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PRODUCTION OF SUGARCANE AND TROPICAL

GRASSES AS A RENEWABLE

ENERGY SOURCE

FIRST ANNUAL REPORT

1977 -1978

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PRODUCTION

W SUGARCANE AND TROPICAL GRASSES AS A

RENEWADLE ENERGY SOURCE

Firet Annual Report

1977-78,

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The United States Department of Energy

Gak Ridge Operations Office, and the Division of Solar Energy

Fuels From? Bionass Branch

Washington, D. C.

By

The University of Puerto Rico

Center for Energy and Environsent Resoarch

?Through

?The Office of the President

University of Puerto Rico

CONTRACT NO.: EG-77-G-05~5422 (AES-UPR Project C481)

PERIOD COVERED: June 1, 1977 - May 31, 1978

ENDORSEMENT:

Leg B2 Cotsssucle

?Alex 6, Alexander

Project Leader

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FIRST ANNUAL REPORT

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PRODUCTION OP SUGARCANE AND TROPICA!, GRASSES AS

?A RENEWABLE ENERGY SouRcE 2/

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UPR Agricultural Experiment Station and Mayaguez Faculty

university of Merto Rico

ansrRAct

1s from Saccharum and related genera are betng evaluated

tes for intensive production of solar-dried biomass. Categories

of candidate grasses include short-, intermediate-, and long-rotation spe~

ches for intensive co-production with conventional food commodities. Mini-

mup-tillage candidates are also sought for extensive production on marginal

Lands. The hybrid forage grass Sordan 70-A\(Northrup-King Company) isthe

outstanding short-rotation plant tested to date. It completes both the

Ussue-expansion and maturation phases within 10 veeks, yielding at least 4

tons of oven-dry biomass per acre. Napier grass (var. Common Merker) 1s a

promising internediate-rotation cfop which possibly say be exceeded by sev-

eral napier grass hybrids. Interspecific Saccharum hybrids and the Saccharum spectes §. spontaneum and S. sinense are being gated for both Tong= votation and minimin tillage cropping. Direct comparisons of sugarcane hybrids with napier grass indicate that sugarcane is an inferior candidate for short-term production of tropical forages. Sugarcane responded well to narrow spacing for about 6 months after seeding. Napier grase failed to Fespond to close spacing. Both species increased yields with decreasing frequency of harvest. Fertilization rates based on conventional sugar and forage Production data were inadequate to sustain maximim bionaes yields. candidate Brasses have shown two discrete biomass production phases, ie, tissue expan sion which {s highly visible but consists mainly of water, and tissue saturation vhich has Ifttle visibility but yields the bulk of the plants? éry matter. Additional progress was made in sugarcane grovth control with chemtcal grovth regulators.

T/Gontrect Wo. EG-T7-G-05-5422 (AES-UPR Project No. C-681)

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PRODUCTI® OF SUGARCANE AND TROPICAL GRASSES AS

?4 RENEWADLE ENERGY SOURCE 1/

TRODUCTION

?The Plooass production studies herein reported uere initiated June 1,

1977 as a contribution to the bionase energy program of the UPR Center for

Energy and Environment Research (CEER). This research d

is with sugarcane,

tropical grasses related to sugarcane, and other tropical grasses having

Large growth potentials on a year-round basis. Ite basic premise is that such plant materiais can be produced as a renewable, domestic source of fuels and chanical feedstocks that will substitute for imported fossil

energy sources.

Project Objectives

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

feasibility of mechanized, yea

?round production of solar-dried bionass,

through the intensive management of sugarcane and napier grass as tropical

forages, and (b), examination of alternate tropical &1

es as potential

sources for intensive biomass production. A secondary objective concerns

the selection and breeding of new sugarcane progeny having superior biontes

productivity as their principal attribute.

Scope of the Project

Eaphasis {6 directed tovard a highly-intensive and mechanized production

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

AJ Contract No. £G-77-G-05~5422 (UPR-AES Project No. C-481)

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woe

conventional cane and cattle feed production in that total dry matter rathec

han sugar and food components is the principal salable connodity. Manage~
ues

nent of production inputs=pa-ticularly vater, nitrogen and candidate species, together with harvest frequency, vill vary significantly from established procedures. On the other hand, advances in mechanized production and har= vest operations within the sugar and cattle forage industries will be utilized to the maximum extent possible for dry biomass production.

Optinized production operations require the identification of a few select clones and the conditions required for thet management in an econon=

feally-realistic operation. This is being accomplished in three phases,

including greenhouse, field-plot, and field-scale investigations (7:

1e :

A fourth phase, comercial-industrial operations, follovs logically but les beyond the scope of the present project. The firet-year's work herein

reported deals with the gr

house phase and initial fLeld-plot experinents. -

?The tropical grasses have never before been evaluated under conditions such that biomass energy vould be the principal salable product. As a con= sequence it {8 necessary to screen a broad range of candidate cultivars if the optimal yield capacity of these gencra is to be realized. Under certain cfroumstances existing eugar-and fiber-producing varieties nay excel also tn total biomass yield, but it is generally recognized that the grovth

actetbute hi

ot been fully intensified in the hybridization programs

that led to the present-day varieties of commerce (1,2) /. screening

studies have therefore included older hybrid varieties no longer produced

commercially, ?noble? or pure intraspecific clones, superior selections

1/ Munbers in parenthesis refer to relevant published Literature,

Complete citations are Listed on pages 54 to 56

---Page Break---

fron wild populations, ad more primitive forms searing the germplasm from

hich modern genotypes have been assembled. A screening technique was

adopted for this purpose in which botanteal, physiological, and agronoute

attributes are evaluated in a stepwise program involving greenhouse, field:

plot, and field-scale trials, In certain respects this 1s tropical appli-
cation of the herbaceous species screening concept recent ly formulated by
the DOE Fuels Froa Bionass Progra (3).

A breoding progran designed to intensify the bionass-yielding attribute of Saccharuz and related species Les 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 synchrontze flovering periods at the intergenerie level, and basic genetic research to break some serious constraints operating to prevent the

?exchange of germplasm anong Saccharum species and between Saccharum and

allied genera (4). At a very wodest level some Limfted breeding is included in the present project. This work is confined to a few obviously desirable parent clones that have suitable flowering characteristics and which can be incorporated without inconvenience into an on-going breeding progran. Certain progeny originating with the AES-UPR sugarcane breeding progran are also being considered as long-rotation 1/ pionass candidates, Under these circumstances sone prospect is created for the enrgence of superior new progeny at very

Little expense.

/ Categories of tropical-grass candidates for biomass production are Aiscussed in detail on pages 41-45.

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?This report covers the period June 1, 1977 through May 31, 1978. Some of the longer-term experiments were not initiated until after July 1, 1977. In these instances final harvests were not complete at the close of Year 1. For example, the £ir.t major field-plot study, a 12-month experiment dealing vith harvest frequency, varieties and row spacing, was completed only through the tenth month at the end of May, 1978. The compiled date thus include five of six 2month harvests, tvo of three denonth harvests, and one of tuo 6-

month harvests, Similarly, statistical analyses are confined to ?within

harvest" variables, since the "between harvest" analyses would have Little meaning {f besed on an incomplete set of data. The finalized data for Year 1 will appear in the first quarterly report of the project's second year.

Certain of the results recorded in this report vere presented in fragnenie tary form in earlier quarterly statenents, In a few cases these findings vill be retterated here as they were originally given. However, to the maximum extent possible, prior findings will be represented in the clearer perspective of one year's experience. From this point onvard earlier interpretations vill

be strengthened by the project's statistical analyses which begin to appear

for the first eh

in this report.

TECHNICAL REPORT

GREENHOUSE STUDIES

The project's greenhouse phase {s concerned with the screening of can~

Aidate tropical gré

Jes and the response of superior cultivars to growth input

?and managenent variables. Much information of this nature 1s obtained nore

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rapidly and cheaply than {s possible under fLelé conditions, Greenhouse data are not definitive in the sense that dixect field responses and cultural recomendations can be stated, but perhaps tuo-thirds of the total

data package needed for a herbaceous candidate can be gathered in this vay.

For $i

wun and related species ordinarily propagated in populations of

30,000 to 300,000 plants per acre, the greenhouse offers a level of prect= sion for control of the individual plant that ts not renotely possible in the {eld (5). This method {s currently used in Puerto Rico for its economy of project resources; under tenperaterclinate conditions it offers an econoay Of time since field ork 1s seasonally Matted to four or five favorable

mouths per year.

Greenhouse Metho

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

pots, or in 1:1 oF 2,

ixtures of soil and cachaza contained in 10-gallon galvanized drums. Sand culture offers precise control of water and nutrient

variables. Soil-cachas

sixtures are convenient media for determining relative srouth rates, grovth curves fron germination to the young-adult stage, responses to chemical growth regulators, and tolerance to frequent recutting of candi-dates having superior grovth potentials, Most candidates to date have been established with ston cuttings of uniform size, age, and vigor. A fev cans Aidates such as svect sorghus vartettes and the sorghum x sudan grass hybrids

are established with true seed.

Insects are controlled with weekly applica~

tlons of Malathion. All plants receive controlled water and nutrient supplies

that are not rate-Liniting for growth.

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ALL first-year experiments employed the interspecific 2/ sugarcane

hybrid FR 980 as a reference clone having recognized excellence

a high

tonnage producer, In this capacity Pt 980 has not been very satisfactory

Tes major dry matter accumulation begins after 6 ronths and the project

requires sone cultivars that will do this as early as 2 to 3 months after

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

have been identified already as tonnage producers superior to FR 980. Future

reference clones will be selected from the specific category of candidates

under scrutiny, ie, Sordan 70-A for short-rotation candidates, napter gr (var. Merker) for intermediate rotations, and a suitable

spontaneum

hybrid for the Long-rotation category.

Harvest intervals have varied in accordance with the stage of screening ?and bionass parameters under investigation. Preliminary production tests ray involve only @ single harvest at a convenient point in the species? grand period of growth. Definitive grovth curves require multiple harvests during the plant's initial 3 or 4 months after seeding. Grovth-regulator trials require sampling at precise intervals folloving chenical penetration,

?The principal bionass paranoters measured during the first year included total green wetght, dry weight (oven dried to about 6% moisture), dry matter content (% DM), and vater content (% moisture). Leaf samples, including the entire blades of Leaf ranks +1 and 42, 1/ are harvested for foliar mineral

analyses, In sone experinents leaf samp]

/ Saccharum offtcinarum (9/16) x $. spontaneum (5/16) x S$. sinense (2/16).

2/ The uppermost leaf bearing a fully-energed devlap is designated "+1". In sugarcane this is che youngest fully developed leaf. Progressively older leaves are designated +2, +3, etc., vhile progressively younger leaves, still emerging from the spindlé, are 0, ?1, -2, ete.

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eilorephyl determinations. Biomass production characteristics evaluated during Year 1 are presented in Table 2.

Both formally-rep!icated and non-replicated Yobservation" experiments

?are conducted in the greenhouse, The latter usually concern preliminary Brovth-potential measurements tavolving only a few hundred plants in an ares covering roughly 1/200 acre. Replicate? experiments deal with specific growth characteristics in previously-identified candidates. Ordinarily these Anvolve 3 to 5 replications of each treatment arranged in an incomplete ran

domized block design.

Total Growth Performance

Infelal candidate evaluations for total grouth included 25 Sacc!

and tvo Ertanthus clones in unreplicated trials (Table 3). Several comercial

scharwm spectes coupared favorably with PR 980 under greenhouse conditions. Additional features under observation vere germination (rate and percentages of planted cuttings), early growth rates, disease and insect

tolerance, and erectness. The following clones vere selected for seed expan

sion and further growth evaluation: Chunnee, Natal Uba, US S6~19-1, Tainan, NG 28-219, Saretha, and the SES clones 231, 317 and 327,

?The first clearly outstanding candidate to enérge during the first year

is a sweet sorghum x cudan grace hybrid produc

by the Northrup-King Company

(©). Marketed under the trade name "Sordan 70-A", this hybrid hy shown excel-

Lent grovth potential as a cattle forage on Puerto Rico's arid south coast (7).

?Two observation trials were perforned in the greenhouse; one a direct com

parison against the Saccharum standard, PR 980, and a second comparison

?against three sveet sorghun varieties of the "Meridian" series (¥71-5, ¥72-2,

?and 472-3). The veet sorghum variety Rona and the noble sugarcane Badi1l

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together vith PR 980, were also included in the latter trial. In both experi

ments Sordan 70-A easily out-produced PR 980, The sveet sorghum varieties .

simtlarly exceeded PR 980 in dry matter production over @ time-course of 30

days (Table 4), Each of the sveet sorghum varicties have given good ytetd performances in an earlier AES project investigating their suitability as seasonal substitutes for sugarcane in Puerto Rico (8, 9). Hovever, none of these varieties equalled Sordan 70-A in early green matter production oF the rapidity of its conversion to dry matter. -

In a subsequent greenhouse trial Sordan 70-A was compared with napter grass (var. Comnon Merker), tvo Imported napier grass hybrids (PI 7350 and PI 30086), and FR 980. Repeated harvests at S-veck intervals again exphasized - the early grouth potential of Sordan 70-A (Table 5). The napier varieties excelled over longer periods of tine. None of the candidates shoved particu larly favorable dry matter contents when harvested at G-veck sntervals (Table - 6). Dry matter values in excess of 20 percent would be desirable at this time, As discussed elseuhere (pp. 34-37), Sordan 70-A will convert rapidly to dry matter between 8 and 10 weeks after seeding, while napier varieties - require about 15 weeks for dry {eter accumslation to accelerate appreciably.

?The two napier hybrids, PI 7350 and FI 30086, have shown excellent yield

potentials in cattle forage experiments conducted in the mountainous interfor -

of Puerto Rico (10). In those studies they had out-produced Common Merker by

?up 0 70 percent in annusl dry matter yield, Greenhouse results vere 1

encouraging (Table 5); however, yields for PI 30086 comp:

ed quite favorably

with Comon Merker. Both hybrids were transferred to the arid Lajas Sub-

station for field-plot evaluations (pp. 31-37)

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3. Sudan Grars and Sorgiun Hybrids

A series of sudan grass and sorshus hybrids developed by the Northrup=

King Company (the "NK hybrids) are thought to

ve high productivity poten«
tials for the CEEK-UPR terrestrial biomass program. These varieties vere developed as cattle grazing and ensitare feed sources for hot, dry climates (©). Prom this series the sorghum x sudan grass hybrid Sordan 70-A has already shown exceptional promise for Puerto Rico's cattle forage industry fon the Island's arid south coast (7, 11). Sordan 70-A ts technically a cros between @ sale sterile Kafir-milo sorghum and an R sudan gress line produced by Northrup-King via a Piper x Sweet Sudan cross (12).

two other NK Candidates are presently being evaluated within the project's sreonhouse phase; Trudan 7, 4 true hybrid sudan grass, and Millex 23, a érouth= resistant Pearl millet hybrid. The reference variety {e Sordan 70-A. Data fave not yet complete fron these trisis. Additional candidates to be screened during the project's second year include Trudan 5 and the Northrup-King sorghun stlage hybrids NK 300, NK 320, NK 326, and MK 367. Ordinarily the test variety would have to exceed Sordan 70-A in dey matter production by @ significant

factor to be retained for field evaluation. However, oving to the range of

drouth and pest reatatances carried by the NK hybrids, it is conceivable that

fone or more varfeties could extend the Puerto Rico habitat for this type of

biomass candidate without having greater productivity than Sordan 70-A.

4. Grown

weve Evaluations

Project expha:

8 is on candidste grasses suitable for frequent recutting

and management as solar-dried forages using conventional forage-making machin=

ery. A candidate's grovth performance during the iret 2 to 4 months of its

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~-

annual growth curve 4s of decisive inportance,

Grovth performanc

time-course of 5 months have ion measured for 16 varieties fron the genera Saccharun, Ecfanthue, and Arundo (Table 7). Arunde gonax is a tropical grass found in the wild along streams and irrigation canals on the Island's south coast. Sordan 70-A was also included in this group.

In terms of dry matter production per individual plant, Sordan 70-4 clearly exceeded PR 980 during the in{tial evo months (Figure 1). This clone flowered heavily between 5 and 8 wooks and no reliable grovth data vere avatl-able after the second ronth. With reference to total yield per planted area (about 60 sq. £e.), the §. spontaneum clones SES 231 and SES 327, the S.

sine

clone Chunnee, and Arundo donax all compared favorably with PR 960. Siotlarly, the thick-stesmed varieties Crystaling and # 37-1933, although exceeding PR 980 on an individual plant basis, produced less dry matter per planted area ovtng to poorer plant densities, An unidentified wild clone thought to be a §. spontaneun hybrid also produced superior growth during the first two months.

Moisture deterainations for months 1-5 indicate a rapid dehydration of

Sordan 70-A during the second wonth. Tt wi

rapidly becoming a mature plant

within 8 weoks after seeding. This {s an extremely positive factor in the

wrch for fast-growing species requiring frequent cutting and drying. Such

species should not only produce

quick yield of green matter, hich is

largely water, but also convert rapidly to dry matter

Moisture values for thin

ind thick-stened varieties were comparable up

to the fifth month (Figure 2). At this time the more primitive thin-stenmed

plants revealed greater dehydration than Saccharum hybrids and Crystalina

c

officinarum). The unidentified $. spontaneum hybrid produced a dehydration

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-ue

pattern intermediate betucen that of PR 980 and Sordan 70-A, a positive

factor in this clone's favor.

Grosth curves enconpasting a time-course of 3 months have been plotted

for the sorghun vertetios M71-5, M72+2, M72-3 and Roma, together with Sordan

TOA, Badilla, and the reference cane hybrid PR 960 (Figure 3). The supertor-

ity of Sordan 70-A for rapid inies

growth and an early conversion to dry

sntter 1 clearly evident. On an individual plant basis, Sordan 70-A had

produced by 8 weeks as nuch dry matter

PR 980 vould produce in 12 weeks.

Roa is also a superior candidate in this respect.

5. Grouth-Regulator Studies

(@) Growth Inhibitor Responses: It has been shown that the plant growth

inhibitor Polaris (Monsanto Agricultural Products Co.) produces growth in-

creases in sugarcane when applied in low concentrations as an aqueous foliar

spray (13). ?There is some Ifkelthood that biomass yields from tropical grasses

can be increased by this means at very Little expense, Initial trials within the present project utilized juvenile sugarcane propageted by sand culture,

?The Monsanto products Polaris and CP 70139 were Lested at sub-repressive concentrations on 6-veeks old plants of the variety PR 980. The objective of such trials {9 co produce # persistent increase of grovth activity through 4 mild chemical "shock", Positive responses vere obtained vith Polaris Adninistered as aqueous foliar sprays containing 50 to 300 ppm active ingre~ dient (Table 8). These concentrations are roughly 1/10 to 1/50 of those

required for optimal action as @ chenical ripener on the

1c variety.

Internode measurenents (Figure 4) suggest a greater peretatence of the

inhibitor?: stimilatory effect than vould be possible with a plant grovth

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-e

horsone such as gibberellic acid. This persistence ts also affirmed by

direct weight measurements taken at 6

nd 12 weeks following chenteal appli
cation (Table 8). The Monsanto corpound CP 70139 produced grouth repression rather than grovth increases,

Polaris was compared with seversl other plant growth inhibitors during the third quarter. These included Mon 6000 Gionsanto), ACR 1093 DA (Dr. Re Mang, Ltd., Diclsiorf, Svitzerland), and Eabark (3M Company). The test con= centration was 109 ppm active material, che level at which Polaris appears

to be most effects

Embark inereaned growth at « level comparable to Polaris for the first 6 weeks after treatment vhile the other candidate materials remained grovth inhibitory (Table 9). The effects of each mate~ viel simtlarly persisted through the subsequent 6 weeks, The extended dura~ tion of the grouth-stinulatory effect is itself encouraging. Under {dentical conditions, grovth stimulation in the same variety with the growth hormone sibberellic acid (Gig) seldom persists more than 4 or 5 weeks (15).

When used as a chenical ripener the action of Mon 8000 is identical to that of Polaris with the exception that Mon 8000 produces its effect at lover concentrations (13). Hence it was thought that concentrations appre-

efably lover than 100 ppa might also produce grovth increases. This seemed

to be borne out in 2 subsequent trial vhere 10 and 25 ppm active Mon 8000

produced green weight increases of 17.6 and 27.9%, respectively (Table 10).

Moreover, the nunber of harvested stens was also increased by the chenical

when used at these levels.

(b) Tillering Responses: The effects of Mon 8000 on increased stex

production ve

relatively small; however, the growth inhibitor Esbark (3M

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-ue

Company) has a pronounced capacity to increase tillering in sugarcane, These

effects were noted in earlier trials where the materiel wae tested as a chen eal ripener and during the present projcct when Snbark uae coapared with Polaris as a grouth stinulant. Esbark vas further evaluated for ite tillering estects ot concentrations ranzing fon 25 to 300 ppe active satertal (Tabte 11). Shoot production vas increased by all Babeek trestments, the maximum fffect being recorded ot 50 ppm. This concentration vittuatly doubled the amber of shoots per plot.

The ability so titer, ie, co produce a large munber of stens from a single crown, in probably a genetically-controtied factor in the troptca! grasses. within the genus 20a, {eld corm varieties rarely produce a second stom while sveet corn varieties usually retain the tillering festure, In

harum, some elon

tiller heavily alnost from the moment of germination

while othere

wre reluctent ever to do so (16). A majority of clones increase tiller production roughly in proportion to the frequency of harvests. The use of chenical growth regulators that encourage tillering could be of value

An several ways to biomass energy

inters: (a) In any given planting the maximum stem population per acre could be attained earlier; (b) loss seed would be needed; (c) where technical or engineering factors prohibit the narrowing of row centers the Intra-row plant population could be increased fs an alternative: and (8), superior blonass-produeing? candidates that are othervise disquelified oving to an inability to eiller might be retained by chemical means. The latter exaaple appears to be the case at present with « $. spontaneum hybrid having excellent growth potential but a persistent dif> fsculty in establishing 2 satisfactory population.

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- ue

Direct growth stimila-

tfon with plant hormones such ae gibberellic ackd have not given satisfactory

results with sugarcane (14, chap. 12). Very pronounced growth increases occur

?as a tenporary response which is lost iter 2 or 3 joints are Laid down. Gib-

derellin effects can be prolonged by multiple treatments or split applications

of any given dosage (17, 15). Hovever, this is folloved by a slackening of

growth until sub-nornal levels are attained (18). The fet effect is litele

er no tncrease in sugarcane tonnage, oF incre

Jes too small to Justify

material and treatment cost:

Certain plant growth repressants used as chenical ripeners for sugarcane

produce grovth stimulation when aduinistered in very low concentrations. Pola~

ris and Babark will produce thie effect a2 will 6-azaurac{i (19) and several

other analogs of pyrimidine, ?The function of such responses is not clearly understood, but it is reasonably certain that the growth control mechanisms for sugarcane have sufficient flexibility to "comand" increased growth active ty uhen the presence of an inhibitory chentcal is sensed by the plant. This may be viewed as a compensation by the plant for ?anticipated? grovth stresses, oF perhaps & nore efficient usage of existing growth mechantoms and of growth resources already avatlable to the plant.

Wuether plant growth increases of an appreciable magnitude can be pro- duced by grovth inhibitors renains to be determined. All of the Polaris concentrations used in the first experiment were too low to increase juice quality (Table 12). There is Litele Likelihood that any ripener used in this concentration range vould offer increased sugar as an added benefit.

On the other hand, the Polaris concentration require:

for optimal bionass

yield increases in sugarcane (100 ppm) is only about 1/30 of the Level

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nase

required for optimal ripening. Under field conditions the quantity of Pola

Fis needed to ripen one acre of sugarcane should suffice to increase grouth in about 30 acres. lov material costs and the {nproved prospects of achieving adequate plant penetration operate in favor of using growth regulators in

this manner for biomass production (f sny appreciable yield inprovenent can be dononstrated. the possibilities for seasonal growth improvement or for the breaking of stresses imposed by alverse cLinate, moisture, or mutritional

regimes 2/ atso varcant consideration.

An added advantage would derive from the coadministration of grovth reg-
ulatore vith another material already required by the biomass crop. Under
ME conditions, short-rotation tropical forages vould require a foliar insectt-

cide application some 3 or 4 weeks after planting, and overhead irrigations

at about 4 and 8 weeks. Foliar ures is

ready adninistered as a supplenentai

N source with overhead irrigation water (7). Accordingly, future experinents
with grovth regulatory materials on tropical grasses will include their

condministration vith pesticides and urea.

6. Reprowth Studies

Initial data collection on plant regrowth rates vas initiated during
the second quarter. These measurements will determine: (a) The vigor and
quality of ratoons (shoots) produced by established crowns whose tops have
been harvested; (b), the number of new stens produced, Le, the rate at which
4 single-oye cutting will expand into 2 mult{ple-sten crown; and (c), the

persistence of vigorous regrowth over an extended period of tine,

A/ Gtbbereltic acid is most effoctive as a grovth stimilant in sugarcane

when Plants are undergoing some degreo of physiological stress (22, 23)

---Page Break---

Many tropical grasces have a natural tendency ?0 form "bushes" as they

fare repeatedly cut back. Exceptions to thie my include the unidentified

S$. spontaneum hybrid discussed carlior in this report and the §, sinense

clone Mandalay, both of which appear to produce only single shoots when the

roicary stem is harvested. Vigor of the reprovth fs of equal concern. Even

among Nerdy spocies sich as B. pumice a serious shock t= experienced veg

the top/root ratio ss drastically altered in this manner. The variety Camon

Merker, for example, usually produces only veak ani yelloved shoots for about two vooks aftor harvost before ite vigorous growth habit and green color are reestablished 20)

Feratstence of vigorous resrouth is of even greater concer, Ideally, his project vill sdeneity candidate clones that vill withstand frequent recutting for periods of several years duration. We will be fortunate to find two oF three species that will do this, It may be necessary to establish the crowns and root systens very thoroughly over pertods of 6 to 12 months before initiating 4 tong sersen of ropenced harvests, In this instance the

cutting height, harvest equipsent to be employed, and ws

of grovth-regula-

tory agents for improved crown development will all be contributing factors

to successful Long-term harvesting operations.

7, Mineral Butettton

Two bionass nutrition experiments vere initiated during the project's

Hirst year. One experiment relates to a nvtritionsl disorder observed in

napier grass during the initial fielé-plot trials at the AES-Lajas Sub-

station, It was tentatively identified as a manganese deficiency ina

?greenhouse experiment with the sume variety (Common Merker) propagated by

sand culture, ALl nutrient solutions were prepared with ACS-grade salts in

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once-distilled vater, Two non-replicated blocks of p:

vere propagated

for 7 weeks, one block receiving # complete autrient solution while Ma vas

withheld from the other, Leaf freckling symptoms characteristic of the

field disorder began to appear in spindle Leaves of the minus-Hn plants at

4 wooks

?Traces of the symptom also appeared in some plants of the control group (receiving 0.5 ppe Ma), suggesting that the Mn requirement of this plant is considerably higher than the norm for tropical grasses. It is also possible that the fleld symptons were not purely the result of inaufficient Ma in the

soil, Manganese disorders quite comonty relat

to soil pH and iron levels

Which affect the availa!

Lity of native ta to plants (21).

A second nutrition experiment vas

lished during the fourth quarter

using Sordan 70-A as the test species. Variable nitrate-N levels were provided

to establish the project's first nitrogencresponse curve. Plants vere propa gated in sand culture with vater and all nutrient elenents other than N held constant. The principal objective was to determine the slope of the plant's south response when supplied with progressively higher levels of N. Accord ingly, ¥ supplies were increased in a geometric progression from 1.0 £0 61.0

milequivalents/Liter of Oy. The low-N treatment vas deficient while main= taining some Limited growth; high N (81.0 meq/1) offered a vastly greater

supply than most tropical grasses can utilize. With sugarcane, for example,

Nog levels in sand culture exceeding about 20.0 meq/1 are utilized only in the sense of ?luxury consumption" (14). For sugarcane, 9.0 meq/l of NOs im sand culture are roughly comparable toa field treatment amounting to

100-150 pounds of elemental N per acre year.

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Growth data recorded at 4 and 8 wecks after aceding are illustrated in Figure 5, At 4 wecks there was Little response to N03 levels higher than - 3.0 meq/1, owing in part to the lack of @ root system sufficiently developed in the young plants to make use of so much attrogen. Large increases vere obtained between & and 6 weeks with 9.0 meq/l of N03 being optimal. Nitrogen levels higher than this appeared to be grouth-repressive. Present data are incomplete in that they pertain only to the rapid growth phase and exclude the main period of dry matter accumulation, ie, fron 8 to 12 weeks. .

Nutritional information gathered by the sand-culture technique is not directly applicable to field conditions; however, the pe of the N-response

curve is @ characteristic foature of the candidate cultivar whether $¢ ie

grovn in sand under glass or in an open field. The response curve for Sordan

Tora is in fact a very favorable one, It indicates that there is @ fairly

Alstince point beyond which no further gain can be expected fron increasing -

expenditures of nitrogen fertilicer. The situation would be mich more

complicated if the plant had continued to respond to higher N levels in a

weakening first-order curve. In this case a net-energy balance scenario for .

Sordan 70-A would require sone elaborate field-plot work to pinpoint the

correct cut-off level for applied N. Te aight never be deterained with any

appreciable precision. -

8. Importation

?A nunber of

1d Quarantine of Candidate Tropical Grasses

scharun clones and clones from both related and unrelated

genera were available in Puerto Rico for screening as biomass candidates when

the project vas initiated on June 1, 1977. However, the vast majority of

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

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Sn national and intarnstional collections, Mr. T. L. Chi, a project collabo-

rator and a recognized authority on $. and allied species, traveled to the US mainland during Decenber of 1977 to evaluate cultivars there as potential candidates for blonass screening in Puerto Rico, He visited USDA collections at Canal Point, Florida, at Houma, Loufsiana, and at Beltsville, Maryland. A total of 73 clones wore identified a5 suitable candidates and

arrangecents were sede for their shipment to Puerto Rico. An additional 379 clones from Indonesia (1976) and 25 from New Guinca (1977) were observed at

Belesvill

however, these were still in quarantine and several years nay pass before any of this material {s available for export.

The first fourteen clones vere received from Houna during January, 1978, and at present are in quarantine at the AES-Gurabo Substation, This group in

Stsel? greatly expands the germplasn selection for bion

screening in Puerto Rico (Table 13). They are all intergeneric or interspecific hybrids representing parental material from the genera Saccharum, Eccoflopus, Sor;

anthus, Ext and Ripidive 1/, gach of these clones

Sclerostachya, Mf

ch

and those to arrive during 1978 have d{splayed an exceptionally robust growth

habit and profuse tillering.

B. FIELD PLOT STUDIES

1, Saccharum Species Candi

Gurabo sub:

?The initial harvest vae performed fron an observation f1eld-plot trial

with candidate Saccharus spect

This group consists of S. spontancss

clones imported for conventional breeding purposes during 1976 and 2 series

U/ Mpidium vas formerly classified os an asiatic aub-group of Erianthus.

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Of S. spontancum and §. ginense clones that had already shown desirable bio-

mass properties under greenhouse conditions (

ble 14), ?They vere planted

in non-replicated, 1/200 acre plots en a clay-loam soil at the hunié Gurabo Substation, PR 980 served as the reference clone. All candidates vere planted at standard row centers (150 cn) and received standard fertilization plus supplemental overhead irrigation when needed.

?The initial harvest, taken at 4 months, tended to favor the Saccharun hybrid PR 960 and other thick-stomed candidates. At this stage of develop~

ment such plants already bear a 2 to 4 foot fleshy stem vhich would be dif=

Heute to dry in forage-naking operations, eventhough their Connages will be Avicteasing more rapidly than those of the wiry-stemed candidates more suited to forage production Nonetheless, two of the S. spontancun candidates

equalled or surpa

wed the dry matter yield of PR 950 (Table 14, US 67-22-2 and US 72-70). Two other candidates, Tainan (S. sinense) and US 72-166 (S. spontaneyn) also compared favorably with PR 980 while not quite equalling its yield. Te should be noted that under conditions of maximized plant density

most of the

chorus species would vastly exceed PR 980 in the number of

plants produced per acre. An Ertanthus clone included in thts experiment

gave an unremarkable yield oving largely to poor germination.

Two additional harvests vere conpleted during the project's first year,

at 6 months and at 8 months (Table 14). Total yields for the S-nonths

Ancerval show a very superior performance by two §. spontaneum clones (US

(67-222 and US 72-70), each producing about 1/3 wore dry matter than PR 980. -

An additione! §. spentancum clone, SES 231, had difficulty becoming eatab-

Lshed and produced very poor yields at 4 months, but it was clearly the

superior bionass producer at 6 months and 8 months. This was largely the -

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=a

result of an excellent tillering perfornance following the inittal harvest

(Table 15). Bach of the three $. spontancun candidates has shown sufficient potential relative to PR 980 to varrant further evaluation at the fLeld~

plot level.

2. Sugarcane and Napier Gri

?The project's first replicated field-plot experiment vas established

Beisle; Lajae Substation

during July 1977, at the seat-arld AES-Lajas Substation. Controlled variables Include varieties, row spacing, and harvest frequency (Table 16). There are three hybrid sugarcanes (PR 980, NCo 310, and PR 64-1791) and one napier grass variety (conmon Merker). Each variety {s recognized as a superior producer

of biomass tonnage under Puerto Rico conditions.

(a) Field-Plot Methods: This experiment was planted on a moderately well-drained Fraternidad Clay soil. Plot size s 1/50 acre and there are ?s(x replications of each treatment arranged in a randomized block design ALL clones receive constant water and fertilizer levels at roughly double

the commercial rates for this region. Fertilizer was applied in three incremente; 1/3 at planting and 1/3 at 4 and 8 months after planting. Nitrogen in the form of amonium sulfate vas supplied at the rate of 200 pounds per ?acre year for sugarcane and 600 pounds for napier grass. Water was provided 44s needed by flood irrigation delivering in the order of 2 acre inches per application.

Woole plots consisting of « 600 square foot area are harvested at the appropriate interval, te, at 2 months (six times per year), at 4 months (three times per year), and at 6 sonths (tvo tines per year), Two sub-

samples of 10 plants each are harvested for dry matter determinations and

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for tissue samples used in various tissue-component analyses. The latter

include W, Py Ky 8, St and ash for leaves, and invert:

soluble protein,

and sugars for weristem samples, Plans have been made to maintain this

experinent for the duration of the project. This 4s the only study where

long-term responses to biomass production vartables can be measured over

time-course of several years.

(b) Establishing Fleld-Plot Paraneters: The project's field-plot phase

fis essentially an extension of the greenhouse screening studies, Because

biowass candidates will comonly vary at the genus Level certain decisions

have to be made as to the establishment and maintenance of controlled para

meters. At @ planning conference on herbaceous species screening held recently

in Washington, D. G., there was a consensus that equal and constant production

inpot paraneters should be es

yblished for all spectes, at Least at regional

levels in the continental US. Candidate species for much of the screening work there will have Little of no h{story of intensive cultivation or genetic improvenent. This is particularly true of wild plants and arid-land species being evaluated as energy sources for the first tine. This {8 not true of

sugarcane and napler grass, both of which have long histories of intensive

cultivation, genetic improvement, and advanced technologies for mechanized

production and harvest. To apply equal production-input standards for the

?two groups would constitute an important, step backward in the art of biomass production.

The nitro

(600 1bs/acre year) was set at three

n level for napier gr:

tines that of sugarcane in accordance with the higher consumption rates known

for napicr grass. Similarly, the standard and narrow row centers for napier

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grass vere set at 50 ca and 25 cm, rather-than at 150 cm and 50 em ao vas

dons with sugarcane. Harvest intervals of 2 and 4 nonths are a recognized

advantage for nepier grass vhereas intervals of G-sonths or nore are expected

to favor sugarcane, Management practices that are equel for sugarcane and

napier g

8 include the level, method, and frequency of irrigation, the

iwing and method of multiple fere<lizer applications, and all pest control

procedures.

Of greater concern was the location of napter grass plots together vith

sugarcane within a single experimental design. The possibility exists that

soluble nutrients may move laterally underground from areas of higher ferti-

Meer application (24). Under semi-arid conditions this could theoretically soil water is replenished in stepwise flooding operations requiring

two or three

xyS to cross the experinental ary

Moreover, the Lajas Sub-

station canal systen carris

water continuously from one side of the Station

to the other. The lateral movement of water from these camals to

WJoing

experiments is @ recognized possibility, depending upon the respective sot

class ond its vater-receiving capacity at any given interval (25). This is

?also contributing factor vhere so{l drainage problens occur.

factors were considered vhen the firet pajor field-plot expert-

ment was established; hovever, no decisive comproai:

were expected by

cane and napier grass within the same experimental design.

Following the intt{al 2-nonth harvest, foliar discolorations possibly

indicative of nutrient defictency appeared in some of the napier grass

plots. At about 3 1/2 months foliar eynptons similar to manganese deft-

clency appeared in virtually all napter grass plots. None of the sugarcane plots revealed foliar symptoms eventhough these had received

ly 1/3 of

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the fertilizer level given napier grass. The symptoms in napler grase were

greatly diminished or &{sappeared entirely folloving a second fertilizer application to all plots at 4 months. Tf the suspected deficiencies in napice grass are verified by foliar diagnosis it will be necessary to consider still higher fertilizer rates together with micronutrient additives to

the fertilizer mixes administered to napier gr

1s in the Lajas valley.

Production: By the close of Year 1

ffeld-plot data had been gathered for 10 months. This included five of six

2enonth harvests, two of three d-monthharvests, and one of tvo 6-nonth har~

vests. The cont

fe first-year data vill be sumarized in the first quarterly

report for Year 2.

Biomass yield data for the initial 10 months have shown the following

trends: (a) Napter grass is superior to sugarcane

source of dry matters .

(®) sugarcane responds more readily to narrow row centers than napier grass,

but decreasingly so with advancing age: (c) dry matter ylelds increase with decreasing frequency of harvest; (4) early maturation of the candidate

apectes, te, the capacity for rapid conversion of succulent new growth to

ary matter, is 6 decisive factor in determining ultimate yields; and

(@)s fertilization treatments based on conventional sugarcane and cattle -

forage production da

are Inadequate to sustain optimal biouass yields:

(@ Varietal responses; Sugarcane ve Napier Grase: Napier grass hes

generally out-performed sugarcane as a producer of bionase during the first

ten months. Their differences were most evident at the first 2enonth har=

vest when the ability to quickly estublich a root system and to enter #

zero-order growth phase overshadowed all other factors (Table 17), Total

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dry natter ylolds for the 1-months interval indicate a persistently higher yield capacity for napier grass (Table 18). When harvested at 2-month

tncerva

sugarcane yields approached those of napier grass only at the 4~

and Semonchs harvests (Table

20). These two periods coincide with the
longest intervals folloving incremental fertilization, and hence reflect an
inferior capacity of napier grass to produce vith a diminishing soil nutrient
supply.

Yield disferences anong individual sugarcane varieties at times

eeained
statistteal significance (Tables 19 and 21), but generally rensined snail in

a quantitative sense, The sugarcane hybrid NCo 310 vas moderately superior When harvested at 2-nonth intervals while PR 960 was the leading producer wher harvested at 4- and 6-aonth intervals (Tables 22 and 23).

(©) Close-Spactng Responses: The nerroving of row centers increased biomass yields for sugercane but had Little effect on napier grass. Sugar= cane Juice quality not appreciably affected ax evidenced by hand refrac toncter values (Table 24). The sugarcane yield increases vere most pronounced ?at 2 montha (Table 17) and statistical significance vee still attained at 4 12 6 months (Table

21 and 19, respectively). Whon harvested for the first

tine at 6 months, each of the cane varieties produced significant green

tonnage increases at narrow rov centers (Table 23). The magnitude of {n=

fe id not exceed 302 for green or dry eights. The highest gre

matter yield at 6 months vas 48.5 tons/acre for sugarcane variety FR 980,

and the highest dry matter yield vas 13.6 tons/acre for napter gré

variety common Mecker. There vere no appreciable differences for sugercane

?After 6 months from the time of planting or for napier grass after 2 months.

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DOE studies on cane row spacing in Louisiana and Florida have produced

somewhat similar responses (26, 27). Yield inerea!

from close spacing

vere larger in Louisiana (around 602) than in Florida (about 102), eventhough the experinental procedures had been carefully synchronized between the two regions, This {s an important finding for Louistana vhere the shorter groving season is restrictive against conventional cane production.

canopy closure does not appcar to offer a complete explanation for the lack of narrow row responses at 8 months and later. Plants reharvested at 2enonth intervals do not completely close their canopy but the narrou-row response was lost nonetheless. The time-consuming development of cane root systons {8 probsbly a contributing factor, since a far nore vigorous croun developsent and tillering capacity was obtained at standard row centers vith the passage of tine for each of the three cane varleties.

In the Puerto Rico experiment all cane varieties had relatively weak land undeveloped crowns at the first 2-nonth harvest, At that time the narrowing of row centers was the only real means available for these clones to increase their stem densities. Fron 4 months onvard the established crows at standard row centers seemed to do this nearly as well as the sore closely-spaced crowns. If this is correct, the best means of improving sugarcone density may be to plant a greater number of seed pieces within the row at standard row centers. Some evidence to this effect hax been reported from intrarow seed density studies at Louisiana State University (26). Problems incident to cultural managenent and harvest operations vould be cased considerably if standard row spacings can be retained for the inten

sive production of sugercane bionas:

?Together with the varietal factor, the longer growing season in Puerto

Rico (as compared with Florida and Louisiana) does not seem to offer a

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=a.

reasonable explanation for the lors of narrou-row responses after 6 months.

However, in the event that tuo G-wonth crops per year are contemplated for

Puerto Rico's future, the Island"

12-aonch growing season would constitute

a distinet advantage for intensive biomass production:

(2) Harvest Frequency vs Matur,

cin: In planning this project the capac~

ity of sugarcane to respond to frequent recutting was greatly overestimated.
As indicated in Table 18, sugarcane harvested once at 6 months exceeded by

more than 60 percent the combined yiclds of five 2-oonth harvests. High cane
yields as they are knovn today require a massive stem which cannot be produced

in 8 veoks, Na

fracs was much more responsive to frequent recutting than

was ugarcane (Table 18). However, oving apparently to inadequate fertilizer, the superior grovth potential for napier grass was not fully utilized between months 2 and 4, and betveen months 6 and 8 (Table 19). During the course of the first year @ short-rotation candidate superior even to napler grass was found in the sorghum x sudan grass hybrid Sordan 70-A.

Supercane yields increased progressively as the interval between harvests was lengthened from 2 to 6 months (Table 18). A single harvest at 6 sonths excoeded by 23 percent the combined yields of tvo 4emonth harvests. Napier grass continued to produce nore dry matter than sugaxcane with Lengthening harvest interval but the differences wore becoming less pronounced, The

\go at 10 months was that, to obtain maximum dry matter from sugarcane, the established cane stands should be Left in place at long as possible before

thoy are harvested. Hybrid sugarcanes are no longer regarded as a Likely

source of short-rotation candidates 2/

A/ More primitive saccharun species such as S. spontaneum and S. spontancun

hybrids might be suitable candidates for frequent Tecutting operations.

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To large extent the optinal harvest interval for # given candidate will relate to its maturation profile, that {s, its ability to convert suc= culane new growth to dry matter. ?This is a far more deceptive characteristic Of candidate tropical grasses then was at first recognized. For example, the ?green weight data for the first Senonch harvest (Table 23) indicate signifi- cantly greater tonnages of sugarcane then napler grass, while dry weight ton ages show that napier grass was significantly core productive than sugarcane. ?The explanation for this ies in a more rapid conversion of green matter to

fiber by napier grass. once, while the sugarcane vé

rieties ranged fron 19.1

to 20.9 percent dry matter, napier grass ranged from 31.5 to 32.9 percent

(rabte 25)

Both sugarcane and napter grass are quite succulent during thetr juvenile and early-adult grovth phases. They yield in the order of 15 to 18 percent DM when harvested repeatedly at 2omonth intervals (Table 26). When allowed to grow for 4 months between harvests, sugarcane retains a character= istic succulence while napter grass increases DM by up to 90 percent (Tables 27 and 28), Tn 6-ponth old sugarcane the dry matter content continued to ee behind that of napter grass (20% vs 32%, Table 29)

Napier grass shows Little outward change during the 8+ to 16- vecks interval save for the energence of sone tassels and a few yelloving leaves. Jn Sordan 70-A the rapid conversion to dry matter begins 4 or 5 weeks earlier

than in napier grass and is accelerated by very heavy tasseling. A comparable

maturation would not ordinarily begin in sugarcane until 8 or 9 months, oF neil forced by cultural practices (withholding W and water). Sone cane varieties also Eend to produce fther ae a consequence of a profuse tasseling

habit, but many sore varieties produce feu or no tassels in the course of @

year (14)

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on a future encrgy plantation producing solar-dried tropical forages

the principal salable product vould be dey mitter. Species designated for

rapid grovth and frequent recutting vould neod to change swiftly from an

early vegetative grouth phase to # fiber-accumlating maturation phase,

Flower induction ss @ natural means of initiating this change, although it

night also be accomplished by use of chonical grovth regulators, Mowever,

?the maturation phase in growing bicnacs (producing fiber in place of water)

is rarely montioned in bloxass-oriented Litérature, In some reports dry

matter fs en Similar

joumed constant percentage of green weight valu:

assumptions are still found in the ISSCT Proceedings and prestigious jour-
nals uch a# Plant Physiology and Zlant Lfochemistry. This is an erroneous
concept and one especiatly to be avoided in bionass production projects
dealing with herbaceous specter. At this point in the present work on tro}
ical grasses, the candidate's ability to terminate vistble expansion and to
get on with the accumulation of fiber seens equally important as the early
rapid grovth of succulent green tissues.

(e) Responses to Incremental Fertilization: Nitrogen Le the decisive
grovth-Limiting nutrient for both sugarcane and napier grass. Ammonium
sulfate was the N source in the present experiment, with sugarcane and

napter grass receiving 200 and 600 pounde/acre year, respectively. For

both spectes 1/3 was applied at planting and 1/3 imediately following the

4+ and B-months harvests. ?These levels vere thought to be adequate by pres~
ent commercial standards in Puerto Rico, but yield data indicate that they
wore inadequate to sustain 4 consistent dry matter yield (Tables 18-20).

?This trend vas particularly evident in the data from 2emonth harvest

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increments where very poor yields wore ubtatned from the 2 to 4 months and
6 to 8 wonths growth periods, The inadequate fertiization was generally
macked {n data fron 4+ ani! Genonth harvest intervals (Table 18).

As deptered graphically in Figure 6, maples grass was constrained far

more than sugarcane eventhough ite {crt{ligation rates exceeded those of cane by 2 fai

Jr of three. Hence, av the 4+ and Genonths harvests, napier

grees ylel

© not appreciably different than sugarcane, Putting this another way, the superior productive expertise of napier gress was eliminated fron about 4 onths of the 10 months grotth period.

Since the late 1940's such information has been gathered on foliar tissue

analysis as @ means of wonitoring the macronutrient requirenents of sugarcane (28, 29). Unfortunately, this inferastion is based on conventional sugar cane production where sucrose rather than energy is the princ{pal salable

product. Abundant growth {s not necessarily a good thing vhen the cane planter has sucrose in mind. In Puerto Rico, for example, plantation mana= gers have hesitated to apply nitrogen later than 8 weeks into the nev ratoon crop because to do so can reduce recoverable sucrose sone 8 to 10 months later (14). For the present experiment foliar N data are available only through the B-months harvest; however, the leaf nitrogen content ranged from about 1.5 to 2.0 percent anong all varieties, @ rangé that should have been adequate by traditional standards (29), Second-year plans for the same experiment {nclude doubling the Nefertilization levels for both sugarcane and napier grass and splitting the applications inte six 2-month increment: At this point in time it is suspected that a mininum fol{ar N level of 2.0 percent for sugarcane and 2.5 to 3.0 percent for napier grass should persist

An an optinally-forced operation having dry matter as ite principal objectiv

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(h) Sugarcane Prospects as a Short-Rotation Grop: At present, hybrid

sugarcanes are not regarded as prime candida

for frequent-recutting opera

tions, Other candidates have emerged that seem more productive than sugar~ cane in short-term cropping situations, Hovever, future investigations can do several things to improve upon the sugarcane responses presently reported. one obvious factor in the selection of better varieties. For exanple, a new Yarbados polycross hybrid (B 70-701) recently obtained by the AES-UPR cane breeding program seons vastly superior to the canes used in this experiment (30). Use of more primitive Saccharus clones and increased fertilization fare also valid considerations. Perhaps more important would be a different handling of the cromeestablishnent process. Rather than to initiate imoe- diately the frequent recutting operations, a better response might be gained by first establishing mature crowns over 6= co 12-nonth intervals, Short

rotation harvests might then be inttiated in planned sequences that provide

a periodic reestablishment of a normal top/root ratio. Whether or not sugar=

yne yields could be raised by these means to the levels of napier grass or

Sordan 70-A remains a matter of conjecture.

Sora

Grsee Teiate

1d Napioe

?A second felé-plot study was established during January of 1978 for

?direct evaluations of Sordan 70-A and napier grass (Comon Merker) as short~

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

tested for the first tine

possible replacements for Common Merker. PR 960

was retained as a reference clone, This exporiment is being conducted at the

semi-arid Lajas Substation under soil and elimatic conditions identical to

those:

seerthed earlier (31), Comon Merker, the napier hybrids, and PR 980

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were planted at 50 cm row centers, approxinately the commercial epactng for

napier grass but about 1/3 the comercial distance for PR 960. Sordan 70-A

was seeded at 25 cm row centers, slightly farther apart than the standard

seed-drill setting of 22.5 em for this crop. Harvest intervals are at 2,

4 and 6 months. Overhead irrigation asounting to about 2 acre inches was

TROPICAL GRASSES EVALUATED AS SKORT-ROTATION caNDIDATES:

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omen werter??_enisetn punernen oe

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vr s08s aie ee

sertan ont forte x sites Wield as

administered at planting and et 4 weeks and by flooding at 10 weeks. Ferti-

User was given in three ineresents; 1/3 at planting, 1/3 at 2 months, and

1/3 at 4 months.

Marvests for this experiment are only partially complete, Data are

Teported for two of three 2-month harvests and one 4-nonth harvest. Final

data vill be tabulated in the first quarterly report of Year 2.

(@) os

Dey Mattes

Napier Geass ve Sordan,

From the initial 2-

month harvest Soréan 70-A energed

superior short-rotation candidate,

producing about 18 green tons and 4 dry tons/acre in the course of 8 weeks

(fable 30). This yield vas significantly greater than that of the napier

hybrids, and the latter in turn outy{eléed comon napier grasa. The second

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2enonth harvest revealed a decline of Sordan 70-A to about 17 green tons and 3 dry tons, while the napier hybrids greutly increased their productiv- ity (fable 30), At this time each of the napier hybrids again outyselded common napier grass by a significant margin.

?An entizely different pleture energed ven the plants were allowed to grou for 4 wonths before harvest (Table 30). Green-veight values for Sordan

JO-A were lover than at either of the 2-month harvests. Meanwhile its dry matter content rose from roughly 20 percent to 32 percent; in effect, the plants had sinply stood there accunalating fiber and producing no new visible grovth from about the eighth week envard. ?There vere no significant, yield aifferences between common napler grass and che napier hybrids at this tine, ?The napier hybrid PI 30086 retained 2 significantly greater dry matter con tent, approaching 22 percent as opposed to 19 percent for comon napier grass, This cultivar produced the highest yield to date, enounting to 9 fovensdry tons and 42 green tons/acre over a time-course of four months.

?The reference variety, PR 980, was unable to keep pace with any of the short-rotation candidates in terms of dry matter yields (Table 31).? Sordan To-A exceeded its production by more than 800 percent at 8 weeks, and at 16 weeks FR 960 still had not attained the production level reached by Sordan T0-A at 8 veoks

A conparison of total yields from two, 2-nonth harveste versus a single Aomonth harvest indicates that tvo categories of candidates have energed from the short-rotation experiment (Table 32). It te evident that, given

two harvests in a d-nonth period, Sordan 70-A could exceed the napier

hybrids by & anal margin and easily exceed connon napier grass. However, to delay harvest until 4 months would result in maJor losses for Sordan 70-A,

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while each of the napter candidates would greatly benefit from this delay. The message here is thit the napter clones are not really short-rotation candidates at all but rather occupy an intermediate position between long-rotation plants such as sugarcane and a true short-rotation plant such as Sordan 70-A.

(®) Rates of Dry Matter Accusation: Sordan 70-A plants revealed 9 superior dry matter content (percentage) at both the 2+ and G-nonth harvests (Table 30). Actually, dry matter will tend to accumulate in conformation with @ saturation curve that characterizes a given species, Dry natter accunlatfon vas presently eonitored for all candidates with plant samples harvested veekly from veek 4 to 16, The mo{sture percentages for whole

Plants during the same interval are depicted graphically in Pigure 7. Several

features are inmediately evident from the plotted data: (a) The three napter clones reveal essentially common moisture curves (and hence conmon dry matter trends); (b), the curves were variably sensitive to irrigations applied at

weeks 4 and 10;

(©), Sordan 70-k revealed a persistent and drastic moisture decline or maturation curve, ubich vas insensitive to irrigation; and (@), the maturation curve appeared to initiate at week 5 or 6 for Sordan 70-A ond at week 13 or 16 for the napier clones.

The onset of maturation coinctdes very closely with the initiation of flower primordia in Sordan 70-A. By the eighth week virtually all stens of this clone bear a maturing seed stalk. Flowering also appears to play some

role in the maturation of napier types, At least sone scattered tasseling

4s evident in these clones from the twelfth veek onvard.

Irrigation vas not a controlled variable in this experimest; none~

theless, tha moisture curves presented in Figure 7 indicate soue distinct

---Page Break---

water requirenents for saxisum grovth anong the candidate grasses. The napler hybrids PI 7350 and PI 30086 vere quite sensitive to applicd water and probably did not receive enough water to sustain maximum growth during the frst 12 weeks. Alternately, Lt vould appear that the irrigation of Sordan 70-A after the sixth weck is mainly @ waste of vater insofar as

ELssue expansion is concerned. Hovever, some vater is probably necessary

to sustain a naximun dry matter accumulation.

(©) Tissue Expansion vs Maturation: As previously noted there are tuo

seportant phases in the plants? production of herbaceous bionass, one being

1 rapid expansion of tissues vhichare highly vistble but consist nostly of

water, and a maturation phase in vhich much of the tissue space is occupied by fiber and various solide collectively termed "dry matter", Maturation has Little outward visibility aside from a fev symptoms characteristic of aging tissues. In the search for short-rotation candidates it is necessary to find species that will perform both phases within a short period of tine,

For our present purposes this {s preferably within a 6= to 12-veek interval.

?The two grovth processes can be presented graphically by directly plotting doth green- and dry-natter increnents against a connon vertical axis, In this instance, tvo S-shaped curves would appear on the ?horizontal oF time axis, slightly overlapping but a

1y separated in time, ?The dry matter curve would be the smaller of the two since it deals with only about 8 to 35% of the total plant composition. A more conventent method is to plot the indi~ vidual green weight increments as percentages of the total green matter harvested during the sampling interval, and alternatively, the increnental

percentages of the total dry matter produced over the sane time-course.

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?The growth and maturation phases for Sordan 7O-A are plotted in this wanner in Figure 8, Plotted as incremental percentages, both phases appear in the sane general order of magnitude. Because both processes are in

fact occurring simultancously but at difforent relative rates, both appear

on an identical time-course with frat the green matter curve and then the dry matter curve predominating. An inportant feature is the abrupt break tn the upward slope of both curves which occurred at the tenth week (Figure 8), This break coincides with the optinal point in time for harvesting the species, that 46, the time perfod in which both the tiseuecexpansion and maturation procestes have exerted their saxinus effect. Thereafter, each succeeeding week's increment vill be smaller, rather than larger, than that of the preceding week, From.on agronosic and botanical point of view the best course of action {s to harvest at 10 weeks and either reseed the crop

OF produce a new 10-veek stand from existing crows.

Similar data plots for napter grass and the Saccharum reference clone

PR 960 were less conclusive. It appears that napier gr

may have reached

its optimal period for harvest at 16 weeks, but several additional weeks

of sampling would be necded to affire this, For the sus clone both

phases were accelerating rapidly at 16 weeks and ite optinal harvest period

may not have been reached for an additional 4 to 6 months.

(@) Moisture Content ve Harvest Period: From data illustrated in

Figure 8 it was surmised that Sordan 70-A should not stand mich longer than

10 weeks before it is harvested. It {s equally ioportant that this cultivar 4s not harvested too early if saxinum production is to be realized. This

point is illustrated by the Sordan 70-A moisture curve presented in Figure 9.

---Page Break---

Rspectally teportant {s the rather slight, loss of mofsture (gain of dry matter) before the seventh ueek and after the eleventh week, and an alnos! Linear loss of motsture from weeks § to 10, The minimum dry matter con- tent possible for Sordan 70-A is about 10 percent, in novly-germinated seedlings, and this value roughly doubles by the eighth week (Figure 9). In the following two weeks, from weeks 8 to 10, the dry matter content more than doubles again. Because outwardly there {s no visible grovth increase after the efghth week, one must take care aot co harvest when tissue expen=

es for there 1s much to be gained by waiting two or three weeks longer. After weck 11 there te 11ttle to be gained by delaying harvest

operations

Plant population counts reflect @ more

vigorous germination and tiller development for napier hybrid no. 30086, anong

candidate grasses planted at 50 cn row centers (Table 33). There was a vastly greater population of Sordan 70-A plants at the 25 em row spacing. However, when inspecting these plots a persistent impression was that the Sordan 70-A

population renained inadequate, There w

considerable Light penetration
of the foliar canopies and there secned to be excessive space between steas within the planted row. Second-year studies with Sordan 70-A will therefore

include seeding rate increases from the present 60 pounds/acre up to 120

©, BREEDING STUDIES

Some limited breeding vork has been conducted during the project's first

This includes: (a) Evaluation of local germplasm sources,

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- 38+

(b) Mlovering control in a wild $. spontaneum hybrid; (?) evaluation of con

ventional sugarcane brecding progeny as possible biomass-producing sources;

?and (4), crossing a wild $. spontancun hybrid vith commercial canes.

(a) Evaluation of Local Germplusm Sources: Four local clones bearing

pou"

echarun germplasn have been selected for further evaluation (Table 34).

[AIL have potential value as male parents, thet is, under conditions such that their flovering stage can be synchronized with the flovering of a suitable wale-sterile clone £0 serve as the fenale parent. ALL have shown the $. spontancug characteristic of flovering sone 6 to 8 weeks in advance of com mercial hybrid sugureanes.

?Two of the $. spontancug clones are found in the wild in considerable abundance near Rio Pledras. No attempt is being made to formally cultivate thos. A third wild clone, an unidentified spontaneum hybrid, is a very . promising bionsss producer in its ovn right and 1s to be propagated at the Gurabo and Lajas Substations. The clone ?Aegyptiacun"? has been propagated Sn the greenhouse and at present is undergoing seed expansion at the AES | Garabe Substation,

(®) Flowering Control in §. apontaneun: Efforts were made to synchronize Flowering of local $. spontaneum sources vith the flovering of comercial hybrid canes suitable for feaale parents. The objective is to produce Fy

progeny having dry matter production as their principal attribute. Synchro-

nization studies includ

(a) Freezing of vhole tassels from early-flovering

(®) freezing of pollen collected fron early tassels; and (c), delay

of early &

jel production by physical and chemical means. Pollen and

whole tassels from four $. spontancun clones were frozen during September

---Page Break---

fang cetober, 1977. Pollen viability t

by the starcheLodine method indi=

cate chat from 20 to 50 perceat of the frozen pollen could be viable.

Initial attenpts were made to delay early tasseling with the uniden=

tified spontaneum hybrid at evo sites near Rfo Piedras, This consisted of

spontaneum

cutting the stalks back to ground level on June 1, 1977. The regrowth mate=

rial was still in the juvenile (non-flovering) stage when che clone's noraal

floral induction period passed in July, The new plants were intended to

become adults (capable of flowering) at about the tine that floral initia

tion occurs in commercial sugarcanes, te, during early Septenber. A fo

16 did emerge on one of the test sites, lovever, they were still

relatively carly, erging from October 20 £0 28, and we were unprepared

fo atten crosses at chat tise

The same method will be tested 4 1978 vith sone modifications in the

time that spontancus plants are cut back. fforts will also be made £0

olay flowering by treataent of euttable §. spontaneum stands vith the grouth

hormone gibberellic actd. In this ins

snce the objective will be to delay

the shift from a vegetative to reproductive status, without totally elimi=

nating the plant's capability to flover

(©) Evaluation of Local Breeding Progeny: For many years the ABS cane

breeding program has screened its new progeny with a view tovard increased

sugar and tonnage yields, sultability for mechanical harvest, disease

resistance, and regional

ability (32, 33, 34), Total biomass per se hae not

yen a decisive parameter in the selection of new sugarcane hybrids.

Nonetheless, a nusber of new canes have energed that do have exceptional

promise as biomass encrgy producers, at Least on the basis of regional

---Page Break---

trials. Plans have been made to establish sone 12 to 15 of these in an

observation ?nursery? at the AES Lajas Substation. Depending on the avail-

ability of seed these plots will range from about 1/50 to 1/2 acre in size.

They will not be replicated but vill enable us to make preliminary evalua:

tions of the clones! productivity potentials under semt-arid conditions.

iey Will also provide seed for those candidates warranting formal study under replicated fleld-plot conditions.

(A) $. spontaneum Crosses: Two crosses vere performed during December

of 1977. Two nale-sterile hybrids vere used

female parents; one hybrid,

F-106, originated in Taivan and the other, PR 63-227, {e a local sugarcane

(35). Both crosses utilized frozen pollen from the early-flovering

spontanaun hybrid noted above. Although pollen tests by the starcheiodine

method had indicated a probable viability, only 5 seedlings vere obtained

from these crosses. This suggests that freezing 4s almost totally destructive

of the pollen. It is also possible that the S. spontaneum hybrid is itself nearly male-sterile. In any case a fev hybrid progeny are available for

evaluation.

PROJECT OUTLOOK: FOOD AND ENERGY INTEGRATION

A number of distinct types of candidate tropical grasses have already ?emerged in accordance with thelr management and time-frame requirenents for optimal production, Several of these categories are also compatible vith

fam eventual integration of energy planting with the production of traditional food commodities. The need for establishing such categories is evident from

fata trends and from the claims that biomass energy production will

ake on land and water resources from the mid 1980's onward (36).

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1. Categories of Bioware

?At least three broad categorics are required based on the candidate

excises! suitability for rotation with food crops or other energy crop:

Cultivars from the first group would have only a brief occupation of land

otherwise comitted to © conventional food or fiber crop. Ordinarily, such

?GATEGORIES OF CANDIDATE TROPICAL GRasses

Production Interval

Cropping Category Qtonehs)

Short Rotation 2a

Tatermediate 12-18

Long Rotation 30-60

plunts would occupy a truck-crop site to prevent leaching, erosion, and weed devolopment until it is replanted with the more valuable comedity. In sugar

cane land rotations they would serve

ground cover between the harvest of a final ratoon and the seeding of a new plant crop. The bionass candidate

should be directly seeded and have a rapid tls

suevexpansion phase folloved by an equally rapid conversion to dry matter. Te should be a good "scavenger" crop utilizing residual fertilizer and it should quickly shade out the native weed species. Potential sources of such candidates include the hybrid forage srasses. Among these, the eropical forage Sordan 70k (Northrup-King Com pany), has shown very excellent promise in greenhouse and field-plot trials.

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Te scons highly improbable at this point that a shorterotation candi date apprectably superior to Sordan 70-A will be found during the time- - course of this project. It is the fastest-growing candidate examined to the Present time, This hybrid is propagated fron true seed and hence can be soun with 9 conmerctal seed éri21, This alone is an important advantage over plants such 98 sugarcane and napicr grass chat are propagated through a cumbersome contly processing of sten cuttings. Sordan 70-A germinates very quickly--within

about 3 or 4 dayse-and this 4s followed by a very ri

i tissue-expansion phase lasting about $ weeks. during this interval the daily grovth increases are quite visibly evident each evening. Native weed species are quickly shaded out. Another positive feature 1s the plant's early shife fron a vegetative to reproductive regine, occurring perhaps as early as the fourth week. By the sixth week immature tassels begin to energe. This enables the plant to reduce ity vater content and accumulate dry matter mich earlier than the sugercene and napier grass candidates examined thus far. With optimized managenent Sordan 70-A would appear capable of producing in the order of 8 to 10 dry tons per acre in the course of four months

[A second category includes forage grasses that vill establish quickly and withstand frequent recutting for year or preferably 18 months before

Hescoding is necessary. A sufficient number of harvests is needed to cover

eotablishaent costs and to bring an acceptable return for the energy planter's

investment. Energy is the predominant agricultural commodity in this ins!

Tt constitutes the principal claim on land, water, and other production re- sources in the cropping sequence, Napier grass (Pennisetum purpureun, var.

Merker) As the outstanding candidate in ehis category at the moment. At Least one napier grass hybrid has similarly shown promise in fteld-plot

trials

---Page Break---

A third category consists of the very durable grasses that must with=

stand repeated harvests over a period of 2 1/2 to 5 years. For this clas-
sification, candidates are needed that are suited both for intensive culti=
vation ond for minimum tillage regines where plant productivity {s too low
to justify resceding at nore frequent intervals. This long-term capacity
for grovth will be difficult to waintatn tn comercial forages. Napier
grass might possibly muccaed if sufficient water and fertilizer ts expended
and if occasional "rest" periods of 4 to 6 sonths duration are alloved for
the crowns to reestablish @ full top. within this eategory a series of
Saccharum hybrids bearing # large dosage of §. spentanews germplasa {= being
evaluated. these plants are sinilar to sugarcane in outward appearance but
are characterized by a more robust grouth habit and higher {iber contents
then the sugarcanes of commerce. It is also possible that certain of the

high-tonnage Sac:

run hybrids previously thought too fibrous for cultivation wil] contribute to this category. In this case at least some sugar

would be recovered as a co-product of fiber.

2. Minimup Ti1age Candidates

In addition to the biomass catezories noted shove there {4 4 nead for species that vill produce at least moderate yields with the barest sinimun of production inputs. This requirment is underscored by tuo factors: (@) Puerto Rico's water resources, even in fully developed, vould supply only about half the wator needed for highly intensive production throughout the Island (5); and (b), economic considerations will not alvays pernit a saximun expenditure of production resources even where such resources are

otherwise available, Hence, the decisive requirenent of @ minimum tillage

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=u

candidate As a relatively large yield capability over « period of at least 3 or 4 yoars with only a marginal input of water, fertitizers, and pest{~

cides. This fs the wost difficult candidate to identify. Plant survival ?and prolonged productivity in # sent-wild state become important attributes not generally found in commercial forages and forage hybrids. More pris tive grasses auch as the wild forms of Saccharum are the principal candi~ dates at this time. Many such clones have survived in the wild and improved thenselves over several geologic ages, and it would seen likely that this toughness con be harnessed for service in energy agriculture.

Under Puerto Rico conditions minimum tillage would mainly involve the preparation of a secdbod followed by irrigation and fertilization just suf ficient to establish the forage crovas. Natural rainfall vould be the only

EqUEREUTDNS ANTTCTFANTO FOR TROPICAL FORAGE CANCHEATES 16 PUERTO AICO

Anticipaced Annual Rogetrarente For arvest cxep

astca __Teekuntten __Fertdldsetion esticidos _taterval(s) Suratéon (Yes)

only GE Roots

brid At Planting At Flasetng © one ? a

source of water thereafter under huntd conditions, In arid to semi-arid

regions only subsistence irrigation anounting to about 2 acre feet/year

would be given. Warvest frequency vould be reduced to about 6-month

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tne

?als. This would allow more tine for dry matter accumulation thon is

Possible under intensive production regimes with 2-3 month harvest inter=

vals, Limited fertilization would be adainistered after the G-month harvest,

and under dryland conditions one of the infrequent trrigatioay would be

Fiven at thts tine, Ho pesticide usage is anticipated within either humid

or arid growth rexines,

3. Production Targets

From project data gathered to the present time, and from prior exporience

sn 7R bionass production, the optizal yield and production-cost values for

topical forages crm be stated in at least general terms. Under intensive

Propagation regimes it appears that 40 dry tons per acre year might be pro

duced at 2 cost of roughly $22 per ton. A higher heating value in the order

0f 15,000,000 BIU"s per ton is assumed on the basis of published BTU values

BIOIATS YROOUETTON "FSRCETS" FOR TROPICAL GRASSES

Totat Productivity 40 Dey tons/Acre Your

Production Cost $22/0ry t09

nerey Yield 35,000,000 ETU/t0n

for other biomass sources. & solar-dried ton in this case would consist of about 18 to 204 mo{sture, that is, about 6% more moisture than s present in conventional dry cattle forages and about 12% more moisture than is contained

in the oven-dried materials prosently reported in these stud?

The production cost estimate of $22 per dry ton includes delivery of

baled material to a hypothetical thermaconversion facility at Nayague:

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about 15 miles fron the production site, .This cost figure would be unat~ tatnable without the 4O-ton yield. With a conventional yield of 10-12 dry tons, the production input costs presently anticipated would raise the product value to the order of 80-90 dollars per ton.

Yield estimates vould be sealed dovn for short-rotation energy crops and for mininus tillage operations. Short rotation crops are seen as essen

ty a periodic filler for lands otherwise committed Eo food commodities of higher value. Minimum tillage operations would be directed tovard low to noderate productivity from marginal lands that otherwise vould ranain

?out of production. Such operations, if properly managed, might be equally

profitable to ehe energy planter

4, Status of Gandidate Screening

First-year screening of tropical grasses has made good progress, Cate

gories of tropical grass sources have been defined both in terns of the

souree groupsthat will be required by future energy planters and the groups that are realistically available {n a botanical and agronomic sense, The four principal categories together with present candis

esfor each category

are {Ilustrated graphically in Figure 10,

sordan 70A is believed to be the definitive tandidate for short rotation cropping. On this basis, Sordan 70-A vill be carried into mechanized #ielé-scale operations that begin during the project's second year. ?he final source selection for the intermediate rotation category could well ?ve any one (or all) of the napier grass clones exanined to date, The naptor grass hybrid PR 7350 appears to be the superior source under Lajas conditions

bot only by @ modest margin of productivity. There does not appear to be

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= ane

any other napier grass hybrid available to Puarto Rico at this time that WALI seriously chellenge the present napier candidates (37). One development we would Like to seo is the emergence of @ true-seuded candidate for intermediate-rotations that can be planted mechanically with a seed drill.

The collection and handling of napler grass sten cuttings is at best a

jon. In this connection the failure of

cumbersoue and expensive operat

napicr grass to respond to close spacing ie ren as a highly positive fac-

tor. The establishment of thie plant at nairow row centers would be attended

with logistic difficultires and excessive expense in a connercial-seale oper:

Sion. Thore remains some possibility that one of the directly-seeded KK

hybrids way replace or supplement the napier clones sn this category

At this point in tine the longerotation category is quite clearly the

Fealm of the comercial Saccharuen hybrids. Although shou to be totslly

inappropriate as short-rotation sources, there is no reason to believe that

they would not exceed all other tropical grasses if alloved a year or more

to express fully their tLasue-expansion and maturation phases. In this respect the technical problems &

dent to their harvest aay be as decisive

fas che selection of specific clones, fe, tf will be necessary to harvest

standing bigwass in excess of 80 green tons per acre.

?Also at this time it appears that the mininun tillage category belongs

to the wild tropical grasses, or possibly to the sen{-iild and primitive

forns of Saccharus

Here the main interest lies in species that vill

Literally manage themselves. In fuerte Rico's humid regions certain com

mercial species such ss nap:

sr grass (Var. Merker) seem az content in the

Wild state as they are under cultivation. Im sen{-arid regions the clone

?Arunda donax performs well in @ totally wild state. Under arid conditions

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?a series of Panicum bunch grasses arc extrenely durable vith Little or no

monayenent following their initial seeding.

?The ultimate minimum e{llage source could quite possibly derive from

the primitive species of Saccharun, particularly forms of

3. spontaneum and

Some of these have survived over several goolosic ages involving extensive climatic chenges and almost continuous competition frou other herbaceous species (14), This genus is not native to the vestern hnom{ sphere, hoxever, and carly explorers and botanists brought to Puerto Rico only "noble" oF §. officinarun clones that had experienced sone prior dosestication. ven in vory recent tines, certain Island officials igno= rant of the genetic value of $. spontencus hesitated to import clones of

thio species for fear they would eetablish thenselves as noxious weed

The local "vila" §. spontaneum forms described earlier in this report ere found in the tumid gone near Rfo Piedras where they probably escaped fron ABS breeding stock collections during the 1930's and early 1940's. Their performance under arid conditions vill be studied for the first tine during the project's second year.

Additional Sacchar

and related species will be imported for screening fas bionase sources during 1978. Anong these there will be several inter- generic hybrids. One clone incorporates Saccharum, Miscanthus, and Ertanthus gormplasn, and has aroused considerable interest anong authorities at Houna, Louisiana (38).

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HE, SUWOARY OF PIRST-YEAR PROGRESS

1. Sreenloure Studies

Greenhouse

porinonts delt with the rapid screening of comercial Saccharun hybrids, primitive Saccharuz species, and species from the genera Ronnisetun, Sorghus, Erfanthus, Aruno, and Panicun. Prinetpat test para meters included total bionass-producing capability, ?characteristic grouth ?curves, recutting tolerance, maturation profiles (conversion of green tissues to dry matter), response to chemical growth regulators, and response to var Sable nitrogen supplies. Progress vas made in the following area

(@) Total biomass production cepabilicy was examined in over 60 clones fron the genera Saccharum, Sorghum, Peontsetua, Erianthus, end Arundo. ALL were evaluated against 9 highetonnege Saccharum hybrid, PR 980, serving as the standard or reference clone. superior performances vere obtained vith the Saccharus spentanoun clones US 67-22-2, US 72-70, and SES 231, an untden-tified wild 8. spontaneus hybrid, the sorghun variety Rona, and @ commercial hybrid originating fron a sudan grass x sorghum cross (Sordan 0A; North« up-King Co.)

(®) Sordan 70-A was identified as an authentic short-rotation source of biomass. Its tissue expansion phase proceeds rapidly for about 6 weeks from the time of seeding. This is folloved by an equally-rapid maturation Phase terminating at 10 co 11 weeks. Its dry matter potential is at least 20 ovensdry tons/acre year.

(©) A very favorable nitrogen response curve wi

established for Sordan

70-A plants propagated by sand culture.

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(2) Chesteal grouth regulator experiments with PR 980 confirmed that

che Nonsanto product Polaris produces growth increases in the order of 25

to 5% when administered as an equeous foliar spray. Its effective concen

fon range {8 50 to 300 ppm, The stimulatory action persists for at

oat 12 weeks following chentcal application.

(©) A nutritional disorder o

Jerved in napier grass field plots was

tontatively identified as manganese defictency. This vork was performed

wit) the sane varlety propagated by sand culture,

2. Hel

Fieldeplot experiments were established at the semi-arid AES Lajas Sub-

station, Controlled variables included varieties (3 sugarcane, 3 napier grave, and Sordan 70-A), row centers (150, 50 and 25 cm), and harvest fr

quency (2, 4, 6 and L2enonth intervals). The following observations are svcd on partially-complete data obtained over a time-course of 10-nonths.

(w napier grass (var, comon Merker) {8 superior to comercial sugar= cane hybrids as a biomass source under conditions of short~ and intermediates rotation cropping

() sugarcane responds well to close spacing for approxinately 6 months after planting; thereafter the response virtually disappears in each variety.

(© Napier grass docs not respond to close spacing.

(@) Fertilization levels based on conventional sugar~ and forage-production practices are totally inadequate to sustain maximum bionass production.

(e) bry sattor yields for both cane and aapier grass are increased by

Lengthoning the interval between harve:

2 (for exanple, a single harvest

fat 6 months exceeds the combined yield of five 2enonth harvests)

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(e) For all field-ploe candidates (sugarcane, napter grass, Sordan 70-A)

Diomass yield was a function of two growth phases, fe, tissue expansion and Uisoue maturation, Each candidate's yield potential {s very heavily depend=

feat on the maturation pha

(g) For Sordan 70-A (short-rotation source), maturation is complete by 10 or 11 weeks after seeding); more than half of the dry matter is prow duced between weeks 8 and 10,

(h) Complete maturation requires at least 16 weeks in napser grass and probably up to 12 months in sugarcane. For optimal yields sugarcane should stand at least 6 months between harvests.

(@) The napier grass hybrids, PI 30086 and PI 7350,appear to have sig nificantly larger biomass-production potentials than docs common napier

grass (var. Morker).

F, REVISED WORK PLAN FOR YEAR 2

Funding constraints will not permit second-year research to proceed at the level originally proposed. These reductions relate to a DOE cutback of ?about 30% from the original second-year budget, plus a UPR doubling of the project's overhead deductions. The Year 2 work plan will retain the original objectives and as many features of the original work plan as can be retained with reduced funding. Cutbacks and modifications will be made in the fol-

lowing areas:

1, Bersonnel: The project will not hire an Agricultural Engineer and 4 Plant Physiologist as originally intended. Certain of the physiological analyses will be conducted by the project leader if time can

nade

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available. Student participation will be reduced to one graduate plus one

or two undergraduates.

2. Candidate Screening: Sereoning objectives will be modified to obtain one oF two superior clones per category of bionass candidates, ?This will ultimately have the effect of confining the project's findings to the main production stee, fe, the Lajas Valley. Tt will eliminate about half of the repstitious field plot work. However, response curves for water, nitrogen, row spacing, and horvest frequency will have to be retained for the fev cand!

dato clones identified for the respective categories.

3. Hield Plot Tests:

?These experiments will be reduced in number to about 2/3 of those originally planned, Duration of experiments will also be reduced whenever the incoming data is judged to be sufficient for the experi-nent's objectives, Several test paraneters will be eliminated, including

aitrogen-source variables, moving heights, and season of planting. Tt should

be possible to rationalize th:

fe factors to some degree insofer as prior

Gata is available on the bionass candidates. In those fel

plot experi

rents that have to be performed it aay be possible under certain conditions

to reduce the nunber of replications from 6 to 4.

4, Bleld-Scale Experiments: Fleld-scale work wil begin earlier but vill be confined to fever bionass candidates. Harvest frequency, total yield, and performance of harvest equipment with variably-aged candidates will be

the prinary variables for evaluation, The initial field-scale candidate vill

be Sordan 70-A. The earliest field trials a

planned for the second quarter

of Year 2

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5. Breeding: Breeding studies will be confined to a fov crosses with 4 few existing parents that can be incorporated at Little expense into the ?existing AES cane breeding program. This will enable us to attenpt sove important corrections in otherwise desirable candidates for the long-

Yotation and winimun-tillage categories.

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FABLE 1, RESEARCH PIASES FoR EY@MASS PRODUCTION

STUDLES WITH TROPICAL GRASSES

Rescareh rhase Class of objectives

Greenhouse Phystologtce1-Botanseal

Held plot Botantcal-Agrononie

Field Seale Agronomic-Econonic

Comercial-Industrial Economie

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TABLE 2. BIOMASS PRODUCTIVITY PARAMETERS BEING EVALUATED

DURING THE PROJECT'S GREENHOUSE PHASE

Perfornance (Relative to Reference Clone

Paraneter PR 980) Required For Field Plot Fhase

Total Biesass Superior

Gresth Cerve Superior

Regrovth Rate Superior

N Response Equal Or Superior

Water Response Equal Or Superior

Recutting Tolercnce Superior

Insect Tolerance Equal

Disease Resistance Equal,

Tissue Composition 1/ Equal Or Superior

TAllering Density Superior

A/ Total Ach, Silicate, Sulfur

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?TROPICAL GRASSES OVEK A TIMECOURSE OF 7 HUNTS

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[ARLE 6. DRY HATTFR CONTEME (:) POR RAPLER CXASS, NAPIER IVBRIBS, AND SORDAY

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TAREE 8, GREEN MEICHT RECPERSES of NeWTURE gucAROAME To mE

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4 weeks of ate.

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TAULE 9, GKOIIH RESEORSES oF DAWTURE SUGARCANE vO FLAK

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TABLE 11, strmuuatony errecTs oF moas 1/on rruuen (Hoot)

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bs 66-40-1,

Ds 61-39

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Saccharum x Miscanthus vs 67-971

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TABLE 33. PLINT POPULATIONS FOR NAPLER GPASS, Ni2TER

HVORIDS, AND SORDAN 70-A AT & WEEKS APLER PLANTING

Cultivar	?Stems/Acre 1/
PR 980	90,192
Napiey Grass (Var. Morker)	107,092
Raptor Hybrid No, 7350	102 456
Rapier Hybrid No. 30086	150,490
Sordan 70-A	316,650

4/ Calculated froa ston counts on 1/50 acre plots,

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TABLE 34, PR SACCHARIRE GERIPLASM SOURCES SELECTED FOR BREEDING

CANDIDATE BI@MSS CLONES

Source Breeding Stage

B. spont. (Aegyptiacus) Frozen Pollen

Frozen Whele Tassels

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Frozen Whole Tassels

Flower Synchronization

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