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**SHORT-ROTATION WOODY-
CROPS PROGRAM**

**Quarterly Progress Report
for the Period Ending
August 31, 1981**

J. H. Cushman
J. W. Ranney

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1902

MASTER

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ORNL/TM-8157

Contract No. W-7405-eng-26

ORNL/TM--8157

SHORT-ROTATION WOODY-CROPS PROGRAM

DE82 013374

Quarterly Progress Report for the Period Ending
August 31, 1981

J. H. Cushman, Technical Assistant
J. W. Ranney, Field Program Manager

This report contains material prepared by
the individuals listed on the following page.

ENVIRONMENTAL SCIENCES DIVISION
Publication No. 1902

NOTICE: This document contains information of
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This document contains reports from the principal investigators of research projects in the Short Rotation Woody Crops Program. The investigators who prepared reports, their institutions, and the relevant grant or contract numbers are listed below.

Institution	Investigator(s)	Contract Number
University of Arkansas	T. T. Ku	UCC-ND Subcontract No. 7941
BioEnergy Development Corporation	T. B. Crabb	UCC-ND Subcontract No. 9061
University of Florida	D. L. Rockwood	UCC-ND Subcontract No. 9050
University of Georgia	K. Steinbeck C. L. Brown	UCC-ND Subcontract No. 7860-X02
University of Houston	J. R. Cowles H. W. Scheld	UCC-ND Subcontract No. 9059
University of Illinois	G. L. Rolfe	UCC-ND Subcontract No. 9052
Kansas State University	W. A. Geyer	UCC-ND Subcontract No. 7934
Michigan State University	J. W. Hanover	UCC-ND Subcontract No. 9053
Michigan Technological University	R. L. Sajdak	UCC-ND Subcontract No. 9058
University of Minnesota	R. S. Farnham	UCC-ND Subcontract No. 9073
Mississippi State University	S. B. Land, Jr.	UCC-ND Subcontract No. 9051
North Carolina State University	D. J. Frederick R. C. Kellison R. Lea	UCC-ND Subcontract No. 9054
North Central Forest Experiment Station USDA-Forest Service	D. Dawson	Interagency Agreement DE-AI05-800R20763
The Pennsylvania State University	P. R. Blankenhorn T. W. Bowersox C. H. Strauss	UCC-ND Subcontract No. 7928
The Pennsylvania State University	W. E. Sopper D. R. DeWalle S. N. Kerr	UCC-ND Subcontract No. 9075
Seattle City Light	L. S. Dolan	DOE Grant No. DE-FG51-78ET20593
Texas A&I University	P. Felker	UCC-ND Subcontract No. 9066
Utah State University	C. M. McKell	DOE Grant No. ET-78-G-01-3076
University of Vermont	F. Laing	UCC-ND Subcontract No. 9060
Virginia Polytechnic Institute and State University	W. B. Stuart	UCC-ND Subcontract No. 7733-X04
University of Washington/ Washington State University	R. F. Stettler P. E. Heilman	DOE Grant No. DE-FG01-78ET-20599

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ABSTRACT

CUSHMAN, J. H. and J. W. RANNEY. 1982. Short rotation woody crops program quarterly progress report for the period ending August 31, 1981. ORNL/TM-8157. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 112 pp.

Progress of twenty-one projects in the Department of Energy's Short Rotation Woody Crops Program is summarized for the period June 1 through August 31, 1981. Individual quarterly reports are included from each of the projects. These reports discuss accomplishments within specific project objectives and identify recent papers and publications resulting from the research.

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1.0 SUMMARY

This report covers the progress of the Short Rotation Woody Crops Program (SRWCP) from June to August 31, 1981. The SRWCP is designed to improve the productivity and decrease the costs of short rotation systems for growing wood. The program is supported by the Department of Energy's Biomass Energy Technology Division. Oak Ridge National Laboratory (ORNL) provides field management.

This quarter, the SRWCP consisted of twenty-two research projects. Participating institutions and investigators are listed, by geographic region, in Table 1. The major ORNL activity was defining work scopes and instituting subcontracts for 1981-1982 research for all projects in the program. Contracts, subcontracts, or interagency agreements were signed for eighteen continuing and two new projects this quarter. Negotiations are continuing on three new and two continuing projects.

All projects are on schedule. In all regions, the major activities this quarter included the summer tasks of controlling weeds and monitoring insect and disease levels. Continuing drought in the Southeast forced a decision to abandon some of last year's plantings. The Northeast, Northwest, Midwest, Lake States, and Texas all report excellent growing conditions this year. Most projects will begin 1981 growth measurements next quarter. Some preliminary results may be reported next quarter, though most projects will report annual growth and production data in the March 1982 annual report.

Table 1. Short Rotation Woody Crops Program (SRWCP) Projects by region

Institution	Investigator(s)	Title
<u>Northeast</u>		
The Pennsylvania State University	P. R. Blankenhorn T. W. Bowersox C. H. Strauss	Net energy and economic analyses for producing <u>Populus</u> hybrids
The Pennsylvania State University	W. E. Sopper	Maximizing woody biomass production using municipal wastewater
University of Vermont	F. Laing	The production of biomass for energy on abandoned farmlands in the Northeast
<u>Lake States</u>		
Biosys Corporation	C. W. Vail	Land for mini-rotation silviculture in the Western Lake States
Michigan State University	J. W. Hanover	Tree species and management strategies for biomass production in the Lake States
Michigan Technological University	R. L. Sajdak	Application of sugar maple and black locust to biomass/energy plantation concept
University of Minnesota	R. S. Farnham	Wetlands for production of woody plants for energy
North Central Forest Experiment Station, USDA-FS	D. Dawson	Establishment of <u>Populus</u> energy plantations
<u>Great Plains</u>		
Kansas State University	W. A. Geyer	Great Plains energy forest
University of Illinois	G. L. Rolfe	Woody biomass production through solar energy conversion
<u>Pacific Northwest</u>		
Seattle City Light	L. S. Dolan	Cultural treatment for selected species for the Pacific Northwest
University of Washington/ Washington State University	R. F. Stettler P. E. Heilman	Evaluation and genetic improvement of black cottonwood for coppice

Table 1. (continued)

Institution	Investigator(s)	Title
<u>Southeast</u>		
University of Arkansas	T. T. Ku	Use of understory vegetation as a renewable energy resource
University of Florida	D. L. Rockwood	Biomass and chemicals from woody species in Florida
University of Georgia	K. Steinbeck C. L. Brown	Increasing biomass of short rotation coppice forests
University of Houston	J. R. Cowles H. W. Scheld	Cultural and management practices for the Chinese tallow tree as a biomass fuel source
Mississippi State University	S. B. Land, Jr.	Genetic selection of American sycamore in the mid-South
North Carolina State University	D. J. Frederick R. C. Kellison R. Lea	Species selection and silvicultural systems for biomass in the Southeast
Virginia Polytechnic Institute and State University	W. B. Stuart	Short rotation harvesting machines and systems
<u>Semi-Arid Southwest and Mountains</u>		
Texas A&I University	P. Felker	Production of woody biofuels from mesquite
Utah State University	C. M. McKell	Selection of high producing shrubs of the Western United States
<u>Subtropics</u>		
BioEnergy Development Corporation	T. B. Crabb	Eucalyptus plantations for energy in Hawaii

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2.0 BACKGROUND

The Short Rotation Woody Crops Program (SRWCP) is a Department of Energy research program designed to improve the productivity and increase the cost efficiency of growing and harvesting woody plants for fuels and petrochemical substitutes. It is a field-oriented long-range research program which includes research projects at institutions across the United States. Oak Ridge National Laboratory provides field management for the program, which is sponsored by the Department of Energy's Biomass Energy Technology Division.

The Short Rotation Woody Crops Program began in 1977. Many projects in the program date from 1978-1979 and originated with proposals written in response to the original program research and development announcement. Until the summer of 1981, the program was called the Fuels and Chemicals from Woody Biomass Program. The name has been changed to reflect the program's emphasis on research related to growing woody biomass.

The major SRWCP research areas are: (1) species screening and genetic selection; (2) stand establishment and cultural treatment; and (3) harvesting, collection, transportation, and storage. Species screening and genetic selection projects emphasize the selection of promising species, or strains within a species, for biomass production under short rotation intensive culture. Because these projects are looking for species that will grow rapidly under cultural practices which are also the subject of research, they often have components such as spacing trials or herbicide treatments which are also found in the stand establishment and cultural treatment studies (Area 2).

Stand establishment and cultural treatment is the largest research area in the program. The establishment period is critical in intensive silviculture. Stand establishment studies are looking at methods of site preparation, production and treatment of planting stock, planting techniques, fertilization, irrigation, and weed control. The goal of stand establishment studies is to produce a stand of healthy, rapidly growing trees at a specific spacing. Cultural treatment studies are determining the effects of spacing, length of cutting cycle, fertilization, irrigation, and site differences on biomass yields. Many of the establishment and management studies are using more than one species and can also be considered species-screening studies.

Research Area 3 (harvesting, collection, transportation, and storage) is the smallest area in the program. Short rotation coppice forestry will need harvesting systems that can handle large volumes of small material. Cutting mechanisms that will sever multiple sprouts from a single stump, and carriers that do not damage the stumps and root systems are two important criteria for short rotation harvesting machines.

This report covers the progress of the SRWCP from June to August 31, 1981. During this period the project consisted of twenty-two research programs. Twenty were continuations of work begun earlier. Two (Texas A&I University and Biosys Corporation) were new projects which started during the quarter. This document consists of quarterly progress reports from the projects in the SRWCP. Introductory material discusses major ORNL activities and summarizes progress in each of the major program areas.

3.0 MAJOR PROGRAM ACTIVITIES

3.1 RESEARCH SUBCONTRACTS AND INTERAGENCY AGREEMENTS

Twenty continuing SRWCP projects and nine new studies were approved for 1981-1982 funding. The funding mechanism for most projects was changed from DOE grants to research subcontracts through the Union Carbide Corporation-Nuclear Division, which operates ORNL for the Department of Energy. Preparing 1981-1982 subcontracts was the major activity at ORNL this quarter. New contracts, subcontracts, or inter-agency agreements for twenty new and continuing projects were in place by the end of the quarter. Funding was slightly delayed for a few projects with early renewal dates. Those delays did not affect any planned activities. At the end of the quarter, negotiations were continuing on five new and two renewal projects.

3.2 ANNUAL CONTRACTORS' WORKSHOP

The 1981 workshop for SRWCP contractors was scheduled for September 22-25 in Issaquah, Washington. At least one investigator from each major SRWCP project is expected to attend. Three major sessions will be devoted to problems in stand establishment, propagation of plant materials, and methods for economic evaluation. The workshop participants will visit the Seattle City Light/University of Washington SRWCP project's research plots on the Cedar River Watershed and the University of Washington/Washington State University SRWCP project's genetic study sites of black cottonwood (Populus trichocarpa) and cottonwood hybrids (P. trichocarpa x P. deltoides) at Puyallup, Washington.

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4.0 MAJOR PROJECT ACTIVITIES

4.1 SPECIES SCREENING AND GENETIC SELECTION

The five projects in this category emphasize species screening and genetic selection of clones or strains from within a species. These species and varieties are being evaluated for rapid growth, site adaptability, and resistance to pests. In all the projects the species are being tested under a variety of management regimes and site conditions. Projects at Mississippi State University and the University of Washington/Washington State University are evaluating genetic selections of American sycamore (Platanus occidentalis) and black cottonwood (Populus trichocarpa), respectively. At Michigan State University and the University of Vermont, a variety of species (over 30 total) are being screened for biomass production. Utah State University is comparing the growth of four species of semi-arid shrubs.

The Mississippi State University project, now in its final year of research, destructively sampled 384 trees this quarter. These trees represent four open-pollinated families from each of 16 geographic seed sources. Data were collected from the last two of four field sites and are now being analyzed. Results will be published in forthcoming reports. The University of Washington/Washington State University project reports excellent growth of the black cottonwood hybrids and clones this quarter. Trials of the hybrids were monitored and, as expected, F_1 hybrids displayed a high degree of uniformity, whereas F_2 hybrids varied in height growth, degree of branching, and leaf morphology.

Investigators at Michigan State University report that the trees in their field trials grew well this summer due to adequate moisture and weed control. The most promising species at all sites and under all management regimes is European black alder (Alnus glutinosa). Preparations began for rangewide seed collection of black locust (Robinia pseudoacacia) and tag alders (Alnus incana and Alnus serrulata). In addition, cutover sites are being prepared for 1982 planting.

The University of Vermont reports a delay in obtaining growth data on wild biomass trials and in planting a new site because of continuous rains. A harvest is planned for the coming quarter at which time the most productive species will be identified and slow growing species will be removed.

4.2 STAND ESTABLISHMENT AND CULTURAL TREATMENT

Stand establishment and cultural treatment, with 15 projects, is the largest area of research in the SRWCP. These studies emphasize a variety of management practices to achieve successful plantation establishment, including planting techniques, weed control, fertilization, and irrigation.

Projects in the Northeast, Lake States, Midwest, and Texas report excellent growth due to abundant rainfall during the spring and early summer months. In most cases weed growth required cultivation and herbicide application. Investigators at The Pennsylvania State University (Blankenhorn, Principal Investigator) developed a herbicide program which successfully suppressed more than 90% of competing weed growth. A new greenhouse study began at Kansas State University to monitor the

effects of various herbicides on tree seed germination. Researchers at the University of Houston determined that glyphosate is an effective herbicide in Chinese tallow tree (Sapium sebiferum) stands, and began experiments to evaluate the effect of this herbicide on seedlings.

Two projects at the North Central Forest Experiment Station and Texas A&I University reported insect and disease problems. Mortality at the North Central Station was attributed to a pathogenic/physiogenic complex. At Texas A&I, problems were caused by the mesquite twig borer. A North Carolina State University site near Goldsboro, North Carolina, was abandoned because of severe drought conditions over the past 18 months. Only two of six species planted at the site survived.

The University of Florida reports fresh weight yields for a 1.7-year-old eucalyptus (Eucalyptus grandis) selection trial and for experimental E. grandis plots receiving nitrogen and phosphorus fertilizer. Several projects are preparing to harvest plots at the end of the growing season. At the University of Georgia, harvesting equipment was obtained and four-year-old plantations will be harvested as planned.

Additional activities for this quarter included planting for new field trials, plot maintenance, and economic studies. Seattle City Light initiated an economic feasibility study on biomass plantation operations. The North Central Forest Experiment Station project completed a financial cash flow evaluation of intensively grown hybrid poplar plantations for the Lake States area. The BioEnergy Development Corporation planted 63 acres for species selection, fertilizer, and herbicide trials. The University of Minnesota propagated 50,000 trees for field trials from nursery stocks of 10 Swedish willow varieties.

The University of Georgia project reports over 90% survival of out-planted black locust and princess tree (Paulownia tomentosa) plantlets derived from tissue culture. In general, all projects in this category are on schedule with few projected delays.

4.3 HARVEST, COLLECTION, TRANSPORTATION, AND STORAGE

Virginia Polytechnic Institute and State University's project "Short Rotation Harvesting Machines and Systems" is the only SRWCP research effort in this category. The major objective of this project is to design and develop an integrated harvesting system for use in short rotation plantations. Progress to date is on schedule. The first set of trials to evaluate severance devices has been completed. One saw did achieve the desired clean cut with little damage to the cambium. Difficulty was encountered in controlling the fall of the severed tree. Alternative designs are now being considered for a positive method of controlling the fall of trees.

5.0 SPECIES SCREENING AND GENETIC SELECTION REPORTS

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FUELS AND CHEMICALS FROM WOODY BIOMASS

QUARTERLY REPORT

Name: James W. Hanover

Institution: Michigan State University

Project Title: Tree species and management strategies for biomass production in the Lake States.

Reporting Period: June 1, 1981 to August 31, 1981

Introduction:

During the three-month summer period successful species in the biomass plantations over the state grew well due to adequate moisture and weed control. These species and clones are now well established and it appears that both species and genotype x site interactions will be important considerations in any future strategy for energy plantations. Perhaps the most promising species over all the test plantings is European black alder. Extensive preparations were begun for the collections of black locust and tag alder seeds over the range of the species. In addition we plan to collect Populus deltoides throughout the State in 1982. Cutover site preparations are underway in anticipation of planting in 1982. Species being considered for these plantings include jack, red, and white pines, aspen, hybrid pine, European black alder, red oak, the larches, honeylocust, and black locust.

Tasks: 1. Advisory and Coordination

Meetings were held with those cooperators in the Michigan State Cooperative Tree Improvement Program who are involved in biomass related activities. Discussions were held with Menasha Corporation, Champion Timberlands, and the Michigan Department of Natural Resources regarding reforestation of cutover sites, and with Michigan Consolidated Gas regarding biomass and genetics plantations on their land. Dr. Keith Huston, Director at large of the North Central Region Agriculture Experiment Stations, toured the Tree Research Center. Talks at that time centered around production and conversion of biomass for energy use. Meetings were held among project personnel including inspections of biomass plantations.

In August we assisted Champion Timberlands in conducting a herbicide test on cutover lands in the Upper Peninsula of Michigan. Herbicides tested include 2-4, D (TM Esteron 99), Tordon 101, Garlon 4, and Roundup.

We have received some reports this quarter from the 4-H cooperators who are involved in the hybrid poplar statewide evaluation.

2. Seedling Production

Seedlings of a number of biomass species are currently being produced. Seedling production for the aspen progeny test is continuing in the nursery. This material includes trembling and bigtooth aspens as well as their hybrids. These seedlings will be field planted at 5 locations throughout the Upper and

Lower peninsulas of Michigan in the spring of 1982. Greenhouse production of red pine, jack pine, and hybrid pine (Pinus nigra x densiflora) is also underway. These pines will be field planted for evaluation and possible conversion to seed orchards. These seed orchards should produce genetically improved seed for increased biomass production in these species. Seedlings of the honeylocust rangewide test are being hardened off this fall and will be ready for field planting in the spring of 1982.

3. Site Preparation

The seven acres of hardwood forest at Chatham, Michigan which was clearcut last quarter was sprayed with Roundup herbicide (3 qts/acre) in order to control sprouting and volunteer seedlings. A second, older clear cut was also treated with herbicide at Russ Forest Southern Michigan. Each of these cutover sites will be evaluated in spring of 1982 for effectiveness of herbicide control and then planted in the fall of 1982. Species selection for these sites will be based on species performance in the existing biomass plantations near where these cutover sites are located.

Site preparation was also begun on 5 old field sites for the aspen progeny test, 2 sites for the honeylocust rangewide test, 1 site for the hybrid pine, 3 sites for the jack pine and 2 sites for the red pine.

In addition to the assistance given to Champion Timberlands in conducting site preparation experiments, a second experiment was begun in conjunction with the Michigan Department of Natural Resources. Herbicide trials were begun on lands near Shingleton, Michigan in the Upper Peninsula. Roundup was sprayed at 2 qts/acre on sites that have proved hard to regenerate in the past. Herbicide control was evaluated 3 weeks later by sampling the sprayed area with 36 mil-acre plots. Data recorded were number of bracken fern fronds, and percent cover of lichen, grass, and blueberry. This area will be remeasured in the spring and summer of 1982. This same area will later be planted in order to test variations in planting stock, species, and planting method.

4. Plantation Establishment

No new biomass related plantations were established this quarter.

5. Plantation Management

Species trial plantations were mowed and spot-sprayed with herbicide as needed. Other plantations of direct interest to this project were also maintained. Plantation maintenance will continue throughout the fall.

6. Progeny Testing

Pruning of a 12-year-old jack pine progeny test was begun in preparation for measurement, analysis, and thinning to produce a seed production area for the species. The extensive test of the native aspens and their interspecific hybrids has grown extremely well in the nursery beds over the summer. Early differences in growth rate are pronounced.

7. Plantation and Site Evaluation

No measurements were taken this quarter.

8. Tree Selection and Seed Collection

A number of apparently superior seed sources of biomass species were identified through the "Sweet Tree" program of the Michigan State Cooperative Tree Improvement Program. Promising seed parents were identified in tamarack, jack pine, red pine, and aspen. Seed will be collected from these trees when it is available.

Preparations are underway for fall collections of two species included in the biomass species trials. These species are black locust and eastern alder. Collection forms are being mailed to cooperators throughout the ranges of these species. Approximately 650 people in all are to be contacted. We hope to obtain 400-500 sources of each species. These collections will precede genetic improvement work designed to increase the biomass producing capability of these promising species. Examples of the collection forms sent to cooperators are included with this report.

9. Economic Analysis

The economics graduate student is continuing his studies into the financial aspects of tree production and improvement. Better data are expected to be collected on the costs of plantation establishment and maintenance as the project progresses. Additional work is being done on the financial aspects of seed orchard establishment for production of genetically improved seed. He is also working on a computer program that uses linear optimization for developing tree improvement strategies using economic criteria.

- Presentations:
- A.
 - 1. Tom Stadt
 - 2. Chatham Forest overview
 - 3. July 16, 1981
 - 4. John Bartholic, Assistant Director Agriculture Experiment Station and Gerry Haarer, MSU Land Manager.
 - B.
 - 1. Glenn Howe
 - 2. Biomass research at the Tree Research Center, MSU.
 - 3. July 23, 1981
 - 4. Dr. Keith Huston, Director at Large of the North Central Region Agriculture Experiment Stations.
 - C.
 - 1. Tom Stadt
 - 2. Chatham Forest overview
 - 3. July 20, 1981
 - 4. Upper Peninsula County Agents
 - D.
 - 1. Tom Stadt
 - 2. Chatham Forest overview
 - 3. August 5, 1981
 - 4. Larry Tombaugh, Chairman Department of Forestry, MSU and Gordon Guyer, Cooperative Extension Director, MSU

- E.
 - 1. Jim Hanover
 - 2. Biomass production reserach at MSU
 - 3. June 17, 1981
 - 4. County Commissioners of Michigan
- F.
 - 1. Jim Hanover
 - 2. MSU Energy Research Program
 - 3. August 14, 1981
 - 4. Dr. Inger Christian, Umea, Sweden.

FUELS AND CHEMICALS FROM WOODY BIOMASS

QUARTERLY REPORT

NAME: Samuel B. Land, Jr.

INSTITUTION: Mississippi Agricultural and Forestry Experiment Station
Department of Forestry
P. O. Drawer FD
Mississippi State, MS 39762

PROJECT TITLE: Genetic Selection of American Sycamore for Biomass
Production in the Mid-South

SUBCONTRACT NO.: 9051

REPORTING PERIOD: June 1, 1981 to August 31, 1981

Introduction:

This subcontract is a continuation of a previous project funded by the Department of Energy through the Midwest Research Institute, SERI Division. In that earlier study, genetic differences in biomass production were determined from five-year-old progeny-test plantings at two sites in Mississippi. The present subcontract covers the collection of similar data on the same progeny families at two additional sites. Site effects and geographic seed source effects on biomass prediction equations will be examined from the combined data over all four sites. Selection of seed sources and families within seed sources will be made for maximum above-stump biomass production at each site type and for maximum performance over all site types.

Task 1. Cut trees at 2 sites and take biomass samples.

Three-hundred-and-eighty-four trees in progeny tests established in 1976 at two sites in Mississippi have been destructively subsampled for determinations of green weights, dry weights, volumes, moisture contents, and specific gravities of above-stump tree components. These trees represent four open-pollinated progeny families from each of 16 geographic seed sources. The data are currently being punched and verified for use in computer analyses. Task 1 has been completed on schedule.

Task 2. Obtain lab measurements on samples.

Seventeen lab measurements have been taken on the biomass samples from each tree. These include the weight of water displaced by wood and by bark for each stem or limb subsample, green weights of subsamples, and over-dry weights of subsamples. The data are currently being punched and verified for use in computer analyses. Task 2 has been completed on schedule.

Remaining Tasks:

Remaining tasks involve recording disease incidence and mortality in the progeny tests, developing biomass prediction equations, and assessing genetic variation in biomass production at the four sites. Standing-tree measurements taken on all trees in the project will be used in the prediction equations to obtain biomass estimates for each tree. These estimates will be subjected to analysis of variance to assess genetic variation in biomass distribution per tree and biomass production per hectare.

Quarterly Report, September 1, 1981

The Production of Biomass for Energy on Abandoned Farmlands
in the Northeast

Union Carbide 9060

Overwinter damage to some species as reported in the June, 1981 Quarterly Report has been difficult to quantify. With few exceptions most of the damaged plants have recovered to some extent; the amount of recovery varies in the same species in the same blocks. Because these plots are all to be harvested following leaf-drop this autumn we plan to divide each damaged tree into dead and living portions and obtain separate, and total, weights wherever justified.

The exceptions noted above are bristly locust at Site 9 in South Burlington and a few black locust plots at Sites 5 and 9. The bristly locust will be removed from the trials because they are very difficult to work with, haven't shown sufficient aggressiveness and have shown high rate of mortality. The black locust mortality will be cut at harvest time and the data kept separate and reported as 2 year growth.

An error was made in the last quarterly report when the spacing at Site 11, Johnson, Vt. was stated as 1 x 1.5 meters. The initial planting made in 1980 was spaced at 2 x 4 feet; the plantings made this spring are at the same spacing. Black locust and white ash have produced the best growth to date on these new plantings.

The 1980 planting of silver maple at Site 12, Burlington, was heavily deer-browsed over-winter. The plants were dug up and heeled in on the site while the block was clean cultivated at the same time the areas for two additional blocks were being prepared. The silver maples were then replanted as one of the 4 species in Block 1. The others are black locust, red maple and hybrid poplar.

Differences in planting stock received caused us to plant Blocks 2 and 3 to silver maple, black locust and 2 plots of hybrid poplar in each block.

Personnel of the Miner Agricultural Research Institute, Chazy, N.Y. started preparation of about 1/3 of the total area to be used for Site 13. The area was plowed, harrowed, and fertilizer and lime added. Drainage ditches were also installed. Before planting could be started a 2 inch rainfall, which turned out to be the first of a series of heavy rainfalls extending through August 15th, made any immediate use of the area impractical. The decision was reluctantly made to delay planting until the Spring 1982. Meanwhile, as conditions permit, the total area will be prepared and all 3 blocks can then be planted at the same time. The planting stock has been lined out at the Site 10 nursery for use next year.

Considerable effort has been placed on weed control. In addition to the fall 1980 application of Roundup (glyophosphate) at Site 12, directed spraying of Dacthal, spreading of Ronstar 2G and between row applications of Roundup have been used. The Roundup is applied using a Driftmaster applicator; this is simply a roller over which the solution is distributed and then rolled on the foliage. This method prevents damage from spray drifting. Cultivation between rows using a small tractor has also been tried, alone and in combination with Dacthal application.

Other formulations will be tried at Site 13 as fall and/or spring treatments depending upon soil conditions.

The almost continuous rains have interfered with obtaining growth data on wild biomass trials. Harvesting of several of the coppices, first cut by us in 1978, will be done after leaf-fall. This time span is roughly coincident with our 3 year 2' x 2' plots which are also to be harvested and therefore provides some basis for comparison. Estimates of growth on interplanted and cut-only areas also await dry weather.

It seems that a fuel densification unit is finally available in Vermont (see enclosed brochure). The operator of the plant, Dr. Russell Laslocky, has expressed interest in the growth of hybrid poplars as a feed stock source for his mill. Further contacts are necessary to obtain some idea of his potential production. His operation is located in Shoreham, Vt. near the New York border but south of our present operations except for Sites 7 and 8 on the eastern side of the state.

Many of our native hardwoods produced no seeds this year, presumably because of the late spring freeze. Seed collections of silver and red maple were therefore not possible. Even box elder are seedless this season at least in this area.

FUELS FROM WOODY BIOMASSQUARTERLY REPORT

NAME: Reinhard F. Stettler and Paul E. Heilman

INSTITUTION: University of Washington and Washington State University

PROJECT TITLE: Evaluation and Genetic improvement of Black Cottonwood for Short-Rotation Coppice Culture

REPORTING PERIOD: May 31 - Aug. 31, 1981

Field Trials -- 1A and B

Both field trials continue to show excellent growth and health.

The trickle irrigation system was put to good use, notably during the exceptionally dry month of August. Further refinements were introduced to its effectiveness; tensiometers were installed to monitor available water, and the filter system was improved to better handle the silt-laden glacial river water.

Nine 30-foot towers were installed to permit closer observation of a number of selected clones. These had been chosen for a comparison of exceptionally fast and slow growers. Morphometric studies were conducted on these clones to elucidate how patterns of leaf development, leaf distribution, leaf orientation, leaf retention and senescence, shoot elongation of main and lateral shoots, contribute to the overall growth. The data will set the stage for later physiological studies examining transpiration and photosynthetic efficiency of these clones.

In the mixed alder-cottonwood plantation 1B, foliar sampling as well as the determination of nitrogen fixation by alder root nodules (acetylene reduction technique) have been completed.

Field Trials -- 2 and 2a

The outplanted seedling produced in 1980 show excellent growth. Variation patterns in the hybrid seedlings (Trial 2a) have become remarkably pronounced. As expected, F_1 hybrids display a high degree of uniformity among members of a family, whereas F_2 hybrids are extremely varied, and backcross hybrids somewhat intermediate. The variability in F_2 plants expresses itself in height growth, form, degree of branching, leaf number, size, shape, color, and orientation. Many rather unique recombinant types have been identified which deserve attention in future breeding work.

There is hardly a better example to demonstrate the power of the breeding approach in manipulating and extracting variation than these F_2 families. Combined with vegetative propagation this approach permits the isolation of clones with specific character combinations desirable for particular sites and uses; once isolated they can be mass propagated for testing under different conditions to reveal their suitability under operational conditions; furthermore, the best among them can be subsequently used in the breeding for specific character combinations.

1981 Crosses

All 3414 seedlings resulting from our 1981 crosses (interspecific, inter-and intrapopulational) have grown quite rapidly in the greenhouse, and in the meantime, have been transferred outside for hardening off. They will be outplanted in the field in early spring of 1982.

Meetings

R. F. Stettler participated as panel member in the review of the Ontario Ministry of Natural Resources Fast-Growing Hardwood Program. (Ottawa/Toronto, August 17-21).

FUELS FROM WOODY BIOMASS

Quarterly Report

Name: C. M. McKell

Institution: Utah State University-Institute for Land Rehabilitation

Project Title: Selection of High Producing Shrubs of the Western United States for Energy Biomass ET-G-01-3076
1-79ET20026.002

Reporting Period: June 1, 1981 through August 31, 1981

Task 1: First year of field production (October 1979-September 1980).

- A. Measure 1 year's plant regrowth of selected shrubs in field sites harvested in 1978. This job will be accomplished in September 1980. Accomplished.
- B. Observe plant response to overwinter stress. Accomplished in April 1980.
- C. Perform field tillage for competition removal to be accomplished in May 1980. Minimal tillage was used to reduce weedy plants. Accomplished.
- D. Establish small plots for testing herbicides, drip irrigation, pruning etc. Studies were established during May and June 1979. Growth and vigor will be evaluated during September, 1980. Accomplished.
- E. Measure field-growth characteristics of space planted shrubs. Plant height cover and

survival will be measured in September, 1980.

Accomplished.

- F. Prepare reports. Final report is being prepared. Due October 31st.

Task 2: Second year of field production (October 1980-September 1981).

- A. Observe plant response to overwinter stress (April). Accomplished.
- B. Perform minimum tillage, record time and costs (May). Accomplished.
- C. Plants were harvested for biomass determination and plant material samples were taken for lab analysis (August). Accomplished.
- D. Measure field growth of all species (October).
- E. Monitor results of small plots (October). Accomplished.
- F. Reporting - as scheduled.

Task 3: Third year of field production (October 1981-September 1982).

- A. Observe plant response to winter stress (April).
- B. Perform minimum tillage, record time and costs (May).
- C. Measure growth in small plots (September).
- D. Collect propagating materials from superior plants and vegetatively reproduce them for any future use by DOE and scientists (Spring and Fall).
- E. Harvest some plants for biomass yield (September).

- F. Analyze selected plants for BTU, ash and sulfur content to compare with earlier field results (September).
- G. Prepare final report and manuscripts for publication. Data will be presented in final report.

Presentations and Publications

None

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6.0 STAND ESTABLISHMENT AND CULTURAL TREATMENT STUDIES

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Quarterly Report

Fuels And Chemicals From Woody Biomass Program

September 1, 1981

Name: Timothy T. Ku

Institution: University of Arkansas at Monticello

Project Title: The Use of Understory Vegetation as a Renewable Biomass
Energy Resource

The following tasks were performed during this reporting period:

- *Revised budget estimates for renewal proposal and subsequently a renewal contract was awarded for 1981-82 dated 8/13/81.

- *Continued the laborous work of clearing understory in field plots. Accomplishments were slow but sure.

cc: Dr. D. S. Ousterhout
Dr. L. O. Warren

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Fuels From Woody Biomass
Quarterly Report

Name: Thomas B. Crabb, Vice President and Manager

Contractor: BioEnergy Development Corporation
C. Brewer and Co., Ltd. subsidiary
P. O. Box 1801
Hilo, Hawaii 96720

Project: Eucalyptus Plantations for Energy Production in Hawaii
DE-FC03-78E T20074

Reporting Period: June 1, 1981 to August 31, 1981

General: From June through August, 63.1 acres were planted, resulting in a total of 159.6 acres to date in 1981. Project work focused on the installation of several experiments:

1. Euc-Legume Ratio Test at Kamae F-27C, F-26B
2. Herbicide Effect Trial at Akaka F-54C
3. Species IV Trial at Kamae F-27C
4. Species V Trial at Kamae F-26B
5. MagAmp III Trial in the Nursery
6. Potting Media Trial in the Nursery
7. Osmocote (2 months) Trial in the Nursery
8. Osmocote 21-9-9 Trial at Kamae F-27C

Harvesting: Dr. Roger Arola, U. S. Forest Service Forest Engineer, visited the project to evaluate future harvesting needs and will shortly be submitting a complete report on alternative harvesting systems. Large, open-field planting areas currently not in experiments will be utilized for future harvesting trials.

Environmental: BioEnergy Development Corporation is planning to clear and plant eucalyptus trees in 341 acres of conservation-zoned land. The Environmental Impact Statement for this area has been completed by Juvik and Juvik, Environmental Consultants. Richard Webb, previously contracted to write the EIS, was forced to withdraw because of ill health.

Task 1: Site selection

Three sites of different climatic and edaphic areas for research field plantings have been selected.

Task 2A: Species selection

Dr. James P. King, U. S. Forest Service Geneticist, is conducting ongoing provenance trials of Eucalyptus grandis and E. saligna. Provenance trials of E. globulus are currently being established.

Task 2B: Site preparation and planting methods

A small trial has been installed to study the possibility of placing Osmocote fertilizer in the same planting hole as the tree seedling. Initial observations indicate some salt damage.

Task 2C: Fertilization

The fertilizer trial at the Akaka site showed a marked growth response to nitrogen fertilization in the first year that was still maintained after 2 years of growth. Response to phosphorus fertilization was found only at the highest level of nitrogen fertilization.

The fertilizer trial at the Ka'u site also showed a large growth response to nitrogen fertilization, although not as dramatically as the Akaka site. Response to phosphorus fertilization was found at all levels of nitrogen fertilization greater than zero.

The fertilizer trial at the Amaulu site, however, showed no growth response to nitrogen fertilization alone. Response to nitrogen fertilization was found only in the presence of phosphorus.

The results from these fertilizer trials illustrate the differences in nutrient availability at the three sites. The Akaka site was very deficient in nitrogen, the Ka'u site was slightly deficient in nitrogen, while the Amaulu site was deficient in phosphorus.

Perhaps the Akaka and the Ka'u site, which were on abandoned cane land, had insoluble phosphates remaining from previous crop fertilizations, which the eucalyptus trees were able to utilize. The Amaulu site, which had never been in crop production, lacked this added supply of insoluble phosphates.

Task 3: Weed Control

Herbicide trials are ongoing. Recent results indicated that Roundup + Simazine is a very effective herbicide mixture for weed control. Unfortunately, the cost of Roundup is skyrocketing, and so less expensive alternatives are being investigated.

Task 4: Monitoring growth

Leaf samples were taken periodically from all fields in order to monitor growth and formulate fertilization schedules. Crop logging data sheets were modified from those used by Mauna Loa Macadamia Nut Corporation. Careful records of tree growth and foliar nutrient content are being maintained.

Task 5: Establishment of nursery propagation practices

Experiments to evaluate the various types of nursery media available were set up. One promising mixture to date is a 2:1 peat: perlite mix. It is less expensive and lighter in weight than the standard 2:1 peat: vermiculite mix.

Experiments to compare the effectiveness of MagAmp and Osmocote fertilizers were installed. Osmocote (3-4 mos.) often resulted in too succulent a seedling at time of outplanting. MagAmp resulted in a hardier seedling at time of outplanting, probably because it contained a more soluble form of nitrogen.

Task 6: Optional propagation methods

Vegetative propagation by rooting cuttings is currently being investigated. To date, the success rate is very low.

Task 7: Phenotypic Selections

Activity was delayed due to lack of success in vegetative propagation.

Task 8: Land use capability appraisals

Completed previously.

Task 9: Testing various mixtures of bagasse/woodchips

Eucalyptus woodchip samples were taken from 50-year-old E. robusta harvested by Capitol Woodchips Company. Bagasse samples were taken from Hilo Coast Processing Cooperative's mill. These samples were then taken to the University of Hawaii where heat values were determined on a Parr oxygen bomb calorimeter.

Sample	Heat Values, Kcal/g			
	I	II	III	Ave.
100% Bagasse	4.376	4.350	-	4.363
75% Bagasse/ 25% Woodchips	4.428	4.389	-	4.408
50% Bagasse/ 50% Woodchips	4.489	4.505	-	4.497
25% Bagasse/ 75% Woodchips	4.601	4.598	-	4.600
100% Woodchips	4.608	4.642	4.622	4.624

Task 10:Modification of the handling equipment at the generator.

According to Mr. Larry Iwami, Hilo Coast Processing Cooperative Power Plant Superintendent, no modifications of the handling equipment are necessary, provided woodchips are delivered to the mill in diameters of one inch or less.

FUELS FROM WOODY BIOMASS

QUARTERLY REPORT

NAME: Donald L. Rockwood

INSTITUTION: School of Forest Resources and Conservation
University of Florida, Gainesville, FL 32611

PROJECT TITLE: Energy and Chemicals from Woody Species in Florida

REPORTING PERIOD: 1 June 1981 - 31 August 1981

TASK 2: SPECIES AND TREE SELECTION

Activities in Task 2 were closely related to the other tasks in the project. Eucalyptus grandis progenies in the Selection and Nelder trials at Labelle were harvested at 1.7 years. Biomass yields are summarized in Task 4. Vigorous and plentiful coppicing in the Nelder trial has been observed as a rule, with some differences among progenies evident for number of sprouts and sprout size. Progeny differences for wood properties in the Selection trial are summarized under Task 3. E. grandis and E. robusta established at 1 x 1 m. spacing at Belle Glade were harvested at 1.25 years of age; six progenies (100 trees total) of each species, common to the Labelle planting, will be assessed for growth and biomass yields. The rapidly growing slash pine in the Nelder trial at Trenton were measured, and progeny differences for height were detected.

In addition, new plantings were installed to meet several objectives. Over 50 E. viminalis progenies, including several which had demonstrated good growth and frost hardiness in an earlier test, were outplanted in Nassau County. Progenies and trees to be selected in this test may provide suitable parent material for future use. Sixteen Casuarina progenies which had done well in the earlier plantings were included in a major replanting effort at Labelle.

TASK 3: BIOMASS FUEL AND SILVICHEMICAL PROPERTIES

Specific gravity and moisture content determinations for the 1.7-year-old E. grandis in the Labelle Selection trial were partially completed. Means and standard deviations for the 20 progenies are presented below:

<u>Progeny</u>	<u>No. of Trees</u>	<u>Specific Gravity</u>	<u>Moisture Content</u>
993	22	.38 + .03	148 + 21
1517	23	.36 + .03	141 + 24
1002	24	.39 + .03	157 + 17
90	21	.39 + .03	151 + 12
1510	22	.39 + .03	147 + 21

Observed fresh weight yields of *Eucalyptus grandis* progenies 1.7 years after planting with deviations from yields predicted from (DBH)² and (DBH)² HGT models. Deviations are observed + predicted.

Progeny	Observed Yield			Deviation from (DBH) ² Model			Deviation from (DBH) ² HGT Model		
	mt/ha			Crown	Bole	Total	Crown	Bole	Total
	Crown	Bole	Total						
90	6.2	18.0	24.1	.51	.93	.77	.56	1.01	.84
1516	8.4	22.6	31.0	.54	.93	.78	.62	1.06	.89
965	8.2	23.2	31.3	.57	1.04	.86	.61	1.11	.92
State Nursery	10.6	21.9	32.4	.71	.94	.85	.78	1.01	.92
1002	8.1	24.1	33.2	.51	1.00	.81	.52	1.03	.84
849	9.2	25.1	34.3	.58	1.00	.83	.61	1.05	.88
988	10.6	24.6	35.2	.61	.92	.80	.67	.99	.87
993	9.3	27.7	37.0	.51	.98	.79	.54	1.03	.84
869	11.7	26.6	38.2	.63	.92	.81	.70	1.02	.89
1510	8.9	30.1	39.0	.47	1.03	.81	.48	1.05	.82
867	11.6	27.8	39.4	.66	1.02	.88	.69	1.08	.93
1003	11.7	29.4	41.1	.62	1.01	.86	.63	1.02	.87
1011	13.6	28.2	41.8	.73	.98	.88	.76	1.01	.91
1035	12.4	31.3	43.6	.61	1.01	.85	.66	1.09	.92
1517	12.3	32.2	44.5	.54	.93	.77	.57	.97	.81
898	10.0	34.9	44.9	.43	.97	.76	.44	1.00	.78
847	17.4	40.4	57.8	.61	.95	.82	.63	.97	.84
997	17.5	42.9	60.4	.66	1.07	.91	.65	1.06	.90
1012	17.2	44.4	61.6	.63	1.07	.90	.61	1.04	.87
888	18.7	50.0	68.7	.60	1.06	.88	.57	1.02	.84

<u>Progeny</u>	<u>No. of Trees</u>	<u>Specific Gravity</u>	<u>Moisture Content</u>
997	24	.39 + .03	156 + 18
849	23	.37 + .02	147 + 37
1516	21	.37 + .02	156 + 12
1011	24	.38 + .03	153 + 30
898	24	.35 + .02	161 + 15
965	22	.40 + .04	159 + 17
847	21	.38 + .02	147 + 16
1012	24	.38 + .03	167 + 17
1035	23	.38 + .03	158 + 20
867	22	.38 + .02	158 + 16
888	24	.35 + .02	165 + 16
864	24	.37 + .02	147 + 21
1003	23	.39 + .03	155 + 15
988	21	.36 + .02	161 + 13
H	22	.39 + .03	150 + 20
	<u>x</u>	.38	154

TASK 4: BIOMASS YIELD

Actual yields of the Labelle E. grandis Fertilizer and Selection plots that were harvested in March and April were compared to fresh weight yields predicted by regressions developed in December 1980 (see accompanying tables). Over the range of total observed yields in the first table, both DBH² and DBH²·HGT models performed equally well with an average deviation of less than 5% for boles. The large deviations noted for crown biomass in both tables are due primarily to freezing and subsequent leaf drop which occurred between the time of regression development and time of harvest.

As shown in the second table, the DBH² model was more reliable than the DBH²·HGT, particularly for extreme plots. The control plot should be disregarded since many trees had not reached breast height and thus had no predicted biomass. Observed total yields in the fertilizer plots, which were within 6% of the predicted values, were better estimated than in the progeny plots, which deviated by 15% from predicted total yield.

TASK 5: SILVICULTURAL REQUIREMENTS

Some causes of the poor nursery performances of Melaleuca and Casuarina reported in the last quarterly report have been determined. The low germinability of the Casuarina can be attributed to reduced seed viability after two years of seed storage. Melaleuca, in addition to have reduced germination because of low seed viability, was also affected by salts in the nursery water. The drought in south Florida and resulting salt water intrusion preclude a second Melaleuca sowing. Salt leaves of less than 1000 ppm, while not detrimental to most trees and vegetables, are known to affect Melaleuca and Eucalyptus.

Observed fresh weight yields in mt/ha of Eucalyptus grandis 1.7 years after planting on fertilizer trials. Deviations (Observed + Predicted) of observed from predicted values are given for (DBH)² and (DBH)² x HGT models. Bars in observed yield indicate range of values seen in progeny test (first table).

<u>Fertilizer</u>	<u>Observed Total Yield</u>	<u>Predicted Total Yield</u>	
		<u>(DBH)²</u>	<u>(DBH)²HGT</u>
0	1.9	8.55	1.61
100/0 FTE	14.8	1.01	1.26
10.5 t/ha sludge	25.7	.92	1.05
21.0 t/ha sludge	35.9	.92	.92
300/0 FTE	39.0	1.02	1.08
0/50	42.6	.90	.90
100/50 FTE	91.2	1.02	.77
300/50 FTE	137.6	1.02	.73

Portions of the original Melaleuca planting (4 Nelder plots and 18 Fertilizer plots) are resprouting following last winter's freeze. These plots and the 1980 replanting will be assessed for resprouting and height growth late this year. The Melaleuca lysimeter plots and associated facilities were lost when the tractor operator inadvertently disked outside the area scheduled for replanting.

The Casuarina replanting has been completed at a reduced scale due to the nursery shortfall. The planting site was rotivated in May and treated with Roundup in July. The new planting will evaluate 8 fertilizers and 16 progenies at one spacing and bulk lots of C. cunninghamiana and C. glauca at three spacings.

TASK 6: WATER AND NUTRIENT USE

Since the disappearance of the watertable below wells due to drought conditions at the Austin Cary Forest, soil moisture fluctuations have been monitored by a Troxler soil moisture probe. Figure 1 compares readings taken with this probe with associated plant water potential measurements from a Scholander Pressure Bomb. Although correlations are weak at this time (R²'s between .44 and .75) due to small sample size, it seems reasonable to believe that as soil volumetric water content decreases linearly, plant water potential increases experimentally or geometrically. Data collected thus far seem to indicate that Eucalyptus viminalis maintains a lower water potential at its leaf surfaces than slash pine for an equal soil water content. Eucalyptus may be more consumptive of water than pine due to lower evaporative resistance at its leaf surfaces.

Austin Cary Forest Fuelwood Plantations

Figure 2 is an update of the mass conservation equation, values plotted being averaged daily water loss, accounting for the addition of precipitation. No observable trends yet exist, due probably to the fact that soil water drainage has not yet been reliably accounted for. A more elegant model, accounting for saturated and unsaturated soil water fluctuations, depth to confining layer, and plot leakage hopes to develop better results.

TASK 7: PROJECT SYNTHESIS - ENERGY EXPENDITURES

A standard form of the soil expectation model was used to test the effect of several variables on optimum slash pine rotation using Frampton's^{1/} yield data.

The before-tax form is:

$$SE = [Y_n * P_n - CP(1+i)^n] / [(1+i)^n - 1]$$

The after-tax form is:

$$SEAT = [Y_n * P_n(1-RC) + CP * RC - CP(1+i)^n] / [(1+i)^n - 1]$$

In these equations:

- SE = land expectation value/acre, before-tax.
- SEAT = land expectation value/acre, after-tax.
- Y_n = green biomass yield in tons/acre, stemwood and bark.
- P_n = price per green ton, dollars.
- RC = capital gains tax (assumed to be 28%).
- CP = regeneration cost/acre, dollars.
- i = capitalization rate.
- n = rotation age, years.

In the models only those variables are included which we feel will affect rotation age; property taxes, for example, which could be expected to be unaffected by rotation length are not included. In their present forms the models do not identify the profitability of a rotation but rather the rotation of maximum profitability or minimum loss.

Yields for two populations were used, one of genetically improved slash pine and one of unimproved slash. Yield data for ages 8, 9, and 11 were available.

On both a before-tax and after-tax basis and within a reasonable range of the variables included in the model, the optimum rotation for improved slash was 11 years in every case.

^{1/}Frampton, L. J., Jr. 1981. Genetic variation of traits important for energy utilization in sand and slash pines. M.S. thesis. Univ. of Fla.

For the unimproved slash optimum rotation age tended to decrease as price increased and to increase with planting costs. These effects were the same in both the before- and after-tax models.

The effects of the several variables on rotation age in the case of unimproved slash are what might logically be expected. In the case of improved slash, the extremely high rate of growth is probably the reason for the failure of rotation age to change with changes in the variables.

These models are being revised to incorporate changes in the federal tax code which will have a significant after-tax effect on regeneration costs.

To provide additional data for estimation of optimum slash pine biomass rotation, a series of 20 plots have been established in high density serially-seeded stands. Densities in the 6- and 10-year-old stands range from 1,500 to over 25,000 trees per hectare. Current biomass yields are being estimated, and the plots will be reinventoried at a future time to determine growth rates.

PUBLICATIONS:

- Riekerk, H., J. C. Hendrickson, and W. S. Gain. (in press). Site and environmental effects of tree biomass silviculture. Proc. 1981 Internat. Gas Res. Conf., Los Angeles.
- Rockwood, D. L., L. F. Conde, and R. F. Fisher. (in press). Maximizing woody biomass production in Florida. Proc. 1981 Internat. Gas Res. Conf., Los Angeles.
- Wang, F. C., J. Richardson, K. C. Ewel, and E. T. Sullivan. (in press). Preliminary energy analysis of utilizing woody biomass for fuel. Proc. Symp. on Energy and Ecological Modelling, Ann Arbor, Michigan.
- Wang, S. and J. B. Huffman. (in press). Botanochemicals: supplements to petrochemicals. Econ. Bot. 35(4):369-82.

PRESENTATIONS:

- Rockwood, D. L. 7/7/81. Woody biomass production. Low Energy Technology in Agriculture Workshop, Dept. of Energy, Gainesville, FL.
- Rockwood, D. L., R. F. Fisher, and L. F. Conde. 8/25/1981. Production potential of *Eucalyptus grandis* grown in short-rotation, close-spacing systems. 13th Internat. Botanical Congress, Sydney.

PROJECT TECHNICAL STATUS REPORT

Date: October 10, 1981

Period: July 1 - through September 30, 1981

PROJECT:

Title: . Increasing the biomass production of short rotation coppice forestry.

CONTRACT:

Basic Agreement No. 7860; Project Authorization No. X02

Start Date: 11/15/80

Completion: 11/14/81

This project is a continuation of a project started 10/1/77; with completion date of 9/30/82.

Old project number: DE-AS09-77ET0006

Contractor: University of Georgia
School of Forest Resources
University of Georgia
Research Foundation
Athens, GA 30602

1.0 CONTRACT OBJECTIVE

The purpose of this research is to determine ways of increasing the biomass production of short rotation hardwood forests. Procedures which will be employed involve screening a variety of hardwood species on such soils as might be available for energy production; evaluating intensive cultural practices such as cultivation, mechanical and chemical weed control, fertilization and irrigation; selection of superior individuals and geographic seed sources of promising species; development of tissue culture techniques for mass cloning of hardwoods; determination of the biomass production of nitrogen-fixing woody species in pure and mixed stands; assessment of changes in soil fertility and organic matter status under pure and mixed stands; and education of students in hardwood silviculture.

2.0 CONTRACT TASKS

Task 1 Maintain plantations

The growing season ended with the plantings in good condition. The dead and dying black alder were removed from the Tattnall Co. plots. Dry weather during the summer reduced vegetative growth in the plots but did not appear to adversely affect the deeper rooted trees. A final bush-hogging was carried out to facilitate the harvesting operations scheduled for the dormant season.

Task 2 Monitor plantations

Growth and soil nutrient analysis have been carried out on data and samples collected to date and the results will be reported in the yearly progress review. The soil analyses are of interest since these will furnish the basis for monitoring nutrient changes following coppicing. Removal of complete trees will presumably affect the soil nutrient cycle. These short rotation operations should lead to a better understanding of soil nutrient depletions following repeated coppicing.

Task 3 Genetic improvement

The first year progeny tests on the B. F. Grant and the Savannah River plantings came through the first growing season in good condition despite the dry and hot summer.

The seed from the 168 randomly selected mother trees of sycamore collected in the Southeast have been grown in the Whitehall Nursery and will be ready for field planting during the winter of 1982.

Pure culture cloning studies on hardwoods concentrated on developing plantlets from mature trees. While explants can be obtained regularly from juvenile material it has been deemed important to be able to clone older material since desirable characteristics show only with age.

Over 90 percent of outplanted black locust and Paulownia plantlets derived from cells grown in pure culture adapted to field conditions. While black locust made good growth the Paulownia transplants showed adverse reactions to site and weather.

An indoor greenhouse was built in one of the laboratories where growth conditions could be controlled leading to better conditioning of plantlets for existence under field conditions.

Task 4. Nursery techniques

Germination and survival of sycamore in the nursery were generally poor in 1980. This was caused by surface clay which hardened and reduced hypocotyl emergence and root penetration. During the 1981 planting period sand on top of the seeds alleviated the condition. It was evident that more thorough mixing of the soil in the nursery and the addition of organic material were needed to provide uniform growth conditions. Hence much of the nursery was planted to cover crops which were plowed under during the summer to enlarge the area suitable for growing sycamore and other hardwoods in 1982.

Task 5 Cooperation

Steinbeck presented an overview of short rotation forestry as an energy alternative before the Royal Dublin Society (Ireland) on July 17, 1981. All expenses were paid by the society.

Steinbeck attended the DOE Contractors meeting in Seattle, Washington on September 23-24. He also attended the American Pulpwood Association, Southwide Energy Committee Meeting in Atlanta in September. He talked on short rotation forestry.

Sommer attended the Annual Meeting of the Society for Horticultural Science on August 11-14 in Atlanta, GA. He co-authored a paper on hardening off of tissue-cultured sweetgum plantlets and a poster depicting the process involved in the propagation of azaleas in tissue culture.

Sommer also attended the Southern Tree Physiology Workshop at VPI September 2-4 and participated in discussions on recent advances in tissue culture of trees.

Task 6 Harvesting plantations

The harvesting equipment has been received and will be used to coppice 4-year-old material during the fall and winter season.

Task 7 Energy balance

Activity was confined to maintaining records of fuels used in travel, and various operations involving trucks, tractors, etc. The energy expended in fuels, etc. will be compared to potential energy from the wood obtained from the coppice operation.

Task 8 Storage of chips

This task has been abandoned because of the lack of sufficient material to make tests meaningful.

Task 9 Slit fertilizer trials

Survival and growth data taken during the growing season indicated no adverse affects from placing fertilizer in the bottom of the slit made by the planting machine at the time hardwood seedlings were planted. However, there appeared to be little discernable difference in growth the first season from fertilizer placed at the time of planting.

Task 10 Graduate education

Orley Sims enrolled in the graduate school in 1981 and will pursue a research program in the general area of biomass production when he reaches the point in his program where a specific project will be initiated.

Dr. Donald Dickmann from Michigan State University completed the data collecting phase of his leaf area study on sycamore and black locust and returned to Michigan in September. A final report will be completed during the coming months.

3.0 TECHNICAL APPROACH OR WORK PLAN CHANGES

Nothing to report.

4.0 VARIANCE PROBLEMS

Some variations in rate of expenditure of funds and manpower. These arising from equipment purchases and seasonal requirements for plot maintenance and data collecting.

5.0 OPEN ITEMS

None.

6.0 RECENT AND PLANNED ACHIEVEMENTS

Nothing unusual.

Klaus Steinbeck

Klaus Steinbeck
Claud L. Brown
Principal Investigators
School of Forest Resources
University of Georgia Research
Foundation
Athens, GA 30602

Attachments:

Contract Management
Summary Report

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FUELS FROM WOODY BIOMASS

-- Quarterly Report --

NAME: Joe R. Cowles and H. W. Scheld

INSTITUTION: University of Houston

PROJECT TITLE: Cultural and Management Practices for the Chinese
Tallow Tree as a Biomass Fuel Source

REPORTING PERIOD: June 1 - August 31, 1981

GENERAL PROGRESS

Work during this reporting period has largely involved observation of general growth and maintenance of experimental areas. Rainfall has continued to be exceptionally heavy and it is anticipated that measurements, to be made at the end of the growing season, will show very high seasonal growth rates. The crop of seeds this year also is exceptionally large and attention has been given to preparation for an extensive collection activity in the fall. Soil samples collected earlier this year were prepared for analysis. Described below are the specific activities undertaken and results obtained.

TASK I. Biomass increase in established stands.

Activity in this task was limited to general observations and maintenance of access trails.

TASK II. Growth rate under coppice management.

Activity in this task was limited to observation and maintenance of access trails.

TASK III. Growth rate of planted stands.

Activity in this task has been limited to observation and maintenance of access trails. Sprouts of the coppice sub-experiment initiated this year are now in excess of 8 feet tall.

TASK IV. Growth and properties of superior trees.

Cuttings have been taken from stimulated sprouts on selected trees and are being rooted.

TASK V. Economical establishment of stands.

Data collected in the study of flowering patterns reported last quarter have been summarized for publication. Complementary observations have been begun to record progress of seed ripening and leaf fall.

A number of experiments have been carried out to evaluate the effectiveness of glyphosate in weed control. Preliminary tests indicate that tallow trees are relatively insensitive as compared to grass species which are the major competitors in newly-planted tallow tree plantations. Application rates which control grass appears to kill or retard only the growing terminals of the tallow seedlings; the seedlings can recover. Experiments are underway and additional ones are planned to evaluate the decrease in growth rates associated with the observed damage to the seedlings.

WOODY BIOMASS PRODUCTION THROUGH SOLAR ENERGY CONVERSION

ET-78-C-01-3067

Gary L. Rolfe

University of Illinois

Quarterly Report

June 1 - September 1, 1981

Task 3.6 Irrigation

All installation of field irrigation equipment has been completed. A permanent access lane to prime lines extending from the pond source has been cleared and construction begun. Summer rains at all sites have been sufficient enough (e.g. at Sites A and B, we have received greater than 60 cm from May 1 - August 1) to render irrigation unnecessary this year.

Task 3.7 Growth Evaluation and Plot Monitoring

Weeds are more prevalent this year than during the previous two years of this study. Heavy rains throughout the summer have diluted the effects of herbicides and increased mechanical cultivation has been necessary to control weeds. Tree establishment and growth has been otherwise excellent.

Data has been taken to evaluate the growth and vigor of coppice rootstocks harvested in 1980-81.

Task 3.8 Harvest II - 1981

Planning for fall harvesting has been under way since early July. Preliminary testing of devices for cutting and handling harvested material continues.

Task 3.9 Vegetative and Soil Chemical Analysis

Vegetation and soil samples removed from study sites continue to be analyzed for vital nutrients.

General

Greenhouse herbicide trials and pilot study test plots have been planted for an investigation of direct-seeding techniques with the aim for eventual utilization for biomass production.

Presentations

1. White, T. A. and G. L. Rolfe. 1981. Woody Biomass Energy Plantations - Problems or Promise? Presented to the Spring Meeting of the Illinois Technical Forestry Association, Inc., Morton, Illinois, June 25, 1981.

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FUELS AND CHEMICALS
FROM WOODY BIOMASS PROGRAMS
QUARTERLY REPORT

NAME: Wayne A. Geyer
INSTITUTION: Kansas State University, Forestry Department
PROJECT TITLE: Great Plains Energy Forest
REPORTING PERIOD: 6-1-81 to 8-31-81 No. 7
USB CONTRACT NO.: 7934 Union Carbide Corp.

GENERAL COMMENTS:

Maintenance of all plantations has continued--weed control the first two years, followed with occasional mowing during subsequent years. Abundant rainfall has produced conditions which should be conducive to good growth. Fall collection of ground line diameter and overall height measurements will show us how much growth has actually occurred.

Three additional sites have been selected as potential locations for plantings in 1982.

The coppice study which was implemented on 5-year-old silver maple is progressing normally. Survival, height and diameter measurements on this study will be collected this fall.

TASK: Determine productivity potential on high plains in western Kansas

Three sites were planted this spring in western Kansas. The first site is on an alluvial sandy loam, the second on an upland silt loam, and the third on an upland sandy loam. All sites were planted with 1:0 Siberian elm, black locust and honeylocust.

All newly established sites in western Kansas have had sufficient

precipitation to provide good to very good seedling survival. The exception is the black locust which were planted on the sandy loam site in Garden City (50%). Early May frost damage, which resulted in some leaf dieback, has been overcome, and seedlings are healthy.

The best means of weed control appears to be cultivation. Casoron and Ronstar application worked early in the growing season; however, late growing grass and weeds were not adequately controlled with either herbicide.

Measurement of survival and seedling height will be completed at all sites this fall.

TASK: Test the toxicity of various herbicides on tree seed germination;
Study the affects of seed protectants and their ability to negate herbicide
toxicity

Greenhouse studies have been implemented to monitor the affects of various herbicides (Lasso, Surflan, Lorox, Dacthal, Devrinol, Princep, Enide, and Ronstar) on tree seed germination. The tree seeds used are black locust, honeylocust and Kentucky coffeetree.

Through the use of seed protectants, otherwise toxic herbicides can be used prior to seed germination. The plant protectants to be used in this study are activated charcoal, Screen (Monsanto) and Protect (Gulf), and will be implemented this winter.

PRESENTATIONS/PUBLICATIONS/MEETINGS/TOURS

1. Presentations:

W. A. Geyer - June 11, 1981 Short-rotation biomass . . .
Georgetown, S. C.

2. Publications:

- a. W. A. Geyer. 1981. Growth, yield and woody biomass characteristics of several short-rotation hardwoods. Wood Science. Vol. 13 (4).
- b. W. A. Geyer and Gary G. Naughton. 1981. Short-rotation biomass yields and cost analysis in eastern Kansas. Proceedings Southern Forest Biomass Workshop at Georgetown, S. C.

3. Meetings: None

4. Tours:

- a. Biomass energy planting given to a dozen foreign agricultural administrators 2 July 1981.
- b. Biomass energy planting to Agriculture ministers of African nations. 23 July 1981.

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SHORT ROTATION WOODY CROPS PROGRAM

QUARTERLY REPORT

Name: Robert L. Sajdak, Project Leader
Institution: Michigan Technological University
Project Title: Application of Sugar Maple and Black Locust to the Biomass/Energy Plantation Concept
Reporting Period: June 1, 1981 to August 30, 1981

1) Plantation Establishment and Evaluation

Statistical analysis of 1980 soil samples showed higher levels of fertilizer elements on treated plots. For this reason, 1981 soil analysis has begun to monitor soil nutrient levels. Analysis also showed differences between sites which parallel biomass production.

Analysis of height and biomass data has dictated an increase in the sample size for sprout measurement from 839 stumps to 1027. These measurements for the end of the 1981 growing season have begun.

Additional biomass samples will be taken to rebuild biomass estimating equations which will account for sprout age.

2) Growth Potential of Locust

Evaluation of locust survival and growth will take place after leaf fall.

3) Nitrogen Fixation

In an effort to test black locust-Rhizobium symbiosis, glass beads were used as a mechanical support for the black locust. A mixture of sizes was used to approximate the texture of the field test plot soil. Because the beads were found to be very alkaline in nature, the testing trial was terminated. Subsequent work entailed attempts to stabilize the pH of the beads and investigation of alternative methods to the glass beads.

A greenhouse study was also initiated using six different black locust seed sources and two different Rhizobium strains. Differences are evident between seed sources. The growth of one source in particular surpasses that of all others.

Differences are also evident between the Rhizobium strains. The black locust inoculated with the Indian River Rhizobium surpass those inoculated with the Hancock Rhizobium in height growth, color, and survival. This is consistent with the results of the culture tests of the Rhizobium. The Indian River Rhizobium grew in acid media as well as neutral media. The Hancock source, however, did not grow when in acid media.

4) Biomass of Young Natural Stands

Processing of the maple biomass samples obtained in the fall of 1980 has been completed. Regression analysis, using the logarithmically transformed allometric equation with basal diameter as the independent variable, resulted in very close fits for all data sets. Comparison of these for possible site/age differences is nearing completion. Methods employed include analysis of covariance and Neuman-Keuls multiple range test.

Efforts have begun in verifying biomass estimating equations. Field sampling has progressed through the summer and should terminate this fall.

Two locations were sampled for Speckled Alder (Alnus rugosa) biomass. These will be summarized in the annual report.

5) Characterization of Biomass

Thermal gravimetric analysis of sprout biomass continued at a reduced rate during the summer and was terminated in mid-August.

FUELS AND CHEMICALS FROM
WOODY BIOMASS PROGRAM

Quarterly Report: September 1, 1981

Title: "Use of Wetlands for Production of Woody Plants for
Fuels and Petrochemical Substitutes"

Institution: University of Minnesota
Department of Soil Science

Period: June 1 - August 31, 1981

Principal Investigator: Professor Rouse S. Farnham

D.O.E. grant No. ET-78-G-01-3082

I. PROPAGATION

A. Greenhouse Construction

A 144' by 30' hoop house was erected at the Wilderness Valley Farms Peat Research Facility (WVF). A mist system which covered approximately half of the hoophouse area was assembled above the propagation benches. A convection tube heating system was installed below the propagation benches to maintain a constant temperature for optimum softwood cutting propagation.

B. Willow Propagation

1000 stock plants of each of the ten Swedish Salix varieties were transported to the W.V.F. facility. These stock plants were then cut into three node softwood cuttings. These three node cuttings were drenched in a miticide solution, dipped in a rooting hormone and placed in the multipak flats under mist. A total of 50,000 macropropagules were produced by this method. The majority of these plants were ready to plant within seven weeks after cutting from the stock plants.

C. Alder Propagation

Half of the 15,000 Alnus seedlings were inoculated with a slurry containing the Actinomycetes endophyte occurring in native Alnus rugosa nodules. These seedlings were transported to W.V.F. to be planted in the field.

II. FIELD WORK

A. Equipment

A transplanter was assembled at the research facility. It was then calibrated to the nearest metric equivalent to achieve the desired spacing. Some modifications were found to be necessary for improved performance on organic soils.

Because the bearing strength of organic soils is not as great as mineral soils, our plot tractor was equipped with rear flotation tires.

To improve the physical structure of the planting bed, a field roller was constructed.

B. Field Preparation

Fields to be used for research were sprayed with herbicide to eradicate standing weeds and rotovated several times to prepare the planting surface. Both the nursery and the Salix varietal and spacing trials were fertilized with 300 lbs/acre of 4-12-36 plus micronutrients. The demonstration energy forest was fertilized with three separate treatments, 300 lbs/acre of 4-12-36, 450 lbs/acre of 4-12-36 and 450 lbs/acre of 4-12-36 plus micronutrients. All the research fields were then rotovated and rolled to prepare the soil for planting.

C. Planting

1. Demonstration Energy Plantation

A total of 15,000 hardwood cuttings of native Salix interior (Henderson ecotype) were planted. This plantation consisted of three plots 32 meters by 80 meters in size.

2. Nursery

A total of 10,000 Swedish Salix stock plants (1,000/variety) were planted in 13 x 71 meter plots. The roots were pruned before planting in order for them to pass through the planting shoe. These plants will be a source of plant material for future research.

3. Cultvar Screening and Spacing Trial

- a. Salix - 112 18 meter by 18 meter plots were to be planted by this time. However, due to a lack of suitable planting material of some cultivars, only three of the projected four repetitions were completed. It was felt that it would be better to plant the fourth repetition the following spring with freshly propagated uniform material. As the three repetitions were planted in late August the variation between the fourth repetition and the other three repetitions will be minimal.
- b. Alnus - A total of 10,000 seedlings of three different Alnus species were planted in six separate plots. Both innocualted and noninnoculated seedlings were planted at a 1 x 1.5 meter spacing and a 1 x 2.0 meter spacing. No fertilizer was applied to these plots.

III. PROBLEMS ENCOUNTERED

The propagation of the Swedish Salix cultivars was delayed due to the arrival of the hoophouse three weeks after the contracted delivery date. Fungus and insect damage of softwood cuttings during propagation also delayed progress. Some problem was encountered

with fungal infestations of hardwood cuttings during storage which affected sprouting percentage. Alnus inoculation was attempted twice in the greenhouse with no success.

IV. PRESENTATIONS AND PUBLICATIONS

A. Woody bioenergy research at the W.V.F. facility was presented to:

1. The Northeastern Minnesota Development Association.
2. The Arrowhead Regional Development Commission.
3. Numerous newspapers and television.
4. Representatives of Indian Reservations throughout the state.

B. Publications of woody bioenergy research:

1. Connolly, B.S. Biomass estimations of tall shrubs in wetlands areas and its relationship to some edaphic factors. M.S. Thesis, July 1981.
2. Garton, S., P.E. Read and R.S. Farnham. Micropropagation of Salix spp. Presented to the American Society of Horticultural Science. August 12, 1981.

V. TRIPS

A. American Society of Horticultural Science Conference

August 10-14, 1981. Met with Klaus Steinbeck and toured his research sites.

B. North American Poplar Council Meeting

July 22-24, 1981. Toured Fry Nursery.

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FUELS FROM WOODY BIOMASS

QUARTERLY REPORT
September 1, 1981

Name: Dr. Douglas J. Frederick, Project Leader
Dr. Robert C. Kellison, Co-Project Leader
Dr. Russ Lea, Co-Project Leader

Institution: North Carolina State University
School of Forest Resources
Hardwood Research Cooperative
Raleigh, N. C. 27650

Project Title: Species Selection and Silvicultural Systems
for Producing Fuels from Woody Biomass in the
Southeastern United States

Reporting Period: 6/01/81 - 9/01/81 Contract Number: DE-FG01-78CS-84006

Task 1.1: To review and summarize approximately 50 species-site tests established by the N. C. State Hardwood Research Cooperative and determine nutrient levels in trees and soils. (Note: This task is not in the original proposal but was added as Supplement to Volume 1 - Technical Proposal.)

Analysis of foliar samples for nutrient concentrations in plantation-grown sycamore is continuing and results should be available during the next quarter. We expect this information to be of immediate practical use because sycamore is emerging as one of the best short-rotation plantation species we have tested.

Graduate student Michael Messina is continuing work on determining nutrient distributions in southern hardwood species and is currently preparing a paper describing the final sampling technique.

Task 1.2: To screen and identify tree species and genetic sources most suitable for intensively managed, short-rotation biomass production.

The species-site trial in Wayne County, North Carolina near Goldsboro has been abandoned because of severe drought conditions over the past eighteen months. Survival was extremely poor despite intensive postplanting care. Of the six species planted, Ligustrum and sweetgum were the only survivors, but both had less than 50% survival, which we judged inadequate for species-site evaluation. Our older species-site planting in Granville County, North Carolina has maintained good survival and growth which is most likely due to better root system development. White ash has the highest survival and best growth, compared to water-willow oak and Virginia pine in this trial.

Task 1.3: To identify the optimum level of plantation site preparation, stand establishment, and management of the most promising species identified for potential use in energy plantations.

The Piedmont planting in Granville County, N. C. is showing good growth despite the dry conditions and has been maintained by disking (6/10/81) and fertilizing (7/1/81, 250 lbs./ac. ammonium nitrate). European black alder continues to be the best growing species but is showing signs of early flowering. Sweetgum and loblolly pine show moderate growth followed by black locust which is highly variable in growth and survival.

The bottomland site in Bertie County, N. C. was disked (6/25/81) and mowed (7/21/81) and shows the least effect from the drought. Sycamore shows the best growth, followed by green ash, European black alder, cottonwood and sweetgum. The water-willow oak has shown significant growth this season after a slow start but still is well behind the above five. Loblolly pine is growing very poorly on this site.

The Riceboro, Georgia planting was fertilized (6/23/81, 250 lbs./ac. diammonium phosphate) and disked (7/15/81). Survival continues to be high but growth has suffered because of the dry conditions. Green ash and sweetgum show best survival while E. macarthurii and viminialis have the best growth.

Task 1.4: To employ present and refined genetics breeding programs to locate and/or develop suitable trees to be grown for fuel.

Graduate student Barbara McCutchan is in the process of analyzing data relating graded superior sycamore tree parameters to energy production. Other work on selection and evaluation of select indigenous trees continues.

PRESENTATIONS AND PUBLICATIONS:

Frederick, D. J., H. A. I. Madgwick, M. Jurgensen and G. Oliver. 1981. Dry matter and nutrient relations in 8-year-old Acacia dealbata, Eucalyptus regnans and Pinus radiata. Australian Forest Nutrition Workshop, Canberra. 8 pp.

ESTABLISHMENT OF POPULUS ENERGY PLANTATIONS^{1/}

Quarterly Progress Report
for the Period

June 1, 1981 - September 30, 1981

David H. Dawson
Principal Investigator

Work Performed Under
Interagency Agreement #DE-AI05-800R20763

^{1/} Registered Trademark Intertechnology Solar Corp.

Introduction

The period of this report (June 1 to September 30) is essentially the growing season in northern Wisconsin (100 frost-free days).

This year the season was cool and moist. A 6-inch rain on June 13 and 14 (10 inches for the month) caused parts of the experimental farm to be flooded. The primary damage was the leaching of recently applied linuron into the root zone causing some mortality in newly established studies.

I. Planting and Establishment Research

The test plantations established in 1980 are growing excellently. One plantation in July (1½ growing seasons) had an estimated mean height of 12 feet. The 1980 plantations were established with the planting and cultural methods developed during the last four years. It is apparent that establishment technology has reached a point where a manager can successfully establish a Populus plantation if guidelines are followed.

II. Insect and Disease Research

Tree mortality has occurred in some 1976 plantations. It appears that a complex of pathogenic and physiogenic factors are involved. A late frost this spring, use of peat pellet containers for planting stock in 1976, deep plowing, use of herbicides, and wind throw all may have weakened the trees prior to infection by Cytospora. Leaf diseases caused by Marssonina and Septoria were much more severe on susceptible clones this year due to favorable weather conditions for disease buildup and affected trees were prematurely defoliated. A potentially serious canker disease caused by Septoria was found affecting two clones at the Harshaw Farm. Biology and life cycle studies of the important pathogens are continuing and clones resistant to various diseases are being identified.

Progress has been made on identifying the necrotic gall injury on young cottonwoods. A species of Myridae has been associated with the injury and symptoms have been reproduced in greenhouse studies with this insect.

At this time no pathogen has been implicated, however, greenhouse and laboratory work is continuing on this problem.

III. Propagation Research

A field study was initiated to determine how early in the fall Populus cuttings could be collected and the best temperature at which to store them. Cuttings of seven different clones were collected every month from September through December and stored at four temperatures from minus 20°C to plus 2°C until planting in late May. The importance of length of dormant hardwood cuttings and depth of planting to early survival and growth are also being evaluated in a field study established this spring.

IV. Economics Research

A recently completed financial cash flow evaluation of intensively grown hybrid poplar plantations for the Lake States area showed mixed results. Two non irrigated and fertilized systems were evaluated. They offered reasonable after tax returns of about 8 percent. Two irrigated and fertilized systems both showed slightly negative returns.

Sensitivity analyses were performed in these past studies to provide additional information on the impacts of important factors on the rates of return. However, decision makers still need better and more systematic information with respect to the risks and uncertainties involved. Current work is centering on developing a study to use risk analysis so that the measurement of risks and uncertainties can be incorporated directly into the rate of return calculations.

PUBLICATIONS RELEASED THIS QUARTER BY THE R&D PROGRAM

Dawson, Jeffrey O. and David T. Funk. 1981. Seasonal changes in foliar nitrogen concentration of Alnus glutinosa. Forest Science Vol. 27, No. 2, p. 239-243.

PUBLICATIONS cont'd.

- Lothner, David C., Dietmar Rose, J. Zavitkovski, and Karen Ferguson. 1981.
A financial analysis of poplar intensive cultures in the Lake States.
Energy From Biomass and Waste V Symposium Papers. Institute of Gas Technology.
Lake Buena Vista, FL., Jan. 26-30, 1981. p. 145-163.
- Roberts, Pamela S. and J. Zavitkovski. 1980. Growth of hybrid poplars, white spruce, and jack pine under various artificial lights. U.S. Department of Agriculture, Forest Service, Res. Paper NC-206, North Central Forest Experiment Station, St. Paul, MN. 5 p.
- Rose, Dietmar, Karen Ferguson, David C. Lothner, and J. Zavitkovski. 1981.
An economic and energy analysis of poplar intensive cultures in the Lake States. USDA Forest Service, Research Paper NC-196, 44 p. U.S. Dept. of Agric. For. Serv., North Central Forest Exp. Station, St. Paul, MN. 44 p.
- Zavitkovski, J. 1981. Small plots with unplanted plot border can distort data in biomass production studies. Can. J. For. Res. 11:9-12.
- Zavitkovski, J. Some promising forest ecosystems of the temperate zone for biomass production and energy storage. Energy From Biomass and Waste V Symposium Papers. Institute of Gas Technology. Lake Buena Vista, FL., Jan. 26-30, 1981. p. 129-143.
- Zavitkovski, J. 1981. Structure and seasonal distribution of litterfall in young plantations of Populus 'Tristis #1'. Plant and Soil 60, 409-422.
- Zavitkovski, J., R. M. Jeffers, H. Nienstaedt, and T. F. Strong. 1981. Biomass production of several jack pine provenances at three Lake States locations. Can. J. For. Res. Vol. 11:441-447.

VISITORS AND CONTACTS :

Typical of the summer season in this Laboratory there were a large number of visitors who received from a few minutes to a few days of presentations and/or demonstrations of the Short-Rotation-Intensive-Culture System:

- 1.) 13 tours of children and adult lay people including tours sponsored by organizations such as Trees for Tomorrow, the North Central Technical Institute, Antigo, WI, and the Wisconsin DNR Youth Conservation Corps program. Total of about 285 people.
- 2.) Foreign Scientists or Students
 1. Dr. Stig Larsson - Sweden
 2. Dr. Ryszard Siwecki - Poland
 3. Ditte Swendsen - Denmark
 4. Claus Jespsen - Denmark
 5. Mr. Th. Sjurson, Dir. State For. Serv., Norway
 6. Mr. Magnus Tennas, Norway
 7. Mr. Bjorn Akre, Norway
 8. Mr. Dali Tao, Chinese People's Republic
- 3.) U.S. Scientists, Engineers, Technologists
 1. Dr. Phil Jones - DOE
 2. Dr. Mason Carter - Purdue University
 3. Dr. Jack Coster - University of West Virginia
 4. Dr. Jeff Dawson - University of Illinois
 5. Mr. Gordon White - Champion International Corp.
 6. Mr. Ted Risberg and Dr. Ken Dougan - Aspenal, Inc., Virginia, MN
 7. Dr. Alan Wolsby - Argonne National Lab
 8. Mr. Dale Cline - Flambeau Paper Co.
 9. Dr. John Parker - Institute of Paper Chemistry
 10. Mr. James White - Deltic Farm & Timber Co., Arkansas
 11. Mr. Paul Mann - Simplot, Inc., Caldwell, ID

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FUELS AND CHEMICALS FROM WOODY BIOMASS PROGRAM

NAME: P. R. Blankenhorn, T. W. Bowersox and C. H. StraussINSTITUTION: The Pennsylvania State UniversityPROJECT TITLE: Net Energy and Economic Analyses for Producing
Populus Hybrid Under Four Management StrategiesREPORTING PERIODS: June 1 - August 31, 1981

The energy and financial analyses for this project will consider the inputs for producing, harvesting, transporting, and processing forest biomass. Subsequently these inputs will be balanced against the recoverable energy from forest biomass, taking into account the conversion efficiencies of the energy recovery system. Comparisons within both the energy and financial analyses using linear programming will establish the sensitivity and relative significance of the various inputs and energy recovery systems. Since these inputs are related to the outputs and these input/output factors are created during different annual periods, the analytical frame work for this model will also incorporate a time dimension.

The objectives of this study are to establish and analyze: 1) energy and economic inputs for producing short-rotation hybrid poplar using four management strategies (control, irrigation, fertilization, and combined irrigation/fertilization), 2) production yields as a function of management strategy, 3) wood properties related to use as a source of fuel or chemicals as a function of management strategy, 4) energy and economic analyses of selected conversion strategies (direct incineration, pyrolysis, gasification, and liquefaction) for each of the management strategies, 5) sensitivity analyses of the selected conversion strategies to energy inputs for each selected management strategy, 6) a comparison of the energy and economic analyses for selected management and conversion strategies, and 7) recommendations of the most advantageous combination of management and conversion strategies in light of energy and economic considerations.

TASK 1 - ESTABLISH PLANTATION

This task is concerned with measuring the energy and economic inputs needed to establish the short-rotation plantation under four management strategies (control, irrigation, fertilization, and fertilization/irrigation). Plantations have been established on two sites with either favorable (Basher silt loam soil) or unfavorable (Morrison sandy loam) inherent conditions for high yields. Each plantation site (1.2 ha) consists of six replications (0.2 ha each) with three replications planted in the spring of 1980 and 1981 respectively. Each replication consisted of four treatment units (0.05 ha each for control, irrigation, fertilization, and fertilization/irrigation). Populus hybrid NE-388 cuttings were planted in rows 0.8 meters apart and 0.6 meters between trees in a row for a 0.48m² of growing space per tree. In each treatment unit, trees were designated for annual destructive sampling and continuous inventory over a four year period.

Plowing and disking prior to planting was the only weed control in the plantation treatment units established in 1980. Weed growth in these replications was a major problem and retarded the first years growth. Chemical weed control was not possible in the 1980 planted replications because of the limited knowledge on safe herbicides for Populus hybrids.

Weed control for 1981 planted replicates started in August 1980 when herbicides (roundup, glyphosate, at 2.24 kg/ha and banvel, dicamba, 3.36 kg/ha, active ingredients -a.i.) were used prior to October tillage. Potential pre- and post-emergence herbicides were screened in greenhouse studies conducted between January and April 1981. These studies, three separate trials, were conducted with soil collected from each plantation site and included seven chemicals that were reported to control the site specific expected 1981 weed species. The objective of this screening was to evaluate the effect of the chemicals on the developing root and shoot tissue. We assumed the knowledge of weed species control was complete.

From these screening trials, a herbicide program was developed for each site that would provide >60% control of the weed community until July 1. We calculated that if the trees were at least 60% weed-free by this date than weed competition would not be a growth limiting factor. The herbicide programs were:

- a. Basher site - a pre-emergence herbicide to control nutsedge (dual, metolachlor, at 3.36 kg/ha a.i.) plus a pre-emergence to control other grass, grasslike, and broadleaves (goal, oxyfluorfen, at 1.12 kg/ha a.i.).
- b. Morrison site - a pre-emergence herbicide to control grass and grasslike, weak on broadleaves (devrinol, napropamide at 8.97 kg/ha a.i.).

Ocular estimates of the weed communities at both sites on July 1 indicated that 90% or more of soil surface was free of herbaceous vegetation. Late growing season inventories of oven-dried herbaceous vegetation will be conducted to determine the amount of herbaceous vegetation growing in the 1981 plantation replications and these will be compared to non-herbicide non-tree occupied native vegetation plots.

The net result of this herbicide program can be witnessed in the total height growth of the 1981 plantation replications. For the control trees, no fertilization and/or irrigation, total height as of August 14 averaged 125 cm at both the Basher and Morrison sites. In comparison, the control total height in the 1980 plantation replications averaged 55 cm on August 19, 1980 on both sites. Also, there has been no noticeable total height reduction at anytime in the 1981 growing season as there was in the 1980 growing season. The first year tree growth in 1981 compared to the 1980 first year tree growth cannot be completely ascribed to weed control programs because of seasonal growing conditions. But, at the very least, chemical weed control was achieved in 1981 and the total height growth was not retarded.

In June 1981, a trickle irrigation system on both sites was installed. In preliminary testing of the irrigation system, the well cavern at the Morrison site collapsed and sand was induced into the system completely

destroying the pump. The well cavern was reestablished and became operational on July 24. Fortunately, during this period we had abundant rainfall (above average) and the trees were not limited in growth by available water.

The operation of the irrigation system is determined on an individual plot basis. Amount of water in the soil upper 20 cm at 1/3 and 15 atm has been determined for each of the irrigation and fertilization/irrigation treatment units. The amount of available water in the soil, in relation to field capacity (1/3 atm), is determined daily. Individual treatment units are irrigated when the amount of available soil water drops below 75% of field capacity. Water added to the individual treatment units is dependent on the soil water holding characteristics of the unit, measured soil moisture, and the amount of water necessary to return the soil to field capacity. Records are being maintained on the amount of water added per treatment unit, daily temperature, relative humidity, pan evaporation and rainfall values.

Soil samples of the 1980 plantation replications and the land planted in 1981 were collected in November 1980 and March 1981. The nutrient levels measured in the soil from these two samples were averaged and fertilizer recommendations were made for the 1981 growing season. In all cases, fertilization rates were made on the basis of achieving 47 t/ha (field weight) of corn silage.

Although the 1980 plantation fertilization units were amended with the same nutrients and rates (one recommendation for the Basher soil and one recommendation for the Morrison soil) when established, the fertilization treatment units were retreated individually at the beginning of the 1981 growing season. This retreatment was designed to account for variations in individual plot nutrient status and to reestablish the non-growth limiting macronutrient benchmarks. There was a range in the amount of nutrients added per plot, except N, but average amounts added per plot were:

Basher -168, 67, 112, 1390 and 104 kg/ha for N, P, K, lime and Mg, respectively.

Morrison - 168, 90, 130, 3830 and 117 kg/ha for N, P, K, lime and Mg, respectively.

All fertilizer except N, was top-dressed prior to April 1. Nitrogen was top-dressed in May when the leaves began to expand.

The 1981 plantation replications at the Basher site were fertilized at the uniform rate of 168, 114, 189, 4343 and 0 kg/ha for N, P, K, lime, and Mg, respectively. Fertilization rates for the 1981 plantation replications at the Morrison site were 168, 134, 168, 4763 and 151 kg/ha for N, P, K, lime and Mg, respectively. All fertilizer, except N was applied and disked into the soil prior to planting. Nitrogen was applied in early June when the first set of leaves were fully expanded.

Foliar tissue will be collected at the end of August and soil will be collected in November. Nutrient values from these samples will be used to determine nutrient status at the end of the growing season.

TASK 2 - PLANTATION BIOMASS PRODUCTION

This task is concerned with obtaining the energy and economic inputs needed to operate and maintain the plantations under the selected management strategies. In addition, biomass production yields, growth rates, and biomass properties related to use as a fuel or chemical feedstock will be measured.

Tree height growth of the one year old trees in the 1981 growing season has been greater than the amount measured in the 1980 growing season. Total height for the 1981 plantation replications are presented in Figure 1. As of August 14, the combined total tree height averaged over all treatments and sites of the 1981 replications was about 125 cm which is double the 60 cm of average total height for the 1980 replication values measured on August 19, 1980. As of August 14, 1981 there has not been a noticeable differential total tree height growth due to treatment or plantation site.

The second growing season elongation values for the 1980 plantation replications indicate a differential growth pattern for some treatments and between sites (Figure 2). In general, the Basher trees are growing faster than the Morrison trees, particularly for the non-fertilized trees. At both sites the fertilized trees are elongating at a rate which is about twice the rate for the non-fertilized trees. Although it is too early to be certain, it appears that the irrigation treatments are starting to attain a greater elongation growth than the non-irrigation units. These data and end of growing season values of total height and stem diameters will be statistically analyzed to evaluate the effect of treatment and site on biomass production.

Biomass production yield and growth rate data for the 1980 plantation first growing season have been collected. These data when combined with the 1981 plantation first growing season results will be statistically analyzed and reported. Yield values will be presented on both a green weight and oven-dry weight basis. Integration of the yield values with the chemical and energy values will be helpful in estimating the harvesting and processing energy and financial requirements to achieve usable energy and chemical outputs.

Selected physical and chemical properties, related to the use of Populus hybrids as a source of fuel or chemicals, will be analyzed for variations associated with the different cultural strategies. Specific gravity (Table 1), moisture content (Table 2), gross heat of combustion (Table 3), ash content (Table 4), extractive content (Table 5), holocellulose (Table 6), Klason lignin (Table 6), and macronutrient content (Table 7) data have been collected for wood, bark, and wood/bark composite specimens from the 1980 plantation treatment units. The bark holocellulose values in Table 6 contain an error related to the lipid and wax-like material content in the bark. Standard holocellulose procedures do not remove the lipid and wax-like material from the bark prior to holocellulose determinations. We are in the process of developing procedures to remove the lipid and wax-like materials from the bark prior to determining the holocellulose content. These data in Tables 1-7 will be analyzed statistically in coming months. It is important to note that the data in Tables 1-6 are divided into control, fertilization,

irrigation and fertilization/irrigation treatments, but neither site was irrigated during the first year (1980). Hence, for all practical purposes the data can be combined into two data sets; 1) control and irrigation, and 2) fertilization and fertilization/irrigation.

TASK 3 - ANALYSIS OF BIOMASS ENERGY AND ECONOMIC DATA

This task is concerned with analyzing and comparing the energy and economic data for the selected management/conversion scenarios. Energy and cost analyses will be performed on each of the selected management strategies for each conversion strategy. Data collected on the project will be compared with published research for the analyses. Biomass production yields, growth rates, and properties will be used to standardize the data. Linear programming will be used to analyze the various input requirements, associated constraints, and outputs for the combinations of the various production/conversion scenarios. This permits an evaluation of the production/conversion scenarios that would maximize net energy flows, net value flows, and the sensitivity of change in any variable to the resultant outputs. It is anticipated that a range in values will be used for the variables. Coupling the management and conversion energy and economic data base will provide the opportunity to recommend a management strategy for each conversion strategy with the most favorable energy and economic consideration.

A prototype for the linear programming model has been established. The objective function will be directed to either maximizing net energy flows or net financial returns; subject to the biologic, engineering and economic constraints of the operating system. The basic variable within the model will be the hectares of land coming into solution from different soil types, subject to particular treatments under given management strategies during various points in time. The model will be subdivided into three phases; biomass production, harvest and transit, and energy conversion. Several growth and harvest cycles will be represented in the complete production period under study for a given plantation.

Current attention has been directed to analyzing the plantation establishment function in the first phase of the model. The types of equipment, their production rates and seasonal periods of work were established for each facet of the establishment function. From this analysis the size of a "working unit" in hectares was established based upon the most critical piece of equipment pursuing its given task during a fixed work period. From here, the remaining equipment needs for all other facets of the operation were determined.

A standardized record keeping system is being used in determining the cost requirements (financial and energy) for particular types of equipment and their underlying facets of production. All machinery will be evaluated in terms of; fuel and labor inputs, insurance and license needs, shelter and maintenance, and the costs of depreciation and interest on principle. The "working unit" measure provides the basis for establishing the expected annual rate of equipment usage and their life time of operation. Allied material costs, management and overhead expenses will be included within the appropriate facets of operation. An annual rent payment will be included within the model to represent the opportunity cost expected of the land input.

In its current form, the model will determine the optimal management route for maximizing the present net worth of a total investment system over a complete production period (probably 16 years) in both monetary and energy terms. As such, any particular cost or return item occurring beyond the initial point in time will be subject to a rate of discount. All discounting will be based on a real rate of return (or discount), net of annual inflation rates. A range of discount rates will be used in the present net worth analysis in keeping with the general design of the study of establishing probable ranges of values for critical features of the biomass system and testing the sensitivity of the model to these alternate values. Currently, rates of from 0% to 8% are under consideration. This range would include (1) a "long-term" zero-discount view of society in which the rights and values of those in the future are considered equal to those in the present (2) a moderate 4% real rate, currently advocated by forest economists in the public forestry sector and (3) a conservative 8% rate representative of industrial expectations for working capital.

Figure 1. Preliminary average one-year old total height values of the 1981 plantation replications for fertilized and non-fertilized treatments. Basher and Morrison values were averaged. Separated points for a particular measurement date are noticeable differences and not statistical differences.

Figure 2. Preliminary average two year old elongation values of the 1980 plantation replications for the Basher and Morrison sites, by treatment. Separated points for a particular measurement date are noticeable differences and not statistical differences.

Table 1. Summary of Specific Gravity Data after 1st year.

Specimen ¹	Specific Gravity (g/cc) ²			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Wood	0.404	0.314	0.347	0.412
Wood/Bark	0.447	0.368	0.398	0.388
Bark	0.589	0.511	0.553	0.514
----- Morrison Site -----				
Wood	0.375	0.428	0.409	0.377
Wood/Bark	0.453	0.431	0.439	0.426
Bark	0.612	0.612	0.606	0.566

¹Specific gravity values are based on an average of 9 specimens.

²ASTM D-2395, specific gravity = oven-dry weight/green volume.

Table 2. Summary of Moisture Content Data after 1st year.

Specimen ¹	Moisture Content (%) ²			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Wood	104.8	106.6	116.3	109.4
Wood/Bark	106.4	116.2	119.0	121.8
Bark	93.3	116.3	106.7	116.0
----- Morrison Site -----				
Wood	112.2	108.3	110.7	103.5
Wood/Bark	104.4	106.1	106.9	107.4
Bark	85.3	87.6	72.1	85.6

¹ Moisture content values are based on an average of 9 specimens.

² ASTM D-2016, moisture content = $\frac{\text{wet weight} - \text{ovendry weight}}{\text{ovendry weight}} 100$.

Table 3. Summary of Gross Heat of Combustion Data after 1st year.

Specimen ¹	Gross Heat of Combustion (cal/g) ²			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Wood	4393	4338	4351	4321
Wood/Bark	4484	4387	4460	4701
Bark	4536	4463	4674	4476
----- Morrison Site -----				
Wood	4356	4394	4356	4360
Wood/Bark	4493	4782	4499	4451
Bark	4441	4533	4697	4588

¹Gross heat of combustion values are based on an average of 3 specimens.

²ASTM D2015-66.

Table 4. Summary of Ash Content Data after 1st year.

Specimen ¹	Ash Content (%) ²			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Wood	1.58	1.00	1.69	1.50
Wood/Bark	2.98	2.32	2.47	2.29
Bark	5.86	4.48	3.86	3.82
----- Morrison Site -----				
Wood	2.31	1.34	1.81	1.68
Wood/Bark	3.01	2.48	2.98	2.48
Bark	4.10	3.76	5.03	4.05

¹Ash content values are based on an average of 3 specimens.

²ASTM 1102, ash content = $\frac{\text{weight ash}}{\text{ovendry weight}} \cdot 100$

Table 5. Summary of Extractive Content after 1st year.

Specimen ¹	Extractive Content (% of Oven-dry Weight)			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Wood	14.67	12.98	12.87	14.91
Wood/Bark	28.44	23.86	27.82	23.42
Bark	41.64	43.54	46.17	46.35
----- Morrison Site -----				
Wood	16.48	14.11	18.27	14.83
Wood/Bark	29.29	25.86	29.75	26.59
Bark	45.78	46.93	44.67	45.30

¹ Extractive content values are based on an average of 6 specimens.

² ASTM D1105-56.

Table 6. Summary of Holocellulose and Klason Lignin Content.

	% of Oven-dry Weight			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Wood				
Holocellulose ¹	69.04	69.03	65.57	68.93
Klason Lignin ²	14.48	15.00	15.69	15.39
Wood/Bark				
Holocellulose	53.50	54.92	54.02	59.06
Klason Lignin	15.18	16.26	17.91	18.73
Bark				
Holocellulose	31.95	28.45	29.50	27.60
Klason Lignin	17.60	17.06	15.38	17.37
----- Morrison Site -----				
Wood				
Holocellulose	67.64	69.29	63.58	68.01
Klason Lignin	14.69	14.49	14.78	14.90
Wood/Bark				
Holocellulose	49.97	52.21	46.69	50.88
Klason Lignin	18.46	19.67	21.17	16.99
Bark				
Holocellulose	30.76	29.42	27.20	26.20
Klason Lignin	17.23	16.06	18.15	16.64

¹ Holocellulose values are based on an average of 3 specimens (Browning, B. L. Methods of Wood Chemistry, Vol. II, Interscience Publishers, New York, 1967).

² Klason Lignin values are based on an average of 3 specimens (ASTM D1106-56).

Table 7. Summary of average^{1/} concentration of N, P, K, Ca and Mg in the one year old wood, wood/bark and bark samples of the 1980 replications of Control, Fertilization, Irrigation, and Fertilization/Irrigation treatments, by Basher and Morrison sites.

Nutrient-Specimen	% of Owendry Weight			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Basher Site -----				
Nitrogen				
Wood	.73	.59	.65	.65
Wood/Bark	1.04	.88	.89	.85
Bark	1.47	1.57	1.51	1.57
Phosphorus				
Wood	.10	.08	.08	.08
Wood/Bark	.12	.10	.11	.10
Bark	.14	.14	.14	.14
Potassium				
Wood	.32	.25	.27	.25
Wood/Bark	.48	.38	.41	.34
Bark	.75	.72	.68	.68
Calcium				
Wood	.53	.35	.41	.40
Wood/Bark	1.05	.77	.77	.71
Bark	1.74	1.48	1.35	1.43
Magnesium				
Wood	.08	.06	.07	.07
Wood/Bark	.13	.09	.09	.09
Bark	.13	.09	.09	.09

^{1/} From a sample of 3.

Table 7. Continued

Nutrient-Specimen	% of Oven-dry Weight			
	Control	Fertilization	Irrigation	Fertilization/Irrigation
----- Morrison Site -----				
Nitrogen				
Wood	.78	.60	.64	.58
Wood/Bark	.82	.69	.86	.82
Bark	1.30	1.38	1.28	1.34
Phosphorus				
Wood	.09	.07	.09	.08
Wood/Bark	.10	.07	.09	.09
Bark	.13	.13	.13	.13
Potassium				
Wood	.30	.28	.29	.27
Wood/Bark	.37	.29	.34	.34
Bark	.61	.65	.61	.65
Calcium				
Wood	.54	.46	.53	.44
Wood/Bark	.88	.58	.82	.72
Bark	1.54	1.53	1.49	1.50
Magnesium				
Wood	.08	.07	.07	.07
Wood/Bark	.10	.07	.09	.09
Bark	.20	.18	.19	.20

FEASIBILITY OF USING MUNICIPAL WASTEWATER AND
WASTE HEAT TO MAXIMIZE BIOMASS PRODUCTION
IN ENERGY PLANTATIONS

Quarterly Report for the Period
June 1, 1981 - August 31, 1981

William E. Sopper

October 14, 1981

Report Prepared by

William E. Sopper

David R. DeWalle

Sonja N. Kerr

Institute for Research on Land and Water Resources
The Pennsylvania State University
University Park, PA 16802

under

Subcontract ET-78-G-01-3066

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
U.S. Department of Energy
Contract No. W-7405-eng-26

TASK NO. 1: Evaluate the effect of municipal wastewater irrigation on biomass production in a hybrid poplar plantation.

Weekly wastewater irrigation treatments were initiated June 8 for the 1981 season. Wastewater was irrigated at a rate of 5.0 cm per week continuing until September 28, 1981. A total of 79 cm of wastewater was applied to one half of the poplar plantations in 1981. Total tree height and basal diameter growth measurement for 1981 were initiated in all three plantations. Foliar biomass samples were collected, oven-dried, weighed and foliar biomass will be calculated from the results. Due to the massive infestation of gypsy moths in the county and the resultant damage, it is estimated that the annual biomass will be reduced significantly. Separate foliar samples were collected for chemical analyses. Sample of the herbaceous vegetation were collected from each plantation for the determination of ground vegetation biomass and chemical analyses.

TASK NO. 2: Evaluate the efficiency of the energy plantations to renovate the wastewater.

The irrigation system in the coppice plantation was changed from an above-canopy system to a below-canopy system. Monthly samples of soil water percolate were collected from suction lysimeters installed at the 120 cm depth in each growing space subplot of both the wastewater irrigated and control plantations. Samples were analyzed for selected nutrients and trace metals. Based upon the results of these analyses in the coppice plantation it may be possible to determine the affects of the placement of the irrigation system on the renovation capabilities of the energy plantation ecosystem. Results of the analyses of soil percolate water collected from the control plantations will be used in comparison to the results obtained from the wastewater irrigated soil percolate samples to determine the renovation efficiency of the energy plantations.

TASK NO. 3: Evaluate the use of municipal wastewater as a commercial fertilizer substitute.

Samples of the wastewater were collected during each irrigation period. These samples were analyzed to determine the total amount of nutrients applied on each spacing plot in 1981.

TASK 4: Evaluate the effect of waste heat and wastewater on biomass production.

Research on this phase of the research is now complete and terminated. A draft report summarizing the results has been drafted and, pending internal review, will be submitted for publication in Energy and Agriculture.

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Quarterly Report

June 01, 1981 - August 31, 1981

CULTURAL TREATMENT OF SELECTED SPECIES
FOR WOODY BIOMASS PRODUCTION

Linda Sutliff Dolan
Biomass Project Manager

Seattle City Light
1015 Third Avenue
Seattle, WA 98104

Continuing work under
U.S. Department of Energy
Grant #DE-FG01-78ET20593-A002
and
DE-FG51-78ET20593-A003

Cultural Treatment of Selected Species
for Woody Biomass Production

Quarterly Report
June - August 1981
Seattle City Light

Administrative Activities:

Negotiations with the U.S. Department of Energy (DOE) over program content and funding for fourth year project operations have been completed, with a resulting grant award of \$120,087 made on August 05, 1981. Federal administration of this grant award has been transferred to the Bonneville Power Administration (BPA) as of August 31, 1981.

Selection of consultants to conduct economic feasibility studies on biomass plantation operations has been completed. The economic assessment will be conducted as a joint venture between Shapiro & Associates and Synergic Resources Corporation (SRC). Work is presently underway and is scheduled for completion by December 31, 1981. The assessment will include an examination of plantation operating costs, markets for biomass fuel, environmental mitigation, land availability and equipment system costs.

The fourth year contract with the University of Washington to perform basic research on the plantation sites is presently under negotiation, lacking only acceptable research design and budget proposals. This information, requested by City Light over two months ago, is presently scheduled for submission no later than early September 1981, assuming a positive response from the University.

Work/study students, employed on a fulltime basis for the summer, are being used as field laborers in the application of herbicides and repair of the irrigation system. Selection of a permanent technical contracts specialist should be completed by October 1981, following the resignation of the former contracts specialist. In the interim, the position has been filled by a temporary City employee.

A formal review of third year contract performance by the University of Washington was completed August 28, 1981. Specifications for improvements in performance during the fourth year were presented and agreed upon by the University.

Technical Activities:

The irrigation system at Cedar Falls has undergone extensive repairs as a result of freezing damage during the past winter. For the first time since its installation, the system is also operational from an engineering standpoint. Numerous changes were made to achieve this, including: addition of another 4 hp pump connected to the storage pond; installation of wood and metal bracing for corners and support; changes in sprinkler head height and location; and change in pipe size on the plantation. The irrigation system is presently being operated to maintain soil moisture at ≤ 40 centibars.

Weed control on selected research plots at Lee Forest is being achieved by passive application of Round-up. A rope-wick applicator is used to apply the herbicide via direct contact with the weed cover. Although this application method is time consuming, risk to the crop trees is minimal. There is no drift or soil residual and the weed competition is eliminated.

Standardization of laboratory procedures and calibration of equipment for fuel characterization of plantation biomass are completed. Field collection of samples for characterization is progressing and will be completed by September 30, 1981. The table below summarizes existing data on red alder from various literature sources.

Preliminary Data: Fuel Characterization, Red Alder

	Higher Density Value (BTU/ovendry/ton)	Volatiles (%)	Char (%)	Ash (%)
WOOD				
Average	8,290	86.0	13.5	0.5
Standard Deviation	227	1.4	1.5	0.1
BARK				
Average	8,532	72.6	24.9	2.4
Standard Deviation	144	1.6	1.6	0.1

A complete redesign of both research plots and statistical analysis methods was completed in June of 1981 with Dr. Charles Peterson, UW-CFR statistician, providing the supervision for the changes. The most important changes were an increase in sample size and a reduction in the number of variables analyzed. As part of the redesign, the three-year old cottonwoods at Cedar Falls were removed due to poor performance. Areas where the cottonwoods were removed have become alder spacing trials (1.2 X 1.2, 1.2 X 1.8, 1.8 X 2.4 m) or will be replanted with cottonwood whips in the spring 1982.

Field testing of the whole tree baler, loaned from Dr. Bill Stuart at Virginia Polytechnic Institute, is underway. A front-end loader has been obtained and production rates in young (5-7 yr.) and middle-aged (20 yr.) red alder stands are presently being collected.

Site Visits:

John Ericson, U.S. Forest Service, Washington, DC, visited the Cedar River site to discuss U.S.F.S. research on plantation equipment.

Paul Groner, Seattle City Light Mechanical Engineer, made field inspections of the irrigation system and completed the design work for its repair.

Publications:

Dolan, Linda S. 1981. "Biomass Energy: The Seattle Experience," Energy In the Man-Built Environment. American Society of Civil Engineers, Vail, Colorado. August 1981.

Contribution to "Wood Residue Energy Report." Wood Energy Resources Group, Pacific Northwest Utility Conference Committee, Portland, Oregon. June 1981.

Biomass Plantation and Wood Residue reports, Energy Resources Data Base. Seattle City Light. July 1981.

Photo and text display, "Wood Energy Trade Show and Conference," Seattle. June 1981.

Production of Woody Biofuels from
Mesquite Prosopis (spp)
Quarterly Report for
Period ending: 1 September 1981

Peter Felker
Caesar Kleberg Wildlife Research Institute
Texas A&I University
Kingsville, TX 78363 (512) 595-3922

General

We are grateful for renewed DOE financial support for this project at Texas A&I University. The Caesar Kleberg Wildlife Research Institute at Texas A&I is providing substantial financial and logistic support for this project which will allow DOE money to go much further. After minor delays concerning patent rights, the contract has been signed. The Kleberg Institute has provided an additional 2 months salary for DOE sponsored personnel in the interim.

Field Research

Since transfer of this project from the University of California Riverside (UCR) to Texas A&I in December 1980, a greenhouse has been constructed, 4 growth chambers repaired, 9,000 seedlings raised and nine experimental plantings occupying 27 acres laid out and planted. Unseasonal heavy rains precluded cultivation from 10 May till 30 June, when Johnsongrass, nutsedge, prickly mallow, sunflowers and other weeds got completely out of hand despite a 1 quart/acre treflan application. Test strips with the post-emergence herbicide dalapon proved too phytotoxic to mesquite while MSMA looked good. An aerial application of MSMA at 3 acres/gallon caused approximately 30% mortality and stunting to many of the trees. Many of the trees have grown out of the damage and most of those that died have been manually replaced. The field has since dried out and the weeds between the rows have been mowed, disced and subject to sweep cultivation.

Considerable rabbit damage occurred to the seedlings until two large and two small jack rabbits were eliminated from the plots. An insect (mesquite twig girdler) which severs 1 cm diameter seedlings, 5-10 cm above ground level cut off 100 seedlings in early July. Recently, damage has been considerably lower which may be due to orthene applications. Trials with contact insecticides Sevin XLR and Lindane with long residuals are being planned.

Clonal Propagation

Dr. Mark Lesney, a plant pathologist with research background in tissue culture has arrived from Michigan State to begin the tissue culture program. Kleberg Institute funds have been used to purchase \$17,000 of equipment and supplies and to begin renovation of laboratory facilities to handle autoclaves, dishwashers, hoods, etc.

7.0 HARVEST, COLLECTION, TRANSPORTATION, AND STORAGE REPORT

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Virginia Polytechnic Institute and State University
W. B. Stuart
DOE QUARTERLY REPORT

May 1, 1981 - July 30, 1981

Activities and events included during this quarter are:

The evaluation of the baling concept, the baler infeed, and banding system was completed. Results of this effort are included in the thesis entitled "The Development of an Infeed Mechanism and Strapping Device for the Forest Residue Baler" by Alan Gleason, attached to this report.

A project addressing the lower limits of utilization for fuelwood in conjunction with conventional operations was also completed. Results of this effort are included in a thesis entitled "A Method of Assessing the Lower Limits of Utilization of a Conventional Harvesting System Performing Integrated Harvests on a Variety of Stands", by Franklin King, Jr., attached to this report.

A report on a conceptual design of a model for optimal and resource management was received from Dr. Joel Nachlas of the Industrial Engineering Department here at Virginia Tech. Dr. Nachlas proposes a dynamic programming model as appropriate for this particular problem and includes a generalized listing of variables affecting the process. A copy of the report is attached.

A report on the economics of harvesting wood fuels from a pulp-mill standpoint was received by Dr. Harold Wisdom of the Department of Forestry addressing the problem from an individual mill and procurement area standpoint. Discussion with Dr. Wisdom since the receipt of the report has identified problems experienced with rationalizing machine balance and productivities. These will be corrected and an amended report submitted with the final report of this effort.

Components were ordered and construction started on the banding system for the baler. The shear knife on the unit was modified, several minor repairs made, and the machine shipped to Seattle for testing on western species. This testing will be completed during the last six months of 1981.

The first set of trials were conducted with test machines for evaluating short rotation severance devices. A 24" carbide-tipped pegged tooth cut off saw was used as the initial device. Power requirements for this saw (less than 20 horsepower) could cut 4-6 inch stems at the rate of 1-2 per second, seemed very reasonable. This particular saw design leaves very clean cuts with little damage to the cambium layer of the stump. Saw stability proved to be excellent at the 15 rpm range used. High speed photography was used to evaluate butt movement immediately after severance. This demonstrates that the severed stem tends to ride on the saw after cutting. The saw is held perfectly flat, 0° lead angle, 0° tilt angle, the butt is moved to the rear of the saw and ejected from the back. If the lead angle is increased the ride time is decreased significantly. Increasing the tilt angle causes the butt to eject to the side of the saw. Although the heterogenous nature of most stems makes it very difficult to generalize upon the direction and degree of movement while riding on the saw, it does appear that careful consideration of lead and tilt angle can be used to expedite the capture of the tree after harvesting.

Material used in this test was single stem meshed hardwoods and pines ranging from 2 inches to 8 inches on the stump and from 18 to

30 feet tall established in an artificial plantation on a 4 x 4 spacing. Considerable difficulty was encountered in controlling the fall due to entanglement of limbs in the higher portions of the crown making it obvious that the harvester will have to have some positive method of controlling the tree and pulling crowns apart. Alternative designs looking at the mechanism for performing this task are under consideration. Considering the criteria of machine weight, power requirements, and degree of control exerted on the tree.

Two journal articles resulting from the work under this contract were accepted for publication. The first, Economics of Modifying Harvesting Systems to Recover Energy Wood by William B. Stuart, Carl D. Porter, T. A. Walbridge, Jr., and R. G. Oderwald, is scheduled for publication in the August 1981 Forest Products Journal. The second, The Harvesting Analysis Technique by William B. Stuart, is scheduled for publication in the same magazine in October or November 1981.

Three papers touch upon the work conducted under this grant. The first, entitled Logging Cost by Diameter Class was presented at the Small Tree Harvesting Conference sponsored by the Forest Products Research Society in Syracuse, New York and will be included in the proceedings of that conference. A copy of the full paper is attached. The second, entitled Getting the Wood Cut, was presented at the Appalachian Regional Commission Wood Energy Conference in Winston-Salem, NC on April 7, 1981. A copy of this paper is attached.

The third and more general paper entitled Can We Harvest the Resource? by William B. Stuart, was prepared for the Hardwood Research Council Meeting at Pipestem, WV in May, 1981 and will appear in the published proceedings from that meeting. A copy of this paper is also attached.

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