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PRODUCTION OF SUGARCANE AND TROPICAL

GRASSES AS A RENEWABLE

ENERGY SOURCE

THIRD ANNUAL REPORT

1979-1980

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THE UNITED STATES DEPARTMENT OF ENERGY

ENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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Third Annus] Report; 1979?1980

To

?The United States Departaent of Enersy

Oak Ridge Operations Office, and the Division of Solar Technology

Biomass Energy Systems Branch

Washington, D. C.

By

The University of Puerto Rico

Center for Energy and Enviroment Rescarch.

Piedras, Puerto Rico

CONTRACT NO.: DE-ASOS-78ET20071 (AES-UPR Project C-481)

WeATION: Rfo Piedras, Puerto Rico

PERIOD COVERED: June 1, 1979?May 32, 1980

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Project Leader

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A RENEWABLE

ENERGY SOURCE

Table Of Contents

---Page Break---

Subject

2

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33634

35-37

3871

---Page Break---

-2e

INTRODUCTION

The bionass production studier herein reported were initiated June 1,
1977 as a contribution to the Bionain Enervy Progran of the UPR Center for
Energy and énvironnent Research (CEER-UPR), This research deals with sugar~
cane, tropical graves related to susareane, and other Eropical grasses having
large grows potentiats on a year-round basis. Tes basic prenise is that such
plant materials can be produced continuously as a renevable, domestic source

of fuels

snd chemical feedstocks that vill substitute for inported fossil

energy. The present report covers the period June 1, 1979 to May 31, 1980.

1. Project Objectives

Primary objectives include: (a) Determining the agronomic and econonic

feasibility of mechanized, year-round production of solar-dried biceaes,

through the intensive managenent of sugarcane and napier grass as tropical

forage:

and (b), exanination of alternative tropical grasses as potential

sources for intensive bionass production. A secondary objective concerns the

selection and breeding of new sugarcane progeny having superior biomass pro-

ductivity as their principal attribute.

Scope of the Project

Baphasis is directed toward a highly-intensive and mechanized production

of tropical grasses as solar-dried forages. This is a deviation from convene

tional cane and cattle feed production in chat total éry matter rather than sugar and food components is the principal salable commodity. Management of Production inputs?particularly water, nitrogen, and candidate species, together with harvest frequency?varies significantly fron established procedures. Oa

the other hand, advances in mechanized production and harvest operations within

---Page Break---

the sugar and cattle forage industrius avo being utilized with considerable

success for production of solar-dried bic

optianzed production operati

ne cequire the identification of a few select

clones and the conditions required (or their managenent in an econonicallyrealistic operation. This is being accompli

shod in the continued developaent

Of three project phases, including greenhouse, field-lot, and field-scale

investigations (Table 1). A fourth pha

+ conmercial-industrial operations,

follows logically but ies beyon! the scope of the present project. The work herein reported deals with a continuation of the greenhouse, fiel¢-plot, and field-seale phases begun earlier (1, 2) 2/*

The project's screening operations are designed to identify high-yielding Brasses thit can be harvested on a yeur-round basis. They have indicated three broad catezories based on the tine required after seeding to maximize total dry matter (Table 2). Anong sugarcane cultivars the superior grovth rate per ge, a

botanical Feature,

as not been recognized historically as a desirable attribute unless conbined with an acceptable Level of sugar production (3, 4, 5, 6, 14, 15). Similarly, the tropical forage grasses have required acceptable digestibility and nutritive characteristics rather than high yields of dry matter (7, 8). Accordingly, ovr screening progran often deals with long~ established cultivers, but in @ manner that would have astonished their original developers. Tn sone respects this is a tropical application of the herbaceous species screening program formulated by the DOE Biomass Systens Program (9, 10).

A breeding progran designed co intensify the bionsss-yielding attribute of

Saccharum and releted species lies beyond the scope of this project. Thorough

Af Mumbers in parentheses refer to relevant published Literature. Coaplete Gitations ere Listed on pages 33 and 34.

---Page Break---

breeding studies would require and justify a separate project. This would include thy screening of candidate parental eypes, a physiological phase to synchronize flovering periods at the interseneric Level, and bs

genetic

esearch ti break some serious constraints operating to prevent the exchange of

sereplasn <2ong,

charvm and allied genera (11, 12, 13, chap. 1). At a very

modest level sone linited breeding is included in the present project. This

work ia con

ined to a fev obviously denizable parent clones that have oustable

Hovering characteristics and which can be incorporated without inconvenience

into an onsoing breeding progran for sugarcane (1, 2). Certain progeny orig-

inating vith the AES-UPR sugarcane breeding program are also being considered as

tong-rotation 1/ yionass candidates (16). Under these circumstances sone prospect

is created for the energence of superior new progeny at very little expense.

3. Statenont on the First Quarter of Year 3

A separate report on the first quarcer of year 3 vas not considered justified fand the project Jeader received authorization to conbine the first cvo reports for this year's work. Oving to funding delays the period June 1 through August 31 was essentially on ?hold?. Emergency funding amounting to about 15 percent of regular Levels enabled sone Linited progress to be made at the greenhouse level where candidate screening ané nutrition experinents can be performed at relatively low cost.

?The project's principal collaborators were retained during the first quarter but without labor support. The gost important experiment was kept active during this period, This included the varietal, row-spacing, and harvest= frequency studies with first-ratoon sugarcane and napier grass. Field-scale

2/ Categories of tropical-grass candidates for biomass production are discussed in detail elsewhere (1).

---Page Break---

plantings of Sordan 70:

, for mechanized harvest studies, vere discontinued and nev plantings previously scheduled for August vere postponed until January,

1980, ving to exceptionally goo! weather during October of 1979 (ordinarily the wettest part of the PR rainy season) it vas possible to plant six acres of

napier gross for subsequent study of mechanized harvest equipuent and procedures.

?TECHNICAL REPORT

AL GREEMIOUSE SmuDIES.

The project's ercenhouse phase i# concerned with the screening of candidate tropical grasses and the response of superior cultivars to growth input and

management variables. Much

foraation of this nature is obtained more rapidly

and cheaply than is possible under field conditions. Greenhouse data are not

definitive in the sense that dir

field responses and cultural recornenéations,

can be stated, but perhaps two-thirds or nore of the total data package needed

for @ herbaceous candidate can be gathered in this way. For Saccharum and related

species ordinarily propagated in popu?ations of 30,000 to 300,000 piants per

acre, the greeshouse offers a level of precision for control of the individual

Plant that is not renotely possibie in the field. This method is currently used

in Puerto Rico for its econoay of project resources; under tenperate-clinate

conditions it offers an econony of tine where field vork is sea nally Limited

to four or five favorable months per year.

Both replicated and non-replicated ?observation? experiments are conducted in the greenhouse, The latter usually concern preliminary grovth-potential measurenents involving only a fev hundred plants in an area covering roughly 1/200 acre. Roplicated experinents deal with specific grovth characteristics in previously-identitied candidates. Ordinarily these involve 3 to 5 replica

tions of each treatment arranged in an incomplete randomized block design.

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1. Candidate Sereoning

?Tue firer clearly outstanding tropical grass candidate to emerge from the projec:'s screening tests vas a oveet sorghun x cudan grass hybrid. Developed »y the Northrup-King Company and nacketed under the trade nane "Sordan 704", this is an extrenely rapid-crowing grass vhich completes its srovth and maturation processes within 10 to 12 weeks after seeding (1, 2). Subsequent screening tests revealed other candidate clones aoderately superior to Sordan JOA, particularly under conditions of moisture etre

c

All of

these grasses are clearly short-rot:

on apecii

?A number of additional clones became available to the project whose correct

categories for field-plot testis

wore lose clearly defined, These range from

potential short-rotation species (Johnsen grass, SES-231) to potential long~

rotation species (US 6722-2, US 72-70). Seven of these grasses were propagated in the greenhouse during the spring and sumer of 1979, using the interspecific comercial cane hybrid PR 9?0 as che reference clone (Table 3). This type of

?experinent is conveniently termed ?oultiple rotation", and it enables cultiple~

species and category screening to proceed sim

wneously. The species and methods used in this experizent are descrived in more detail elsewhere (2).

One-third of the plants was harvested cach at 2,4 and 6 wonths after feeding. These tine intervals correspond ko short-rotation (2 wonths) and to Both early and late intermediate rotation (4 and 6 months, respectively). Long rotation experiments (12 to 18 months) cannot be maintained adequately with potted plants. In tems of DM yield/planted area (Table 3) and waturity

(Table 4), Johnson grass clearly exerged as the Leading short-rotation candidate. The 1:

ier grace hybrid PI 30086 vas the leading intermediate-rotation candidate,

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=

As iDlustrated graphically ir Figure i, ail clones except Johnson grass made cnormis yield increases when harvest was delayed from the second to the fourth month after seeding. Only in tie case of Johnson grass vould greater yields der.ve fron sinply repeating the 2-aonth harvest over and over again. Alternativ. ly, all. species shoved relative yield decline as harvest was delayed fron the fourth to sixth gonth otter sueding. This Latter trend is misleading

in the care of valid long.

otstion caidivates such as PR 980 and US 67-22-25 in field p-ots these clones would save begun their heaviest dry matter accumula~ tion arounc 6 or 7 months after planting. On an individusi plant basis napier

grass was che superior producer at exe of the three test apes (Table 5).

2. Matwrar

8 Profiles Of Three Ni Hybrids

?The NorthruprKing hybrids Serdan 77 and NK 326 gave very favorable growth performances in previous direct comparisons with Sordan 7A (2, 17); In subsequent greenhouse trials the maturation curves for both candidate grasses were determined using Sordan 70A as the reference variety. Dry matter yields for NK 326 clearly exceeded those of Sordan 704 from the 8th to 13th weeks after seeding (Figure 2, Table 6), Although there were no large differences in the rate of ery matter accumulation, Sordan 77 conrained significantly wore dry matter than the other candidates from about the 9th week onward (Table 6), Sufficient data

are now available to justify field-scale comparivons of the three tropical grasses.

3. Screening of Dekalb Company Hybrids

Screening trials vere begun during the third quarter on a series of tropical grass hybrids developed by the Dekalb Company. Like the NK hybrids, these prassce incorporate both sorghun and Sudan prass gemplasa and are basically intended

for surmer production as cattle forages. Preliminary (unreplicated) yield data

---Page Break---

for six Dekalb gracees are presented ia Table 7. The MK hybrids Sordan 77 and

Trudan $ were also included in chi tvial At six wesks of age the variety

Dekalb F5-25 a+ compared favorably with Serdan 77 and Teadan 5. At 10 weeks,

all of the Dekalb grasses were at leust equal te Soréan 77 and Trudan 5 in dry

matter yield white Dekalb PS-25 a+ ais Dekit SN-L7 + indicated moderately higher

yields, The latter two hybrids were also superior on a per plant basis (Table 7).

4. Nartable

Moisture Rezines

The sare Wi and Dekalb candidutes noted above were subjected to variable moisture reiines in an unreplicated serial initiated during the ehird quarter.

Given a series of tropical grasues having comparable yield potential under ideal

growing conditions, the ability to =

tain a high yield performance under condi-

tions of noisture stress is 2 decisive factor in the final screening process

Moisture regines ranging fron excessive water supply ("humid") to inadequate vater supply ("seai-arid") were siculated by varying the frequency of irrigation. AIL plants vere propagated under glace using a 2:1 co{d-cachaza mixture as the srouth wedium. Plant sanples vere harvested at chree intervals over a time-course of 11 weeks.

All of the Dekalb grasses equalled or exceeded Sordan 77 (the project's principal shore-rotation hybrid) in dry natter yield (Table 8). Under hunid conditions the varieties Dekalb ST-5 and SX-16a exceeded the Sordan 77 yields by at least 30 percent. However, none of the candidates maintained a sat:

factory

grouth performance when vater supply vas cut back in a eimulated seni-arid regine.

The need for additional &:

ting of these grasses as ?low-till" candidates is

clearly indicated.

Mean values for dry matter content, an indication of plant maturity, did

not vary consistently ancng moisture vegines (Tuble 9). A pronounced increase

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of dry matter was recorded vith increasing plant age (Table 9). The latter

response was quite distinct anong all moisture regines.

5. Mins

1 Nutrition

A nitrate-ti nutrition experizent established late in Year 2 was completed during the first quarter of Year 5. Variable nitrate levels were adninistered

to Johnson grass to establich the plant's Neresponse curve. As in earlier nutrition experinents with Sordan 70A and napier grass (1, 2), the objective was to establish the slope of the dry matter response to progressively higher levels of N. Accordingly, nitrate-¥ eupplics were increased in # geonetric progression to Johnson grass propagated in sand culture. Nitrate levels ranged froa 1.0 to 81.0 nilequivalents per Liter, in nutrient solutions given three tines each week over 4 Line-course of 10 weeks.

Dry matter yield and content data (Tables 10 and 11, respectively) suggest that the maxinun growth response vas obtained at around 9 neq/1 of NOy; however, both visible and real growth inprovenent was obtained fron the 27 neq/1 treatment as well, This vas particularly evident as plant age (and hence root development) was advanced to 10 weeks. Johnéon grass is the only candidate at this point in time to show major grouth responses to 54 meq/1, and an absence of grovth repression by 81 seq/i of NO, (Figure 3). Ironically, as a ainizun tillage candidate Johnson gras is less Likely to receive fertilization than ?species from other cropping categories.

With reference to nutrient uptake, Johnson gra

id not respond to W

levels higher than 27 meq/1 of NO, (Table 12). A surprisingly high foliar K

content was recorded, ie, in the range of 2.4 to 2.8 percent on a dry weight

basis. These levels are more typical of sugarcane which accumblates relatively

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Jarge ssounts of pot:

harvest regrovth data indicate that high NO,

Levels (above 27 meq/1) are repressive against both the munber and weight of

new shoots (Table 13).

B. FIELD PLOT STUDIES

1, Saccharur Species Candidates

?An observation field-plot study vith candi¢ate S. spontaneum and S. sinense

clones has been undervay at the AES-UPR Gur

0 Substation since October, 1977.

The principal objective vas to define che total bionsss-producing capabilities of these candidates. A second objective vas to determine their qualitative value when sufficiently-aged plants becane available.

The candidate clones Listed in Table 14 vere harvested at 2-and 4-nonth

intervals for one year, and subsequently harvested after six more months had

elapsed flats sumarized elseviere (2)7. ae that point the experine:

converted to an observari

"Low till" study in which the plants were allowed to

?subsist on rainfall and native soit fertility. Harvests are planned for 6-nonth

intervals for the duration of the project.

?The first 6-nonth yields under mininua tillage conditions are presented in

Table 16, The s.

spontaneun clone SHS 231 continued to be the superior éry

matter producer, followed closely by SES 317 and Chunnee. Each of these clones

attained an advanced state of

curity during their G-nonth growth period, ie,

each exceeded 35% dry matter. SES-231 is a very inpressive candidate at this

time; hovever, it did require nearly a year to establish a vigorous crow. Its present growth is vigorous

dark green in color, and generally unmarred by

nutrient deficiency synptons or pest injury. SES 231 is presently regarded as

@ late short-rotation or early intermediate-rotation candidate, Its thin, wiry,

---Page Break---

ane

and persistently upright etens should Len? themselves well to zechanized

harvest and solar-drying operations. Field-scale plantings of SES 231 will

be made for eechanized harvest trials during the project's fourth year. At present

the clones PR 980, Saretha, and Natal Uba are rapidly dying out (Table 14).

2. Mininum Titlage Experinent;

Jae Subst

There is a need for tropical grasses that will produce at least soderate yields with the barest sininus of production ingute. The characteristics and principal requirenents of minimum tillage candidates for Puerto Rico are Giscussed at Length in prior reports (1, 18).

[A long-term mininun tillage study on species was initiated at

the AES-UPR Lajas Substation during n:d-Fobruary of 1977, There are four $-

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

the control. Receiving no production inputs since the original planting, harvests

Ihave been taken at 6-

jonth intervals. The fourth such harvest was performed during the third quarter. Although dey matter yields are relatively low, it is evident that all of the S. spontancus clones are sustaining thenselves far more effectively than the commercial hybrid PR 980 (Table 15).

The superior clone at this stage of the experiment is US 72-72, Ite gr

and dry matter yields were 3.92 and 1.36 Lons/acre, respectively. By way of reference, the PR cane industry is producing approxinately 9 green tons/acre and 3.5 dry tons/acre,

4an Island-wide average, over a comparable time-course.

Both production costs and energy inputs for US 72-72 are nil. Production costs for the PR industry cane are approximately §64.00/0D ton} the energy ovtput/ input ratio for this cane is approxinately 3.5/1.

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3. Seed Expansion Fron "Energy Care" Plancings

From the seed gources available in 197', three sugarcane varieties vere

Selected for the project's initial studies on cane biomass. Each variety hi

history of high yields for borh sugar and bagasse ov:

a range of PR soil and

rainfall conditions. Moreover, see! was available in adequate quantities for project needs. Nonetheless, there vss no question but that these canes represented something less than the maxinur bioxass yielding potential of Saccharum in Puerto Rico. Seod expansion for more promising biomass enersy cones was begun late in 1979. The . spontaneun clones US 67-22-2 and B 70-701 have shown especially favorable promise as biouass producers and are included in the seed expansion phase, This material is being propagated at the AES-UPR Gurabo Substation. Field-plot expcrinents using both varictios will be established at the AES-UPR

Lajas Substation during August of 1980, Additional plantings of US 67-22-2 and

B 70-701 will be ade on privately-owned Lands near Hatillo (on the hunid north

coastal plain) during August of 1980, It is believed that these varicti

Produce about 40 0D tons/acre as primavera cane (10 to 12 months old at harvest)
?and close to 50 OD tons/acre as gran cultura cane (16 to 18 months old at harvest).
By way of reference, the highest yields attained to date with conventional vari-
eties averaged about 25.5 and 33.6 0D tons/acre, respectively, for the "plant" and

"tirst-ratoon" crops.

4. Sugarcane and Napier 61

s Ietale

A large field plot study on row spacing, varieties, and harvest frequency
for sugarcane and napier grass has boon underway at the AES-UPR Lajas Substation
since 1977. The intent of this experiment is to maximize rotal bionass yield

for the two speck

lover a three-year cropping eycle, ie, for a "plant" crop plus

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sae

two ?ratoon" crops ©/, re is believed that three crops, fe, the plant crop

plus two ratoon crops, probably represent

we best tine-frane package for energy

cane production in Puerto Rico.

Yield trends for the first six conths sustain the results of years 1 and 2.

These trends include: (a) A superiority of napier grass over sugarcane when harvested frequently (at 2+, 4-, and 6-ronth intervaic); (b) a failure of marrow row spacing to increase yields over seondard row spacings and (e) reletively small varietal differences for sugarcane given suitable tine for development (6 wonths), while 2/3 of the cane varieties continue to weaken in response to

2emonth harvest interva

Growth data fron the (iret five 2

wronth harvests (Tables 16 t020; Tables

24 and 22)reconfimm the fact that sugarcane will not respond favorably to frequent.

cutting (2, 2). During this intervst the maximum dry matter yield

F sugarcane

vas 0.64 tons/acre (Fable 16, var. NCo SIC) while papier grass exceeded this amount by a factor of about 3. Contrary to the plant crop results, but consistent with data from the first ratoon crop, narrow row spacing for sugarcane failed to increase yields. There was in fact a tendency for close spacing to reduce yield in two of the three varieties tested. Napier grass (var. Nerker) was not consist ently affected by narrow row spacing.

Two of the sugarcane varictics (PR 980 and PR S4-1791) indicated continuing decline of vigor in response to frequent recutting. Variety NCo 310 vas core

tolerant of this harvest interval (Tables 16-22). A seasonal effect on sugarcane

jor was also evident (Tables 21 and 22). Hence, bionass yields for

Ne third

LL Coomercial sugarcane in Puerto Sico is managed on a S-year cycle while napier

grass plantings are generally indeterminate, sometines remaining a generation or Longe?

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-u-

2-gonth interval (Novesber 15 to January 15) were only 1/3 of the yielés

obtained fron the first 2-sonth interval (July 15 to Septesber 15). Napier

was auch sore tolerant to tho cooler "winter" temperatures, While mean

sugarcane yield declined by 66% (fron 0.30 to 0.10 0D tons/acre/? onthe)

apier grass yield declined by 262 (froa 1.96 to 1,45 OD tons/acre/? months) «

Yields from the ?-month harvests were in some respects sinilar to the

2eonth harvests, Sugarcane variety NCo 310 renained dominant over PR 960 and

PR 64-1791, and cloge spacing had a generally deteinental effect on growth (ables 23 and 24; Tables 21 aud 2

Hovever, the importance of delaying

harvest frequency as a eans of increasing dey matter yield was very pointedly

Aenonstrated. For sugarcane the sonthly dry eater yfelé averaged 0.06 ton/

?acre when harvested at 2eaonth intervals and 0.75 ton/acre when harvested at the

4-aonth interval, Tor napier grass, the average sonthly yield rose from 0.40 to

1.92 tons/acre

harvest frequency vas delayed from 2 to 4 monthe, Hence, by

merely doubling the time interval allowed for tissue expansion and maturation,

A2-feld and 4-fold yield increas:

vere obtained for sugarcane and napier grass,

respectively. Moreover, equipment usage vas reduced by 50 percent, with all

that this implies relative to reduced fuel expenditure, soil compaction, and ies and wanes

?A seasonal grovth response, suounting in effect to

Antor" growth decline,

was also evident for the ?month harvest intervals, Mean DM yield for sugarcane

was only 1.4 tons/acre during the period November 15 to March 15, whereas it hed

?been 3.0 tons/acre between July 15 anc Novenber 15. This was a decline of 53%.

Napier grass was again more tolerant of the eeasonal change, with DM yield

declining by only 31% (Table 22),

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?The first 6-month harvest revealed that NCo 310 vas still the superior sugarcane variety midway through the second-ratoon crop (Table 25; Tables 21 and 22). A soderate but persistent depressing effect on dry matter yield was being exerted by the close-spacing treatsent. At this tine napier grass continued to exceed the average sugarcane yield but the difference vas less Pronounced than at 2-and d-nonth harvest intervals, The average cane DM yield for a single harvest at 6 gonths was 10,5 tines greater than the combined yield of three, 2-sonth harvests (Table 22).

Mean values for dry matter content (Table 26) indicate that napier grass had essentially reached peak maturity by the fourth conth after cutting. Sugar-cane piogressively increased DM content from the 2-to 6-nonth harvest intervals.

?Ae six nonths into the second-ratoon crop sugarcane yields were in the ?order of 20 to 30 percent lover than the first-ratoon crop, and very slightly

lower than the plant crop. This suggests that the 3-year cropping cycle plan-

ned for energy cane is a correct interpretation of bionass yield potential. Puerto Rico's sugarcane industry enploys a S-year cropping cycle which is

based on sugar production rather than total biomass. Sugar yields can actually

y

increase in plants whose grovth rates are declining (13, 14, 15) 2! wien

bionass replacing sucrose as the primary comodity a more frequent replanting may

be justified.

?The apparent yield decline at 6 months might also reflect an unseasonal

drouth affecting the Lajas Valley fron late Septenber to mid-November.

Ordinarily this is a warm and hunid period highly conducive to cane growth.

??___

2/ Sugarcane ?ripening? (gucroae accunslation)

Fepression induced cithsr by chenicals or vy

) is directly dependent upon grovth

natural mean:

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Irrigation was increased during the unexpected dry spell but this may not have

compensated completely for the reduced rainfall.

©, FIELD-SCALE sTuDrES

1, Minimum Irrigation of NK Hybrids; Lajas Substation

?The Northrup King hybrids Sordan TOA, Sordan 77, and NK 326 were exenined

vith minisua irrigation in small field-scale plots ranging from 1.8 to 3.6 acres

in area, Both Sordan 77 and NK 326 have shown considerable tolerance to

simulated arid conditions in conparisons vith Sordan 70A (2, 19). Both Sordan

7OA and Sordan 77 respond to high water supply.

Each variety was planted at the rate of 60 pounds of seed/act.

The

seedbed received 100 pounds/acre of elenental H, 50 pounds of P;0,, and 50

Pounds of K,0, broadcast and disced in just prior to planting. Two acre inches of water were a

inistered by overhead sprinklers imediately after seeding.

?The experiment was planted on Decenber 20, at the onset of Puerto Rico's dry season, vhen irrigation is needed to assure rapid germination and seedling establishment. No further irrigations were adainistered. During the subsequent 10 weeks an additional 2.75 inches vere received as rainfall. The approximately 4.75 acre inches total received between planting and harvest amounts to about 40 Percent of the water requirenent for maxisun yield of Sordan 70A and Sordan 77.

At 10 weeks the three varieties vere moved with a rotary scythe-condi-tioner, solar dried to 15 percent moisture, raked, and compacted vith a bulk baler producing 1000-to 1200-pound round bales, All equipment itens performed designed without problens. Positive results from this experiment include the

following: (a) Sordan 77 was verified as a superior short-rotation candidate

(

}¢ 27); (b) an appreciable yield potential was denonstrated for Sordan 77

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=e

(2.23 dry tons/acre

and (c), the yield potential vas denonstrated under condi

tions generally unfavorable for grouth, fe, with a short grovth interval (10

weeks), during the least favorable season (late Decenber to early March), and with

4 low water input.

Cost and energy-balance anslyses for this experinent have not been com

pleted. It is possible that the savings in water expenditures (about 7 acre

inches) will not compensate for the reduced yield (in the order of 1.8 dry tons/

acre). A decisive factor here ie the relatively high fertilizer expenditure with

an inadequate noisture supply for optinal nutrient utilization.

Mineral §

100 pounds/acre/10 weeks, is by far the most costly and energy consumptive input of the study. It is possible that superior cost and enersy figures would have energed if water had been given at norsal rates and fertilizer rather than water had been lovered to 40 percent of normal. Experiments are planned in vhich the effectiveness of low vater x lov fertilizer and norsal water x low fertilizer

regines will be examined.

2. Mechanization Trials; Napier Grass Planting

Napier grass planting is traditionally a hand-Lebor operation in Fuerto Rico. The seedbed and rov furrows are sonetines prepared mechanically, but the ?seed stexs themselves are carried manually into the field and dropped into the furrovs. They are then cut into two-eye or three-eye segments by laborers walking along the furrows with eachetes. The seed pieces are covered with soil ?as a final manual operation. This process is very costly. An added cost to the arover is the lose of viability of napier grass seed stent which often stand in open piles in the sun for several days while the hand operations are underway. Wovever, since napier grass is usually planted on small lowland acreages or

uplands too steep for machinery, no attempt wi

made to develop a planter for

this purpose.

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During the third quarter approximately eight acres of napier grass were planted for future mechanized-harvest trials. A two-row sugarcane planter wa rented froa the PR Sugar Corporation in an effort to reduce planting costs

land to speed up seeding operations. Two napier grass varieties vere planted having different age and stem condition at the tine of cutting for seed. The rapier grass stem is considerably thinner and Lighter than sugarcane and has 2 greater adhcrance of dead leaves. There is also a greater tendency for the rapier grass stem to bear lateral shoots and roots, and to be excessively curved, especially if the selected seed steas are overaged and have lodged prior to

cutting. . None of these factors prevented the sugarcane planter from perforsing

quite effectively with napier gr

A few steas were discarded oving to

excessive curvature but this is necessary for sugarcane algo. The stens vere

laid etraighter and the seeded furrovs were covered with soil wore evenly than

is possible by hand labor. This implesent automatically cuts the stens into

billets as part of the seed placement process. Sone damage to seed ?eyes"occurs.

On the whole, both the planting operation with this implenent and the

subsequent seed germination were quite satisfactory. The only problens vith

femmination could be traced to overage seed, or, very rarely, to "skipped"

?areas in the row where there had been sone delay in feeding steas into the

planter. By reference to our previous napier grass planting (6 acres seeded by hand) planting cost was reduced by 82 percent and planting time by about 65

3. Rotary Scythe And Round Baler Trists

Tuo harve

implenents are of special interest to this project, These are
the rotary-scythe conditioner and the round baler, They are viewed as potential

answers to the harvest and post-harvest management of tropical grasses having,

---Page Break---

standing tonnages at harvest far in exess of conventional forage grasses, but
sovewahat lover tonnages than sugarcane, Initial trials performed on mature
Johnson grass and 6-to LMeweeks old Sordan 7OA were described in a previous
report (2). These tests posed no problens of any kind, even in heavily lodged
and natted Sordan 70k, Solar drying, raking, and baling operations also were
perforned without incident, More recent trials with Sordan 70A, Sordan 77,
?and 8K 326 were also successful (p. 16). Hovever, the actual tonnages in these

tests did not exceed about 14 standing tons/acre.

(a) Napier Grass; Three Months: Napier grass vas submitted to sechanized

harvest and forage-naking oporations for the first time during the third quarter.

(var.

Approxinately four acres of Senonths old napier er er) vere mowed with the HAC rotary scythe conditioner. This naterial vas solar-dried and baled With the Ney Holland Yodel 851 round baler. At 3 months of age, the total biomass confronting harvest sachinery was only slightly greater than chat of equally-aged Sordan and there were fever steas/acre. The primary difference lay in the much thicker ond more succulent stems of napier grass. These offer a sovevhat different and possibly nore difficult task for the sten-shattering or

"conditioning" propertios of the rotary scythe. The solar drying taske are

definitely nore difficult oving to the greater thickness of napier gras atens 2/, Raking and baling operations are also complicated co some extent by the relative coarseness of the dried material.

ALL of the harve

f and post-harvest operations were performed successfully,

but they required sonowhat more drying time and machinery work tine than short=

A/ Te has been suggested that the best way to renove water from napier grass font might be to grind thea ina sugarcane mill and then solar dry the napicr grass "bagasse" (20).

---Page Break---

rotation species such as Sordan and Johnson grass. Moving heights vere varied from 2 to 8 inches. No cromm injury was evident at the lover stubble height, bur inch stubbie posed some difficulty for the forage Fake. An additional day was required for solar drying. Occasional sten billets could still be found that vere pliable (containing 25 to 30 percent moisture) rather then brittle (containing 14 to 16 percent moisture) Round bales were produced without

4ifticulty. These vere coneshat rougher in app

srance than Sordan bales owing

to protruding stes segments.

(b) Hopicr Grass; Six ?onthe: The ultinate eest of the rotary scythe= conditioner is encountered with 6-nonths old napier grass, Such naterial is in an advanced state of eaturity with dry satter content approaching 3 percent. Stems appear nore woody than herbaceous and are succulent only in the upper canopy area. Standing bionass is in the order of 30 to 40 tons/acre. Stands of grasses having greater mass than this would be approsehed with a sugarcane harvester ratier than forage-naking equipment.

The first trials of the ¥-C rotary scythe on G-nonths old napier grass

vere performed in mid-March of 1980. The varieties Como!

Merker and P1_7350

were harvested at two stubble lieights and tuo tractor spocds (Table 26). The

jamcinun engine speed vas approxinately 1900 rpa for all tests.

Because the M-C rotary scythe was designed to harvest forage crops that are orphologically different from napier grass and harvested at less advanced stages of maturity, several discrete kinds of problens vere anticipated for thie implement when operating in mature napicr grass. Any one of these could eliminate the rotary seythe as a candidate harvester if it could not be corrected by adjusting the implement, by modifying the inplenent's design, or hy noditying ite mode of operation by options availeble to the tractor driver. Anticipated

Problen areas included the following:

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(2) An excessive height of napier grass, in the order of 9 to 12

feet, 28 opposed to a naxisus of 2 to 4 feet fer conventional forage

crops. Since the "cut" grasses mast first fai} forward and thea be araum backward beneath the inplenent to be conditioned, the taller

napiet grass could not have been harvested had it fallen backward on

to the upper surface of the rotary scythe. In the actual tests chere

vas no tendency for any naterial to drop backuard on the inplenent's

surface. The leading edge of the rotary scythe strikes the napier

grass steno with sufficient force to push then foreard, even when

operating at the lovest cutting height. Moreover, the elongated stens

were forced forvard suifictently far into the standing grass to enable

thea to be dram back with ease beneath the rotary scythe. There was no

ppreciable realignzent of the stens, that is, no turning at right

angles to th

path of the inplesent, vhich could tead to bunching of

th

stens and clogging of the rotary scythe blades.

(2) An Excessive sass of the napier grass, anounting to approxizately

30 to 40 standing green tons/acre, as opposed to about 10 to 12 green tons/

acre for a typical forage crop. Tt vas thought that the additional sass confronting tho inplenont might cause ite blades to becons clogged with bunched material; alternatively, such material could effect a continval breaking of shear pins. The latter are incorporated into the inplenent's design and are intended to shear off when overloaded to prevent more

serious damage, Duting the precent tests there was no clogging oF breaking of shear pins.

The implenent's performance was generally ragged and unsatisfactory

hen the tractor was operated in second gear. There wos a tendency for

---Page Break---

the rotary scythe to pass over or only partially condition a seall Percentage of the stens. This was corrected by shifting to low gear

and increasing the tractor's engine speed. While outwardly sloving

the harvest process, ic, the visible movenent of harvest aachinery across the field, the decisive factor is the quantity of biomass being harvested per unit of tine, In 6-nonths old napier grass the rotary seythe was conditioning biosass at full capacity vhen operated in the tractor's low gear.

(3) Inadequa:

?tens. Under normal circusstances the retary scythe ?bonditions"

Ee conditioning of the relatively woody napier grass

forage crops that are relatively ismature, succulent, and easily disintegrated, The forage plant is shattered by repeated striking of

the blades at distances of 4 to 6 inch

?along the stem. This greatly

enhances the solar drying of such naterials vhile e ing the windroving

fand baling operations. Stens of G-nonths old napier grass were quite

effectively conditioned by the rotary scythe. Solar drying procesded

normally, Approximately one additional day w

needed to attain 152

soisture (four days for napier grass as opposed to three days for Sordan) «

Increased drying tine vas mainly a function of the greater sten thickness

and total mass of material per acre for napier grass

(@) Inadequate preparation for raking and baling operations.

Mature nopier grass plants are 3 to 4 meters long with stens up to 3

centineters in diazeter. In order to manage such gaterial as solar=

aried forages, it is necessary not only to shatter the etens but also

to reduce then to shortened, pliable segments that can be raked into

windrows and fed successfully into balers for compaction (rectangular

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= 23

for cube bales) or organization into round bales. In the pri

trials these requirements were net very effectively.

In practice, the rotary scythe completely disintegrated those steas offering the greatest resistance to the rotating blades. In circusstances vhere shattering was incomplete (lodged plants, ?excessively heavy stands), the stens vere rendered flexible by partial shattering plus conplete severing at fairly frequent inter vals. Only rarely could one find a stem seguent exceeding 40 to 45 centimeters in length, The longer plant segnents that reaained intact?both tops and stens?ordinsrily hore severe bruises from repeated striking by the rotary scythe blades. These were sufficiently pliable to pass through the subsequent raking and baling operations

without difficulty.

(c) Kaking And Baling; 6-Yonth Kapier Grass: The very excellent performance by the rotary scythe-conditioner enabled us to solar-dry, Fake, and bale mature napier grass which othervise would have been completely un~ wnanageable vith existing forage-making equipnent. Problens which did? arise

related mainly to the excessive mass of material to

managed per unit of vorking

?area, To sone extent these problens were alleviated by operating the tractor in low gear with increased engine speed.

The rake used in these trials is a "heavy-duty" model but one designed for conventional forage crops offering a maximin of shout 5 dry tons/acre, At normal

raking speed (in second gear) the i

plement tended to slip over a significant

fraction of bionacs being raked for the first tine. This wus corrected by

slowing the tractor to low gear and increasing engine speed, by partially

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raising the rake vhen laboring in heavy material, and by reraking the skipped areas. After the windrows had been formed there vere no further difficulties

dn raking, fe, vhen turning the windrovs over a second or third tine.

Avsore serious problem was the frequent breaking of the rake's tines as they snagged against the napier grass eros. This vas especially true of high stubble (8 to 10 inches) but occurred in low stubble (1 to 2 inches) as vell. The crown of a mature napier grass plant offers considerable resistnce, more Like the stunp of @ sapling tree than a conventional forage grass. Although tines are easily replaces, the rate of breakage on napier grass stubble was prohibitive.

Moreover, @ significant quantity of bionass lying flattened between the stubble

Fenained unraked.

Ut is believed that the problens of tine breakage and unraked material can

be elininated by use of a different type of implement, one commonly described

"ehee!

rake, This rake is not driven by @ power take-off but rather

operates through contact of its tines vith the ground surface. The tines are

mounted on a

fries of independent vheels which offer greater flexibility for

Penetration of @ heavily-stubbled surface. Plans have been nade to test a

Farahand sodel wheel rake vith solar-dried napier gracs and sugarcane trash during the project's fourth year.

Baling trials on the 6-nonth old rapier grass with a New Holland round baler Proceeded normally. Although the napier grass stens vere far heavier than Sordan or conventional forage grasses, they were sufficiently broken up and veak- ?ened by the rotary scythe to be organized into round bales without difficulty.

?As vas the case with the rotary scythe and rake, it was necessary to operate the

baler in low gear owing to the very large mass of vindroved napier gr:

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4, Direct Firing Of Napier Grass

The first direct coabustion tests for the solar-dried tropical grasses

of this project were performed by PR Sugar Corporation engineers during late January of 1980. At the onset of a new canpaiga, sugar mill engineéra need to ignite their fornaces to raise stean and process heat before the first harvested

cane arrives at the mill, For this purpose alnost any combustible uaterial ie

wsed?old luster, discarded railroad ties, wood scraps and refuse of varying

description. Mill vorkers at Central Gi

?ica, located about 10 miles fron the

Project's Lajas Valley site, learsed of the bionass bales accumulating there and

received authorization to use some of these for start-up fuel. Sone 50 bales of

solar-dried napier grass vere obtained for this purpese. Although no formal data

were gathered, the engineers wore highly pleased with the conbustion performance

?and handling properties of this material. No fuel o{1 was needed to assist

ue

ignition as is the case with bagasse 2/, This vas the first instance vhen the

Proj:

t's experinental tropical grasses vere actually used as fuel.

D. BREEDING

In Puerto Rico sugarcane breeding is performed froa mid-Novenber to mid=

Decenber, Crosses coupleted during Novenber of 1979 are summarized in Table 29.

Each of the five tabulated crosses was performed by tie. T. L. Chu in conjunction

with the AES-UPR sugarcane breeding program. All were performed vith biouass

rather than sucrose as the primary objective. One cross, B 70-701 x ST-NG-54,

has a high probability of producing offspring with a predominantly high-fiber

attribute (16), The ronaining crosses could produce seedlings vith both high

fiber and high fermentable solids attributes (Table 29).

J Central Guinica ordinarily aéés 4 gallons of residual fuel oil to each ton

f

)

?f bagasse (about 512 noisture) to promote conbust ion.

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?Three subsequent crosses vere made in December using an early-flovering

+ Spontancus hybrid as the male parent. This is an extremely vigorous clone

found in the wild near Rio Piedras. Its early tasseling habit has been overcome

to a Limited degree by cutting back wild stands during the late spring. This

forces the ratoon plants to pass their normal floral induction period in the

Juvenile etate, and t0 enter the adult (reproductive) phase in a later tine~

frane wore consistent with potential crossing partners.

Three comercial Puerto Rico sugarcanes served as the fenale parents,

including PR 960, PR 67-1070, and PK 64-1618 (Table 30), Nearly 1000 sedi.

Were obtained from the crosses with PR 980 and PR 67-1070. Only about 20 cecd=

Lings were produced by the cross with PR 64-1618. At this writing none of th

Progeny appear to resemble the male parent. Sufficient material is available to

begin evaluating the transm:

ion of a high-fiber attribute to hybrid progeny (16).

B, ECONOMIC STUDIES

1

For Enerty Cane Production

Prelininary cost analyses for energy cane production were performed on the

basis of first-ratoon yields. A breakdown of production input charges is

Presented in Table 31. These figures pertain to a family-owned, 200 acre opera

tion yielding 33 ov:

ity tons of biomass per acre year. The mont expensive

?equipnent items, @ whole-cane harvester and lov-bed truck, would be hired from

the P.R. Sugar Corporation together with the equipment operators. In an energy=

cane industry such ivens would probably be family omned, in which case the

operation and maintenance costs vould be appreciably lover. Both water and

fertilizer charges are entered moderately higher than project data actually

indicate, mainly oving to potentially large consumption differences as varietal

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?and ecological Life zone factors. Total costs, including delivery to the

milling site, anount to $25.46 per oven-éry ton, or about $1.70 per million BIUs.

By vay of reference Puerto Rico is presently paying about $4.30 per million BTUs

in the form of petroleun toiler fuels.

Im an energy cane scenario about 68 percent of this dry matter would be

burned as boiler fuel. The renainder would be extracted es fermentable solids

during the cane devatoring process and later sold as constituents of high-test

nol

es. Neither ray sugar nor refined

Jar sales are antfeipated. Cane

milling costs in Puerto Rico today are presently about $5.00 per ton, The ferment~ able solids from one acre of eneruy cane (ie, with yields of 33 0D tons/acre), ?would be valued at $1,500 t0 2,000 dollars if marketed today as high-test molasses. The Puerto Rican emphasis on molasses rather than boiler fuel is quite real and probably justified. Rum is one of Puerto Rico's leading sources of revenue,

yet hier molasses feedstocks are increasingly derived from foreign supplier.

Puerto Rico was one of the world's najor molasses exporters in 1934 (21) but has declined to an 88% dependency on imported eolasses in 1979 (22). Because of this, local interest in the energy cane herein described is directed mainly tovard its

polasses yield potential rather than its role as a renevable domestic boiler fuel.

2. Gost Conparisons; Energy Cane vs Conventional Sugarcane

Production cost estimates for conventional PR sugcrcene vere conputed during the third quarter for direct comparison with energy cane eatinates (Table 32).

Sugarcane cost estimates are based on data obtained from Central Aguirre for the 1979 milling season. They probably constitute a "best case" for production opera

Hons in the PR sugar industry as a hole, As indicated in Table 32, production

costs for energy cane are higher than sugarcane in five areas

Seedbed preparation,

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reed, fertilizer, harvest operations, and delivery of harvested cane, Energy cane seed and fertilizer expenditures vere double those of conventional sugarcane. Marvest operations and cane delivery expensea were 67 percent higher, and ceedbed Preparation costs were 50 percent higher. Tt should be noted also that the ?sugarcane cost estinates pertain to a private planter (or "Colono") for whom the sajor machinery itens are rented rather than self-owed.

The overall cost for producing a ton of energy cane was 4b percent higher ?than conventional sugarcane. However, the decisive difference between the tvo ?managenent scenarios lay in the total dry matter yield per acre year (Table 32). Energy cane yield exceeded sugarcane by a factor of about 3.7. Hence, th Increased cost of ?pushing? sugarcane, ie, to maxinize tocal bionass rather than sucrose, was nore than compensated by even larger increases in dry matter yield.

?As a result of its relatively lov productivity the PR sugar industry cane cost

in the order of $65.00/0D ton, oF about $4.31/nillion BTUs.

F. ENERGY BALANCES

The final energy balance figures for energy cane will be based on sean Production yields from a 3-year cropping cycle. Preliminary analyses vere Performed during the third quarter using the firet-ratoon crop weans for varieties FR 980, NCo 310, and PR 64-1791. These varieties averaged 33 0D tons/acre yesr for the first-ratoon erop. Energy input estimates for thie material are sum marized in Table 33 /,

Total energy inputs for energy cane production are in the order of 28 x 108

Brv/acre year. Energy output anounts to 279 x 106 BTU/acte year (Table 34).

A/ Entinates prepared by Dr. Levis Saith, Consulting Economist, CEER-UPR Bionass Energy Progran.

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?The latter figure is conputed on the assumption that most of the fermentable solids fraction of the total dry matter yield will be extracted at the sugar

mill, The extracted fermentable solids anount to about 640 1bs/0D ton of enersy cane. This

igure 8 based on a recorded nean Brix value of 33.1" for enctey
cane juice and an assumed 80% extraction at the mill. tn this instonce only
1360 pounds of dry matter/0D ton, or 22.4 tons/aere, will be used as boiler fuel.
On a steam recovery basis, assuming 85% efficiency for « utility bofler, an
?energy output/input ratio of 9.95/1 is obtained (Table 34),

Sone authors have simply diviged the total calorific value of their samuel
00 product by the total production energy input (23). By thie method energy cane
would have an energy output/input ratio of about 7.7/1.

ie i

instructive to note that nearly half of the total energy expenditure
vas for cineral N alone (Table 33). Mence, while the faverable enecgy balence
obtained to date is mainly a reflection of high DM yield, future inprovenent of
this balance can be gained both by increasing yields and by reducing the input
of mineral N. One means of lovering N input is to apply the elenent as a soluble
component of the irrigation water, particularly water applied via txickle ireiyas

tion (20). The increased efficiency of lover N supplies should compensate for the

relatively inefficient plant v.

wee of dry fertilizer adsinistered in larger

faeounts to the soil surface. Another potential means of lowering mineral

expenditures ie through increased usage of N-fixing legumes in conjunction with

bionass energy crops. A large musber of underutilized tropical legunes have been

identified for possible use in this context (24, 25).

SUMMARY OF THIRD-YEAR STATUS

?At the close of its third year the project has progressed to the approximate

pone envisaged for year 3 in the original S-year vork plan. There have been a

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series of developments more favorable than expected, and one unforeseen

developnent that hae required sone linited woJification of the project's work

plan.

Bionass researchers working with tropical grasses in a tropical climate

have nany factors working in their favor. Nonetheless, oxceptionslly favorable

trends enurged for us in three distinct areas. First, the botanfcal attributes

of candidate tropical grasses conformed more faverably than expected with

domestic energy resource requirouents. Te was possible to develop short-to long~

Fotation categories of grasses that would supply large quantities of biomes,

on a year-round basis,

@ solarcdriud state that minimized dewatering and

transportation costs. Second, the project's agricultural engineering phases were

erormously eased by prior developnents in forage-naking machinery. A very appreciable vork-load renains in our field evaluations of the rotary scythe, the

bulk baler, and heavy-duty wheel rake: however, it is already evident

J these

machines «

Perform in the relatively massive biomass scenarios imposed by

tropical grosses. If any one of them had failed to accommodate such materials

4 large engineering gap would have renained in tropical grass fuels technolosy.
The third development favoring this project is a highly positive trend in produce
Slon-cost and enery-balance data, The project's staif feels that considerably
better data will emerge vith inproved yields and refined production operations
during the final phase of the project.

One important concept has not developed as planned. The original plan to
manage hybrid sugarcane as tropical forages had failed to perceive clearly the
Pime-span needed for a long-rotation species to maximize tonnage. Hence, the
Fepeated harvests at 2-and 4-nonth intervals were highly detrimental to dry
matter yield, They sinply underscored the need to allow augarcane at least @

year to couplete its growth and maturation phases. Alternatively, it was found

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that short.

ind Intermediate-rotation species, such as Sordan and napicr grass, could fi11 the role originally planned for sugarcane. They have responded vel to the repeated harvest, solar-drying, and bulk-baLing operations for which sugar~ cane is completely unsuited. Noreover, these grasses can be stored for off-

Season wse whon sugarcane is not being harvested. By this means a continuous

Year-round fuels supply is provided in a convenient wix of bagasse and tropical

sracses.

W. REVISED WORK PLAX FOR YEAR FoUR

The fourth-year vork plan conforss basically vith ?evolutionary? changes Projected at the onset of the project. Accordingly, the following changes of ewplasis are planned for year 4: (a) A reduced level of candidate screening; () reduced greenhouse-phase studies in general: (c) increased enphaais on field= scale studies; (d) increased work on mechanized harvest and post-harvest technol- epies; and (©), expanded work on produstion-cost and energy-balance analyses.

Field-plot studies for the first three years have concentrated on hybrid ?eugarcanes and napier grass. Particular attention was given to varieties, row spacing, harvest frequency, and fertilization. In year 4 this enphadis vill be redirected tovard a "second generation" of sugarcane varietics specially selected for their high-bionass yielding attributes. Row spacing, together with frequent Fcharvesting, is being dropped as a controlled variable for sugarcane. Nitrogen variables plus 6-and 12-month harvest intervals will be retained. A" gran cultura" cropping interval (16 to 18 wonths between harvests) will be incorporated for the firse tine,

A second generation study on sugareane for biomass (depicted as "energy cane" by the project staff)

being plonted at the AES-UPR Lajan Substetion during the firae quarter of year 4. apier grave etvdies are being shifted to

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the {ield~scale phase. Special exphasis will be directed tovard the mechanized harvest, storage, and transport of G-nonth old material, Post-harvest handling land storage operations for bulk bales (1000 to 1500 1b. round bales) will be studiedin 2 roofed storage facility presently being constructed for chis purpose. ?This phase includes the evaluation of storage behavior for grasses baled at

varying stages of solar drying.

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DRY MATTER (g/Plant)

rions 2.

?oeciaa) propagated te 2

by Sordan Ton and E396 (Oath short-rotation

ietachasa ainture with adequtte

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oomtay® eaname ian

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~~

TABLE 1, RESEARCH PHASES FOR BIOMASS PRODUCTION

STUDIES WITH TROPICAL GaASSES

Research Phase Class of Objectives

Greenhouse Physiological~Botanical

Field Plot Botanical Agronomic

Field Scale ?Agronomic-Econosic

Commercial-tndustrial Economic

ees

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~-

TABLE 2. CATEGORIES OF CANDIDATE TROPICAL GRASSES

cropping Groveh Interval 2/ ow Maximus 2/

Category ?(onths) (oaths)

Short Rotation +6 a3

Internediate Rotation 8-18 6

?Long Rotation 36-60 12-18

Miniaun Tillage Indeterminate a

vy

2

Replanting frequency; at least two ratoon crops are anticipated.

Tine required physiologically to maximize dry matter.

---Page Break---

?UOLE 3. ORY MATTER PRODUCTION BY EIGHT CANDIDATE TROPICAL GRASSES HARVESTED

2, 4, AMD 6 MOWTNS AFTER LASTING 1/

ren ee

I ceartsces Aca) Ya woh =

Gutcivar can 6 Species 2 : ?

m0 fecune word 0. tay anaes

ws ame ww miie koe ete

vs ras0 mest Wire onda

se a & mines Lot eae

sn ume wacte tare nas ase

waa Emm mst ee nary inate

some namin surutt 3.038 aT

stato cre fart alee oka ne

ee

ete

1M propagaced in a 1:1 solt-cachasa aixture vith adeqace water wwly,

2 appronina tety 30 aguare feet.

Y naan values in the sane column bearing velite letters ditt

(7 05)." Values bearing at least ove Leteet ia comme

stgnitieanehy.

gniticancty

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TABLE 6. ORY HATTER CONTENT OF EIGHT CANDTOATE TROPICAL GRASSES HARVESTED

AT 2, 4,

280 B HOTMS AFTER PLANTING 17

Di CB) At Month ?

cultivar Genus & Specter z * .

Mean

7 980 Sacchanas Wybeid wre 2.68 B56 ne

5 67-22-2 apne. hybrid ante se oad Bo

Ws 72-70. apone. Hybrid wos 2 wd Pag

ses 2 5 soontanew 04 32.008 4.6 be 2.9

?aisan 5. spans. tybrid Mbbe a ote 2.0

was S apone. tybese 92 ad 25.6 v3

Pr 3008 Pennisatus purpurem = hdc Shae. 26.3

mae ade ane

eas 7a

#1 gol-cachasa abxture with adequate water supply.

(P£.65)." Values bearing at lease one Letter in common do net differ significantly.

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-ae

TUBLE 5, DRY MATTER PRODUCTION. INDIVIDUAL PLOT BASIS, BY EIGHT TROPICAL

GRASSES KANVESTED 2, 4, AND 6 MONTHS AFTER FLAMING 1/

Bi Gg/Piace) AL Month ?

cutiver Genus & Species z + ?

PR 980 Saccharus Hybrid 60.8 be

5 67-22 §. spone. ybria So. ca

0s 72-70 5. sponte. wybrid Weee

ses 231 S. spostanem aot

Tafsan Ss apne. wybria 19.2 of

wag 5. apone. tybria 29s Weed 5.70

Pr 30086 Pennisetum purpura 8.0 8 95.84

Johnson Grass Sorghun halepense 4.28 oad

Meas 38 0.2 a

?© vropagated in 4 1:1 soti-cachasa sinture with adequate water supply.

Y wean values io the sane coluan bearing valike letters difter signiticancly

(F <:05)." Values bearing at Least one Letter in comon do not dither

sigaiticancly.

---Page Break---

ou wees

---Page Break---

TABLE 7. DRT MATTER PRODUCTION BY EIOET CANDIDATE THOPICAL GRASSES.

Oven A Tova~counse OF 10 MEEKS

DM Mista (ig/Piot) Mae week ?

piety « @ 10 Mean

Sodan 77 os Oss OTL 0.32

Truden 5 00 Osea 0.32

Dena F5-4 oie es ze 850

Detalb F5-25 « + oie alse O80 ost

Beka st-6 os OSs ge O54

Dekalb ste + 033053 otra 0:53

Dekalb st-le a e328) lan 052

Dekalb stirs oly Osh ko 0.34

eas 00 Osh Oe

Dekalb F525 a +

Dekalb s1-6

Desaib Si-8 +

Dekalb St-i6 a

Dekalb Sk-17 +

Men

Dekalb st-s +

Deualb st-l6 3

Dekalb S?-17 +

A Approxinately 1/200 acre,

---Page Break---

-us-

TABLE 8. GRY MATTER PRODUCTION SY EICIT CANDIDATE TROPICAL GRASSES PROPAGATED

itu VARIABLE MOISTURE REGIMES OVER A ThAe-cOURSE OF Il WEERS

m (Ke/Pice) 1 ac week ?

Motature

egine, variety 1 ° u Mean

oT te

ante Sorgen 77 38 1

Tradae 5 a So

Dealb 5-4 fa Sa

Delalb #525 a + et

Dekalb §1-6 3609

Deealb Si-e + ss lag

Delalb Sk-16 a 8S

Delalb st-17 + oie :

Nene ?oo a E

?_?S]7

Normal sorden 77 re sr

Trudan 5. eG 56

Detalb #5-4 Se it Se

Dekarb rs-25a+ lege

Devalb S1-6 to er

Dewalb sts + be

Smi-aeis?Sordan 77 2 ae mn 238

rodaa 5) 30 te ?6 Be

Dealb F5-< cho ae Sto

Deiatb P2541 te te

Desale ste Bee 3

Detalb stot Ss fo

Dekalb Stale a eS nto

Dekalb Stal? + ee 8 ie

?a a

Mean Ey :

ee

LU Approxiaately 1/200 acre.

---Page Break---

{SLE 9, DRY MATTER CONTENT OF EIGHT CANDIDATE TROPICAL GLASSES FADPAGATEO

[WITW VARIABLE WOTSTURE REGIMES OVER A TIME-COURSE OF 11 WEEKS

woistore Bi (&) AT Week =

Regine Variery 7 ° in Mess

and Soréen 77 16.5 2.6

Traden 5 Ms 26

Dekalb 5-4 8 Ba

Dekalb F5-25a¢ 1213 a

Dekalb st-8 1 Bi

Detalb si-8 + ue nis

Desalb si-l6 «| Be 23

Dekalb Stl) + a6 Be

ee

Mean ma 25.2

Noraal 16.0 as

iso 28

2s BS

Be 32

Be Sse

2 bie

Detalb Si-16 a BS jo

Dawaib star + be Bi

?Sae ees

Mean a 2

ec es Ty

SemtcArid?Sordan 77 3 saa 23

Trodan 5) wg 235

Dekalb F< i390? e Bs

Dekalb P5254 © 12 gs de rd

Detalb ste 2203s Ba

Deals ste + 2 RB ao

Delalb St-16 pi ws Ba 2033

Detalb Stl? > m7 ela 8

a

Mean 6 a 2S

as

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-a-

TUBLE 10. DRY MATTER PRODUCTION BY JOHNSON GRASS PROPAGATED WITH

VARIABLE NITRATE SUPPLY 18 SAND CULTURE

Dm (g/Piant) Ac week YM

?aah 7 «6 ww eae,

a met oe ine ise 0.99

3 Abe Le 1908 278 ase

° Sa Lee 68a sae 25s

» a 192 aoe 5.68 ay 2a

se Tab 20360 6S 3.38

os ?Tab 2.2008 3.38457 29

?

4 nutrient treamente vere iniciac

?The initial arvest

Plaace vere four weeks of a4

vies seedlings vere tvo weeks of

taken tuo weeks thereafter, Sey vhen the

Y ean values in the same colunn bearing unlike Letters differ aignif-

icantly (e.03). Values bearing at least one Letter in coust

After aigoiiicanely

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{UGBE LL, DRY MATTER CONTENT (2) OF JOHNSON CRASS PROPACATED WITH

VARIABLE NITRATE. SUPPLY 18 SAND CULTURE

DM (3) Ae Week ~

Wo, tever | GD A aa

deg) z * ? 20 Mean

2 wre! wie 2.50 Mae 2.9

2 Bsa ee 24 He na

. Woe 15.58 84 20.68 v9

2 120 be Wo be 18.38 25.78 coy

Ps Be ae mre Ib wa

a Be abe mse MA 16.

Mes SSS

v

© wean valuas in che sane coluns bearing unlike letters differ

significantly (P<.05). Values bearing a least one Letter in com

ston do nor differ eigaiticantly.

---Page Break---

"Gita tanta atvenie Sober iif crue 17

Foliar Content (¢ Dey We.) For ~

cada/t) ¥ ? ©

1.07 0.25,

> 1a 0.23

> Ls 0.28 230

a 2a 0.29 237

o 2a 0.27 23?

a aay 0.25 233

wens Ln 26 2st

Y aneive blades of Leaf tanke 1 § 2, harventad at veek 10 of varia

mo trestaente,

2 ant Figures are the computed means of three replicates.

---Page Break---

TUMLE 13. POST-KURVEST RECROATH AY JONNSON CRASS PLANTS PROPAGATED|

Mini VARIABLE NITRATE SUPPLY TW SAID CULTUAE

s/Mant for ?

Teles) shots/miot__ireen Wty Dry We. ro

5 28 ama aa

2 wa wks ba

. a m0 a ae

» ws was wa

? ne wie 2 on

8 1 m2 30.7 ma

1 nacut four veeks after cernnation of the variable NO, ereatuents,

?aar'Figucee ace the Conpced beats of three replicate,

---Page Break---

sae

TUSLE 16, DRY MATTER PRODUCTION BY CAIDTDATE §. SPORTANELY AND §. SINENSE

(Lowes GIVEN MINIM TILLAGE FOR Si MONTIS 17

Mieta/Pioe (Ka) For ?

Species Clone Green Matter Dry Mateer zm

Sacchane Wybrid PR 980 ast 240 28.2

S. sioease aretha 1s 2.

Ghunnee aoe bs

fatal Ube 3.08 22

Talnen oer 385

. sponeanom ses 2 94.08 wa 36.3

sts 317 a3 a8

ses 327 18.82 6.62 333

Us 67=22-2 t3on wet io

Us 67-34-24 wae 5.62 26

us 72097 we 24:00 mn

0S 72-70 2/ (CLoeoaptece paza)

bs 72272 37 3.20 12.38 as

De Tee 2s kas 14.88 at

---Page Break---

?TABLE 15. BIONASS PRODUCTION BY FIVE SACCHAREM CLONES UNDER MINDEN

TIUAGE CONDITIONS; AUG, 1, 1979-488. 11, 1980 1/

SMonehe Yield (tona/Acre)

clone Green Matter Dry Matter zm

me 980 aaa 0.9 2.0

vs 67-2202 0.86 waa

us 7272 136 sa

vs 72-93 1.65 0.19 6

S. spoat. tybria sas 0.96 so.

4 rourth, G-month harvest. Originally planted during February, 1997.

---Page Break---

- se

UBLE 16, BIQUASS PRODUCTION BY THE SUCOND RATOON CROP OF THREE

SUCARCAME VARIETIES AND ONE NAPTER GRASS VARIETY PAO?

?care WIT VARIABLE" BOW CENTERS; FIRST 2-AOHTH HARVEST

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

culesvar iso 50 7 change

Px 980 owe! othe 6.3

Seo 310 reas S928 tied

Pe eei7a ie oisk oat

50 on se

Mapier Crane 22.08 « 12.78 4 5

Dry Macter (Tous/Acre)

mm 980 one! owe 9.0

eo 310 ola 8 Ose ans

Pr eini791 tke ole SSo'0

Napier Crass napa 2.04 a 9.0

Dry Matter Content (2)

Bae 14.3 ab 73

12 a 102 ob °

iiss wa ab a43

13.5 a 16.0.4 32

2/ Maan vaiues bearing unlike Letcers differ signtficmely (P4 .05)

those bearing at least ove letter in common do aot differ signiticaniy.

---Page Break---

TABLE 17, BIOMASS PRODUCTION BY THE SECOND RATOON CROP OF THREE

?SUGARCANE VARIETIES AND ONE NAPIER CRASS VARLETY PROP-

ACATED ITH VARLASLE BOW CENTERS; SECOND 2-MONTH KARVEST

Screen Matter (Ton/A), At Row Center ?

cutetvar Toe oe Change

380 ost a! a3

Sto'3i0 Xo e 25

Pr eini751 asa a cole

Pe

Sepier Grass 2.256 uo

Dey Matter (Tona/here)

mst 0.09

Sto 310 os b

me eeiz one

apie Grass par

Dry Matter Content (2)

580 Bae 13.8 ab 4.5

wee 30 15.0 a Bue aoe

meee. Kos won cad

sapter Craze 15.6 08 aoa aa

Af Maan values bearing unlike letters differ significantly (P-<.05)

?hoan bearing at least one letter in sowmon do'not differ significantly.

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TABLE 16. BIOMASS PRODUCTION BY THE SECOND RATOOK CROP OF THREE

SUCAREANE VARIETIES AXD OME NAPIER GRASS VARIETY PROP

?CATED WITH VARIABLE HOW CENTERS; THIRD 2-MONTH HARVEST

Green natter (Tons/A), At Rov Center ~

culesvar 150 es oe Chasse

PR 980 0.28 > Y 42.8

eo 310. Le 8. ?03

PR eran Perky ~28'9

Napier Grave tia = 3.8

Dey Matter (fona/A)

PR 980 0.08» 0.08 » 30.9

feo 310 oh9 orb iS

PR 6e-i791 0105 & 0105 & °

Napier Crass 1.48 @ aaa -67

1.0 = Tae

ae eo

Boe °

12.5 07

1 Mean valves bearing ualike Leteere difter significantly (P< 05)

?hose having at least one Letter in common do aot differ significantly.

---Page Break---

TABLE 19, BIOMASS PRODUCTION BY THE SEOORD RATOOK CROP OF THREE

SUGARCANE VARIETIES AND OME AAPIER GEASS VARIETY PROP?

[ACATED WETW VARIABLE ROW CENTERS; FOURTH 2-NORTH RARVEST

Grown Matter (Tone/A), At Row Center ?

PR 980 cage 0.32 04 654

eo 310 265 8 a & 9

Pe eei7e. 058 ee oat é mas

oe ee

Napier Crane 11.60 9 10.21 <9

Dry Mateer (Tone/Aera)

re 980 0.02 0.07 250.0

Seo" 310 oi on19 a4

PR e179 0.08 02 ote

Mapier crase 1.29 13s aan

Dry Matter Contest (2)

1m 980 119 be Be

co 310 130 a

me eeive1 ios =

Mapier Crass nize so

A Mean values bearing unlike letters 4i¢far significantly (P <.05)

?hose bearing at least one Letter in comon do aot differ sigeiticantly

---Page Break---

?UBLE 20, BIOWASS PRODUCTION St THE SECOND RATOON CROP OF THREE

SUGARCAXE VARIETIES 48D OSE NAPIER GRASS VARIETY PHOP-

GATED VITW VARIABLE ROW CEXTERS; FIFTH 2-AOTH HARVEST

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

cuteivar ioe Es 1 change

7 980 owe! ose = 38

e310 20k ? Tote 263.

meee oo 8 one i685.

om asco

Mapier crane 15.258 16.5 a

Dey Matter (Toas/Acee)

3 980 0.06 0.07 © 16.7

ee" 310 00 & ona 20:0

PR eei791 08 bos ¢ ?es

Kaytee Cease 23s nae °

ey matter (2)

ra 980 wre 20.8 a 68

Be 310 13.) ey Ee

reece 28 aes ao

epier Crase mae 14.5 & 23,

1 Mean valves bearing unlike Letters differ aigniticantly (P<.05)

?hose bearing at least ove letter in comon do not differ significantly.

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SS een

(roe toe , cx og mre

7 tiem

(ov scene ?

ony

° om nme &

iene a oF n Ter

TA RTT TT OS tee

?TIVO FIVIEVA 2¥ GRLSZAETE EEVED TALEWA QW ANOWOO J 400 MOLTE-GONE HAE Wd

BORNE GALI ERD 7 Fi

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_ (ot nee)

?rensaetoe oven et

ee (e200 sratane) ee swnig soraen

oo es seesteing nose 9

oct Coorg sieeoen)

crwg mimsemsen)

Sy ¥

[STVGNEINE TEVA BY GALSUNNWH SEVID LN caY ANOWONS GO JOE WOOIWE-GIODRS

BLL Wu EOTAIA GALIWN

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TABLE 23, BIOHASS PRODUCTION BY THE SECOND RATOOM CROP OF THREE

SUGARCANE VARIETIES 3 OME. NAPTER GRASS VARIETY PROF

[MCATED VETW VARIABLE ROW CENTERS; FIRST (MONTH BARVEST

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

cultivar 150 50 1 change

Px 980 wore! 1.9 6 13.0

eo 310 ay 20.9 3 ye

PR stel7a1 1513 be 35 ¢ ois

soem en

Napier crane nee zte = 6.3

PR 980

PR stet794

Napier crass

Dey Matter Contant (2)

7 980 18.6% 08

io 310 isis ro

Pe 6tei791 is9 8 °

Napier Crass a3.8 4 29

AY Mean valuen beariag unlike letters differ significantly (P <.08)

hose having at Ieast one letter in comon do not differ signiticanciy.

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SLE 24. BIOHASS PRODUCTION BY THE SECOND RATOOR CROP OF THREE

UGAGAREARLEEIES 0) nF MAP GRAS. TAREE PRO

Green Matcer (Tons/A), Ae Row Center ?

cutivar oe De E Gange

7 960 suse gare a5

Sto 310 rae 946 & 22

Pe sei791 Hs be cae aay

epics Grass

PR 950 Lae 1az se -25.8

$e 300 rare. ine Bs

Pr enizs1 10 8 oto ¢ Sto!0

Mapier Cease sa7 a 5.25 a =o

Dry maceer (3)

Px 980 noe 16.9 ab 36

eo 310 17.0 a wis 52

Fe eei79 16.0 38 isa a

Mapier Crass 1208 ante °

2 eae

les bearing valike Letters differ significantly (P< 05);

Those having at leabt See letter in common do net differ #tgaificaseiy.

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sa

?TARLE 25, BIOUASS PRODLCTION BY TE SEOOND RATOON CROP OF THREE

SUCARCANE VARIETIES. 200 ONE AUPIER GRASS VARIETY FROP-

cate Wind VARLABLE Row CENTERS; FIRST MONTHS HARVEST

Grows Matter (Tons/A), At Row Center ?

cultivar 150 = 50 oe E change

900 wea! noe as

Meo 310 358s 33.6 ae

Pr elei791 maa vise

we sea

epser Grane 33.3 30.0 be 3.9

bry nator (Tona/A)

2 980 bab eat a9.6

te '310 ca ren 222

PE 6iet791 Sab are ao

apier Grasse 9.0.4 298 n2.2

FR 980 nga 224 1

Neo 310 23 ave 253 he a

Prats 23% be 2 aoa

Kapier Gras aaa 26.2 ab 3a

Af Mena values bearing unlihe letters aiffer significantly (P .05)4

?hose taving at least one Letter in comon do noe differ significantly.

---Page Break---

worsa sonden

(oveg ereemoun)

- seesaeene room 21

ee oneg oreaoson) ee feeno santen

ve vu soessetns 008 9

rag simaoaen) eat ee rnso sorsen

co re ?sees 804»

ceveg mide) wor est est seg aaro

Wear iT WG) We ee

[vaWint HTWVLeVA ZY GALSZNIN SOMO WELGWW GW WTAE AD GOED NOOK GRAS HAL

won UD WaLGW AAO 9E RTO

---Page Break---

?USLE 27, BIOMASS PRODUCTION BY THREE CANDIDATE TROPICAL GRASSES

PabeacareD TH MINDIRM WATER SUPPLY OVER A TIMECCOORSE

oF 10 vEEKS 17

Aionase Yield (Tons/Ace®)

sea Planted 9

variety (here) Green We. Ory We

Sordan 70K 36 aaa 107

sordan 77 aaa? a

mw 326 9.36 139

AY ALL plots received 2.0 acre aches of water by overhead irrigation

fat planting. vo additional irrigationa vere adeinistered. Rainfall

for? the Lo-veek grovth period totaled 2.75 aaches?

2/ Solar dried to approxinately 15% aoiature.

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oe or or et ?1 eo - 1 woe sor owe

tai Coan ime mE Ta

ony Matam ag aoe

eisinig weatintavsnu dp pete

---Page Break---

TABLE 29, NEW SUGARCANE CROSSES FOR BIOMASS; NOv., 1979

Fenale Parent Male Parent Objectives

B 70-701 x S7HNG-S4 Fiber only

Nco 310 x us 67=22-2 A Fiber &

Fermentable Solid

Nico 310 xB 70-701 2/ Fiber &

Feruentable Solids

PR 62-195 x ST=NG~S4 Fiber &

Fermentable Solide

PR 68-330 x 47-NG-54

A Field cross.

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TURLE 20. NOW SUGARCANE CROSSES FOR BIOMASS, DECROER, 1973

Eatinated Yo.

roms Wo. Female Parent wale Parent Of Seailings

1 R980 x S. spent. tybese 400 to 300

PR OT-1010 x $. apont, Hybrid 500

3 PRGLISIE x $. spent. lybeid 20

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TABLE 31, PRELDMURY COST AUALYSIS FOR TOTAL DRY HATTER PRODUCTION

BY FIRST-RATOOW SUCARCAKE MANAGED AS AK ENERGY CROP

TDRY MATTER YIELD: 33 OD Tons/Acret Total 6600 Tone®

Preliminary Cove Analysie

seat (eltens)

4, Land Rencal, at 50.00/Aer6 10,000

2. Sendbed Preparation, at 15.00/A:re 1,000

3. Water (800 Acre Feet at 15.00/¢0) 22,000

4, water application, at 48.00/Acre Year 9.600

?5S. Sand for Plane crop Pius Two tatoon Crops),

W"fen/ete fete at 15-09/to0 3,000

4. Fertilizer, at 160.00/Acc6 36,000

7, Pawtlesden, a: 26.50/4c¢6 3,300

A, arvent, Including tquipment Charnes,

?Eguipment Deprecition, Aad Labor 20,000

3. Day tabor, 2 Man Year (2016 fre at 3.00/m«) Y 6,048

30. Cultivation, at 5.00/here 2,000

AL, Land Preparation & wainteuance (Pret Post-tiarvest) 600

32, Debivery, a 7.00/T00/3 ailes of Haul 46,200

DB. seeds 132,768

3, Managenests 108 of Subtorad 13,275,

15. Total cont 368,025

A/ labor which i not ncioded in other cones

?otal coue/Ton: (168,023 + $600): 23.46

?otal Cout/Miliion BTUs: (25.46 + 15) = 1.70

* Ope fon of this dry matter vould contain approximately £00 pounds of

fermentable solide, oto? pounds of

Acrmentable solids, equal to about 61 gallone of high-test eclazses,

---Page Break---

6

?TABLE 92. PRELIMINARY COST ANALYSIS FOR ENERGY CAE vu CONVENTIONAL

SUCAACAIE PRODUCTION 18

Porto mice (1979 DoLLags)~

aualyals For A Privately Omed 200 Acre Operation 1!

Estinated Cont (6/Yeur) For ~

1. Land estat, at 50.00/Aer6 10,000 10,000 °

2 2,000 3,000 0

3. Waser, at 15.00/Aere Foot 12,00 12,000 °

4. Maver application, at 48.00/Acre Year 94600 9,600, °

5. Seed (for Plant Crop Plus Tyo Racoon Crops) 4,300 3,000 100

6. Fereitiser 18,000 36,000 100

7. Peaticides, at 26.50/Acr6 5,300 5,200, °

8. warvest, including Equipeent Charn

?Eeulpoeat Depreciation, and Lal 12,000 20,000 o

9 Day Labor, at 3.00/ne 2! 6,088, 6,048, °

20. Cultivation, at 5.00/nere 1,000 1,000 °

AL, Land Preparation & Maintenance (Fre Fost-arvest) 600 00 °

22, Delivery, For 3 tites of aut m0 46,200 o

AP Wield (0.0. Tons/Acre Year): Sugarcane, 9.0; Eaersy Cane, 33.0.

2/ Labor vaich is sot included in other coats.

Total Coet/0.0. To

Sugarcane, $84.68

Boeray cane, 25.66

Total Cost/Miliion BTUe: Sugarcane, 4.32

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s(6t) 18 29 eousen woss poadery /E

aD eae ane

awe ve

ra ro oe o'e, 000'2 aw peas

? Soro ms = ores aq 2097

w ore 000'tT trey wr a <prereeeeny

we owt twee ree ?

we tne cece aries tn

oro ?Teren-ang

on cro oor ae 007, a emyasez0g,

ne ote ox rts

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a a =

a iavaen

a

SOI OLWing NT NOTLONOONA AND ADWANE WOU SHALNT AOKENE TRY Nv ?Ee ATHY

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=n

TABLE 34, ENERGY INPUT AND RECOVERY FROM ENERGY cANE Prooucrion 1!

?Asmat Energy Tnvolvenent

Paraneter = stuincre m= XGai/ia WO Oil/aw

oucput 2/ aeaa 4.40

spat ery

lance 40.96

Ouepue/tepae 9.95 9.95 9.95

Af Based on an anouai dry matter yield of 33 00 cons/acre, Less 640

Tee/0D ton an extracted fersentable solids.

2 Steam recovery basis. Asnunes alternate source of atean is

?lectrie utility boiler having 5: effickency using nor 6 fuel oft,

ed with 6.287 Ge BTU/Eb! of el

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