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PRODUCTION OF SUGARCANE AND TROPICAL

GRASSES AS A RENEWABLE

ENERGY SOURCE

THIRD QUARTERLY REPORT

1978-1979

~

?THE UNITED STATES DEPARTMENT OF EXERGY

CENTER FOR ENERGY AND

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A

RENEWABLE ENERGY SOURCE

Second Annual Pepore

1978-1979

To

?The United States Department of Eneray

Oak Ridge Operations Office, and the Division of Solar Technology

Fuels From Sionass Systens Branch

Washington, D. C.

By

The University of Puerto Rico

Center for Energy and Environaent Research

Through

The Office of the President

University of Puerto Rico

CONTRACT NO. ET-78-8-05-$912 (AES-UPR Project C~481)

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ENDORSEMENT:

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?Alex 6. Aloxander

Prosect Leader

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A.

RENEWABLE ENERGY SOURCE

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSES AS A

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ABSTRACT

Research continved on tropical grasses from Saccharum and related Benera a5 sources of intensively-produced, eolar-dried biomass. Categories Of candidate grasses include short-, interediate-, and long-rotation spe~ cies. These categories are based on the tine interval required for maximum Gry matter production, and on future management requirenents of energy crops for intensive co-production with food crop commodities. Year 1 studies at the greenhouse and Field-plot levels were continued and broadened during, Year 2. This included candidate screening, importation and quarantine of nev clones, breeding, controlled nitrogen and water regimes, chemical growth control, tissue expansion and maturation control, seeding rates, harvest Frequency, and varieble row spacing. Second-year studies were extended to the project's field-scale and mechanized-arvest phases, Those include initial economic analyses for the ehort-rotation category of candidate species.

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8-05-5912 (AES-UPE project C-481).

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PRODUCTION OF SUGARCANE AND TROPICAL GRASSZS AS A

RENEWABLE: ENERGY SOURCE 1/

?NTRODUCTION

The biocass production studies herein reported vere initiated June 1,

3978 as a contribution to the Biomass Energy Program of the UPR Center for

Mnergy and Environment Research (CEER). This research deals with sugarcane, tropical grasses related to sugarcane, and other tropical grasses having

large grovth potentials on a year-round basis. Ite basic promise is that

such plant materials can be produced as a renevable, donestic source of

fuels and chemical feedstocks that will substitute for imported fossil

energy. The studies herein reported constitute Year 2 of a five-year work

plan and the firse year

results under DOE contract no. ET-78-S-05-5912,

1. Project Objectives

Primary objectives include: (a) Determining the agronoaic and econoaic

feasibility of mechanized, year-round production of eolar-dried biomass,

chrough the intensive managene

of sugarcane and napier gre tropical

forages, and (b), examination of alternate tropical grasses as potential

sources for intensive bicaass production. A secondary ebjective concerns

the selection and breeding of new sugarcane progeny having superior bionas:

Productivity as their principal attribute.

© conteact No. #T-78-$-05-5912 (AES-UPR Project No. C-481).

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aphasie ds directed tovard a highly-intensive and sechanized production

of tropical grasses ax solar-dried forages. Tiis ie a deviation from conven=

tional cane and cattle feed production in that total dry aateer rather than

suger and food coaponents is the principal cal:ble commodity. Managenent of

Production inputs-parcicularly water, nitrogen and candidate apectes, together

with harvest requency, will vaty significantly from established procedures.

(the other hand, advances in mechanized production and hatvest operations

within the sugar and cattle forage industries vill be utilised to the aaxinum

extent possible for production of solar-dried biomass.

Optimized production operations require

identification of a few

select clones and the conditions required for their sanagenent in an econom-

ically-realistic operation. This is being accomplished in the continued

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

field-scale investigations (Table 1). A fourth phase, connercial~industrial

operations, follovs logically but lies beyond the scope of the present project.

?The second-years's work herein reported deals with a continuation of the green

house and field-plot phases begun earlier (1), 2/ and includes initia! field

scale studics together with the firet mechanization experiments.

?The tropical grasses have never before been evaluated under conditions

?uch that biomass eneryy would be the principal salable product. As a con~

sequence it is necessary to screen a broad range of candidate cultivars if

the optinal yield capacity of these genera is to be realized. Under certain

circumstances existing sugar-and fiber-producing varieties may excel also in

total bionass yield, but it is generally recognized that the grovth attribute

u

?A unbers in parenthesis refer to relevant published literature. Complete

citations are Listed on pages 48 to 50.

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hes not been fully intensified in the hybridization prograss that led to

the present-day varieties of commerce (2,3,4). Screening studies have there fore included older hybrid varieties no longer produced commercially, ?noble? or pure intraspecific clones, superior selections from wild populations, and mere prinitive forms bearing the germplasm from which modern genotypes have been assenbled. A screening technique was adopted for this purpose in vhich devanieat, physiological, and agrononic attributes are? evaluated in a stepwise

Program involving greenhouse, field-plot, and ficlk

jeale trials

In certain respects this is a tropical application of the herbaceous species screening

concept originally formulated by the DOE Fuels From Biomass Program (5,6).

A breeding program designed to intensify the biousss-yielding attribute of Saccharun and related species lies beyond the scope of this project. Thorough breeding studies vould require and justify a separate project. This would include the screening of candidate parental types, a physiological phase to synchronize flovering periods at the intergencric lovel, and basic genetic esearch to break some serious constraints operating to prevent the exchange

of gereplasm anong Saccharup and allied gencra (7,8). At a very modest level

sone 1

ited breeding is included in the present project. This vork ie confined

to a feu obviously desirable parent clones that have suitable Flowering

characteristics and which can be incorporated without inconvenience into an on

going breeding progran for sugarcane (9). Certain progeny originating with the

AUS-UPR sugarcane breeding program are also being considered as long-rotation 2/

biomass candidates. Under these circumstances some prospect is crested for the

?energence of superior new progeny at very Little expense.

© caregories

in detail on

f tropical~grass candidates for bionas

en h-43,

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?This report covers the period June 1, 1978 through May 31, 1979. Some

(0° the longer-term experiments were not initiated until after July 1, 1978,

and £4

t-ratoon data are presented fron Year 1 plantings. In these instanci

final harvests were not complete at the close of Year 2. For example, the

fixat-vatoon yields of the first major field-plo: study on sugarcane, a 36-nonth

experinent dealing with harvest frequency, variezies and row spacing, vere

?completed only through the tenth month by the end of May, 1979. The compiled

data thus include five of six 2-aonth harvests, tvo of three é-month harvests,

?and one of tvo G-ronth harvests. Similarly, statistical analyses are confined

to "within harvest? variables, since the "between harvest

analyses would

have Little meaning if based on an incomplete set of data. The finalized data

for Year 2 vill a

ar in the first quarterly report of the project's third

year.

Certain of the results recorded in this report were presented in fragnen

tary form in earlier quarterly statenents, In a fev cases these findings vill be reiterated here as they were originally given. However, to the maxisun extent possible, prior findings vill be represented in the clearer perspective of two year's experience. The project's statistical data for Year 2 vill be

Presented both in this report and the quarterly report to follow.

?TECWNICAL, REPORT

?A. GREENUOUSE STUDIES

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

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

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s-

nore rapidly and cheaply than is possible under Feld conditions. Greenhouse slata are not definitive in the sense that direct field responses and cultural vecomsendations can be stated, but perhaps tvo-thirds or wore of the total cata package needed for a herbaceous candidate can be gathered in this way.

Yor Saccharum and related species ordinarily propagated in populations of

20,000 to 300,000 plants per acre, the greenhouse offers a level of preci-

Sion for control of the individual plant that {c not remotely possible in the

field, This

nethod is currently used in Puerto Rico for its econosy of project

resources; under tempurate-clinate conditions ir offers an econony of tine

vhere field vork is seasonally Linited to four or five favorable wonthe per

years

1. Greenhouse Methods

ALL plants are propagated either by sand culture in glazed, 4-gallon

pots, or in 1:1 or 2:1 mixtures of soil and cachaza contained in 10-

Lion

© control of water and

galvanized droas (10). Sand culture offers pre:

nutrient variables, Soll-cachaza mixtures

-e convenient media for deternining

relative grovth rates, grovth curves from germination to the young-adult

stage, responses to chemical grovth regulators, and tolerance to frequent

recutting of candidates having superior grouth potentials. Most candidates to

date have been established vith stem cuttings of uniform size, age, and vigor. A fou candidates such as svect sorghum varieties and the sorghum x sudan grass Iybrids are established with true seed. Insects are controlled with weekly applications of Malathion, ALL plants receive controlled water and nutrient supplies that are not rate-limiting for growth.

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-6

y

Mott of the second-year experiments employed the interspecific 2/

sujarcane hybrid PR 980

4 reference clone having recognized excellence as

4 Nigh tonnage producer, In this capacity PR 980 has not beon very satisfac~

tory (1). Tes major dry matter accuaulation begins after 6 months and the

Project requires some cultivars that will do this as early as 2 to 3 sonths

afcer planting. Also, several Saccharum imports and AES cane breeding progeny

have been identified already as tonnage producere superior to PR 980. When

pocsible, future reference clones vill be selected from the specific category

of candidates under scrutiny, ie, Sordan 70-A for short-rotation candidates,

napier grass (var. Merker) for intermediate rotations, and a suitable $..

spontencus hybrid for the long-rotation category.

Marvest intervals have varied in accordance with the stage of screening and bionass paraneters under investigation. Preliminary production tests may

involve only a single harvest at a convenient point in the species "grand

period of grovth." Definitive grovth curves require multiple harvests during

the plant's initial 3 or 4 months after seeding. Grovth-regulator tri

require

pling at precise intervals following chemical penetration.

?The principal bionass parameters measured during the second year included toral groen weight, dry veight (oven dried to about 6% moisture), dry natter content (% Du), and water content (Z moisture). Leaf samples, including the entire blades of leat ronks +1 and +2, 2/ are harvested for foliar mineral analyses. In some experiments leaf samples are harvested for blade-area and

© saccharun officinatum (9/16) x 5. ens).

pontaneur (5/16) x S$, sinen

2! tue uppermost leat bearing a fully-energed devlap is designated "41",

In sugarcane this is the youn;

leaves are designated +2, +3,

st fully developed leaf. Progreseively older

tc. ubile progressively younger leaves, still

0, ?2, =2, ete.

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a7

chioroplyLl determination. Biomass production characteristics evaluated ducing Year 2 are presented in Table 2.

Boch formally-replicated and non-replicated ?observation? experinents ?are conducted in the greenhouse, The latter usually concern preliminary sruth~potential measurements involving only a fev hundred plants in an area covering roughly 1/200 acre, Replicated experiments deal vith specific Browth characteristics in previously-identified cindidates. Ordinarily these

involve 3 to 5 replications of «

ch treatment arranged in an inconplete

randonized block design.

i

Sereening

?The first clearly outstanding candidate to exerge during the project's first year is a sweet sorghua x sudan grass hybrid produced by the Northrup-

King Company (11). Marketed under the trade name "Soréan 70A" this hybrid

hhas shown considerable grovth potential as a cattle forage on Puerto Rico's

arid south coast (12). For biomass production it is basically a short-rotation

candidate, that is, it makes very rapid growth over a short time-course, and

completes both 2 tissue-expansion

\4 @ maturation phase within about 9 or 10

weeks after seeding (1). Tt is rather severely attacked by insects, is highly

concumptive of water, and is

wceptible to dovny mildew disease,

?A greenhouse experinent cosparing Sordan 70A vith three intermediate

rotation candidates (napier grass and tvo napier hybrids) and ugarcane vas

initiated during Year 1 and completed during the Cirst quarter of Year 2.

Meevested at 6-week intervals over a time-course of 30) weeks, Sordan 7OA was the superior biomass producer at 6 weeks and appr ache? the productivity of

Rapier aress over the entire 30-week period (Tab e 3) Susarecne (

PR 980) was not an effective biomass produce when harvested this froquently

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4 correctly belongs in long-rotation studies allowing 6 to 12 months for

both tissue expansion and maturation to be completed. The napier gra

brid PI 30086 was superior to common napicr grass at 18 weeks (1) and this Telationship persisted through week 30 (Table 3) Although ve have much teas iuforaation about this hybrid in Puerto Rico thon we have for common napier grass (var. Merker), ve have increased seed of PI 30086 during Year 2 as a replacement for Merker in forthcoming biomass field experinents.

Dry matter percentages for the sane (ive clones renained persistently Jow until the Final six veeks of the study (Table 4). At this time each clone appreciably increased its dry matter content. Since the harvested material itself was only six vecks old, as vas true of all prior material, the higher values suggest that the aged crows produce shoots with a better fiber-yielding capability than do younger crowns. Putting this another vay, the age of the ?sioots vas not the only factor governing the shoot's maturation. This in ite self would not be renarkable since maturation rates can be altered by numerous Banagenent and treatment variables; hovever, none of these vere introduced here and the only accountable variable is the age of the crowns.

?Two other NK hybrids vere evaluated during the first quarter using

ston

Sordan 704 as the reference variety. These were Trudan 5, a true hybrid

grass, and Millex 23, a érouth-resistant Pearl

(idlet hybrid (11), Over a time-course of 14 weeks, Trudan 5 and Sordan 70A produced virtually identical Breen weight, ry weight, and Z DM values (Table 5). Millex 23 was inferior to

?Trudan 5 and Sordan 708 (Figure 1). The similarity between Trudan 5 and Sordan

7OA is encouraging in the sense that one variety or the other could be dis

qualified as a biona:

production candidate. This situation could arise oving

to di

ase or insect susceptibility, drouth intolerance, salinity or pl factor:

ete. The principal strong point of Millex 23, its drouth tolerance, vas not =

factor in this experiment where vater supplies vere

sguate for all varieties.

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3. Candidate Gras

Superior to Sordan 704

While Sordan 70A is regarded as an extrenely promising candidate for

ious:

Production, a series of screening experinents have been initiated with

the objective of identifying superior or more versatile candidates. The

reasons for this are as follow

(a) There is a strong 1ikelihood that the sone breeding programs for commercial forage gr

es that produced Sordan 70A

could also yield superior bionass-yieleing varieties; (b) candidates are aceded

with greater tolerance to severe heat and drouth conditions; (ec) greater

disease resistance is needed (Sordan 70A has shown downy nildew susceptibility

in Pucrto Rico); (4); there is 2 need for somevhat longer:

uring gra

to

supplement napier grass and napier hybrids in the intermediate-rotation

category; and (c) there is also need for shorter-naturing grasses to accouaodate

extremely short-rotation situations.

?One screening experinent initiated during the eccond quarter included

seven forage grasses from the

see breeding progran (Northrup King Company)

that produced Sordan 70A. In this instance Sordan 70A was retained as the

standard or reference variety. Dry matter yield values were recorded from weeks 3 through 7 (Table 6). in essence, this covers the period of rapid tissue expansion for Soran 70h. On an individual plant basis Sordan 70A

appeared to outyield cach of the other grat

Jes by wock 7; hovever, the dif
ference vas statistically significant only in the instance of Millex 23. At the tine this experiment was Cerninated it was felt that the total productivity of varieties suchas Sordan 77 and NK 300, when measured in terms of total

ary matter/ acre year, could conceivably equal or exceed that of Sordan 0A. ?This potential was borne out in subsequent experiments employing variable

moisture regimes,

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4. Candidate Screening with Musid~tovarid Moisture Regines

Variable water regime studies vere initiated during the second quarter (9).

Treata:

s consisted of simulated humid, normal, and semi-arid growth regines

with @ series of Northrup-King forage prasses. in additional experiment was

vitiaced during the third quarter which includ?d a simulated severe drouth

(rid) condition together with normal and semi-/rid regimes. Johnson grass vas

else examined for the

rst tine as a candidate sinimum-tillage species.

Seven Northrup-Xing grasses (Sordan 70A, Scrdan 77, Trudan 5, Truden 7, Millex 23, NK 300, and NK 326) pius Johnson grars, were seeded in a 1:2 soil/

cachaza mixture and given adequate water supplics for two weeks to assure

vaiform germination / variable moisture regines were then established by varying the froquency of vatering. Being under glass, with complete reliance upon irrigation, the moisture requirenents of such plants are considerably

intensified and variable degrees of moisture stress are easily simulated. The

First harvest was perforned one week after moisture variables vere established

(at 3 vooks of age), end hary

5 continued at veekly intervals until the plants vere 12 weeks of age.

Although this was an ?observation? experinent without replications,

?everal important trends energed fron the yield data: (a) Sordan 77 was superior toSordan 704 at all moisture levels but progressively more so under moisture stress (Table 7); (b) the varieties NK 300, NK 326, and Johnson grass out yielded Sordan 70A undor moisture stress but not vhen water was adequate; end (©) highest yields under the seni-arid ond arid regines vere only 61% and 46%,

respectively, of maximum yields with normal vater supply.

A/ In an actual field cropping situation, minimum tillage plants vould receive irrigation at the tine of planting to assure germination even under the nost arid conditions.

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Mean values for main effects (for the éifferent moisture regizes at a whole), indicate that Little sore than 50 to 60% of normal productivity can be ?xpected from the present candidate specter when subjected to moisture stress (able 8), Plotted graphically (Figure 2), dry satter yields are not seen to Plateau per se under soisture stress, cad in fact grovth was continuing until the close of the experiment. Hovever, without adequate moisture, the plants vere simply unable to sustain beyond weck 4 the linear flush of growth which characterized normal water regines through week 9.

Of further interest was an inability of woisture-stress regines to induce carller maturation as nain effects (Table 9). In other words, lack of mofeture

cid not encourage the young plants to begin earlier their physiological aatur

ton, as vould have beon evident in data for dry matter content. In sugarcane, for example, the withholding of noisture is the most effective means available to hasten maturation (24, chap. 11). Novever, the sugar planter deals with

Telatively old plants in hich soue level of maturation has already begun. In

the pri

ent experinent the essentially somature plants deprived of moisture simply continued their tissue-expansion processos at reduced rates. As @ varietal effect, Trudan 7 continued to display a tendency tovard early matura~ ton in direct comparisons with Sordan 70A (Figure 3). Sordan 77 shoved a sinilar tendency (Table 8). This property was noted previously in both species (9).

As unreplicated data these trends are not yet verified tistically but

they have important implications nonetheless, They suggest that a fairly large

Pool of short-rotation candidates exists having » productive capability at

least equal to Sordan 70A under favorable groving conditions, and superior te

Sordan 70A under adverse conditions. Putting this another way, a species

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-

offering the sane quantity of biomass a5 Sordan 20A vith less water is one

than can be grown more cheaply, ani under the kind water constraints very

Likely to prevail in Fuerte Rico's future, The emergence of Johnson grass as

4 viable biomass candidate, fron the role of an arid-loving "weed", ie

especially encouraging in this respect.

?One "ratooa!" crop was harvested at four weeks after the experinent's

principal harvest was complete. Yield trends were very similar to those of

the plant crop although total DM was lover owing to the ianaturity of the ratoon

plents, Cosbined DM yield data for the tvo crops and three moisture regines

wore compiled to evaluate varietal performance as nain effects (Table 10).

From these data the varieties Sordan 77 and NK 326 are superior to Sordan 70

by an order of magnitude of 20 co 25%,

?The very favorable performance of Sordan 77 4:

consistent with Northrup

King Company clains of ite greater productivity and drouth tolerance (13), and

ith our on earlier observations (9) in direct comparison with Sordan 70A.

Together with dovny mildew and insect resistance, these properties speak

strongly for the repla:

went of Sordan 70A with Sordan 77 as the project's

principal short-rotation species. However, a definite superiority of Sordan 77

must first be verified in replicated trials. Sinilarly, the superiority of

NK 300 and NK 326 for arid environments must also be verified. The toughness fof Johnson grass and the ease of its establishsent and maintenance also favor

its further study as

short-rotation species for arid and semi-arid conditions.

Candidate Screening; Multiple-Rotation Teste

?The first ?nuitiple rotation" experiment of the project vas begun during

the third quarter. This involves the simultaneous propagation of discrete

spect

having variable grovth habite, and the harvest of part of each species

---Page Break---

population at different intervals coinciding vith shore~and intermediate-rota~ tion cropping periods. This procedure enables sultiple-epecies and aultiple~ encegory screening to proceed continually under conditions such that not all of the seed or cuttings needed for a year's work can be made available at one tise.

Candidate grasses for the on-going experiment include five Saccharua

ynes regarded as potential replacenents, or eupplenents, for napier grass

(Gone:

vetum species), the outstanding interaediate-rotation candidate studied

to date. Grasses in this category would maxinize dry matter at 4 to 6 months after seeding (Table 1). The five Saccharus candidates include the $. sponte eum clones SES 231 and Tainan, the donestic §. spontaneus hybrids US 67-22-2

and US 72-70, and a wild \caneum hybrid collected in the Rio Piedras ai

spontaneum by!

Additional test varieties for this experizent included PR 980, @ confirmed

long~rotation sugarcane hybrid, and the hybrid napier gr:

Pr 30086, The

latter is classified as an interediate-rotation plant (1,15) vith a biomass

Potential moderately superior to coomon napier grass (var. Merker). Also being

tested is comon Johnson grass (Sorghus halepense). Originally brought into

Puerto Rico as a cattle forage, Johnson grass has ?escaped? to the vild and is

regarded as a weed by land omers along the semi-arid south coast. However,

its unattended growth in the Lajas region és sufficiently impressive to varrant testing as both @ short:

intermediate-rotation species. It is also a

potential ?low till" candidate in view of its excellent survival properties

under sen{-arid conditions.

ALL test species were propagated in the greenhouse using a 1:2 soil/

cachaza mixture as the grovth medium. Water eupplics were adequate to sustain

maximum grovth for all candidates. There vere three replications of each

treatment arranged in a randomized block design.

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-

?A single candidate species, Johnson grass, gave a clearly outstanding

performance for the first two-month growth period (Figure 4). It is the only

candidate that appears suitable for further consideration as a short-rotation species, Napier grass hybrid PI 30086 also produced superior grovth (Table 11), but Pennisetum species are already knovn to maxinize their dry matter yields over @ longer tine course, that is, between 4 and 6 sonths after planting (1,15,16). ALL of the six 5:

tharua candidates pave grovth performances that

were roughly equal and uniepressive. Dry matter content ranged from 14.1 pet

cent for napier grass to 20,0 percent for SES 231 (Table 11). This indicates

that none of the species, including Johnson grass, had completed their maturs

tion phase in the 2-month growth period. Johnson grass was the only candidate to begin flovering, and it was believed that this plant vould have approached

30 to 35 percent dry matter

ven an additional 2 to 4 weeks of grovth (17).

A subsequent harvest from the same experizent, at 4 months, did reveal a

DM content of 38% for Johnson gra

(Table 12), although at this tine Johnson

grass vas no longer the leading candidate vith regard to total IM yield/planted

area (Table 13) or DM yield/individual plant (Table 14). As a wultiple-rota~

tion experiment, yield data for sonth 4 will reveal the ost suitable species

for intermediate-rotation cropping, while no longer favoring short~rotation

species (2-3 months) and not yet favoring long-rotation species (12-18 months).

Hence, Johnson gra

the most productive candidate at 2 nonths, vas the least productive at 4 wonths and napier gr:

ss (var. PI 30086) had becone the superior

candidate for 4-nonth cropping (Tables 13 and 14).

?The enormous yield potential differences of tropical grasses within a

tine-frane differential of only two months can hardly be overemphasized. For

?example, the DM content of napier grass increased some 1200% between months 2

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a0 4, while Johnson grass increased DM by only 152% during the sane interval

(Goble 15). Sugarcane (var. PR 980) also made lex}

increases in DM content

by the fourth month, but as a long-rotation candidate it had not yet attained its maxinum productivity and renained inferior tc napier grass at this tine

(abies 13-15).

6. Growth Regulator Experiments

?The plant grovth inhibitor Polaris Gionsanto Agricultural Products Co.)

Produces increased groveh in sugarcane when applied in lov concentrations 5

-#n aqueous foliar epray (18,1). Initial attespts to induce the sane effect in

Sorden 70h vere made during the first quarter of Year 2. Polaris was adain=

Astered to 3 weeks-old plants propagated in a soil-cachara mixture, and whole

Plants were harvested for grovth evaluations fron weeks 2 to 8. Polaris

concentrations ranged froa $0 to 600 pps. Dry weight yields were increased

soderately (about 352) by the fourth week after treatment with 200 ppm Polarie,

?but the effect did not persist to the sixth week (Table 16).

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Dry matter was maximized in all Polaris-treated plants two weeks earlier

?than in control plants (Figure 5). This latter response, even vhen total

yields are not increased, could icself be highly desicable in short-rotation

crops where timing of the harvest is a critical factor. The Polaris effects fon Sordan 70h require further study with special reference to the tining of application.

Efforts were made to repress grovth in Sordan 70A using Polaris concentra

tions of 2000 and 4000 pps. These levels will terminate all ti

ue expansion

Activity in sugarcane and drastically increase the rates of sucrose accumulation (18). Only elight repression was noted in Sordan TOA, even by 4000 ppa Polaris (Table 17). By the sixth week after treatment the high Polaris plants were noderately exceeding control plants in éry matter production. Although this vas only a seal observation experiment, at this point the sensitivity of Sordan 70A to Polaris appears totally different from that of Saccharua

species.

Nuteiton

?A nitrogen nutriton experiment established late in

?Year 1 vas completed during the first quarter of Year 2. Variable nitrate-8 Jevels vere provided to Sordan TOA to establish the plant's N-response curve.

?The objective vas to determine the slope of the dry satter response to progressively higher levels of N. Accordingly, 8 supplies were increased in a geometric progression from 1.0 to 61.0 milequivatents per liter of NOs. The 1.0 meq/t treateent vould be deficient for virtually all plants. By way of

reference, an N supply of 81.0 meq/1 is much more than sugarcane can utilize

efficiently (14).

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-u-

Growth data recorded at 4, 8 and 12 weeks after

eding are illustrated

in Figure 6. Over this tine course, maximum dry weights vere produced by the

3,9, and 27 weq/l treatzents, respectively. This may reflect the plant's

incr

singly well developed root systen with advancing age. There were no

srowth increases as NO, vas doubled to 54 meq/1, and significant growth

repression occurred as NO, was raised to 81 meq/1 (Table 18).

Tt should be noted thet, during the plant's rapid growth phase (froa

© to 8 weeks), there wore no significant growth res

jonses to NO, levels higher

than 9 ueq/1. Higher N levels may be needed to maximize Sordat

fiber

accumulating phase which occurs approxinately between weeks 6 and 10 under field

conditions (1), Optinal éry matter percentages vere a function of N supply in

young eaterial (4 and 8 veeks) but there were no significant W differences for dry matter content in mature plants (Table 16).

Wotritional information obtained by the sand culture technique is not Airectly applicable to field conditions; hovever, iaportant relationships of nutrient supply to grovth potential are revealed in this way. For example, the shape of the N-response curve is a characteristic feature of the candidate variety or species vhether propagated in sofl in an open field or by nutrient

culture under glacs. The response curve for Sordan 70A appears quite favor

able in that a distinct grovth plateau is reached beyond which additional N ?supplies are wasteful (Pigure 6). Moreover, 10, concentrations higher than 9 weq/t reduced significantly the number of plants/plot (Fable 19), while 27 neq/1 very severely restricted the musber of regrouth stems following the

final harvest (Zable 20). By contract, NO, levels ia the order of 54 or 61

tmeq/1 produce very profuse tillering in sugarcane (19).

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Foliar mineral analyses for 12-weeks old plants suggest an inability of Sordan 70A to incorporate N frou solutions containing more than 27 meg/2 of this elenent (Table 21). The 8 absorption data actually corresponded quite closely with the Neresponse curve for dry matter production (Figure 7). Both P and K incorporation was significantly increased at NO, concentrations

3

of 27 moq/t and higher.

(b) Napier Grass: Nitrogen-cesponse curve studies were extended to the

intermediate rotation category of tropical grasses during the second and third

quarters of Year 2. The hybrid napfer grass PI 30086 was used a6 the represent~ ative cultivar. Plants vere propagated vith the sane sand culture technique and nutrient levels employed earlier for Sordan 70A. Samples consisting of six vhole plants per replicate were harvested vhen the plants were 8, 12, 16 and 22 veeks of age.

Yield data for total dry matter indicate that never more than a fraction of the 81 neq/ of nitrate were needed to sustain maximum growth (Table 22). ?There were no appreciable yield responses to NO, levels above 3 neq/1 at 8 weeks (igure 8), possibly reflecting a root zone too poorly developed to absorb much of the higher N level. However, a distinct growth pattern had begun ¢o develop by week 12 showing a repressive effect of high NO,, and this trend vas

chrough week 22. By the close of the study at 22 weeks there w:

no groweh benefit whatever from supplying napier grass with nore than 3 meq/l

of NO, (Table 22, Figure 8).

(e) N Requirements; Bionass vs

examples to date of the need to distinguish between tropical grasses when

tle Forage: One of the clearest

propagated for conventional cattle forage on one hand, and the sane species

Produced for biomass on the other, is presented in Figure 6 where N~response

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we

curves for napier grass are graphically illustrated, As noted above, there

woe no need to supply these planty with more than 3 meq/1 of N05 to maximize

total biomass in the time-frane when they vere botanically most effective in

coducing bioaass, ie, betveen 5 and 6 wonths after planting, Nor was sore

than 3 meq/t of NO, needed to maxinice maturity at this period (Figure 9).

Conversely, 27 tines this anount ef 0, (81 weg/1) vas hardly sufficient to

taxinize bionass when the plants vere only @ wecks of age. Ironically, our

Present understanding of the growth managument requirenents of napier grass

come fro forage studies whore 8-veek old material is almost excessively old

and where harvests are ordinarily perforned at 4-to 6-veck intervals (20,21,22).

0 producing napier er

for cattle feed emphasis is understandably

directed tovard large numbers of succulent stems having a igh water content,

low fiber content, and a high content of soluble protein (20). These condi-

tions are encouraged by high nitrogen fertilizat

mn. Tn one Puerto Rico study

With common napier grass (var. Merker), high nitrogen treatzents in the order

0f 2000 ibs of elesental x

F acre year did not fully maxinize the plants

yields as a cattle forage (22). This level is perhaps three tines the quantity that a Puerto Rican farmer could afford to purchase at 1979 fertilizer costs. Moreover, the ecological impacts of using such high fertilizer levels are wunknown and could very possibly be detrimental if the practice were pursued for any appreciable Length of tine.

A vastly nore favorable picture is enorging for the N requirenents of

napier grass grow

fan energy crop. First, the harvest

sate from froquent

Fecutting (at 6-week intervals) will be lovered appreciably when the sane

species is harvested for energy (at 16-to 24-veek intervals). Second, the nore

ature energy plants should have a correspondingly better root developeent

---Page Break---

~ 20

and hence a sore efficient utilization of applied nitrogen. Third, in a purely

quantitative sense, the eleneatel % needed to produce fiber (mainly cellulose, honiceliutoce, and ligain) is less than that needed to produce soluble protein.

Tohon together with the potential inprovenents in soil ecology (resulting fro

fever heavy machinery operations and lover

Lt applications to agricultural

lands) these factore susgest that cnergy planting vill be a far eippler and

Jess costly operation even vhen dealing

th a species whose managesent needs

Ihave supposedly been known for years.

8. Variable Moisture Regines

?The first varisble-soisture study of the project was performed during the

first and second quarters of Year 2 using the sane Northrup-King varieties

Aiscussed on pages 9 to 12. It vas non-replicated observation experiment in which humid, normal, and seai-arid conditions were simulated by varying the frequency of plant watering. All plants vere propagated in the greenhouse in a 1:2 mixture of soit and cachaza, and Sordan 70A again served as the reference variety. Im this instance the experiment's duration was extended to 11 weeks, thereby encompassing both the tissue-expansion and maturation phases of

Sordan 708 (1).

Sunmary date for all varieties revealed the folloving trends: (a) The ?hunia" regine in vhich the propagation nedium vas kept constently aoist vas repressive for total Di production (Table 23), while che ?normal? regine vas superior to both huaid and seni-arid conditions; (b),mean values for dry matter

content indicate that, as a group, the candidate grasses experienced a rapid

maturation phase froz week 6 to 10 (Figure 10)

(©), individual varieties, in

direct comparisons vith Sordan 70A and propagated with nor

2 vater repines,

revealed a much cuperior maturation curve for Trudan 7 (beth earlier and more

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extensive DM accumulation), and an inferior sacuration curve for Millex 23 (igure 11); (4), under semi-arid regines, the varieties Trudan 7, Sordan 77, NK 300, and NK 326 gave grovth purfornances which equaled or exceeded those of

Sordan 704 (Table 24, Figure 12).

|. Isportation and Qs

A nusber of Saccharum clones snd clones from both related and unrelated

ste Tropical Grasses

genera were available in Puerto Rico for screening as biowass candidates when this project was initiated on June 1, 1977. Movever, the vast majority of

clones from these genera reside outside of Puerto Rico, both in the wild and

in national and internation

1 collections. During the sumer of 1978 two ship

ments of candidate grasses were ?sported into Puerte Rico and placed in quar

antine at the AES-UPR Gurabo Substation, These include a group of five clones

fron the USDA-Horld collection at Beltsville, Maryland, and = group of 32

clones from the USDA-World collection st Canal Point, Florida (Table 25). The

Beltsville shipuent consists entirely of $. robustua clones, # species which has

been notably lacking in Puerto Rico. The bulk of the Car

1 Foint group are

spontancus clones. The latter group also includes geraplasn froa the genus

Ripidiun }/ wiscanthus, and Erianthss, together with the Saccharum species

S. fusca, S. narenga, and

robu:

These candidates were planted in soil-cachasa mixtures and ali but one
kave satisfactory germination. Growth has been adequate though unremarkable
for most clones, Several clones produced tassels (flowers) late in Novenber
and Decenber, 1978. Saccharus species very rately flover under greenhouse

conditions, but the late Flowering trait could be a useful factor in ite ow

YY xipigiua was foruerly classified as an asiatic sub-group of Eri

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right since it would ensiie thess clones tc be crossed with hybrid sugarcanes which normaily tassel at this tine */, the observed flowering could also be an artifact of the plant's greenhouse enviroment or their late-sumser tine of planting.

None of tho imported species are thought to be sulted fer short-retation cropping. They are regarded as candidates for long-rotation and minioun

tillage bicaass crops, although certain of the species may compare

favorably with napier grass and napier Hybrice as snternediate-rotation

candidates. They might also expand tne planting zones of intermediate-and

Jong-rotation species into semi-arid ane arid regions too dry to sustain napicr grass and conventional sugarcane hybrids.

The principal objective of che clone-screening process is still to find superior producers of dry biomice (fiber) for intensive propagation as solar~

dried forages, Added to this is the necé for minimus-tillage candidates that

vill survive and produce acceptable yields under arid conditions and various

types of marginal lands.

5, FIELD PLOT stupie®

A. Sacchavuy Species Candidates; Gurabo Substation

?An observation field-plot etudy with candidate $. spontaneum and S.

sinense clones has been wnderuay at the AES-UPR Gurabo Substation since October,

1977. The principal objective was 0 define the total bionsss-producing capabilities of these candidates. second objective was to determine their

qualitative value when eufficiently-aged plants becane available.

4 the sugarcanes of commerce tend to flover lator than the more primitive Saccharum species. This is an unfortunate trait of considerable inportance to Sugarcane breeders concerned with utilizing the widest possible range of Saccharum geraplesn in their hybridization programs.

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(@) Total Bionass Production: The final harvest completing one year of frouth evaluations was taken during October of 1978 (Table 26). Cut repeatedly at 2month intervals during the final eight months of Year 1, the plants vere

subjected co a reharvest syndrone comparable to that of short-rotation cropping. Under this harvest regine the S. spontaneum clones SES 317 and SES 327 died out, 8 did the one Erfanthus aaxinus cloavs tested to date, NC 132.

Yield values (Table 26), together with tillering and maturation char~ acteristics (Table 27), indicate that three outstanding candidates emerged in two categories. The first group is dominated by the S. spontaneum clone

SES 231, a wiry, thin-stemmed grass having no sugar potential at oi} bu

persistently high fiber production per acre year. It tillers abundantly and has a fairly high dry matter content for 2-sonth old material (Table 27, Figure 19).

s

lar traite were evident to a lesser degree in the $, sinense clones Chunnee ?and Tainan. The second category includes thick-stemed $. spontaneum clones

having a eugar-yielding capability in addition to high fiber production. The

outstanding clone is US 67-22-2, followed closely by US 72-70 (Table 26).
?Their dry matter yields slightly exceed chat of SES 231 while exceeding the comercial hybrid reference clone (PR 980) by roughly 50 percent. Neither US 67-222 nor US 72-70 tillered as profusely as SES-231, but nonetheless they

produced more than double the nunber of stems recorded for PR 980.

Each of the three outstanding grasses is regarded as a potential minim candidate for field plot trials on the Island's seni-arid south coast.

point in tine, SES 231 is viewed as an internediate-rotation candidate

to be harvested as a solar-dried forage at intervals of 4 to 6 months. There

is sone possibility also that it can serve as a dryland short-rotation crop

to be harv

ted at 2 to 3 month intervals. The thick-stenmod grasses, US 67-22-2

?and US 72-70, should probably stand a year between harveste to obtain both

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sugar and fiber, In any case, these varieties would require eilling as a

dewatering step in their processing operations for fuels, They cannot be accomodated by any existing equipment for production of solar-dried forages. ?The 5. spontancus and §. sinease crovns presently established at the Gurabo Substation are being retained for one additional year. This will provide the project with data on the long-term durability of such species without aceruing the added tine and expense of a nev experiment. During the second yeor these clones vill also be managed as minim tillage crops receiving low xater, fertilizer, and pesticide inputs. Harvest intervals are being extended

fron two sonths to six months.

(b) qualitative Characteristics: The first qualitative date for this aroup of species becane available during the third quarter. Very little vas expected by vay of sugar-producing potential and a majority of the candidates in fact shoved very poor juice quality (Table 28). However, surprisingly favorable values for polarization, brix, fiber, purity, and rendinent were

recorded with US 67-22-2. The qualitative performance of this S. spontaneun clone clearly exceeded that of the reference variety, PR 980. The latter is an interspecific hybrid which for aany years has been a superior sugar and

producer in Puerto Rico, Hence, there is a distinct possibility that US 67-22+2 can assune a dual role of biomass and sugar producer in Puerto Rico

suture.

?As expected, the thin-stesmed clone SES-231 contained virtually no sugar but high fiber (Table 28). Very sinilar values were obtained for the unknovn |S. spontaneun hybrid which bas attracted the interest of this project. The qualitative data for this plant strongly suggest that its parents were borh

original §. spontaneum clones (23).

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vas adninistered by overhead aprinklers at planting and by flooding as needed thereafter.

Whole plote were harvested for green-veight determinations at 10, 20, and 30 veeks following seeding. Sub-samples consisting of ten whole plants yer plot were harvested and dried in a forced-air oven for dry matter deter~ winations, Identical sub-saaples were also harvested for foliar mineral analyses. ?he entire blades of leaf ranks +1 and +2 vere oven-dried, ground to pass a do-nesh screen, and subnitted to the AES Central Analytical Laboratory for total N, P, and K analyses.

Although statistical analyses are still pending, aeither increased N

levels nor increased seeding rates appreciably raised the dry aatter yields of Sordan 70A (Table 29). Sinilar results vere obtained for total green aatter (Table 30). While unexpected, these responses do have the effect of minimizing

input costs for future planting of Sordan 70A.

(a) Responses to Variable N Supply: Mean values for increasing N supply indicate that the highest yields of the study were obtained from 600 Ibs of W per acre (224 kg/ha), but that this constituted an increase of only four percent over the yields from 300 Ibs N/acre (Table 29). Similarly, mean values for increased seeding rates reveal that the highest éry eater yields were

produced by 100 Ibs of seed per acre (112 kg/ha).

?This was an increase of only

10 percent over yields obtained fron 60 Ibs/acre. Yield gains of such lov magnitude cannot justify the higher fertilizer and seed costs that vould be incurred.

Foliar N analyses were consistent with the view that Sordan 70h made Little or no response to N-fertiliation levels higher than 300 Ibs/acre

(Fable 31), 1 should be noted that the dry matter and foliar N data are at

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= ore

Least consistent vith earlier data obtained by eand culture during Year 1 (2).

Av that tine the Neresponse curve sevealed an abrupt plateau for dry aatter

which could not be alte!

by large increases in nitrate-N supply.

Tt i now evident that the N-fertilization range established for this

?experiment was too high. The optinal level probably lies within the range of

390 to 300 Ihe N/acre. This point cen be verified rather easily with a seal

field plot experiment far tess elaborate than the one presently described.

(®) Maturation Responses to Variable N and Seeding Rates: Data from the

First harvest (at 10 weeks) indicate that neither the Nonor seeding-rate variables appreciably affected the plants? state of maturation, Mean values presented in Table 32 reflect only snail decreases in dry matter content a= 4 result of increased N supply and plant density, although fairly pronounced changes could have been expected, for example, on the basis of N effects upon sugarcane maturation processes (24,25).

Tissue samples harvested weekly during the plants! grovth and saturation Phases sinilarly reveal Little effect on saturation by the two controlled variables (Table 33). Plotted graphically (Figure 13), the maturation curves for low-H and high-W plants are scen to differ percistently from veek 4 omvard, with Mgh M causing a moderate delay in aaturation, However, this delay enounts only £0 8 week or less in the saturation time-course. Tt ie interesting to note that all plants experienced a minor incresco in dry matter at about week 3 (Figure 13). Tis may have been caused by a teaporary soil soisture

etre:

(©) Plant Density, Lodging, and Dosny Mildew: Increased seeding rates produced moderate incr:

ses in the nusber of harvestable stens (Table 24).

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However, these gains did not reflect the large amounts of seed involved. Mean values for main effects indicate that plant umber vas increased by only 24

percent in response to a 100 percent increa:

im seed. Sonevhat larger gains
in harvestable plants resulted when seeding rates were increased within the
Lowest two N regimes (300 and 600 tbs/acre). These gains were negated in the

higher N regines (Table 34).

Sone evidence of dony mildew wes detected at about the fifth week of the

study. By week 10 the disea

had spread in varying degrees to all plote. The
infection was not sufficiently severe to reduce yields anong any of the treat~
mente; however, the apparent severity of this disease wos visually ranked on

4 numerical scale to deternine whether {t was directly related to the Keand
seeding-rate variables. Sone evidence of lodging was also visible in certain

plots by week 10, and this vas sieitarly rated on a numerical scale while the plots were being harvested. The nunerical rankings indicate that domy mildew became moderately more severe with increasing levels of W fertilization

(able 35). Lodging vas apparently unrelated to the variable N levels. In a sisilar vein, neither dovay mildev nor lodging were related to variations in

seeding rate (Table 36).

3. Sugarcane and Napier Grass Trials; Lajas Substation

Sugarcane and Napier Grass Trials; Lajas Substation

A major study was conducted during Year 1 evaluating high-tonnage varieties (sugarcane and napier grass), row spacing (150 cn and 50 cm for

sugarcane; 50 cm and 25 em for napier grass), and harvest frequency (2-, 4, 6)

and 12-month harvest intervals). Complete data for first-year results vere presented in the first quarterly report of Year 2 (15). The study was continued

during the project's second year with the following objectives: (a) to evaluate

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Fatoon-crop responses, as opposed to ?plant crop" responses; (b) to provide increased fertilization for plants receiving an apparently inadequate N supply during Year 1; and (c), to evaluate longer-term effects of narrow row

centers and frequent recutting on plant crovn productivity.

(@) Ine

od Feces)

ition and Crown Maturity: During Year 1, sugarcane received nitrogen at the rate of 300 Ibs per acre applicd in three increments (2/5 at planting, 1/3 at 4 months, and 1/3 at 8 months). Napier grass received 600 Abs of nitrogen per acre applied in three increments at the same tine Intervals, For Year 2, these levels were increased to 600 and 1200 tbs per acre for sugarcane and napier grass, respectively, by increasing the nusber of increnental applications frou three to six ({e, to six applications at two-nonth intervais).

Growth data for the plant crop had revealed major grovth surges in the

two months following the

ication of each fertilizer increnent, folloved by

Brouth decline for the subsequent tvo months preceeding the next fertilizer

increment (Figure 14). This response was more pronounced for napier grass than

for sugarcane. One potential effect of applying fertilizer at tvo-nonth

intervals rather than four months vould be a persistent grovth surge ehroughout

the crop?

second year. Added to this, the increased maturity of the plant

crowns (particularly for sugarcane) might logically sustal

throughout Year 2,

greater yields

Bionass yields for

the first two 2-month harvests and the first 4-nonth harvest of Year 2 were sussarized and discussed in the previous quarterly report (9). Yields for the third, fourth, and fifth 2-sonth harvests (Tables 37, 38 and 39), and the

second 4~nonth harvest (Table 40) are herein reported.

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Yield increments for the third and fourth 2-month harvests were progres:

ively lover (Tables 37 and 38) than those reported earlier in the ratoon crop

(9). This is possibly a reflection of Puerto Rico's "winter" season (mid December through mid-March). For varieties PR 980 and PR 64-1791, this also reflects a varietal inability to sustain cron vigor under the rather severe

of repeated harvest at close intervals. The fourth recutting, for ?example, produced on the whole Little more than 1/3 of ?the éry matter obtained from July through Novenber. At this writing (une, 1979) nany of these plote fare losing their sugarcane crowns entirely; space formerly occupied by cane

is being overgrown by Johneon gr:

+ The sugarcane variety Nco 310 stilt
retains considerable vigor. Napier grass yields also declined in the Decesber~ March period but proportionately less so than for sugarcane. In no instance vas a consistent trend observed in response to narrow rov centers.

The fifth 2-aonth harvest revealed an increase of productivity (Table 39).

?This grovth interval, covering the

wriod March 15 to May 15, represents
Puerto Rico's spring and early sumer. The renewed productivity is hence interpreted as a seasonal response.

Somevhat more favorable yields were obtained from the second 4-nonth harvest (TAble 40). Nontheless, dry satter production for sugarcane vas only 40-50 percent of the levels obtained earlier under ?sunner" conditions (9). Napier grass yields also were about 40 percent lover for the second ?month harvest. Again, no appreciable differences could be shown for the narrow-rou treatments (Table 40). Hence, seasonal effects on plant yield are more evident

in the fire!

ratoon crop than in the plant crop, since in this case yield

Gecline cannot be attributed to lack of nitrogen.

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(c) Total Yields: + ond 6-Month Harveste: By the end of the

fourth quarter, combined yield data were available for four 2-nonth harvests,

two (nonth harvests, and one 6-nonch harvest. Although the data are

dnconplete, several trends are quite clearly evident for sugarcane and napior gress as main effects (Table 41): (a) Sugarcane yields increase as harvest

frequency is decreased; (b) napier grass yields are far superior to those of

sugarcane at frequent harvests (at 2:

snd G-nonth intervala); and (<) both
sugareane and napier grass experienced major yield declines from months 4 to 8
(ovesber-February). These trends are identical to those reported previously
for the plant crop (9).

Consistent differences have nov eserged in the performances of individual
sugarcane varieties (Table 42). Variety NCo 310 was apparently superior to
PR 980 and PR 64-1791 at each harvest interval. The trend was most pronounced
?at the 2-nonth interval where NCo 310 exceeded PR 980 and PR 64-1791 by 144
?and 86%, respectively. There was no consistency of performance, on a

varietal bas:

at the same stage of data accumulation for the plant crop (9)-

?At the tenth month into Year 2, ratoon-crop yields as main effects

@iffer in several respects from the plant-crop yields (Tables 43 and 44). As

already indicated above, sugarcane ratoon yields were clearly inferior at the

2emonth harvests. The G-nonth harvest totale are about the sane for Year 1

and Year 2, vhile G-wonth data indicate a ratoon-crop superiority of about

33% Gable 43). Napier grass yields are very comparable for the plant and

atoon crops.

?Avong individual clones (Table 44), sugarcane variety PR 980 was most

severely affected by frequent recutting vhile NCo 310 was least affected.

Ratoon crop yield increases at 6 months vere nest pronounced in variety

NCo 310, amounting to SOX more dry matter than chat produced by the plant crop.

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(@) Trash Yer

Since around 1960, vhen mechanical harvest sachines

hod largely replaced hand labor, Puerto Rico's sugt

industry has been dis-

posing of su

wreane trash by burning the mature cane stands as a prcharvest operation (26). By this means less fiber was deliverd to the sugar factory and the sachine operator's task was eased considerably. Pretiarvest burning hos highly variable effectiveness, however, and it was still necessary to clean incoming cane by ?wet" or ?éry" cleaning equippent installed at the sive of delivery. Moreover, the practice is both wasteful of enersy (roughly 12 to 16t of the total biomass energy/erop) and is a source of air Pellution. By law, Puerto Rico's cane industry will be required to cease burning trash in the open field by January 1, 1981 (26).

Hence, sugarcane trash is seen as a valid bionass source which must be

credited to the total energy yield capability of future sugarcane-enersy

Plantations in Puerto Rico (27). Project cane harvests have included the

collection and weighing of trash at the 12-gonth harvest (15). Both cane and napier grass trash vas collected at this tine. Trach fe also being collected and weighed for the ratoon crop, this tise beginning with the 6-onth harvest (Table 45). Yields of this material from both cane and napier grass azounted to Less than tvo tons/acre, This figure should increase several-fold between nonths 6 and 12 (15). Total dry matter yields, fe, standard harvest material

plus trash, are presented in Table 46. Taken cogether

ain effects, sugar-
cane yields at six months into the ratoon crop are 332 higher than at the

seme period for the plant crop, and napier grass yields are Gt higher.

(©) Juice Quality Responses (Year 1 Data): Juice quality data from the rreane ond napier grase trials of Year 1 becane available during the first

quarter of Year 2. Wand refractometer valves (a rough estinate of soluble

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fsclids in rav juice) is presented for cane samples aged 6 nonths and older in Tables 47-49. Moderate increases in juice quality were recorded between onths 6 and 12, although none of the values are especially high. & ?aveee" or high sucrose variety ready for harvest should give hand refractometer Teadings in the order of 22 to 23, Nonetheless, several trends were evident, including a superiority of the variety NCo 310 (Table 48), and of the narrow row center (Table 49). The latter trend may signify considerable importance

Af At holds also for recoverable fermentable solids. Tt suggests that the increased sugarcane densities needed for total biomass production may not result in lower cane quality.

Tee Long-term outlook for Puerto Rico's sugarcane industry holds that igh-test molasses for ethanol production, together with cane fiber as a boiler fvel and feedstock for cellulose-based industries, will be the principal objective for both field and factory managers (28). This is a break fron the traditional eaphasis on refined sucro:

domi

for domestic and foreign sales which

the industry for wore than a century. The change in emphasis reflects the high cost of producing sucrose in Puerto Rico today (about 28 cents/pound

in 1978), but it also underscores the need to develop sugarcane as ?energy cane? (29,20,31,35) while supporting the local rum industry with both qualitative

?and quantitative increases in fermentation feedstocks (28,32).

In an energy cane context the paraneter Brix becones the most seaningful Measure of energy cane quality. Brix values, together with polarization, purity, rendinent, and fiber data from the G-and 12-month horvests of Year 1, are Presented in Table 50, Brix values are elightly lover (at 12 months) than one

would ordinarily expect from conventional cane manag.

for sucrose (a value of

14 to 16 would be normal for PR cane). This probably reflects the higher input

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of wa

and fertilizer received by this cane in our attempt to maximize

total Biomass. There vere no consistent effects of narrow row centers on

Brix data, and only slight differences on a varietal basis. Hence, assuming

?an essentially constant recovery of fermentable solide (85-80% would be

normal for PR cane), the highest production of total fermentable solids should

seinly be @ function of the highest tonnage of m{llable cane that can be

obtained through intensive cane management.

?The importance of maxinising the tonnage of millable cane for increased yields of fermentable solids cannot be overemphasized (28). An example of this is presented in Table 51, using the average yield of Puerto Rico's cane industry in 1978 (30 green tons/acre), plus the approximate mean value for first-year willable cane from the present project (80 green tons/acre). Also Listed is a projected tonnage for first-sad second-ratoon cane from the sane project (100 green tons/acre). Innediately evident is the large increase of

fermentable solids that wil) accrue even with low Brix (13.12) and 2 conserv:

tive extraction estimate (85%). The low Brix value is normal for sugarcane continually forced tovard high biomass tonnage without regard for sucrose. The relatively low extraction estinate reflects the expected sugar losses

arising from higher fiber and cane resid

delivered to the factory (33,34).

?Yet, these "losses" are quite negligible when viewed in the context of the

tworto three-fold increases in tonnage of energy cane over conventional sugar~

cane. Again, in this scenario it is high-test molasses and fiber rather than

that constitute the prime management objectives.

for Cane and Napier Grass: While

the first-ratoon crop data are incomplete at this writing (June, 1979), several

trends are evident for the first six months of Year 2 (Table 52). For purely

botanical reasons the cane plant will normally produce more dry matter for at

---Page Break---

-35-

east tvo ratoon crops following the plant crop (ie, following the first

year's productivity fro the original

jeded cane). However, as indicated

by the sunmary data in Table 52, the first-ratoon response for sugarcane is

heavily reliant on the frequency of harvs

1. Ratoon plants harvested at

2-aonth intervals were no wore productive than were their first-year pre~

decessors. Ratoon plants harvested at d-and 6-wonth intervals produced about

65% and 43% more dry matter than hed the first-year cane, respectively, This

trend tovard a lesser-difference between plant-and first-ratoon cane yields

should continue throughout the second year, » first-ratoon superiority in the

order of 20% being about norua! for PR cane. Second-ratoon yields should

equal or slightly exceed those of the first ratoon crop. For napier gras:

ratoon yields were markedly higher for both the 2-and 4-sonth harvest intervals

(table 52).

A curious feature of the 4-and 6-nonth cane is the much greater increase of

dry matter than green matter in the ratoon plants (Table 52). This effect,

although noted previously (1), is extrenely difficult to explain on a physiol

otical basis. In essence, two sets of plants of the same species, having the sane calendar age and agronomic care shov widely differing physiological ages, that is, in terms of tissue expansion and saturation. The only variable

factor he!

is the age of the crown; hence, the maturity of above-ground shoots ?of equal age can apparently vary as a function of the age or degree of develop~

pent of the cromm and root system.

te

is

4, Sordan 704 and Napier Gra

A second field-plot study was established during January of 1978 for direct evaluations of Sordan 70A and napier grass (Common Merker) as short-

rotation candidates. Two napier hybrids (PI 7350 and PI 30086) were also

---Page Break---

sted for the first tine an possible replacements for Conmon Merker. PR 960

wos retained as a reference clone. This experiment was conducted at the seai~

arid Lajas Substation under soil and climatic conditions identical to those

described earlier (1), Comon Morker, the napier hybrids, and PR 980 vere

Planted at 50 ca row centers, ie, approxi

ely the comercial spacing for

napfer grass but about 1/3 the comercial distance for PR 980. Sordan 70A was soeded at 25 cm row centers, slightly farther apart than the standard seed Grill setting of 22.5 ca for this crop. Uarvest intervals were at two, four, and six eonths, Overhead irrigation anounting to about two acre inches vas

[TUOPICAL GRASSES EVALUATED AS SHORT-ROTATIOW CANDIDATES; LAS, 1978

curesvar species ow Genter (ce) _tarvest Tacerval

7 380 Saccharum Hybrid so 2, 46 6 noathe

Comson Merker Fennfsetve purpureun 30 see

Pr 7350 porpurews lybria % tte

PL 30086 Bs purpureun tybrid %° nd

Sordan 70-h ?Sorghun x Suan Hybrid 25 sane

applied at planting and at four weeks, and flood irrigation was administered

at 10 vecks. Fertilizer vas given in three increnente; 1/3 at planting, 1/3 at two months, and 1/3 st four months.

Warvests for this experiment vere only p.

tially complete at the close

of Year 1, Yields are presently reported on finalized data from three 2-nonth

harvests, one 4-nonth harvest, one d-month plus 2-nonth hatvest, and one

S-nonth harvest (Table 53). Salient findings from this study include the

following:

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© Sordan 70A (an NK hybrid) is a very superior short-rotation

candidate

© Napier grass is a superior intermediat

rotation candidate

© Napier hybrid No. 30086 is superior to comion napier grass

? G-month maximum yields are in the order of 10 ané 15 dry cons/acre,

for Sordan and napier grass, respectively.

These data essentially verify the incomplete results reported earlier (1).
Important implications for biousss research, and for energy planting in

collaboration with food planting, are discussed in deteil in that report.

(a) Final Tonnages; Month Harvest

?The final harvest for this experi

ment was taken during the first quorter of Year 2. The G-month data verified
4 very favorable grouth potential of Sordan 70A when harvested repeatedly at

2-wonth interval

This hybrid equalled or exceeded the yield capacity of the
three napier grasses and vastly exceeded that of PR 980 (Table 53). hen

four months were alloved for plant developuent, napier grass energed as the
?superior producer while the sugarcane control st{11 lagged behind. Sugarcane

improved its yields markedly at eix monthe but remained inferior to napier grass.

?Anong the three napier grass varieties tested, the Plant Introduction hybrid

30086 significantly out-produced the standard variety comion Merker (Table 53).

(b) Trash Yietds:

Trash dats wore recorded for the five varieties at

6 months (Table 54). Relatively Little material was expected yet roughly one

ton/acre

collected for sugarcane and the napier grasses, This ancunts to

approximately 8 to 10 percent of the total dry matter yield over @ tine-court

of six months. Sordan 70A produced virtually no trash. The highest yield for

---Page Break---

- Be

total dry matter (trash plus intact plants) was 15.3 tone/acre, obtained from

napier hybrid PI 30086. This vas significantly higher than the Connon Merker

yield of 12.7 tons/acre /.

(©) Response to Variable Crovn Establichnent Periods: An inportant but

4ifficult question underlying the use of tropical gr:

es for frequently-recut

bionass fs the tine required for eroms and root systens to be fully established,

that is, to develop to the point where they can best withstand the "shock" of

Fepeated harvests at 6-to 10-veek intervals. Yor example, should harvests planned

for 2-nonth intervals be initiated tvo months after se

Hing, or should four

months or @ year elapse before such harvests are begun? The project's linited

Fesources have not allowed this point to be studied as a controlled variable.

Sone limited information w

obtained from the present experiment owing to the

?my and G-sonth harvest intervals tested ina G-nonth study. The plants,

from the (-nonth harvest were recut at six months, thereby providing a "4 months

plus 2 months" harvest in vhich 2-noath old plants were cut from crows having

four previous sonths to become established. This contrasts with prior 2-nonth

harvests, all of which vere performed either two months after seeding or two

months after a prior harvest.

Mean values for the five test varieties indicate that tonnages of 2-aonth

old tops were increased by about 50 percent if crows vere alloved either two oF

four months development tine before the first 2-nonth grovth performance is

measured (Table 55). Putting this another vay, the two months of measured grovth

was significantly less productive when reckoned from the day of seeding rather than from established crovns. This in itself is not surprising since the

Some question remains as to vhether or not conmon napier grass is actually

85 productive than hybrid forns, or whether there {s a difference in the

?amount of vater needed for their axisum yields to be realized (36).

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ee

germination process is a time-consuming factor. However, there vas no appre-

cfable difference between the yields from 2-nonth old crowns and d-nonth old

crovns.. This auggests that the pre-establichnent of crowns is important only

vp to a very limited point in time, possibly just enough tine to compensate for

the growth period lost in the init:

1 germination process. This is substantiated

by the fact that Sordan 70A, the only direct-seeded variety and the only variety

noted for its rapid germination, was also the only candidate producing superior

arovth when measured from the day of seeding rather than fron an established crovn (Table 55).

With Sordan 70h it vould be clearly to the planter's advantage to perform his first 2-nonth harvest at two ronths from the tine of seeding?and this in fact is a principal characteristic of an authentic short-rotation species. Por the three napier grasses it could very well be better to perform the first harvest at four months after seeding. With sugarcane, the question of crown establishment becones a mute point since the plant is obviously neither a short~

nor internediate-rotation candidate. For long-rotation candidates euch as

?sugarcane the process of cron establishsent would be accommodated within the long time lapses between planting and the first harvest, and between all sub-

?sequent harvests.

5, Minimum Tillage Studie

Lajas Substation

A majority of the tropical grasses discussed above are needed for intensive Production of biomass, but there is also a need for minimum tillage candidates, that ie, for grasses that will produce at least moderate yields with the barest iminfmun of production inpute. This requirenent is underscored by two factors:

(@) Puerto Rico's water resources, even if fully developed, would supply only

about half the water needed for highly intensive production throughout the

Island (37

3 and (b), econonic considerations will not always permit a mexinum

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expenditure of production resources even where auch resources are othervise

available. The principal requiresents of minimum tillage candidates in Puerto

Rico are discussed in # prior report (1).

?The first experinent involving minimum tillage conditions was conducted

during the spring and sumer of 1971

Five clones vere planted in 1/50 acre

plots on a Fraternidad Clay soil characteristic of the AES-UPR Lajas Substation

(38), These clones included three with predominantly S. spontaneum germplasn

(US 67-22-2, US 72-72, and US 72-93), @ wild Saccharum clone believed to a

s

spontaneum hybrid, and the interspecific hybrid PR 980 serving as the

reference clone. A single fertilizer application containing 100 Ibs. of N/acre

was given at planting together with about two acre inches of water, Two

additional {rrigations of approxinately two acre inches each vere administered during the course of the experiment. Germination w:

very poor for the

spontaneun hybrid, but all other clones experienced excellent germination and

vigorous early growth,

[A single harvest was taken at six months. The leading biomass producer

was US 67-22-2, while the S. spontaneum hybrid lagged behind owing to its very

sparse stand (Table 56). Both gr

ind dry-natter yields for US 67-22-2 ve

significantly greater than those of the reference clone FR 980, Trash yields wore exceptionally high for G-nonths old plants (Table 57), but this vas

probably a result of the generally lov vater supplic

which totalled only six

acre inches above natural rainfall. Under these conditions sugarcane tends to

shed its oldest leaves as a water-conserving =

jure, Lov ¥ supplies may also

have been @ factor, although no visible deficiency syaptous vere observed.

At firet glance the yield data for total dry matter do not appear impres-

sive (Table 57), until one recalls that this vas only a 6-sonth experiment with

rather meager production inputs. Yields for PR 980 (9.0 tons) were consistent

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with those at six months from a more intensive propagation regime (Table 58, 8.6 tons for PR 980). Moreover, this was exceeded siznificantly by US 67-22-2

(20.9 tons).

?This in fact compares very favorably with the Ieland's sugar

industry average which is placed in the order of about 9 dry tons/year.

©, FIELD-SCALE STUDIES

Purpose

?A major objective of th:

project is to establish methodology for the nechanized harvest and postharvest handling of tropical grasses propagated as biomass energy sources. This objective covers both a broad range of species having varying maturation and stand-density characteristics, and a series of diverse production inputs bearing heavily on subsequent harvest operations.

Solar drying, that is, the use of incident sunlight to renove plant moisture in the field, {8 to be developed to the maxiwum extent possible, The annval dry season at Lajas, of some eight months duration, wes a decisive factor in

Locating this project's field phases at the AES-UPR Lajas Substation.

2. Species Categories

From an agricultural engineering standpofnt the mechanized harvest tasks

to be accomplished are closely tailored to the short-, intermediate-, and long:

rotation species categoris

already established by the project (9). Up to this point these categories had been defined first by species botanical characteris-

ties, and

cond by the need to integrate such plants into food-crop rotations
in which the time-frame available to the biomass crop will vary fron two to 18
months. In essence, the harvesting tasks can be grouped into three classes

based on the density, or standing mass, of plant materials confronting the harvest
machine, and the porcentage of fiber contained by thore materials at the tine of

harvest (39).

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The first category deals with otonding biomass in the order of 15 to 25

green tons/acre. Sordan 704, a short-rotation crop, is characteristic of
species having yields of this sagnitude, The project's approach to such

materials is to harvest thi

1s solar-dried forages. Tue aachinery tasks vill
vary with the state of the crop'e saturity, ie, with plants having from 10 to
12% fiber at six weeks to 30 to 35% fiber at 12 weeks. A second category deals

with standing biouase in the order of 25 to $0 green tons/acre. The represent~

ative species here is napier grass, an interuediate-rotation crop whose dry matter content is maxinized between four and six months after planting (9). Again the crop's state of naturity is critical to the success or failure of

harvest

whinery. Warvested at tvo months of age (8-12% moisture) napier grass should offer no nore difficulty than conventional cattle forages. At six months, offering 35t dry matter and up £0 50 green tons/acre of standing biomass, the harvesting task may possibly exceed the capabilities of existing forage-naking equipnent (39). The project's plan is to try to handle such crops as solar dried forages.

Bioaass crops offering nore than $0 gree tons/acre comprise a third cat-egory of harvesting tasks. The characteristic species here are the hybrid sugar~canes of commerce. There is no possibility of dealing with chese plants as

forage crops. Not only is there

excessive mass of material confronting the

hharvest machinery, but also the thickened cane stems do not lend thenselves to

solar drying, unless First prepared by sone process of milling and juice

expression. Project plans are to use a coshination of solar drying (for leaves

and ?trash renoved in the field) and mill devatering for the cane stalks.

Eagasse issuing from the sugar mill might also be solar dried and baled, or at

least partially dried by stacking in the open air. A harvest machine capable

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fof handling cane in excess of 50 tons/acre is the Klaus Model 1400, single

How, vhole cane harvester. This

\chine renoves leaves and trash in the field with a powerful air blast, thereby preparing a clean, b/lleted, and physically

organized whole cane for delivery to the mill,

3. Initial

Machinery Trials

Most of the project's field machinery arrived on the Istand during the

third quarter of Year 2. Specific itene include a Mode! 8700 Ford cractor, an

WC Model 9-£ Rotary Scythe (with 9-foot moving evath), @ hemy-duty, side-

delivery forage rake (Wow Holland Model $7), a New Holl:ad Model 851 Round Baler,

fang @ Nev Wolland Model 393 Tub Grinder.

ass: Prelininary tests were performed with the

yotary scythe using wild Johnson grass (Sorghum halepense) as the test material.

This inplenent does not cut or mow grasses

does a convent ional sickle-bar

mover, but rather breaks off and ?conditions? che grass with a series of steel

plates rotating at high speed with extrenely powerful force (Figure 15). The conditioned material is deposited in windrovs of adjustable width directly Behind the mover. The rotary scythe {s a thoroughly rugged machine (40). Relatively fey factors can inhibit its performance short of an inadequate pover supply (tractors having less than about 90 hp), oF the encountering of plant materials of sufficient mass to stop the blades or the tractor engine.

No difficulty of any kind was encountered in the first trial wich Johnson grass. This material anounted to roughly 10 to 12 green tons/acre. The rotary

?seythe was moved to a second field where Johnson grass had grova wild for several years

The implenent performed quite adequately, with the exception of "heavy"

areas where accumulating dead Johnson gras had formed sats approxinately two to

three feet thick. In such areas the mats sometimes tended to push ahead of the

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= be

implenent rather than pass under it in contact with the rotating blades. Tt

should be noted that the rotary scythe is designed to function most effectively

on individual plant stems. The stens vould preferably be upright but the

rotary seythe is also designed to harvest lodged saterial.

All of the materials chat were harvested (conditioned) with the rotary

scythe were effectively solar-dried within three to four days. The drying

Process was assisted by turning the windrovs twice with « side-delivery forage rake. The Round Baler performed quite effectively on Johnson grass with initial

ales weighing in the order of 1000 to 1200 pounds.

(b) TeSals With Sordan! JOA: Sordan 70A was the first biomass candidate

Scheduled for Cield-scale harvesting trials. Four blocks of approximately six acres each were planted at the close of the third quarter. Seeding rate vas 60 pounds/acre, drilled in 9-inch row centers in two directions on the field. ?The planting of these fields was delayed approximately two months oving to atypically heavy rainfall in Decenber-January, 1978-79. Harvests for the respective blocks of Sordan 70k vere performed at 6, 10, and 14 weeks after seeding.

Performance ratings for the rotary scythe are presented in Table 59.

?The G-weck old material presented no problens of any kind for this machine.

?The plants werecompletely upright and succulent. Initial concern that the

/

relatively long stens (averaging 5 1/2 to 6 feet) +/ might cause then to fall

backward over the rotary scythe, rather than forvard to pase under the rotating

Viades a8 intended, were unfounded, All of the upright material fell forvard

hen moins conventions) cateLe forsses (as ite sanutsctorer intended) the

rotary scythe will rarely encounter plant materials more than sbout thr 2 feet

hi Hence, he Ieading cig of the ieplencnt which seston the ances a

WATT cone then to fall forutrd without pobloses ihe heat eee

tyve of tropical grasses which are much falter aad chicken

offer greater resistance to the rotary scythe. eaenitaaane colored

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use

without exception (Figure 16). Nor was there any tendency to form balls or

ste in front of the mower, even viien operating at ?high? speed (in the fourth fend fifth forward gears of the Model 8700 Ford Tractor).

A much worse set of harvest conditions vas experienced for the 10-and

Jnweek old crops, but the rotary scythe nonetheless gave a very satisfactory porformance (Table $9). Extremely heavy and unseasonal rainfall was received intermittantly fron veek 8 through week 13. This caused moderate to severe lodging in both the 10-week and Ld-week old planta. In both instances much of the Sordan 70k vas flattened to a height of 8 to 12 inches and was severely matted, that is, the stems had cris-crossed and interlaced in all directions. ?Tue plants harvested at 14 weeks had renained in this condition up to five weeks. During this interval, the sated Sordan 7OA vas further interlaced with herbaceous weeds (both vines and upright grasses) plus a regrowth of secondary Sordan 70A plants stinvlated by the heavy rainfall. Together vith the abnorsslly soft seedbed, these conditions offered the worst possible circumstances that

fone can reasonably expect in harvesting short-rotation crops. Hovever, the rotary scythe performed quite adequately. Ar no tine vas it necessary to stop

uy

and clear the machine 1/ of baited grasses, and only occasionally vas it necessary to shift into a lover operating gear.

A period of intermittant rainfall following the 10-week harvest caused considerable difficulty in drying the conditioned bionass. Good weather

followed the Md-weck harvest.

baling within three days.

Baling operations for the solar-dried Johnson grass and Sordan 70A were

performed withoue encountering major problems (Figures 17 and 18). Minor

© Such stops would have been an almost continuous feature if ve had attenpted to harvest the Ié-week old material with a sickle-bar mover.

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problens incident to hydraulic connections between the Baler (a New Holland product) and the project's Ford tractor were easily cerrected. Because no one fon the project staff vas directly tamiliar with the beler's operation, it vas necessary to practice its hindling on solar-dried weeds and Johnson grass. Yor exemple, the correct acunt of twine needed for # 1500 pound bale , about 150 fect, was deternined by trial and error. Such factors as the baler's best onerating speed, the correct size and compaction of the? bale, and the azount of twine needed to secure the bale for subsequent loading and transport opers-tions are largely a matter of judgesent by the machinery operator confronted

with a specific set of conditions:

D, HCONGIHIC ANALYSES

The project's initial econoaic analyses were perforned at the close of

Yoar 2, Production cost estimates for Sordan 70A, including solar drying, baling, and delivery to a centralized combustion site, were prepared on the pasis of fielé-plot and field-scele data obtained since Sordan 7OA was identified as an authentic short-rotation species during Year 1 (1). Total costs are in

the order of §24.00/oven-dry ton, or about $1.60/aillion BTU's (Tab

6).

Cost estinates are based on @ hypothetical 200 acre energy plantation operating in the Lajas Valley with current production input costs ané doller values for Puerto Rican agriculture, A 200 acre energy farm can be accomodated confortably with a oingle set of foragernaking machinery such ae that being utilized for project studies. Specific Figures for Sordan yields and produc tion input parameters are derived directly from project data compiled during Years and 2. Machinery purchase, maintenance, and operation costs are also

based on project

Biomass delivery cost (at $6.00/dry ton) is the only

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pucely astinated figure in the expeaditure analysis, 1t is based on 1979 rental cates for a 40 ton, lowbed truck (at $125.00/8 hour day), two drivers/ truck/® hour day (at §25.00/driver), field loading of 1he Jou-bed truck with hired equipment and equipment operator, delivery of four 25-ton loads/day/ eruck, and onlosding the truck at the combustion site vith hired equipment and equipment operator.

?The cost estinate of $6.00/ton is probably a bit high. Sugarcane, for example, was being delivered for about $4.80/ton throushout the Island during the 1979 cane harvest season. Moreover, an energy planter with a 200 acre operation would probably purchase his own truck and Loading equipment, there-by reducing delivery charges by @ significant anount.

It is very probable that Sordan 7OA will be replaced by Sordan 77 as the principal short-rotation species during 1980. Sordan 77 should yield at least 20% more dry bionass vith the sane acreages and produc ion inputs expended for Sordan JOA. If this projection is correct, and assuai ig a delivery cost increase of 20%, final costs for Sordan 77 would be in the order of $21-08/

tom, of abort $1.41/m/ Ilion BTUs

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Quarterly Report to ERDA (Project objectives and procedures). Contract
No, EC-77-5-05-5422, Noverber, 1977-

Allison, H. Prosentation to DOE Biomass Harvesting Workshop, Baton Rouge,
?pri, 1979.

Anon. YC Rotary Seythe-The non-Stop Nover-Conditioner. Commercial
Brochure. Mathews Company, 500 Industrial Ave., Crystal Lake, TIL.
60014. 1976.

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?APPENDIX

Appendix Tables 1-60

Appenciix Figures 1-19

---Page Break---

CATEGORIES OF CANDIDATE TROPICAL GRASSES

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{TABLE 2. BIOMASS PRODUCTIVITY PARAMETERS BEING EVALUATED

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TABLE 10, TOZAL t9Y YAETER YEELD OF BIGMT CANDIDATE. HOPLCAL cnasses;

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?TABLE 11, DAY YATTER PRODUCTION BY EIGHT CANDIDATE TROPICAL GRASSES HARVESTED

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bry Matter

cuttivar Genus & Species _g/Planced area 2! g/Piant! zm

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vs enaz2 sont. Hybeis 2,055 ae ana

bs 72-70 S spent. tybetd no 2 18.4

ses 201 S: spontaneum 1,090 aa 20.0

?Teinan spent. Wybrid 1,370 28 16.4

wad Ss spent. lybrid 1a 28 ws

Pr S008 Fenniseton porpurewm 3,032 a0 Ma

JJehason Geass Sorghum hatepense 4,061 a 9.7

24 propagated Sn 4 1:2 s0i-cachaza wixture vith adequate water supply.

21 sgproxinatedy 30 square feet,

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STABLE 12. DRY MATTER COSTEOT OF E1GAT CAMDTOATE TROPTEAL GRASSES HARVESTED

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cultivar Genus 6 Species z ? ?

re 980 Saccharus Hybrid 2 356

ws 6722-2 pont. Wybrid 25.5

5 72270 $a ssont. Wyprsd 2.2 Cncomptace

sus 231 5. montane 2.0 2.0 =

tains ?Se spont. Hybrid wee 4?

wae spent. tybrid ws 2.3

71 e086 Remisutun purgutem Mal 35.4

Johnson Grass Sorghum halepense a7 382

A Propagated Sos 1:1 eoti-cachaza aieture with adequate water 6

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?TABLE 13. DRY MATTER PRODUCTION 6 EIGIT CANDIDATE TROPICAL GRASSES HARVESTED

2) @ AND f MONTHS AFIER PLANTIOIG 1/

re k/Pignces tres) 2! ae nonth -

coleivar Genus & Species 2 ? é

Pa 980 sacchavan Hybeid 0.65, 6

vs ere -apont, Hybedd nos 8

vs 72-70 Se spent. Hybrid om 66

ses. 201 Sa spontanevs Lo

Teinan Se spent. tobrid aay 9.05

wand Sa sponta tpbesa aa

1 30086 Rensisee purmwren = 3.02 19.31

Joinson Grass Sorghus halerense 4066.87

AY Propagated in e302

ét-cechasa winture with adoquate vater supply.

BI Approximately 30 square feet

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TABLE 14. DRY YTTER PRODUCTION, OLWIOUAL PLANT BASES, BY EIGN TROPICAL

GRASSES HARVESTED 2, & AND © MONTHS AFTER PLATING 1/

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corivar Genus & Specie z © é

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vs 67-2202 8. azont, wore ae 288

vs 72-70 S. spont. Hybrid 2.9 20.4 Cincomptece ses 201 ?S spontanese mo

Tainan Sa spooks Hybrid 29

wae Sa apone, Wybet 29

PL 20086 Penaisecen perperese 1.0

Johnson Grats Sorghum helepence aa

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AU Propagated in sIncachars misture vith af

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TABLE 15, ORY MATTER INCREASE, OW AN THDEVIDUAL PLAMT BASIS,

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vs 6722-2 ?Se agents hybrid 1

ws 72-70 So spent. tort 3

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Tainan Se spent. Hybrid on

was Se spent. Wybetd ou

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Johnson Grass Sorghun halepens re

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TABLE 19, PLANT DENSITY VALUES FoR SomDAX 708

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SUARLE 21. POLIAK M, Py AND K COUTESTE OF SORDU 70K PLANTS

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TUBLE 22. CREDY-AND DRY-HATTER YIELDS TOR NAPIER GRASS (Vas. FT 20086)

PROPAGATED BY SAND CULTURE WITH VARIABLE NITROGE? SUPPLY

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[DRY HATTER PRODUCTION BY SEVEN NORTERUP-EING GRASSES PROPAGATED WITH VARIABLE WATER SUPPLY OVER A TIME~COURSE OF ELEVEN WEEKS u

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TABLE 27, TELLERILG aN ORY ?ACTER CHARACTERISTICS OF CANDIDATE $. SFONTANBLNY

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0s 22087 a wt 30.2

08 72-70 oo 35 as

bs 72072 ou 235 ais

08 Fela 383 3 208

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7 YOUDAGeRS SSMOTE WOU SANIT RINVIDGWE SLVGLGAND 4O SASAIVAY AATENLWDD

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UOLE 29, Diy YAITER YEELDS BY somaN 704 FROPAGATED Mim VARIABLE s-FER-

TILYZATION AD SHARING RATES OFER A SESE-COURSE OF TEM HERS

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EATTER YIELDS AY SORDAYE TON PROPAGATED WITH VARIARLE =

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?USLE 31, FOLIAR wtTHoct' CONTENT OF SoRDA 704 PLUTS PROPAGATED WITH

\VaSIASLE N FERTILIZATION AND SEEDING 24735 1/

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TABLE 32. DRY YATTER CONTENT OF SORDAK 70h FROPAGATED WITH VARIABLE X-FER-

TILIZATION AND SEEDING RATES OvER A TIME-COURSE OF TEN UEEKS

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{TABLE 94, EFFECTS OF VARIABLE FERTILIZATION AND SEEDING RATES ON THE MOIMER

(OF BARVESTABLE. STEWS FOR SORDAW 70K TEN WEEKS AFTER PLANTING

n sopply SEea8/Aere (Thousands), At Seeding Race (Lbs/here) ~

GubelActe) © © 100 120 Mean

100 uso 96.8 57.2 161.8 3.6

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{ABLE 25, EFFECTS OF VARIABLE NITROGEN SUPPLY ON TUE INCIDENCE

(OF Do HILDEN AND LODCING IH SORDAN 70K 1/

1 sorpty toners) Ranking For ~

Gae/here)	Dovey Mildew	Lodging
100	3.06	2.35
200	35	2.46
00	aos	3.06
400	5.08	2.83

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on a numerical scale ef 1 to-10 (1'= no ayeptons, 10 = eevere

?tyeptome). Each tabulated nomber ie the arieheetic mean of 2

?Finked ploce: Data were recorded 10 weeks after seeding.

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?USLE 96, EFFECTS OF VARIABLE PLANT DENSITY oN THE INCIDENCE

OF oun HILDEX AND LODGING TH SORDAN 7OA2/

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(as/acee) Demy Miler edeiea

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?Bata vere recorded 10 weeks after seeding.

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TABLE 97. BIOWSS PRoDUCTIOx BY THE FIRST-RATOON CROP OF THREE

SUGARCANE VARIETIES ASD OME NAPIER CRASS VARIETY FROPAGATED

\VUDH VARIABLE Row CENTERS: THAD 2-MONTAS HARVEST

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

cultivar io cn 50 ee £ cnang

Px 980 18s 139 -4.0

eo 310 ems co's

PR sie1791 ear 07 cs

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Napier cress 12.67

Le

Dry Matter ¢Fons/A)

980 0.33 0.28

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Dry Yatter Content (2)

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Pe geet 791 i isl -18

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TABLES. SIQUSS PRODOCZTON BY THE FLEST RATOOY CRO OF TuREE

?SUCABCANE VARIETIES AND OME MAPTER CRASS VARLETY PROPACATED

WITW VARIABLE RAY CEXTERS; POUSTH 2-MCNTW RANVEST

Green Matter (lons/A), AE Rov ester ~

coletvar 150 ee soca Change

PR 980 0.60 2.75 25.0

ee 310 Tes zon 2s

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Napier cease sa 30)

Dey master (Tone /A)

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eo 310 oat out °

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apter cea 0.02 0.87 60

Dry Matter Content (2)

PR 980 19.0 25.7 35.2

eo 310 3531 20.6 a

Peas i ?

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Mapter crane 13.6 16.9 s

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?TABLE 39. BLOWS PHUUUCTION SY THREE StCARCANE VARIETIES.

?80 ONE RAPIER CRASS WARLETY FIRST BATON CHOP,

Farm tr wanvest

Dry Matter (Toss/Acte) At Row center ~

caeivar 150 ee 50 cw

Pe 980 0.38 0.54

to" 310 og 7

PR 6b-t79 oa O54

ee em

Napier crass 2240

F Change

38.4

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Ere

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Pe 980 2.08 2.99

Neo 310 Sa Se

Pe ei-i791 2h

Napier crane y. 2

Green Matter (Tone/Aere) ?

45.1

1)

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aoe eee

Dry Matter Content (3)

tr ttter content

PR 980 w.2

io 30 isi

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SLY 40, IOWSS PRODUCTION BY THE FIRST RATOON CROP OF THREE

?SUGARCANE VARIETIES A10 ORE NAPIER GRASS VARIETY PSOPACATED

[RIM VARIABLE ROW CENTEKS; SECOND G-HOMS MARUEST, YEAR 2

(Geeon Matter (Tone/Aee), At Row Center ~

cultivar 0c Se Tange

Pr 980 ne? oy

eo 310 Sar 37 16

Pe eiei1 eae BD 52

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eptor Gras ake a2

Dry Matter (Teos/Acte)

we 1.6

20 oe

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Dry Matter Content (2)

rx 980 ws 20 83

eo 310 Bay ca

me ee791 ae 30) a

Napier Crass 1 a8

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TILE 45. TASH YIELDS FOR SUCARCARY AND NAPIER GRASS

PROPAGATED AT VARIABLE OS CENTERS; FIRST

HORT HARVEST, TEAR 2

eawh Wield Clons/Acre) At How Conter?

eutivar 180 ce 50 cmt change

PR 980 1a 1.62 2s

co 310 1 Los 33.3

Ph 6ia791 108 an 38.3

Soe te

Nepier Grate 96 ar 2

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TAN SG. TOTAL DRY YATTER YIELDS, ISCLUDING TRASM, FOR SUGAR

(CAME HD STEN GRASS PROPACATED AT TARISAGLE Ow

CERTERS FAST CHLTHS RAREST, TEAR 2

Total DM (Tone/Acre) At Row Center ?

cultivar Ao ce 50cm change

ra 980 122 20.5 Bes

es 219 aa 9

Pe Gee ao a4

20

Ba =)

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TABLE 47, WAND RETRACTOMETER FALUES YOR TIRKE SUCARCANE VARIETIES

PROPAGATED AT

[STANDARD AND BARRO! 1D CONTRA

Netractoneter Neadings AE Indicated Period And Row Center ~

6 Horie 8 Months

Chase 10 en $0 em Ghange 150 cn Sem? change

PR 980 w2eVwse 49 We 22 10.3

ico 310 Mee Wee 06 wae 109 a0

menus ase ee 5a 17.9 se 38.1 aa

20 Months 22 Mone

Pa 980 79> Oe 0.8 1S See 54

ico 310 1.62 20.38 35 WI 252 40

MROLI9L SB 18.0.5 WW. de bade 2.6

Y wean values in the sane colua and sampling period bearing unttke Letters

sitter significantly (P-2-08). Voluca inthe sume row and. sampling, period

bearing utlike tatters aise vary signiticatniy. Means having at least one

etter kn connor are not signiticeatly it ferent.

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TABLE 48, RAND REFLACTON=TEK VALUES FOR THEE SUGARCASE VARIERIES|

AT FOUR SOLIS. 1wTEROALS 27

NF Values At Month ?

é s 10 2 teas

meee

6 1.0 19.0 as

we 0.0 et 18.5

Da 0 ake aa vs

4 tach tigure is ene computed sean of evo row centers

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TTDLE 49. MEAN ua RSVRACTONETER VALUES YOR SUCANCARE PROPAGATED|

IAF STANDARD AX NeanOW ROW CENTERS 1

Row

Spacing (en) ? . 10 2 Mean

130 (eta) M20 et 7a ws

30 M7870 18.1

4 wach figuee 8 the computed sean of thre

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TABLE 50. CWE QUALITY VALUFS FOR THREE SUGARCANE VARIETIES PROPACATEO AT

VARIABLE Row GHi1:25 3 HARVESTED AT 6-AND 12-S0KTW INTERVALS

EHonths Harvest Lasnonens sevest

larization, At Rov Concer Polarisation, At Row Center =

Variety 150 <a SO em Change 150 ca 50cm 3 Change

Px 980 32 4B 28 ans

Neesio $12 S10 ake 10

resem 3:9 33 Te U8

PR 980 aa

Nee sio 918

Peseta 96

Fiber Fiver

PR 9 4.85.7 60 M20 8 Bt

Neo's1o ag 346 ° ie 93 ah

Peel 152 ded 6s west 15.0

Poriey Pority

R90 56.6 52.7 3.0 6 = 5.8

Beorsio s3rt 5:3, Rss °

PRéeim $8.1 50:9 a Bee

Rendinent Rendinent

Pe 960 28022 wae 26 6h ASL

Neo sio = 28253 vie ies 92 TD

meet 3:2 30 ba Bae Tals.

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HOLE 51, EsTuNATED YEELDS ew VALUE OF FEIECTABLE. SOLaDS AND HIGH-TYST

HOLASSES FROM TSTESE"VELT-PROPAGATED SEEARGANE 1/

_ __Batimated vatues Fo =

intable Cane Formentabie Sols

Wolgssss Valve

Gront/hcre't) "*Gronaihcre Ye) Ginere)

20 2.6 655 ar

wt 1 ne ane

x00 2 nae 2183 1638

Y pasuning a wean Brix value of 13.12 and an average extraction of AS.

Worssses value is computed st 95 cente/guitons

2B spproxinate mean value for three

» projected mean value for thre

verieties and two rov conten; first-and

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ante 54, reas 2/ gun TOTAL DRY MATTER YIELDS OF FIVE CANDIDATE

?TROPICAL GhzSSES HARVESTED SIX MOMS AFTER PLANTING

Dey Tons/Acre for ?

cultivar Trash tntace Plante

PR 980 (Keterence) 0.95» 8.024

92 11.82 be

Lata 13.55

omy 14.55 «

race © aoe

fnctudes leat blades and Leaf sheaths chat have

detached from the stem in tecor

processes. This saterial aay contain slightly

hen ovendey tient

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TADLE 55. DRY MATTER YIELDS oF FIVE CANDIDATE TROPICAL GRASSES DURTNG AX

8-WEEE

INTERGAL FOLLEWING VARIAELE PERIODS FOR ESTARLESIDNT OF CROWS 77) ona/A Following Indicated Establishsent Tine (Yonths) ?

cuttsvar ° 2 ?

PR 980 (Reference) 0.41 0.766

Conon Napier Gea Lana 2.096

Napier tybeid 7350 1.8 6 bao e

Napier tybeka 30086 2a gaze

Sordan 708 aaa aaa

ean 1.36 2.96

© saved on mean values from replicated 1/50 acre plots.

2 wean volves in the sane coluon bearing unlike Letters differ significantly

(#<.05)." Hean values havieg ae Least one latter in common do not differ

sigoiticanely

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TABLE 56. DAY MATTER YIELDS FOR FIVE SACCHARIM CANDIDATES

POR MNY TILLAGE FRoDveTTON

Bationted Tons/Acre/6 Hontne Y/

clone Cree ven Dry

vs 67-222 16.5 0 / bbe

emer 15.808 t0

es 1293 Moa sam

smo. yorie! oe ate

980 Chaferenc) nas sae

© sased on data from replicated 1/50 acre plots.

2 riots of the §. apontancus hybrid experienced lese than

?or germinate

21 oan values in the sone colvan bearing wnlike letters

differ signiticanely (P2085).

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TABLE $7. TRASH AND TOTAL DRY SOFTER YIELDS FOR FIVE NONIMEN TELLAGE CANDIDATES

Projected Dry Tons/Aerel6 Hoothey 2! Foe ?

ror

Clone Trash Intact Plante Total ON PR 980

vs 6722-2 ase ue 10.8 aaa

us 72072 23a 6.0 93 203.3

us 72-99 3.5 5.5 ab 0 100.0

spent. Hybrid 2/ Lge 266 as 30.0

Ph 980 (Reference) are sae 9.0 100.0

u 1 from replicated 1/50 acre plot

2

2/ tye 5. spontaneum hybrid experienced lees tahn 4O% germination

2! wean values in the sane colum bearing unlike letters differ significantly

(eo).

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or

pen ter uot @

aa

?(yaa wa-isita) SKANOA ZT 40

?aseooo-il2 ¥ ABHO SIVAMALET STEVTHVA AV GISaANNH Ss¥wO HATA ORY aAVOHVONS

Wo SUTELA MALI AEC ?8S STOVE

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?TABLE 59, PESEORAAICE EVALIATIONS Fox THE Moc AOTARY SCYTHE OPERATING OW

SORDKE 70K PLANTS OF

?varetne WatvRItY aN DECREE CF LoBCIX

Aotapy Sethe ting, A Ladng Sater ?

Co Mean

6 e100 oY ya a a ak 1,00

10 aero hoa aoa a a 2 aaa

&E Gomtetty priehe

LL (Lightly Lodgea)

ME (Hoderately Lodged)

1+ Normal performance, operating as designed; 5 + faulty perform

ste a0 designed

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ZMINARY COST ALALYSIS FoR SORD:N 704 PRODUCTION

1480 AREA: 200 Aeres

PRODUCTION INTERVAL: 6 Yonthe

SSORDAH TOA YIELD: 15 Tons/Acre: Total 3,000 Tons of Over-Dry Material

Prelisinary Cost Analysis

ie Sone (8)

A. Land Rentat, at $50/Acre Year 5,000

2 Water (Overhead Irrigation), 340 Acre ft 2.10

3. Seed, at 60 tbe/hcre 4,000

fe Feresiieer 10,000

5. Peatteses 4,000

6. Equipment Depreciation (6 22.) 2,650

7, Equipment Maintenance (152 of Depreciation) 3,988

8. Equipment Operation (75% of Depreciation)

9. Diesen Foet

10, bay Labor (90.00/bay for 140 Days)

LL, Delivery, at 6.00/Ton

Subtotals

Total Cost/Ton: (71,924 + 3,000): 23.97

otal Cose/ML2Gon BTUs (23.97 + 15): 1.59

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Dav Ht (e/ruset)

Wones arran steptxc

Figure 1. bry matter yiel

?Teodan 5 over timer

for the NK hybride Sordan TO-A, Mittex 23, and

of 10 weeks!

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Div HATTER /PLANT)

aa

Vigore 2. Dry matter yielée for eight tropical grasses

Under ainvlated normal, aeni-seid, snd arid soleture

Feginee. Each corve 42 derivet {fom the computed

?Eebar of seven ?ibd one Serghun species.

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Dry MATTER cosreer (2)

variable

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ay sucren,

ogre 10, he nen natration cunve (ey etter

propagated overs tine-couree of eleven weeha.

Eich plotted value in the computed wean of

even varieties snd three woisture reniee

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? sordan. 708

ny warren, 2

ettex 29

igure 11. Dry matter accunelation in five Worthrup-ting granses propa-

iieted vith a ?normal? water regine over s time-course of eleven

Seeks.

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DRY MATTER (4/ttone)

aie Norma Seni-arid

vorsrome nacnae

Figure 12. Dey matter production by forden 70h,

?Trudan 7, a

iene" ceepeced mean Sf tn plant tanpiee harvested

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MONTHS AFTER PLANTING

Ne ey maeer production by. won

feret iver st planting, 1/3 folloving the

snd 1/3 following the S-nonth harvest.

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