior biomass producer for Year 3 (Table 13).

(®) Maxtmon Bionaes Yields; Year 3: As noted above, the 12-month harvest vas by far the most important for sugarcane while the 6-month harvest gave maxinun yields for napier grass. The highest green matter yield (exeLu~ sive of trash) for Year 3 was 92.0 tons/acre year (Table 12, variety NCo 310);

the highest dry matter yield w:

31.3 tons/acre year, including trash (Table 13, variety NCo 310). As @ point of reference the PR sugar imiustry currently

produces 26 to 28 gr

pn tons and 9 0 10 dry tons per acre year as an Teland~

wide average. Tr:

is not credited to total cane yield by the PR Sugar

Corporation.

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The maximum napier grass yield at 12 months vas 67.8 green tons and

19.9 dry tons/acre year (Tables 12 and 13). A much greater yield was obtained

45 the combined output of three, 4-month harvests (88.9 green tons, 22.4 dry

tons) or two, 6-nonth harvests (88.7 green ton

26.0 dry tons). This is

indicated by sumary data presented in Tables 16 and 15.

Napier grass continued to attain a higher level of maturity than sugar-

cane during Year 3 (Table 16). The maximum average DM content for sugarcane vas 26.7% at twelve months; napier grass achieved a comparable maturity (25.82) within four months. By the twelfth sonth the napier grass DM content exceeded 32% (Table 16).

Although annual napier grass yields were roughly equal for combined 4-month and G-nonth harvests, appreciably less cost would be incurred when only two harvests are perforsed (at 6-nonth intervals). There vould be less

Ganage to plant crows, less soil conpaction, and less destruction of irrig

P

?tion borders by heavy sachinery vhen one of the three harvests is eliminated. A decisive factor here is the vork capacity of available harvest equipaent.

?There is Little point in atteapting to harvest 6-nonths old bionass with

harvest equipment designed to accomodate only 2-months old material. Machinery studies during Year 3 have shown quite decisively that 6-aonths

old napier grass can be harvested with existing equipment (see pages 33 to 36).

(©) Sugarcane Quality: The sugarcane management practices for this

Project are designed to maximize grovth rather than quality of the cane.

Relatively poor juice quality vas obtained for the plant crop and first=

Fatoon crop. The second ratoon plants showed moderately inproved quality

Dut nonetheless would be regarded as substandard in most cane sugar industries

Sucrose content averaged 7.2% for all variet{es and row spacings (Table 17).

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Variety PR 64-1791, at standard row spacing, produced 8.4% sucrose. Fiber

content averaged 16.4 percent, a value which is not exceptionally high.

While the quality of rhe cane herein described as ?energy cane? vas

low, it is nonetheless equal to or better than that of Puerto Rico's com

ercial sugar industry, Comercial sugarcane in Puerto Rico today rarely

Produces nore than 8% sucrose. This is a consequence of a vole series of

field and factory problens which Lie beyond the scope of our discussion.

Mowever, it must be noted thst cane grom for biomass cannot be faulted for low yields of sucrose or fermentable solids vhen these are computed on a per acre basis. For the Year 3 crop the three test varieties averaged 5.18 tons sugar/acre (TSA) at standard row spacing and 5.71 TSA for narrow row spacing (Table 18). By contrast the PR sugar industry produced less than 2.2 TSA in 1980 (22). The Government's Long-term goal of 3.0 TSA (24) appears virtually unattainable under present conditions in the Island's sugar industry,

In the managenent of ?energy cane", fermentable solids have been depicted as a major byproduct rather than the prinary objective of sugarcane produc tion (25, 26, 27). In Puerto Rico, especially when vorld prices for raw ovgar are low, sucrose would be sold to the Island's rum industry as a component of high-test molasses. As recently as the autumn of 1979 sucrose values appeared constant at around 16 cents/pound, and high-test molasses as priced at approxinately 95 cents/galion.

During periods of high sucrose values it could be profitable to recover

part of the sucrose for local or foreign

es. One means of doing this

would be fo retain the "first strike? (containing perhaps 60% of the recover~

able sucrose in cane juice) for rav sugar sales. The balance of the sucrose

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would resain in the molasses. This would be sold to the UP rum industry

aS a somevhat lover quality "high-test? molasses.

(@) Plant Densities: The number of stens produced by the cane and rapier grass croms vas a function of species, harvest frequency, and row spacing (Table 19). Eventhough close spacing failed to increase yields for sugarcane and sapier geass, the number of stens harvested from the second-Fatoon crop continued to reflect the increased seeding rates of theee years earlier. The highest plant density attained by sugarcane was 183,896 stems er acre (variety NCo 310 at close spacing and the 6-month harvest interval). The highest tonnage of the second ratoon exop was achieved with about 93,000 stens/acre, fron variety NCo 310 at standard row spacing (Table 19, 12-nonth

harvest). Variety NCo 310 also produced the highest number of atens for

2

+ and G-nonth harvest intervals.

Napier gr:

s produced nore steas than sugarcane irrespective of harvest interval. The G-uonth harvest period yielded the highest stem counts of the project to date, ie, 511,975 stens/acre for close-spaced napier grass (rable 19). However, Like sugarcane, napier grass yield was not a function of stem numbers but of harvest interval. The maxinun DM yield for napier revs (19.9 OD cons/acre year) was attained vith 199,000 stems/acre, at Standard row spacing and the 6-nonch harvest interval.

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

over thick-stenmed plants.

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C. FLELD-PLOT STUDIES; 3-YEAR TRENDS

With the completion of the second-ratoon harvest it is possible to

begin evaluating some lonp-tem erends in sugarcane and napier grass produc

tion as perennial sources of biomass. As a sugar crop, sugarcane can be

Brow for many years without replanting, but significant yield decline is

lusually evident after the fourth or fifth crop. The PR sugar industry

ordinarily harve

five crops (the plant crop plus four ratoon crops) but a

plant crop plus two ratoons

night be justified under sone circumstances.

?The longivity of napier gras when managed as an energy crop remained am open question. Napier grass vill prosper both as cultivated crop and a5 a wild specimen, The author is auare of napier grass plantings in Puerto Rico that are over 30 years old. Very Little is needed by euch plants in the vay of production inputs; alternatively, neither wild napier

nor conventional plantings for pasture a

forage purposes have been sanaged as energy crops in the past. In particular, the longivity of napier grass crows under harvest repines maximizing dry matter (recut at 4-to G-month harvest intervals) rather than digestible green material (recut at

3 t0 7 week intervals) is @ critically important question. tqually important

is the survival of napier grass crous vhen exposed to the harvest, solar

Grying, baling, aod transport operations that will characterize energy planta tion cropping.

Sugarcane; 3-Year Trends

(2) Maximum Yields: Summary yield values for three years of sugarcane

Browth indicate the folloving trend:

(a) The fixse ratoon exop (Year 2)

Bave the superior yields of both greon matter and dry matter (Tables 20 and 21

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=e

(©), the second ratoon erop was more productive than the plant crop but

less productive than the first ratoon (12-month data); and Cc), for ald crops, yields increased progressively with lengthening tine interval between

harvests. The highest average cane yield for the 3-year etudy vas 33.6 dry tons/acre year, including trash, produced by the Cirst-ratoon crop (Table 21). These results support the view that three crops vill maximize the yield of a piven sugarcane planting vhen managed for total biomas. The inplica~ tion is that the land area should be replanted following harvest of the second ratoon crop. Movever, the 12-sonth plots have been retained for an

additional year for confirsation of the apparent yield decline.

(b) Maturation Trends: Data for dry matter accusulation indicate that

the second ratoon crop was the le

1E mature of the three crops (Table 22).
?The firet-ratoon crop vas the most mature, ?For all crops there vas a marked lack of maturity vhen cane vas harvested at intervals of ess than 12 months duration. The highest average value for dry matter content of sugarcane was 31.0 percent, recorded for the first-ratoon crop at the L2-nonth harvest

interval (Table 22).

et

©

Teendst Three-year grovth performances for each variety

are summarized in Table 23 (2-and 4-month harvest intervals) and Table 24

(G-and 12-aonth harvest intervals). Dry satter yield differences vere not

?extensive among the three varieties; hovever, NCo 310 gradually energed as the

superior variety. Like the other varieties it was unable to produce very

effectively at the 2to G-sonth harvest intervals. It was appreciably nore

successful in r

sisting @ third-year yield decline which drastically affected

PR 980 and PR 64-1791 at these intervals, For the 12-eonth harvest (the only

---Page Break---

harvest of practical inportance), NCo 310 produced the highest yield of millable cane for each of the three crops, It was a relatively poor Producer of trash, hovever (Table 25). The total DM yields, in which trash was included, revealed only seal differences anong the three varietics. NCo 310 vas the superfor producer for the plant crop and second Fatoon crop, while PR 980 slightly exceeded NCo 310 (by 0.5 tons/acre year) for the first-ratoon crop (Table 24).

Trash yields vere clearly a varietal factor. Since only free trash vas eacured, ie, leaf and Leaf-sheath tissues that had detached from the sten and fatten to the ground, 2/ chose differences could reflect a genetic control of cane ?cleanliness? long recognized by sugarcane breeders (16). Variety

PR 980 produced appreciably more trash than NCo 310 and PR 64-1791 for each

of the three crops (Table 25). Moreover, each crop's yield for PR 980 exceeded that of the previous crop. Narrow row spacing appeared to increase trash yields for varieties Nco 310 and PR 64-1791. This vas especially true of the plant crop (Table 25), and to sone degree might simply reflect the

Steater number of plants available to shed leaves at that tine.

(@) Row Spacing Trends: Close spacing failed to increase yields of

A2-wonth sugarcane for each of the three exop years (Table 26). Only for
the 2-and 4-month harvests of the study's plant crop were any appreciable

yield increases obtained from narrow row spacing. The very clear ne

age

from these results is that, under tropical conditions, sugarcane will fi11 in

B/ The teat and leaf-sheath tissues which comprise trash, eventhough they

Bay be long dead, do not alvays detach and accumulate on the ground. Tragh adherence to the stem is probably a varietal characteristic.

---Page Break---



the availalle growing space through cron expansion from standard row centers spaced 150 em apart. Narrowing row centers to 50 cn makes no sense at all unless the energy planter intends co harvest only a single crop within about 6 t 8 months after seeding. Such management for sugarcane in Puerto Rico would be a gross underucilization of the Island's year-round groving season.

Such management vould also ignore the plant's botanical need for at Least

two years to maximize its groveh eapahility (9, 17).

2. Napier Crags; 3-Year Trends

(a) Moxioun Yields:

Taree years of cropping show to distinct trends for

PM production by napier grass: (a) Yields increase os harvest interval is delayed from two to six months, ané decrease as the interval is extended to 22 months; and (b), the first-ratoon erop vas the most productive while the Plant and second-ratoon crops vere about equal (Table 27). Unlike sugarcane, the general decline of DM evidenced by the third-year data wan not expected.

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

The highest average DM yield for the three crops was 27.5 0D tons/acre

year, which

ssived from the combined yield of two, 6-nonth harvests (Table 27).

This compares quite favorably with the highest 3-year average for sugarcane,

ie, 29.0 00 tons/acre year (Table 21).

(®) Row Spacing Trends: Marrow row spacing had virtually no effect on

DM yields by napier grass over a time-course of three years (Table 30). Very

small yield increases were recorded at the 2-and 4-nonth harvests of the plant

---Page Break---



crop, but these subsequently disappeared and there were no consistent dif-

ferences noted thereafter, Like sugarcane, there appeared to be sufficient

Plants at standard row spacing (50 ex) to take conplete control of the area

when sufficient time vas alloved for then to do so. Narrow row spacing

similarly had no effect on trash yields by napier grass (Table 25).

3. Plant Density; 3-Year Trends

(a) Sugarcane: As a main effect the number of sugarcane steas per acre was highest for the first ratoon erop and declined moderately thereafter (able 31), However, for the critical L2-nonth interval the number of ctens increased each year. The highest absolute number was approxinately 115,000 stens/acre, produced by the 4-nonth harvest interval of the first-ratoon crop. ?The lowest number, slightly less than 8,000 stens/acre, was obtained from the

2-month harvest interval of the second ratoon crop.

(0) Napier os

Per acre, approxinately three tines more than sugarcane as a main effect

Napier grass produced an enormous number of stens

(Table 31). Mean values indicate that stem density vas highest for the second Yatoon crop. In teras of harvest interval, the greater number of stens vas Produced ty the 4-nonth harvest and the fewest by the 12-aonth harvest. For oth napier grass and sugarcane there was no apparent relationship betueen the

treatments producing the highest number of tens and the highest connages of

iowa:

4. Seasonal Influences On Cane And Napier Gr

?The project's experiments are being performed at sea level at approx=

imately 18* north latitude. This is @ tropical setting widely recognized

---Page Break---

-a-

for its year-round groving season. Nonetheless there were definite seasonal variations in the growth rates of both sugarcane and napier grass.

The 2nonth interval from January 15 to March 15 was the least productive for both sugarcane (Table 32) and napier grass (Table 33). This is attributed to the relatively cool nights in Puerto Rico during this period. Because this interval also falls within the Island's dry season, sone claim can be sade that the growth reduction was a result of reduced vater supply. This could be a contributing factor, for eventhough the experiments vere irrigated 4? As impractical to sinulate the region's natural rainy season by thie means,

The 4-month harvest intervals correspond roughly with three seasons in

Puerto Rico: Late humid sumer (July 15 to Novenber 15), seni-arid ?winter?

c

vendor 15 to March 15), and early humid sumer (March 15 to July 15).

For both sugarcane and napier grass the season least suitable for grovth was the seni-arid vinter (Table 34), This vas clearly evident for the two Fatoon crops of each species. In the case of sugarcane nearly half of the Fatoon crops? total annual yield was produced in a 4-month period from Jaly 15 to Novenber 15. The importance of the warn, hunid, late sumer ?months to sugarcane grovth has been recognized for many years by sugar

Planters seeking to maximize tonnage. Hence, the Island's "gran cultura?

<Fop was alvaye planted by early August, thereby enabling the cane co pass through two late summer groving seasons before being harvested at 16 to 18

months of age.

D. FIELD PLOTS; SECOND GENERATION ENERGY CANE,

?A "second generation? study on energy cane / vas established at the

AES-UPR Lajas Substation during August and Septenber, 1980. This ie the

???______

2/ ?Energy cane" is sugarcane managed for maximum grovth rather than sucrost

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project's last

jOF experiment designed to desonstrate the upper yield

potentials of tropical grasses.

Essentially three "generation:

of energy cane were envisioned at the

Project's onset in 1977: (a) Existing sugarcane varieties, developed for svgar, whose bionass yields could be improved ty managenent practices oriented te growth rather than sugar; (b), existing varieties having superior biomass yield potentials but othervise unplanted in the sugar-oriented comercial

cane industries

and (c) new progeny to be bred specificelly for the high

MM yield attribute, with fermentable solids (molasses) as a aajor by-prot

From the seed sources available in 1977 three "first generation?

varieties vere selected for the project's initial studies on cane biomass

Fach variety has a history of high yields for both sugar and bagasse over a

ange of PR soil and rainfall conditions. Equally inportant w the immediate

availability of seed from Puerto Ric

super industry, Hovever, vithout

question, these varieties fail to repres

f the maxinun yield potentiale of

Saccharum. A search has b

sn undervay eince 1977 to identify superior bieeaes

canes already extant in Puerto Rican and Federal collections. Seed expansion

for a series of promising candidates was begun late in 1979.

ae otr

sents And Narvest Intervals

?The noviy-established energy cane experinent has 27 treatnents vith four replications arranged in « randomized eplit-plot design (Table 35).

There are thré

primary treatments (harvest frequencies at 6-, 12- and 18+ month intervals), three subtreatmente (varieties PR 960, US 67-22-2, and B 70-701), and three sub-subtreatuente (variable nitrogen at 200, 400, and

600 Ibs/acre year of elemental N). Row spacing is constant anong all

---Page Break---



treatments at standard 60~inches. Irrigation is also constant at approx~

inately 54 acre inct

year administered as needed via border irrigation in

?2-inch increments.

Variable harvest intervals underscore the need for sore than one year

to optinize Saccharum biomas

?An inportant shortcoming of our previous

?energy cane vork was a 12-month maxisun interval between harvests, a reflec-

tion of comercial sugarcane management in Puerto Rico. At least 18 sonths

are needed to maximize total dry matter in eugarcane. Of the thri

cent

varieties, US 67-22-2 and B 70-701 are ?second generation? canes having enor

?mous growth potential under PR conditions. PR 980 is a reference variety

typitying the Teland's comercial sugarcane. For "first generation? canes

managed as bionass crops, about 400 Ibs of el jental N are required per

acre year. The new N variables will indicate the degree to which this

quantity wight be reduced (or profitably increased) in varieties

yecifically

selected for dry matter and molasses. The N source is asmonium sulfate in

6-4-8 fertilizer forsualtion adainistered increnéntally at 3-sonth intervala,

2. Projected Yields

?The first-generation studies completed to dat

indicate an average yield

of 29.0 00 tons/acre year (26). This figure ix the average of three crop

yea

(the plane crop plus two ratoon crops). Annual yields varied frow

25.6 OD tons/acre for the plant crop to 33.6 OD tons/acre for the first,

¥atoon crop. The

cond ratoon crop yield vas intemnittant betveen those of

the firet two crops and subsequent crop years are expected to be still lower

(Figure 5). The yield value of 29.0 0D tons probably represents the highest,

average yield attainable for first-generation energy cane intensively prope

ted under PR conditions in a 3-year cropping cycle.

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ue

With intensive management the second-generation canes US 67-22-2 and

B 70-701 should exceed these yields by a significant margin. Projected DM

yields for both varieties are in the order of 40 OD tons/acre as a 12-nonth

crop and 50 0D tons/acre as an 18 month crop (Table 36)2/, third-generation

canes, chat is, hybrid varieties developed specifically for high yields of dry matter and molasses, could conceivably exceed the second generation

yields by up to 20 0D tons/acre

3. Yields; First 6-Months Harvest

(2) Green

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

fn an individual plant basis, total green veight values again shoved

Little variation snong varietal and N treatments (Table 39). Millable stem

weights vere moderately lover for variety US 67-22-? (Table 40). The latter variety displayed a notably massive

een canopy at this period, vith the

?Breen-leaf area extending dow to the soil surface, The principal varietal

A/ In Puerto Rico conventional sugarcane is sanaged as tuo categories of

crops, the "primavera (10 to 12 months betveen harvests) ant the "gran

cultura? (16-18 months between harvests).

---Page Break---

~ ae

@ifference at this time was a perceptively greater height of 8 70-701. The

stem length for this variety averaged 41 and 57 percent greater than for

PR 980 and US 67-22-2, respectively (Table 41). Sten Length vas not affected

appreciably by variable N.

Varietal differences vere also evident in the sumber of harvested stens

Per acre (Table 42), Stubble counts indicated a moderately greater density of plants for the two ?second generation" varieties (US 67-22-2 and 8 70-701) Which averaged over 45,000 stens/acre, a8 opposed to about 38,000 stens/acre for PR 980, The latter figure is also relatively high for 6-onths old cane

ina "plant" crop,

(b) Dey Matter And Plant Maturity: Dry matter yields vere slightly higher for varieties US 67-22-2 and B 70-701 than for PR 980 (Table 43). ?The highest yield was 11.1 short cons/acre, produced by US 67-222 under a "lov" W regine of 200 ibs elemental N/acre year. The lowest yield was 8.0 short tons/acre year, from PR 980 under "high" N (600 Ibs elenental N/acre year). For the most part there was Little difference in yields anong the variable N regines. By vay of reference the PR sugar industry produced about 9.0 dry tons/acte in 1980 as an Island-wide average for 12-month cane.

?The maturity of all of the cane harvested at this period, as evidenced

by IM content, was quite low (Table 44). DM content aver:

Jed 16.9% for all

treatments at 6 sonths, vhere

approximately 252 DM would be expected at.

12 wonths and 30% or nore for an 18-nonth gran cultura crop. Maturity vas slightly higher for varfety 8 70-701, and within the "lov" N regine of each variety (Table 44). These maturity values suggest that all plants vere Fesponding to an abundance of water and available X irrespective of varietal

and Nefertilization regimes.

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~%-

(e) Juice Quality: Fureher evidence of the plants? otal commitment to growth at this time was the very low qualitative values obtained for ray Juice, For ali treatments, Brix and Pol values averaged 5.4 and 1.4, Tespectively (Tables 45 and 46). The values from variety B 70-701 were lowest for both paraneters; hovever, varietal differences at those levels

of magnitude have Little meuning since there was very Little in the way of extractable fermentable solids contained in this cane. Rendinent levels were Rear zero for PR 960 (Table 47), and negative values were recorded for the varieties US 67-22-2 and B 70-701. The poor quality of this cane was anticipated. Similarly, quite respectable yields of fermentable solids ané

Sucrose should accrue at the I2-and 18nonth harvest intervals, at least on

4 pervacre basis, even if the quality of individual plants reaains low.

y

Fiber content tas generally quite lov, ranging
fron 7.1 to 13.8% (Table 48). There were no consistent differences anong variable N regimes, Fiber was moderately higher in the two second generation varieties than in PR 980.

?Trash yields averaged slightly less than 1.0 ton/acre for all treatnents (Fable 49). This ancunted to roughly 10% of the total dry matter yield at G months. Trash values should increase to about 20-30% of total DM yield for the 12-and 18-nonth harvests. Variety B 70-701 produced slightly less trash than US 67-22-2 and PR 980. There vere no consistent yield responses

to the variable N regimes.

A "Trash" in this instance includes only leaf and leaf-sheath issues that

Bad detached from the stem and fallen to the ground. Te does not include materials still adhering to the ston.

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(e) Lack of S-ertitization Response: The mininal response to increasing

N feres1ization is attributed to two factors: (a) The incorporation of erganic matter into the soil (old bales of Sordan 708, approximately 2 tons/acre) at the tine of seedded reparation, ant (b), conditioning of the upper root zone with a land rotavator prior to seeding. The ceganic matter vas added to help maintain soit structure during the subsequent J-vear period of intensive Production operations. Up to 80 younds of W/acre could become available from this source within one to three months via N mineralization. Perhaps wore

important vas the thorough rotavation of the seadbeds? upper 6 to 8 inches

The Fraternided soil series of this region sre notably heavy and plastic and

excessive compaction of new seedbeds ic a canon occurrence. The rotavation

of this site was the first use of such an implement in the Lajas Valley. Tt

provized =

ht, freeable structure at the tise of planting. Reconpaction

of the soil occurs gradually through the effects of rainfall plus the traffic

of labor and machinery. It is believed, however, that the soil's native

fertility contributed more effec

ively to the plants? establishment and

ly

Brouth performance than was formerly possible. Unfortunately, no control

plots were retained as a check against rotavator effects. A subsequent cane

planting (seed expansion for variety US 67-22-2) planned for mid 1961 will

include woil rotavation as a controlled variable.

E, FIELD-SCALE STUDIES

1. Energy Cane Denonstration Study; Hatille

Through the project's third year a majority of field-plot and field~

scale experiments have been confined to the AES-UPR Lajas Substation on

Puerto Rico's semi-arid southwest coast. This is a najor agricultural region

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having important potential as a future zone for biomass energy cropping.

There is an abundance of rain-free days suitable for solar drying operations.

Irrigation is required for approximately 8 to 10 months annvally.

The project's original work plan called for at least one wajor study ?with sugarcane somevhere on the Island's hunid north coast. A site sore closely integrated with private farms than is possible vith Experizent Station lands was also desired. A favorable opportunity arose for establishing such a study during the spring of 1980. tr. José B. De Castro, fan elderly Landowner having a strong personal interest in biomass energy cropping, offered CEER-UPR the use of 30 acres near the northvest coastal tow of Hatillo, The offer was accepted and an energy cane demonstration study was established there during July and August of 1980.

?The land itself is situated on a deep alluvial plain bordered by the

Casuy River. The predominate soil series is a fee

le Coloso clay loan, much

tess plastic then the Fraternidad clay series at Lajas. The soil appears to

be at least four to six feet deep and is vell drained; in fact, this fam is an ?all weather" site insofar

yricultural production operations are

concerned. The De Castro farm had not been cultivated for seven years and

vas occupied ty a mixture of volunteer sugarcane and wild gr

During the first quarter approximately 25 acres were moved vith a rotary

scythe, plowed, rotavated, Land-

Janned, Lined, and planted into three fiel scale treatments: (a) An energy cane planting, of approximately 17 acres,

in which intensive production operations vill be demonstrated; (b), a control

plot of about 2.5 acres managed as conventional sugarcane; and (c), @ second

control plot, about 6 acr

+ simulating the unmanaged wild sugarcane that had

been occupying the site until the sumer of 1980, In addition, about 2 acres

were planted in the ?second generation? energy cane US 67-22-2, as part of

the seed expansion progran for this variety.

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Production inputs for che three treatments are sumnarized in Table 50,

A single cane variety, PR 980, is being used for all treatments. The energy

cane treatment is double-seeded at standard (150 ca) row centers. Unger

?inated spaces in the row were replanted, and the area was vatered by over~

head irrigation from the Camy River. This cane received 200 ibs of elenental

Nacre applied as a band ben

th the seed in the furrow. An additional 400 Ibe

of elenental N/acte are being adainistered as side-dressed increments at month

4 and 8, A single "gran cultura? harvest will be performed 18 months after

planting. Planned production input costs will be held under $900.00/acre/18

onthe. Our primary objective

to denonstrate yields of at least 90 tons/

acre of millable cane, plus about 15 tons/acre of trash, at costs consensurate

with an attractive margin of profit for north-coast planters.

Additional work vas performed at the Hatillo site during the second

quarter, This includ

1: (a) Subsoiling of all treatments four weeks after ermination of the cane; (b) post-energence ved control operations; and

(©), overhead irrigation of the plants

bout six weeks after germination

?The subsoiling operation is designed to improve root-zone developsent

in a fertile but relatively compacted soil. The cane concept can be applied

with profit to most of Puerto Rico's best a

icultural Lands where soft

ccoapaction in one form or another has been undervay for over four centuries.

The implement used in this study vas originally constructed by the UPR Depart

went of Agricultural Engineering for denonstration use on conventional sugar~

cane, If consists of a heavy-duty tool bar and tvo vertical steel shanks

having @ maximum subsergeable depth of about 30 inches. These are bolted to

the tool bar and can

adjusted laterally to accomodate variable row spacing.

A horizontal blade is attached to the bottom of each shank; these provide

Lateral shattering of the soil directly b+

ch the row center. This implenent

---Page Break---



can be used vith maximum effect at time of planting, or innediately following germination vhen plant rows are clearly visible to the driver. A Category IIT tractor is required.

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

Overhead irrigation was needed to offset an unseasonal dry period during September and October. A very adequate water source is provided by

the Camuy River which

Wjoins the experimental site, The seedbed itself vas

leveled, 1and-planned, and bordered for eventual vater application by flood

irrigation. The necessary pumping capacity for border irrigation of this

?sive (about 1400 gallons/ainute) vas not Somediately available. Alternatively,

@ portable overhead unit was rented at nominal cost from the PR Sugar Corpora~

tion, This is a "big gon? system delivering in the order of 600 gallons of

water/ainute. With this systen the Hatillo site vas provided with approx

imately four acre inches of vater in le

than three days.

2. Supplemental Ireig

Watillo Site

Although the Hatillo site ie situate

in a seni-humid region, @ need

develops for supplemental irrigation each January at the onset of the area's

ary

sason. Irrigation can be

formed to great advantage during four or

five months of the year eventhough private planters there have rarely done #0.

To sustain maximum growth of the energy cane study, flood irrigation was

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-a-

initiated in February of 1981, using « 2000 gpa Rainbow Company puap to

obeain vater from the Canuy River vhich adjoins the experizental fare, The pump is portable, diesel povered, and equipped with a 30 ft. intake tube with screened foot-valve. A 30 £t, discharge tube is also transported with the unit for convenient placement of the pumped vater.

?The Hatillo site was leveled, land-planned, and bordered to receive the seasonal irrigation vater as part of the land preparation operations in 1980. Water is provided co approximately 2/3 of the planted area, the recainder being divided into control plots of unirrigated energy cane and unirrigated

conventional sugareas

Tt is calculated that roughly one additional ton
er acre of energy cane will eventually be harvested for every acre inch

of water provided during the Hatille dry season.

Initial Yields At 6 Monthe; Hatillo Site

?The principal harvest interval for this study is 18 months. It is intended to denonstrate the disproportionately Larger yields to be gained

through delay of energy cane harvest by 6 wonths, ie, by us of the ?gran

custura" cropping system rather than che 12 month ?primavera? aysten employed

For most of thes

jar industry's cane, In the meantine, as an indicator of

crop developnent, cane samples fron each of the study's four experimental

fields are being harvested at 6 months and 12 months after planting. The

G-months data are included in this report.

(a) Green Matter And Mix

?The field demonstration plots at

Matillo include three management variables using the project's standard

high bionass variety, PR 980: (a) A low-tillage control in which cane is

?essentially allowed to grow wild after being assisted in its establishment;

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(b) 4 "Sugar Corporation? control in which the cane is managed according to procedures used by Puerto Rico's cane sugar industry; and (c), energy cane managenent in which the same variety is encouraged to produce maxinun bionass rather than sugar. There is one additional plot consisting of about two acres of variety US 67-22-2, a "second generation? energy cane receiving the sane energy cane production inputs as PR 960. This is a varietal expane sion planting designed to increase seed for the eventual replacement of variety PR 980. For the initial growth measurements, 1000 square feet of each PR 980 treatment and 400 square feet of US 67-22-2 vere harvested at 6 months of age.

Total green weight yields varied but Little among the three PR 980 treatments vhich averaged 34.5 tons/acre (Table 51). Variety US 67-22-2

Produced about 45% more green matter at 50.2 tons/acre. Millable cane yielk

were slightly higher for energy cane (24.0 tons/acre), but for this parameter also the three PR 980 treatments vere et

jentially equal (Table 52). Again,

US 67-22-2 produced the highest yield at 34.7 tons/acre, about 56 higher than the PR 980 average. Top veights (representing the non-aillable green canopy and immature internodes) averaged 7.6 tons/acre for PR 980 and 12.3 tons/acre for US 67-22-2 (Table 53),

?Trash yields similarly varied but Little song treatments (Table 54). In this study, ?trash? refers to leaf and leaf-sheath tissues, both green and partially desiccated, vhich vere still adhering to the sten at tine of harvest. These vere stripped off by hand in order to obtain millable ster

weights. Under mechanized harv

conditions (with a Klass vhole cane

harvester), the

tissues would be largely renoved in the field by a powerful

air blast.

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The "tops" (Table 53) would be removed by a vertically-adjustable set of

circular dises, or

opper?, which is also a component of the Klass

harv

ter. The topper's cutting level is under direct control of the machine

operator; hence, the precise point of topping is a matter of judgnent and

considerable skill of the man operating this machine.

(b) Dey Matter Yield: Dry matter yields were unrenarkable and essen

Hally equal for the three PR 980 treatments, averaging 6.0tons/acre (Table 55).

Variety US 67-22-2 produced 8.8 tons/acre, or 47% more than the PR 980

average. The unspectacular DM yields vere lartely a function of the low

saturity of all cane at this point in the study. Dry

eer content,

averaging 17.5%, was nearly equal for each of the four cane plots (Table 56).

(e) Plant Weight And Density: There were some small variations in

Plant height anong the three PR 960 treatments, ranging from 4.7 to 5.4

feet (Table 57). The avers

fe height of US 67-22-2 was perceptibly lover at

4.1 feet. The principal feature of this variety which accounted for its

superior yields vas an ability to produce a greater number of stexs per

Planted area, Hence, within six months after seeding, US 67-22-2 had

Produced 46,000 stens/acre, some SOX more than PR 980 which averaged 30,700

stens/acre (Table 58)

4. Mechanization Tria

Mechanization studies continued during the first quarter with two

implements of special interest to this project. These are the rotary scythe

conditioner and the round baler. They are viewed

potential ansvers to the

harvest and post-harvest managenent of tropical ¢1

ses having standing

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ses, but

Somewhat lover tonnages than sugarcane. Initial trials on Johnson grass

?and Sordan were very successful (1, 2). Considerably more denanding tests

were begun on 6-nonths old ni

ler grass late in Year 3. The results have

?already been described in detail (3), They seen to indicate that, vith

Limited sodification and correct training of the equipment operators, such

implenents can deal successfully with the high-density biomass offered by

mature stands of napier grass.

(a) Yield pata; 6 Months: A 2.75 acre stand of G-uonths old napier

brass was evaluated for yield and cro injury with the MC rotary scythe

operated at two moving heights. The latter were ?low stubble" (1 to 2 inches)

?and "\Sgh stubble" (8 to 10 inches). Four subplots of 0.69 acres each were

Roved on June 20 and vere solar-dried and baled over a 4-day interval. Drying operations included two days exposure to the sun as the material lay behind the rotary scythe, folloved by windrowing with a conventional forage rake, and turning the windrows over twice with the sane rake. The solar-dried Saterial vas baled on June 24, at which tine the moisture content wae approx= imately 15 percent.

Overall dry matter yields averaged 9.3 tons/acre, with high stubble and Jow stubble plots averaging 8.4 and 10.2 tons/acre, respectively (Table 58). Because of a large variation in lov stubble yields these data are taken oly © @ very preliminary indication of mowing height effect. Moreover, a significant anount of conditioned biomass lay flattened betueen the stubble

and could not be recovered vith the available forage rake 2/,

operates as a single unit

When any portion of the rake is lifted

BY QyBLaRe crown, much of the entire rake is lifted and passes over a daves

of bionass untouched by the implenent's tines.

---Page Break---

-a-

Upon visual inspection some of the stubtle appeared broken and crushed

by the tractor and rotary scythe. Hovever, the sane croms generally produced

fm abundance of nev shoots within a fev days after soving. Tt is believed

that (a) either the latent buds (located at or slightly below the soil

surface) were not injured by the machinery passing above, or (6), more than

4 sufficient muster of bude survive these operations to reestablish @ normal

Plant stand even when sone of the buds are destroyed. It is also possible

Chat some level of crown injury is stimulatory to shoot production.

(©) Fuck Consimption And Estimated Horsepover: Fuel consumption wee

measured for the na

fer grass harvests described above (Table 59). These

essurenents refer to the total diesel fuel consumed by a model 8700 Ford

eractor (a category IIT, 120 hp unit), operating a M-C model 9-E rotary

scythe (9 foot moving swath), both idling and in actual sovenent on the

measured test plot areas. They do not include noverent of the tractor and

Seplenent to and from the fields thenselves. Estimates of the horsepover weilized by the tractor were calculated from the fuel consumption figures in accordance with published Nebraska Tractor Test Data for the model 8700 Ford tractor (rable 60).

Diesel fuel consumption vas somevhat lover than expected, ranging from 2.38 to 2.95 gallons/hour, or 1.92 to 2.69 gallons/acre. A fuel consumption

level in the order of magnitude of sug:

?cane harvesters had been anticipated (roughly 4 to 6 gallons of diesel fuel/hour). Tt should be noted that the Standing green bioass confronting the rotary scythe (ebout 40 tons/acre) exceeded the sugarcane tonnages confronting cane harvesters in Puerto Rico

today (approximately 27 tons/acre as an Island-vide <vorage).

---Page Break---

-36-

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

Worsepover usage by the 8700 Ford tractor ranged from 35.7 hp at high stubble mowing to 41.4 up at lou-stubble moving (Table (0). Performance date provided by the Ford Company indicate that this tractor can supply about 95 grows hp at the power take off with an operating engine revolution range of 1500 to 1800 rpm (29). Hence, less than half of the tractor's vork poten Hal was being utiiized in conditioning the 6-nonthe old napier grass. On the other hand, it is estimated that the rotary scythe itself, although an extremely rugged implement, can utilize @ naxinun input of only about 60 hp without sustaining major damage (30). Exceptionally heavy stands of biomass, ?such as sature sugarcane or 22-ronths old napier grass, could Iikely place the rotary scythe work Load in the 60 hp range. There vould be no purpose in

attempting this since there are cane harvestersavailable to deal vith such

materials,

5. Rotary Seythe Modifications

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

---Page Break---



and (c), @ Farwhand Company wheel rake. The rotary scythe-condtioner is of

decies

ve inportance in the handling of large tropical grasses as solar-dried energy crops. Successful implenentation of this unit would virtually assure an adequate performance of successive nachines needed to deliver a solar-dried feedstock to the biosass processing or utilization center.

Rotary scythe trials on Sordan 70A and Johnson Grass delt with a naxinun favs of about 20 tons/acre of standing green material. No problens vere encountered and the machine completed the work it vas designed to perform. With napier grass, representing 40 to 4S standing green tons/acre, the interior edge of the rotary scythe tended to 1ift fron the ground when passing

over exceptionally heavy or lodged clunps of grass. Tt vas felt that this

Probles could be overcone by increasing the inpleent's weight. A second and nore serious problem lay in its tendency to drag sections of uncut grass along its interior edge, This occurred in lodged and heavily matted materiale

that vere interwoven in a contiguous

8. Such materials extended invard

into uncut grass up to several yards beyond the cutting svath edge. In up-Fight stands or where only partial lodging had occurred the rotary scythe easily sectioned off the biomass in normal avath segnents.

The rotary scythe!

roblen in sectioning the heavy and matted napier

Brass was solved by Fitting its interior cutting edge with a parting knife taken from @ Klass Model 1400 sugarcane harvester. The parting knife consists of @ single 12-inch blade vhich rotates counter-clockwise against @ heavy etal plate and chears off impeding stens in a scissore-Like action. It is nomally driven by a hydraulic motor with a force of about 5 horsepower.

Fortunately, the heavy-duty construction of the rotary seythe offered @ 0.25 inch metal plate to which the parting knife frame and supports could be welded directly,

---Page Break---



Tt was necessary to adapt the parting knife's hydraulic lines to the smaller dual renote outlets of the project's tractor (a Category IIT Model 8700 Ford). The Lines thenselves extend directly backward from the tractor, over the top of the rotary scythe's drive shaft and gear tox, and then across the implenent's backside where they renain free of entanglenent with the conditioning grass stems. As described in earlier reports, the tall grasses being conditioned with this unit invariably drop forvard of its Leading edge and never backward over the machine itself. Otherwise neither the rotary scythe nor its affixed parting knife could perform their taske in heavy tropical grasses.

Tn the Limited tests made to date vith chis systen it docs not appear that we have developed the full cutting force of the parting knife, ie, as designed for operation on sugarcane harvester. Nonetheless, its performance in G-nonths old napier grass has been very good. Tt clearly sections through dense matter and lodged materials vhere formerly a rather ragged division vas ade, coupled with uprooted and dragged crome of napier grass. Moreover, the rotary scythe ceased elevating above the ground in dense materials once

the parting knife became operational. No supplenental weighting of the

inplenent vas necessary. The parting kaife unit weights nearly 100 pounds

#0 this in itself may contribute materially to the performance of the rotary

seythe.

6. Napier Grass Processing

Formal utilization studies on tropical grasses Lie beyond the scope of

this project. Wouever, project personnel have cooperated vith others vishing

to utilize or examine some of the harvested grasses that have no further use

to the project, During 1979-1980, tropical grasses that had been solar-dried,

---Page Break---



baled, weighed, and then discarded, were donated locally for the following

Purposes: (a) As cattle feed by Lajas farmer:

particularly Sordan 70A,

but also mature napier er

5 (presumably mixed with more digestible forages:

(b) as test additives to processed municips

refuss

by @ fire developing

alternative bionass products at Ponce, P.R.t (e) as a start-up boiler fuel

by sugar mill engineers; and (4), as a source of cellulose for enzysic

conversion to glucose in a local fernentation project.

Early

1980, the New York-based firm Combustion Equipment Associates, Ane, decane interested in solar-éried tropical grasses as potential feed-

stocks for a patented fuel product derived from agricultural residues. Temmed AGRIFUEL, the eaterial is a fine powder that can be burned directly in existing ofl-fueled furnaces. Such a product, if show to be technically and economically feasible, would be of immense interest to Puerto Rico. During

June of 1980 9 SEA-LAND van was loaded with baled napier grass plus stor

bagasse and shipped to CEA's processing plant at Bridgeport, Connecticut. CEA requested the materials for feedstock evaluation purposes and paid all

transportation charges.

F. BREEDING STUDIES

1, Seedling Trials; Lajas Substation

?The project's breeding phase ained at producing nev sugarcane progeny vith superior bionass

tributes w

confined to the AES-UPR Curabo Substation

Guring the first three yea

Recently, 92 seedlings shoving some preliainary

evidence of high tonnage capability vere transferred to the Lajas Substation

for second-phase evaluation. They were planted in unreplicated, 5* x 20°

---Page Break---



plots, with standard seedbed preparation, row spacing, fertilization, and

weed control measures.

A total of six crosses are represented (Table 62). All vere made by

Me. T. L. Chu during the autumn of 1979. Al crosses were part of the AES-

UPR Sugarcane Broeding Propran, but in these instances there vore parental

types involved having important blonass attributes. Of special interest is

the S. spon:

eum hybrid US 67-22-2 whieh served as both fenale and male

parent. Under Gurabo conditions this clone has shown very superior potential

for the produc:

19 of both sucrose and total bicaass,

2. Seed Expansion For US 67-22-2

Early in 1980 the clone US 67-22-2 was planted in field plots at the

AES-UPR Gurabo Substation for the purpose of producing seed for a second

generation energy cane study. This study was planted at Lajas Substation

ate in July, 1980, The remaining seed of US 67-22-2 was shipped to Hatillo

4in August and planted on the De Castro farm for seed expansion purposes.

Approximately 2.0 acres vere planted in this variety. At intervals of

8 to 10 months the cane vill be cut and planted in a larger seed expansion

area. This in turn will be used for additional seed es

wnsion. Mithin,

about three years there will be sufficient seed of US 67-22-2 to replace

all older variet:

in the Island's energy cane prograns, including com

nercial-scale plantings of SO acres or more.

3. New Crosses; 1980-1981 Breeding Season

Eight new eros:

were performed in 1980 having the high bionase attribute as the principal objective for hybrid progeny. ALL crosses vere

performed by Mr. T. L. Chu at the AES Gurabo Substation.

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eae

Eleven parental clones were used in five breeding Lines (Table 63).

Four of the clones served both as f

sale parents (contributing the somatic

chromosone muaber) and as male parents (contributing the ganetic chronosome

number), These include PR 68-335, PR 67-1070, the $. robustun clones

S7-NoS4, and a wild S. spontaneus hybrid fron Rfo Piedras (S. sp. RF). The

use of S7-NOS4 represents a long~desired entry of S. robustun germplasm into

the ARS-UPR cane breeding program.

An approximate total of 5,000 seedlings were produced by these crosses

(Table 63). Of special interest is the contribution of both US 67-22-2 and

8 70-701 as male parents in crosses with NCo 310. These are the tvo "second

generation" clones already selected for seed expansion as energy canes in

their oun

ight. About 1150 seedlings vere obtained from these crosses,

(tens 7 and 8, Table 63). The most prolific progeny yield vas obtained

from the crossing of PR 68-1220 (fenale parent) vith the hybrid PR 67-1070 x

S$. 8p. RP (wale parent). Some 2000 seedlings vere obtained from this eros

The total number of seedlings produced by these cros

1s is small by

reference to major sugarcane breeding prograns throughout the world. How

ever, the quality of parental stock and breeding Line selection for the

Intended purpose is very high. For this reason the probability of obtaining new progeny with interesting bionass ateributes is good.

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Relative dry satter production by Sordan 704 and four

Legumes propagated? inthe fr

cachaga grow

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PLANT SEICUT (em)

FIGURE 2. Vertical grovth by Sordan 70K and four tropical legumes

spagated inthe qreeshoure vith s acti/eechase growth sediex.

wed area = 60 f2/apectes/harvent.

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ey KT (Ov g/Ptant)

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Individuat plant weights for Sordan TOA and four tropical

nes propagated in the greeahouse vith a soil/eachazs geosth

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oor senzing ays 1 fon TEVA RIA CAT TAGNS ANVONVDNS 40 OTATA MALE HAG °y THnOTA

cartes Fon

(raw cansra/®) 40

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(0 TonS/ACRE YEAR

FIGURE 5. Total dry matter yielé

heed successive crop years. Extinates for fourtheyear fuel

Gra catoon crops) ate also indicated.? Sugarcane values are the

Couputed acan of three varietien and tuo row spacing

s'ningie Lz-month. groveh incerwal per cop 9

the coabined yields of r¥o Somonth graven tnvervala per crop eat.

by eugarcane and sapier gras

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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 | Botaniesl-Agrononic |
| Field Scale | Agronomic-Econonic |
| Commercial-Industrial | Economic |

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=e

TABLE 2. CATEGORIES OF CANDIDATE TROPICAL. GRASSES

| Cropping Category | Growth Intervat 2/ py (Months) | Maximum 2/ Qonths) |
|---|---|---|
| Short Rotation | 46 | 23 |
| Intermediate Rotation | 18 | 46 |
| Long Rotation | 36-60 | 1218 |
| Minimun Tillage | Indeterminate | oO |

© geplancing frequency: at least two ratoon crops are anticipated.

2

?Time required physiologically to maximize dry matter.

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Laurseen Lovcocene

?Phaossice Tacestaldee

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Percent Dey Waster

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y per planced aren, approxinacely 60 £¢."/apectan/barvent,

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?eciWeAnoW) sane ORY CNW) I!TANS AT GHLAVIA SIGHS SAGE Woe OW VOL aENOD 30 SALVE MlacwO 2ALBrIsN = y FavE

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?avecavon) wy GV (AVN) GAS SI GGLRVLA S419345 WaeGT wn GRY VOL ANGHOS Jo ALAOWD aADLERE ?6 TTWWL

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TABLE 6. GROWTH PERFORMANCE OF TIATURE SUCAKCANE SUPPLIED UITH VARIABLE XO,

TW SAND GULIURE, AND WARVESTED AFTER 5 AND 10 WEEKS OF TREATYENT

y

g/Planted Area ~

Week NO, (weq/2) Green Oven-Dry OD g/Plant zo

5 1 239 80 42 23.6

3 a3 103 a7 2h

3 667 335 a 20.1

7 623 123 5:2 isle

56 688 16 526 21.2

a 642 aa a6 21.9

Mean 37 122 4.9 21.2

10 1 446 107 6.8 23.9

3 658 Ma ma 22

3 133 246 40 a3

a 1140 242 10:6 aa

54 ass 245 10.4 213

aL 703 147 5.7 20.9

Mean a7 188 Be 21.8

2 Approximately 60 £2?,

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6

TABLE 7, BIOMASS PRODUCTION BY FIVE SACCHARUM CLONES UNDER

MINI?UM-TILLAGE CONDITIONS; FES. 11?auG. 5, 1980 2/

SHonths Yield (Tons/Acre) For ?

| Clone | Green Matter | Dry Matter | x om |
|---|---|---|---|
| PR 980 | 173 | 0.52 | 30.0 |
| us 67-22-2 | 31d | 0.98 | aa |
| us 72-72 | aan | 0.38 | 30.9 |
| us 72-93 | 4am | 1.88 | 39.9 |
| spont, Hybrid | 0.86 | 0.26 | 30.0 |

4 siteh Gemonth harvest. Originally planted during February,

1977.

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oo

?TABLE 8, TONASS PRODUCTION BY TIVE SACCHAREY CLONES PROPAGATED WITH MINEIUM CULTURAL INPUGS

380 HALVESTED AT INTERVALS OF SDC ROHS

Tons/Aere (6 Month) Yf ?

Fe. 5, 1978?Aup. 5, 1978 Px 980 16. ba a8

08 Greaa-2 iss eo we

us 22072 16.7 35 are

vs 32093 ye 26 83

S apont. Hybrid 333 us 333

Meas 3 oe a8

hug. 5, 1978?Feb. 5, 1979 PR 980 aoe 0.22

Os 622-2 i 8a?

vs 9272 io 8120,

vs 733 yom OL

5. aponc. Hybrid 2s 0.6

Fed. 5, 1979?hug. 5, 1979 RSH 2.08 2

shops 12, 1979?Feb. 11, 1980

Fee. 11, 1980?zuly 27, 1980

M> originalty planted during February, 1977.

2 Ayprovinately sot germination was obtained at the tite of planting.

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TABLE 9. B1ONSS rRODUCTION BY THE SECOND RATOON CROP OF TAREE

SUGARCANE VARIETIES AND OME NAPIER CRASS VARIETY PROP?

[ACATED MITW VARIABLE HOW CEATERS;,SURTH 2-MOTH HARVEST

As tov Center ?

Cultivar E cuange

eR 980 180.0

ce 310 16.3

PR eeei791 88

Napter Grane a3

Dry Matter (Tone/Aere)

Fe 980 ore 0.036 300.0

Neo "310 Bie ose B1

PR 6tei91 Cee late 80

Mapter cress ze ogee 16.2

Dry Matter (3)

8 960 2.28 20.28 47

Noo 310 19.56 ray ary

PRaketo Bia MISE ata

Napier Grass as 12.8 = $a

2/ Mean values in the wae column bearing unlike letters differ aigaificantly

(@«.05).?"Mean values beating at Least one letter ia counon So sot datas

sigeiticanely:

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9.

USLL 10. BroWAss PRODUCTION BY THE SECOND RATOON CROP OF THREE

SUGARCANE VARIETIES AND OME NAPTER GRASS VARIETY PROP~

[AGATED WITH VARIABLE ROW CENTERS; THIRD G-MOSTH HARVEST

Groen Matter (Tons/A), At Row Center

cultivar 10 oe change

ae eects

PR 980 sce! race ?23.9

Neo 310 18.9» 13.2 be 236

PR sket92 mite 2G o3H8

oe Bee

Mepter oes seo arte

7 980 Lae 1a be

Neo" 30 338 2 be

PR ebei7e1 22 be a9 2

Napier crass gare a6

PR 980 1.7» 2

to 310 18.0 be 2

Pe eteiven a 33

Napier cease 2s. 0.7

ii Moan vaiuen én the ame coluan bearing unlike letters differ eigait=

Seancly (P<-05), "Mean valuan bearing at least One leteer in eomsat do

ot differ signiiicantly

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TUSLE 11. BIOMASS PRODUCTION BY TRE SEOORD RATOOK CROP OF TREE

SUGARCANE VARIETIES AND OME NAPIER CRASS VARIETY FRO?

ACATED ETH VARIABLE ROW CENTERS; SECOND S-MONTH RARVEST

Green Matter (Tona/A), At Row Center ?

cutive 130 Be E charge

mx 980 Yo mare n8.2

eo 310 Mae ree

Pe ee75 we rr

Be

Napier Crass s

Dry Matter (Tose/Acte)

Pe 980

Tae 3.2 be Tra

eo 310 eae aay 31

PR 6tei791 jae see 33

Napier crass 15.64 as.d4 a1

ever 2)

Bre Se

7? be

3953 8

Maas vas

Heantly (F< .05).

sot differ aigaiiicantly.

in the sane colune bearing ualikelecters differ signit=

?Mean values bearing at least one letter in common do

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TUBLE 12. B1OMASS PRODUCTION sY THE SECOND RATOON CROP OF TuREE

[SUGARCANE VARIETIES AND OME NAPIER GRASS VARZETY PROF~

ACATED VETW VARIABLE? ROW CENTERS} 12-HONTH HARVEST

Green Matter (Tons/A),/At Row Center ~

cateivae 150 em Soe F cnarge

2 $80 1.80% nse = 56

Keo 310 32.0 « 9012 ris

PR ee-i700 Bot a3 8 3

oe en

Napier Grass on orte 10

x 980

eo 310

PR otni91

7 980

Wee 310

Pe etri791

Napier Cease

Dry matcer (2)

x 980 Ba ved 26.3 we 7.

eo 310 Bie be Sa

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apier cra Reed 2304

2 Tash excluded,

3/ Moan values in the sane column bearing unlike letters differ

slaniticantty (P<.05)." "Mean valves bearicg at least one letter in

omen donot differ significantly:

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TABLE 13, TOTAL DRY MATTER PRODUCTION BY THE SECOND RATOON CROP OF

TUREE SUGARCANE VARIETIES AND ONE NAPIER GRASS VARIETY

PROPAGATED WITH VARIABLE ROW CENTERS; 12-MONTH HARVEST 2

DM (Tons/Acre) At Row Cent

cultivar 150 @ 50 cm

EE charge

PR 980 26.7 26.2

No 310 313 28.7

PR 64-1791 25.4 278

50 ca. 25 om

Napier cr: 19.9 18.9

A/ Trash included,

---Page Break---

oe

coe

os nun 9

S00

ove pen »

oe eeuont

Prera 104 Teusver

Sense

STAYIN ATVIWWA AY GEISHA SSVHD WATAWN GAY aHVDEVORS 40 40K)

WODLYE-GRTOSS HAE WOM SUTATA WALLA ISRO

ot mee

---Page Break---

sqvoom

a80K 9

exs00% y

naw 2

Teast

Seana

?FIVRLINY FTRVINA JY GALSHANMN SS¥O HBLaWH ONY ?ANCHORS 4 4OHD WOOLWE-GNODAS ML WOH SOLA WALLW Jad ?sq FlevE

---Page Break---

v2 ponndacn ox ey amndes Gora /E

moss wor /T

00H 21

sein 9

wee y

STVAERANE TIENT LY GiLSENIH SYED WaLAYN GV aNYOWONS 40 404) WOOLY GMONS AI

HOM LeainoD KALIWN aa OY He

---Page Break---

cee

TASLE 17. JUICE QUALITY VALUES FOR THREE SUGARCANE VARIETIES

PROPAGATED WITH STANDARD AND NARROW ROW SPACING

SECOND RATOON CROP

Brix Values, At Row Center ?

Variety 130 em 50. ce 1 Change

PR 980 10.92 10.60 9

Nco 310 anes an 92 v4

PR 64-1791 10.34 11,20 3

Polarization

PR 960 cae

Nee 310 = 20

PR 64-1791 32

Fiber

PR 980 17.07 16.9%

Nc 310 16.30 15.68

PR 64-1791 16.42 16.05

Purity

FR 980 79.96 87.45 9.3

Nco 310 76.15 72162 = 46

PR 64-1791 93.28 n16:3

Rendenent (Z Sucrose)

PR 980

co 310

64-1791

---Page Break---

-o-

TABLE 18, TONS SUCROSE PER ACRE (TSA) FOR THREE SUGARCANE.

VARIETIES PROPAGATED AT STANDARD AND NARROW ROW

SPACING; SECOND RATOON CROP; 12-HONTH HARVEST

AS NEMONTE, HARVEST

TSA, At Row Spacing ~

Variety 50a (SO em Change

iF Chance

PR 980 5.22 5.56 6.5.

Woo 310 6.2 5.79

PR 64-1791 7.20 5.78 -

cee

Mean 6.18 5.71 = 7.6

---Page Break---



?YASLELY. PLANT DENSITIES FOR TIGEE SUCARCANE VARIETIES AND ONE NAPIER GRASS VARIETY

PROPAGATED WITH VARIABLE ROW SPACING AND RARVEST FREQUENCY SEGOND RATOON noe (2979-1980)

aa

Stess/Aere, At Indicated Harvest Interval And Row Spacing 2! ?

Wom soem thangs

3685726 79,1 36,409 64,459 77.0

250463 12,306 S317 92,783 assi30 at

Peer ?le "2a 82 sujont "40,257 decd

. Sen se soe 25.4

Merter 224,691 318,08 155.0 175,002 311,975. 192.3

- S-Nonth Interval L2-Nonth Inverval

oc Soe Game Toc Om k Game

Pe 980 64,739 92.387 139,973 ss

Neo 310 971839 suis ?Srna *a

Pr'sieimm ?533!s06 e9.225 121,563 3613

50 en on

Merker 193,406 360,086 6.2 138,290 278,65 101.6

AY Mean vaives {50m two replicates.

---Page Break---

?sBuyoeda nox om pus a2}29]206 29342 103 sonIen Wwe /E

spepmrona wean /T

ok

wooney 8td

send exau04 zt

---Page Break---

peperour yerak /Z

wBayoeds nox om pue soyioysea saay3 105 eeateA eon fF

en190K oF

sx2008

STYAKAINE UEVEBVA 2¥ GRISHANN BRVONENS 40 S4DED KOOL ORL QA GOR) ANVIa HL

WOH SOTHIA WALLA had -W leva

---Page Break---

etponde mos om puo soyietsen sasyy 10) aanten ween /T

ene 21

---Page Break---

---Page Break---

?penny wenn /E

ot ons yo nom posnteon ayy es 920855 QOeR_?e2otdosme o5/ pavoytées weas eenren ween wo prong /T

eters us

oe wate 9

---Page Break---

TWRLE 25, TRASH YIELDS by TUREE CHOPS CP SUGARCANE AID RAPIER GRASS PROPAGATED

SETH VARIABLE? Row sbactN 1/

Sak ae

Trash (lons/acee) AE Row Spacing ~

Species Vartety crop wom oe E change

cet cage

Suparcane PR 980 Plane 3435.97 9.5

est Ratoon 758860 37

Second Raton 7271 7.49 oye

Newn 6

o =a

ce

co 310 Piane Bus as?

Fite Raton $120.36

Second Racoon 4038,

meri eaten te

Mean ere

Et

PR 66-1791 Plane 3.07 seas

Hirst tatcon 5.27 Rs

Second? Raton Sci ?hh

ean ae

Napier Grace 2! yorker Pia

273 saa

Fitet Ratoon 237 ue

Second! Rateon 42 on

?ee

ean 3a ads ~a7

LU Wwelve-nonthe harvest.

2/_ Standard and narrow row spacings for ou

Tespectively.

---Page Break---



TABLE 26. DRY HATTER PRODUCTION FoR THREE CROPS OF SUGARCANE PROPACATED

\WUTM VARIABLE ROW SPACING AND HARVESTED AT VARIABLE TIM INTEOVALS

?otal DM (Tona/Acre) At Row Center U/

Marvest

Teter crop oe oe

2oethe Plant nes

Fitst Ratoon 3a

Second Raton a

Nea ae 38

SMosehs Plant 98 na 4

eat Batson we BT 3

Second Batson a2 35 ave

tens 35 99 ?a

Svonche Plane Bs v0 a2

Firat Raton nse Me

Second fatoon 1810.3 rat

Meas wo 1s 1

a2 months 2/ Plant 3.4 258.6 0.7

Lest Ratoon 33 10:7

Secont'Ratoon 28 23 03,

Mean 3.6 a8 40

A) tach Figure is the computed naan of three vartetien

2 Trash Snel

---Page Break---

spoporsur weean /E

?etuyoede nox om pus 4395208 200 307 sanqen ura /T

---Page Break---

etuyoede nos ony pun K997sns suo 203 sante wroK FE

?popmrone qonas JT

ewok TT

ea 9

STVAWRINY sHWVIWA £V GSISURNVH SvHD KaLAWN 40 SOK WOOLY ONL GW JOID ENVIA

GML WON SETAIA WaLWA RENO >

---Page Break---

seBuroeds nas ont por Aioy3eA 940 40; somtea www /T vw powSipay aw Gy Beste adie Gad

watex 21

ween

uooawa 3eaha

aon ee00K 9

ce

oer

rd syawoH 9

cr 6a

ea eat

verre

al eisv0K 2

: z yeaerer

SIVAYRIN TEVIWWA LV GALSBAN SS¥8D WitaWW 40 SAOVD MOOEVE ORI caw JOND INV HAL WO LNGLNGO WLLYH iad oz FOE

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=

TABLE, 90. DRY HATTER PRODUCTION FoR THREE CROPS OF RAFTER GRASS PROPACATED

[WITH VARIABLE ROW SPACIG AND HARVESTED AT VARIABLE TIME INTERVALS 1

Total DM (Tona/Acre) At Row Center ?

1oce Oem E change

2 Mosths Mant m7 a a8

First Ratcon ite 20 ue

Second Ratoon a o2 2

hea no LT

4 Mosthe Pa ns na

First tazcos m2 Mo

Second fatcon 224d.

Mean Ba Be °

6 Months Plant we aad

Piet Ratcon Bs

Second'Ratoon 246 3.2 :

Mean a8

12 Menthe Plant a3 9.2 ?0.8

Hirst Ratoon 33 38

Second Ratoon 19,3 18.8 20

Me as mS °

AP Variety Comon Mere

2 Trash snctused.

---Page Break---

ABLE 31. STE DEISITIES rom THE PLANT CROP AND THO RATOOM CHOPS OF SUGARCANE

AND NAPER

Glass HARVESTED AT ISTERIALS OF vO 70 TMELVE HOWTIS|

Specten crop ee Mean

y

sugarcane Piane os ns 80.7 65.5 90.4

First Fatoon LS 15.6 82.9 LE 92.4

Second Raton _7-9??75sh_?208.7 105.2, 23.6

Mean STA 106.5 90.1 O88 85.5

Naptor Grass 2/ Plant nes 2s? aa

First fatoon 202.9 903.5 -281.2,195.0 240.9

Second Ratoon 221.4 243.5 276.8 208.5 262.5

Mean wt 2568 288 ton m0

2) ean values for three varieties and two row epacines.

2/ Mean values for one variety and two row spacings

---Page Break---

- a

TABLE 32. SEASONAL INFLUENCE ON DRY MATTER YIELD BY THREE CROPS

OF SUGARCANE; 2-MONTH HARVESTS

X Of crop's Total Yield, For Crop ~

| Period | Plant | 1st Raton | 2nd Raton | Mean |
|---|---|---|---|---|
| July Sse. 15. | | 30.3 | 29.8 | 2a |
| Sept. 1-Wow. 15 | 18.4 | a2 | 20.2 | 19.9 |
| Yov, 15?Jan. 15 | 18.4 | 38.1 | 10.0 | 15.5 |
| Jan. 1SMar. 15 | 12.3 | 6.0 | 9.9 | 9.4 |
| Mar 1SmMay 15 | 26.2 | AS | 20.0 | 20.4 |
| May S?suly 15 | 18.6 | 10.0 | 10.0 | 12.8 |

---Page Break---



TABLE 33. SEASONAL INFLUENCE ON DRY MATTER YIELD BY THREE CROPS

OF NAPIER GRASS; 2-MONTH HARVESTS

% Of Crop's Total Yield, For Crop ?

Perio Plant ist Raton 2nd Ratoon Mean

Joly 1S?Sepe. 1516.50. 21.0 19.2

Sept. I-ov. 15 oak 13.6 15.5

Nov. 1s-Jan. 1523.6 15.9 16.7 wa

Jan. 15?Mar, 15 2.0 2s 13.6 9.3

Mar. 15?May 15 aus 21.8 25.2 26.1

May 15?guly 15 10.2 12.6 us as

SSS

---Page Break---



TABLE 36. SEASONAL INFLUENCE ON DRY MATTER YIELDS BY THREE CROPS

OF SUGARCANE AND NAPIER GRASS; 4-MONTH HARVESTS

Sugarcane

2 Of Crop's Total Yield, For Crop

Period Plant Ist Ratoon 2nd Ratoon Mean

et _ ee Batoon fed Ratoon Mean

July 15?Now. 15 30.6 ara 46.8

Nov. 15?Mar. 15 32.8 16.2

Mar. 15?July 15 36.9 38.6

Napier Grass

nc

July 15?Nov. 15 25.2

36.3 32.7

Nov. 1S?Mar. 15 37a 23.6 27.8

Mar. 15?July 15 37.6 39.4 a9 39.6

---Page Break---

TABLE 25. TREATMENTS AND HARVEST DATES FOR THE ?SECOND GENERATION" ENERGY CANE

STUDY AT AES-UPR LAJAS SUBSTATION

OS ee

eervan 2/ ?

Fleaentat x Harvest Date, At Interval

Variety bs/Acre Yr) 6 Months 12 Months 18 Months

i 2 Months

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

ico 3 } a

ooo ? * *

US 67-22-2 200 ? .

?co . "

&o . *

B 70-701 200 « . *

io ? :

too : * .

/ For plant exop only.

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= 85

TABLE 36. PROJECTED DM YIELDS FOR SECOND GENERATION ENERGY CANES PROPACATED

TW PUERTO RICO'S LAIAS VALLEY

ON

Projected DM (Tone/A), For Crop 4/ ?

Variety Category Prinavera Gren Cultura

? riers Gre Culture

PR 980 Ast Generation 2/ 27-29 36-40

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

3B 70-701 2nd Generation 38-42

ee

4! yeash included.

2

2! Reference variety.

---Page Break---

TABLE 37. TOTAL GREEN WEIGHT FOR THREE SUGARCANE VARIETIES UNDER

VARIABLE N AND HARVEST REGIMES

ye

Blevental ¥ GY (Tons/A), At Month

Variety (Lbs/Acre Ye) 6 2 1 Mean

PR 960 200 49.9

400 33.8

600 51.0

Mean 51.6

us 67-22; 200 60.2

400 60.9

600 61.5

Mean 60.8

B 70-701 200 52.3

400 52.9

600 56.3

Mean 53.8

AJ Bach figure is the mean of four replicates.

---Page Break---

TABLE 38, TONS MILLABLE CANE PER ACRE (TCA) FOR TURE SUGARCANE

VARIETIES UNDER VARIABLE N AND HARVEST REGIMES

cA, At Month 2! ?

Elenental N

riety (Lbs/Acre Yr) 6 a2 18 Mean

PR 980 200 31

400 35:0

600 36.6

Mean 34.9

us 67-22-2200 33.7

400 36.4

600 31:3

Mean 33.8

sr

B 70-701, 200 31.6

400 bila

600 ara

Mean 33.0

A/ Each figure is the mean of four replicates.

---Page Break---

TABLE 39, GREPN WEIGHT OF WHOLE PLANTS FOR TAREE CANE VARIETIES

UNDER VARIABLE AND HARVEST REGIMES

Hiecenta: x Plane Me (Lbs), At Month ?

Variety (lbs/Acre Yr) 6 2B 8 Mean,

PK 980 200 2.97

400 2196

600 2155

Mean 2.83

US 67-22-2200 2.45

400 2:56

600, 2st

Mean? Debt

8 70-701, 200, 2.80

400 2.98

600 2197

Mean 2.92

A/ Each figure is the mean of four replicates, Six plants were

vested per replicate,

---Page Break---

?TABLE 40. WEIOHT OF MILLABLE STEMS FOR THREE CANE VARIETIES UNDER

VARIABLE N AND HARVEST REGIMES

ve

Flenentat » Sta Wt (Lbs), At Month

Variety (Lbs/Acre Yr) 6 12 18 Mean

sey Gheiere te) 6 Maan

FR 960 200 1.97

400 1.93

600 1.83

a

Mean 1.92

a

US 67-22-2 200 1.37

400 1.53

00 ay

re

Mean 1.36

–

B 70-701 200 1.69

400 177

600 1.96

eS

Mean 1.81

A/ Each figure is the sean of four replicate

harvested per replicate.

Six plante were

---Page Break---

TABLE 41, LENGTH OF MILLABLE STEMS FOR THREE CANE VARIETIES UNDER

VARIABLE 8 AND HARVEST REGIMES

Stem Length (Ft), At Month 2 ~

Elenental ¥

Variety (Lbs/Acre Yr) 6 2 18 Mean

PR 980 200 4.63

400 4156

600 any

Mean 445

us 67-27-2200 4.29

400 ae

600 3162

a

Mean 4.01

ea

3 70-701 200 6.6

400 6.27

600 6b

oo

Mean 6.29

o_O

A/ Each figure is the mean of four replicates. Six stens were

Harvested per replicate.

---Page Break---

-oe

TABLE 42, STEM COUNTS FOR THREE SUGARCANE VARIETIES UNDER VARIABLE ©

AND RARVEST REGIMES

See

tenencat y Stene/ACTHousands) At Yonth 2!

Variety (ibs/acre te) 6S ean

tele _Gisincre yy) 6 seen

me 580 220 29.4

?so i:

eo 38:

a

ean

???

vs 67-22-2200 46.3

ico 63

too ia

tena

eS

nro7 200 46.0

ico so

éeo eo

?

na

L/ Each figure is the mean of two replica

---Page Break---

TABLE 43, DRY MATTER PRODUCTION BY THREE SUGARCANE VARIETIES UNDER

VARIABLE X AND HARVEST REGIMES

Hoouie DA (Tons/A), At Month

Variety (Lbs/Aere Yr) 6 2 38 Mean

PR 980 200 8.7

400 88

600 0

Mean 8.5

US 67-22-2200 wat

400 9:6

600 9.6

Mean 10.1

B 70-701 200 9.6

400 9.6

600 9.3,

Mean 2.5

A/ Fach figure ie the mean of four replicates.

---Page Break---

TABLE 44. DRY MATTER CONTENT OF THREE SUGARCANE VARIETIES UNDER

VARIABLE WAND HARVEST REGIMES

uy

pienental x PAGE) At Monet

Variety (Lbs/Aere Yr) 6 2 18 Mean

PR 980 200 17.5

400 16.4

600 15:7

Mean 16.5

Us 67-22-2200 18.4

400 35.8

600 15.6

Mean 16.6

AJ Each figure is the mean of four replicates.

---Page Break---

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

AND HARVEST REGIMES

Elemental ¥

Variety (Lbs/Acre Yr) 6 R 18 Mean,

PR 980 200 6.16

400 5.80

600, 5:58

Mean 5.85

us 67-22-2 200 6.14

400, 3.27

600 5.57

Mean 5.66

3 20-701 200 4.40

400 4193

600 4:30

Mean 45h

A/ Tach figure is the mean of four replicat

---Page Break---

TABLE 46, POL VALUES FOR THREE SUCARCANE VARIETIES UNDER VARIABLE ¥

AND HARVEST REGIMES

ue

Elenental w POL Reading, At Month

Variety (Lbs/Acre Yr) 2 18 Mean

PR 980 200 23

400 180

600 168

Mean 1.87

Us 6722-2 200 2.90

400 1:40

600 Las

Mean 1.48

I

3 70-701 200 0.88

400 0:93

600 0:80

a

Mean 0.87

A/ Each figure is the mean of four replicates.

---Page Break---

TABLE 47. RENDIMENT VALUES POR THREE SUGARCANE VARIEXTES UNDER VARIABLE 8

AND HARVEST REGIMES

SSS

a

Elemental N At oath

Variety (Lbs/Acre Yr) 6 2 18 Mean

???x___ Stn

PR 960 200 0.05

400 0.17

600 0:34

Se

Mean 0.19

SE

us 67 22-2 200 0.33

400 0166

600 Ber)

Sa

Mean 0.70

i

B 70-701 200 -0.99

400 n135

600 =1l0s

a

Mean =1.05

2/ ¥ach figure is the wean of four replicates.

---Page Break---



TABLE 48. FIBER VALUES FOR THREE SUGARCANE VARIETIES UNDER VARIABLE

AND HARVEST REGIIES

eS SSS

? we

Hlenentat W Fiber (2), At Month

Variety (Lbs/Acre Yr) 6 2 18 Mean

ST erm SE

PR 980 200

400

600

ee

Mean

us 67-22-2 200 20.21,

400 to01

600 9.6

i

Mean, 9.79

a

3 70-701 200 gan

400 13le2

600 8.75

a

Mean 10.56

42/ Fach figure is the mean of four replicates.

---Page Break---

TABLE 49, TRASH YTFLDS FOR THREE SUGARCANE VARIETIES UNDER VARIABLE ¥

AND WARVEST REGIMES.

ue

Ftesental y Toms Trash/Acre, At Month

variety (oe/acre v=) 6 2 18 Mean

FR 980 200 0.84

00 ras

600 099

Mean LoL

vs 67-222 200 0.96

00 or

00 ms

a

Mean 1.03

a

B 70-701 200 0.74

?00 oe

600 0:73

ee

Mean 0.72

s+?

A/ Trash that had detached and fallen to the ground. This does not

include trash adhering to the stens and requiring renoval by the cane

harvest machine or by hand stripping.

---Page Break---

?TABLE 50. PRODUCTION INPUTS FOR AN EXERGY CANE DEMONSTRATION O A HUMID

ALLUVIAL PLAIN

MATIULO, PR

opvt ?ecray Cone Standard Control tow-¥il Control

Seedbed prep. Standard Standard

Seeding rate ouble-seeded Singie-seeded

ow spacing Standard (150 c=) Standard (130 c=) Standard (150 cm)

variety 7 980 PR 960 PR 980

herbicides Pre-k Poot-energence Pre-t Post-anergence

Nitrogen 600 tbe/acee/I8 mo, Ye fereilizarion

water Terigation plus rainfoll Rainfall onty aintait only

Harvest 18 no, gran culture 18 vo. gran cultura 18 eo. gran cultura

AJ Planting completed August 27, 1980.

---Page Break---



?TABLE 51, TOTAL GREEN WEIGHT YIELDS FOR ENERGY CANE HARVESTED AT

VARIABLE INTERVALS; HATILLO PROJECT

$e ATO PROVE

Tot. Green Wt. (Tons/A), At Month ?

Treatment 6 2 18 Mean

sn

Control (Lew Ti11) 36.7

Control (Sugar Corp.) 30.8,

Energy Cane 36.0

Us 67-22-2 50.2

a

38.4

a

---Page Break---



TABLE 52. MILLABLE STIX YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE

INTERVALS; HATILLO PROJECT

Mitlable Cane (Tons/A), At Month ?

?Treatment 6 2 18 Mean

Ee

Control (Low Ti12) 23.2

Control (Sugar Crop.) 19.3

Enerey Cane 24.0

Var. US 67-22-2 34.7

a

Mean 25.3

a

---Page Break---



TABLE 53. TOP WEIGHTS FOR ENERGY CANE HARVESTED AT VARIABLE

INTERVALS; HATILLO PROJECT

Top We. (Tons/A, At Month ~

Treatment 6 2 38 Mean

Control (Low Til) 9.9

Control (Sugar Corp.) 6.4

Energy Cane 6.6

Var. US 67-22-2 123

Mean

---Page Break---



TABLE 54, TRASH YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE

INTERVALS; HATILLO PROJECT

eS

?Trash We. (Tons/A), At Month ?

Treatnent, 6 2 18 Mean

ee

Control (low Ti1i) 5.8

Control (Sugar Corp.) 5.2

Energy Cane 6.1

Var. US 67=22-2 6.2

wo

Mean 5.8

a

---Page Break---

TABLE 55, DRY MATTER YIELDS FOR ENERGY CANE HARVESTED AT VARIABLE

INTERVALS; HATILLO STUDY

em

DM Cfons/AD, At Hoot 2 ?

Treatment oe eon

control. (Low 2611) oa

Coneror (Sugar Corp.) 5.7

toerey cane 59

vac, us 67-222 as

sen

A Oven-dry, approximately 62 moisture.

---Page Break---

= 105 -

TABLE 56. DRY HATTER CONTENT OF ENERGY CANE HARVESTED AT VARIABLE

INTERVALS; HATILLO STUDY

DM Content (2), At Month ?

Treatsent 6 2 18 Mean

Control (Low Ts11) anh

Control (Sugar Corp.) 18.4

Eneray Cane 16.5

Var. us 67-2222 ws

Mean 17.5

ee

---Page Break---

= 106 -

TABLE 57. PLANT REIGHT FOR ENERGY CANE HARVESTED AT VARIABLE

INTERVALS; WATILLO PROJECT

Ee

Plant Height (Ft), At Month ?

Treataent 6 12 18 Mean

oe

Control (Low Tii1) 5.4

Control (Sugar Corp.) 4,7

Energy Cane 4

Var. US 67-22-2 4

Se

Mean 48

Se

---Page Break---



TABLE 58. NIMGER OF STENS PER ACRE FOR ENERGY CANE HARVESTED AT

VARIABLE INTERVALS; HATILLO PROJECT

unrest OCT

Stens/A (Thousands), At Month ?

Treatment 6 2 18 Mean

en

Control (Low 1411) ane

Control (Sugar Corp.) 28,4

Energy Cane 32.5

Var. US 67=22-2 46.0

a

Mean 34.6

a

---Page Break---

TABLE 59. DRY MATTER YIELD FROM NAPIER GRASS FIELD PLOTS MECHANICALLY

HARVESTED AT 6 MONTHS OF AGE; FIRST-RATOON CROP.

Rotary Scythe Area ow vietd 2/ crown 2/

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

1 8-10 0.69 7.98 win

2 0.69 8.77 Ni

3 0.68 1.67 wi

? 2 0.69 8.80 mia

OO

A/_ Excluding approximately 20% of the total DM in the form of unraked

Fesidues. This material could not be windrowed with the available forage

rake.

2/ Observations based on subsequent production of new shoots.

---Page Break---

sna sarodseso/a0ente® gsa90'9 M088 (204 0OL8 THK wee oo

wo es ore 7 we

vee 162 ser oer

oer wwe wre wr

wee wr ser

a rooney wiv

mown = aaa

RINK XS GAOW SS¥ED METAWN NY SHOTIH eHELLGO ont Av oNtuMasaD

LMOTLIGIOO-RLLDS AVION DM SAL Wd SWLLWOWAT HRWROIMGS MOWINITENE Oy FD

---Page Break---

~u0-

?TABLE 61. PERCENTAGE INCREASE IN FUEL EXPENDITURE AND

HORSEPOWER FOR LOW CUTTING AS OPPOSED TO HIGH CUTTING;

ROTARY SCYTIE TEST ON SIX MONTHS OLD NAPIER GRASS.

Fuel Expenditure

Cations 29.8

Gallons/Hour 15.9

Gattons/Acre 30.2

BrUs/Acre 30.2

Horsepower 15.9

---Page Break---

=a

TABLE 62. SUGARCANE SEEDLINES SELECTED FOR BTOMAEE YIELD EVALUATION;

AES-UPR

AAS SUBSTATION, AUGUST, 1980,

Momber Of Seedlings ?

ceose

a Feo x us 67-22.2 966 7

5 PR 68-330 us 67-2202 on 2

6 PR 67-1070 x vs 67-2202 160 7

2 US 67-22-2 PR 6#-2061 1200 2%

6 ws 6722-2 x F160 270 5

v PR 68-3061 x US 67-2202 ma a

ee enttinge ee

2 Planted during 1979 48 the AES-UPR Gursbo Substation for tnftial seedling

?evatuation

2/ Planted August 14, 1990, at che AES-UPR Lajas Substation for second-stage evatuasion, Plots are 5" x20" and unreplicated. superior aelecelone fees

?his group vill be planted in 1981 tn 20° x 20" ploss?

---Page Break---

-m-

coc

(48-3

(BED Ux Cae yy

bog

1

s

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