ORNL/TM-9698

ornl

OAK RIDGE NATIONAL LABORATORY

MARTIN MARIETTA

Short Rotation Woody Crops Program

Quarterly Progress Report for the Period March 1 to May 31, 1985

L. L. Wright
R. D. Perlack
C. R. Wenzel
J. L. Trimble
J. W. Ranney

Environmental Sciences Division
Publication No 2586

OPERATED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road, Springfield, Virginia 22161
NTIS price codes—Printed Copy: A07; Microfiche A01

ORNL/TM-9698

ENVIRONMENTAL SCIENCES DIVISION

SHORT ROTATION WOODY CROPS PROGRAM

Quarterly Progress Report for the Period
March 1 to May 31, 1985

L. L. Wright
R. D. Perlack[1]
C. R. Wenzel[2]
J. L. Trimble
J. W. Ranney

Environmental Sciences Division
Publication No. 2586

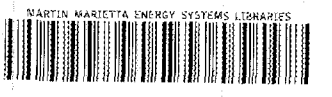
---

[1]Energy Division
[2]Science Applications International Corporation, Oak Ridge, TN

Date Published - August 1985

Prepared for
Biomass Energy Technology Division
Office of Renewable Technologies

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400



EXECUTIVE SUMMARY

This report covers the progress of the Short Rotation Woody Crops Program (SRWCP) during the third quarter of fiscal year 1985. The SRWCP is sponsored by the U.S. Department of Energy's Biomass Energy Technology Division (DOE/BET) and is managed by Oak Ridge National Laboratory (ORNL). This report summarizes ORNL management activities, technical activities at ORNL and subcontract institutions, and the technology transfer that is occurring as a result of subcontractor and ORNL activities. Highlights of these activities are listed below.

MANAGEMENT ACTIVITIES

- The annual technical review of ongoing projects was held March 20-22, 1985.
- Funding recommendations for FY 1985 were presented to DOE on April 16, 1985.
- A briefing on the SRWCP was prepared for DOE staff.
- The draft Multiyear Plan and draft Annual Operating Plan were submitted to DOE.
- The SRWCP management staff made three presentations and had three publications during the quarter.

TECHNICAL ACTIVITIES

- Third-year results of a nutrient utilization study confirmed that there were no benefits to quarterly fertilization with urea nitrogen.
- Testing of one prototype short-rotation intensive culture harvester was conducted on a sycamore plantation on Scott Paper Company land in southern Alabama.
- Coppice yields of European black alder reported by Iowa State University indicate potential productivity of about 7.2 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ if the best trees are selected. Coppice yields were more than double first-rotation yields.
- About 31,000 black locust and larch trees were established in 12 genetic tests at 4 sites in Michigan.

- Seedling rotation productivity rates of 4-year-old hybrid poplar, based on harvest data, were reported by Pennsylvania State University. Rates varied from 4.8 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ to 10.7 dry $Mg \cdot ha^{-1} \cdot year^{-1}$, depending on site, management strategy, and planting year.

- An efficient method for *in vitro* micropropagation of elite genotypes of fourwing saltbush was developed by Plant Resources Institute.

- A new study to evaluate yield/density relationships was established by the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station.

- Dissertation research on the crown geometry of plantation-grown American sycamore was completed by John Schutt, University of Tennessee, under the advisorship of J. W. Ranney, SRWCP Field Program Manager.

TECHNOLOGY TRANSFER

- Nine research papers were published.

- Five popular articles in newspapers were reported.

- Twenty-four presentations were made by managers and researchers in the SRWCP.

- Four institutions (BioEnergy Development Corporation, University of Florida, Oak Ridge National Laboratory, Kansas State University, and Texas A&I University) hosted tours.

- Five researchers provided assistance to local organizations making plans to utilize biomass resources.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Short Rotation Woody Crops Program (SRWCP) was initiated by the U.S. Department of Energy (DOE) in 1978 to address concerns about an adequate supply of biomass for energy use. It is the first and only comprehensive, nationwide program investigating short-rotation intensive culture (SRIC) of trees as a means of supplying energy needs. The goal, objectives, and organization of the SRWCP are summarized below.

Program Goal

The goal of the SRWCP is to provide to the private sector an information base that will include the following types of information:

1. Methods and materials required to obtain high rates of wood (energy) productivity for selected species.

2. Recommendations for producing wood at costs competitive with those of other energy and wood feedstocks for selected site types.

Program Objectives

The desired information base is being obtained by funding research projects that propose to meet the objectives listed below.

1. To identify and improve high-productivity woody species which respond well to intensive cultivation on unused and agricultural land.

2. To identify and improve cost-effective cultural techniques that maximize productivity rates and minimize risks and losses associated with SRIC.

3. To identify the current major economic constraints on producing wood-energy feedstocks by using SRIC and to demonstrate how these constraints can be minimized.

4. To identify the major environmental problems associated with SRIC and to propose methods for successfully ameliorating those problems.

Program Organization

The general organization of the SRWCP is presented in Fig. 1. The institutions performing work for the SRWCP under interagency agreements

SHORT ROTATION WOODY CROPS PROGRAM
ORGANIZATION CHART

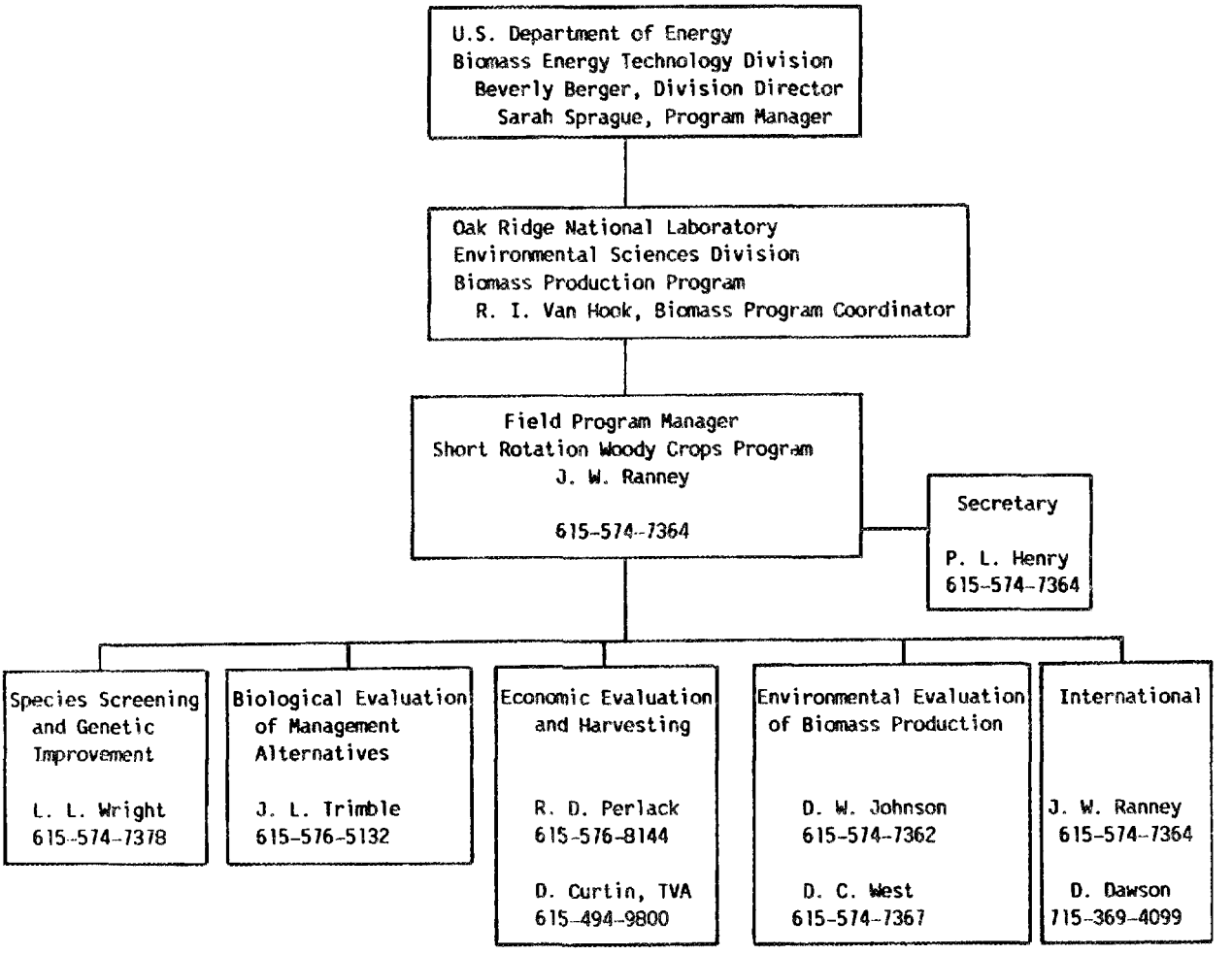


Fig. 1. Organization chart for Short Rotation Woody Crops Program.

or under subcontract during the third quarter of FY 1985 are listed in Table 1. The genetic improvement objective and cultural management objective are being met through field and laboratory research subcontracted to institutions throughout the United States. The economic objective is being met largely through sensitivity analysis and modeling conducted by investigators at Oak Ridge National Laboratory (ORNL) and literature evaluations conducted by the Tennessee Valley Authority (TVA). The environmental evaluation objective is being met through field research and data synthesis performed at Oak Ridge National Laboratory.

Report Format

The following six sections briefly summarize management activities of the SRWCP field-management office at ORNL, research accomplishments of the program, and technology-transfer activities in the program. The section entitled "Quarterly Highlight" discusses in depth one research or analysis activity conducted by the SRWCP. The Appendix presents reports on research progress at all institutions under subcontract to the SRWCP.

Table 1. Institutions and principal investigators who received research funding through the Short Rotation Woody Crops Program during the third quarter of FY 1985

Institution	Investigator(s)	Contract number
BioEnergy Development Corporation	T. B. Crabb	Subcontract 19X-09061C
Energy/Development Inter.	S. Hale, Jr.	Subcontract 19X-89640C
University of Florida	D. L. Rockwood	Subcontract 19X-09050C
University of Georgia	H. E. Sommer	Subcontract 19B-07860C-X02
Iowa State University	R. B. Hall	Subcontract 19X-43391C
Kansas State University	W. A. Geyer	Subcontract 19X-07394C
Michigan State University	J. W. Hanover	Subcontract 19X-09053C
North Carolina State University	D. J. Frederick R. C. Kellison R. Lea	Subcontract 19X-09054C
Pennsylvania State University	P. R. Blankenhorn T. W. Bowersox C. H. Strauss	Subcontract 19X-07928C
Plant Resources Institute	C. M. McKell	Subcontract 19X-89638C
Texas A&I University	P. Felker	Subcontract 19X-09066C
USDA Forest Service, North Central Forest Experiment Station	E. A. Hansen H. Nienstaedt	Interagency Agreement DE-AI05-80OR20763
USDA Forest Service, Pacific Northwest Forest and Range Experiment Station	D. S. DeBell	Interagency Agreement DE-AI05-81OR20914
University of Vermont	F. M. Laing	Subcontract 19X-09060C
Virginia State University	M. S. Joshua	Subcontract 19X-43389C
University of Washington	P. E. Heilman R. F. Stettler	Subcontract 19X-43382C

ACCOMPLISHMENTS

This section includes a brief listing of accomplishments of the SRWCP management staff at ORNL as well as significant accomplishments reported by SRWCP subcontractors or ORNL research staff during the third quarter of FY 1985. Further details of the subcontractor research results can be obtained by referring to the subcontractor reports in the Appendix.

Major Event/Activity Accomplishment

The Short Rotation Woody Crops Program conducted its annual technical review of projects and proposals in Atlanta, Georgia, on March 20-22, 1985. Eleven reviewers from industries, universities, and the USDA Forest Service evaluated progress reports and renewal proposals from all ongoing SRWCP research projects.

The reviewers also commented on overall program direction and priorities. In general, the reviewers supported the current direction, with some recommended change in emphasis. Some of the recommendations are listed below:

1. Genetic improvement should have the highest research priority, but research should concentrate on fewer species. Performance should be followed through to the coppice stage before making final recommendations.

2. Tissue culture and biotechnological approaches should be focused on proven techniques with direct applicability to tree propagation or improvement.

3. Currently established experimental plots should be utilized to gain more information on coppice dynamics and cultural treatment responses.

4. Soil/site/nutrient research needs to become more focused.

5. Large-scale plantation tests are needed to promote private interest in SRIC technology and to evaluate disease and pest risks.

6. Economic evaluations to address trade-offs between productivity, harvest costs, rotation length/number, etc., need to be continued.

Management Accomplishments

1. Funding recommendations for FY 1985 were presented to DOE on April 16, 1985.

A document was prepared for DOE summarizing reviewers' comments for each project and providing justification for the funding levels recommended for each project. Factors taken into consideration in determining funding levels for individual projects included technical quality, overall contribution to meeting SRWCP goals, regional priority, and DOE investment. Since the funding level of most projects was reduced, an analysis of the impact of budget reductions on achievement of program goals was provided. Genetic improvement was one area detrimentally impacted. Data analysis of currently established plantations was given priority over new plantings. New plantings, including several genetic evaluation trials, were delayed at least one year.

2. A briefing on the Short Rotation Woody Crops Program was prepared for DOE staff.

   A 14-page document was prepared that describes the history of the SRWCP, its objectives, current focus, relevancy to other biomass technologies, the industrial involvement in the SRWCP, accomplishments of the program, and future directions. Viewgraphs and photographs were prepared and/or updated. This material was provided to DOE's Biomass Energy Technology Division as a resource.

3. The draft multiyear plan for the SRWCP was submitted to DOE.

   The draft plan was forwarded to DOE on February 28, 1985. It elaborates the program goal, describes the research needs, and establishes the research and regional priorities to be used for future program direction.

4. The draft Annual Operating Plan (AOP) was completed on schedule.

   The AOP was forwarded to DOE on June 3, 1985. This document describes in detail the management and technical milestones and accomplishments expected during the period October 1, 1985, through September 30, 1986, assuming a total program funding level of $4.2 million.

5. The SRWCP management staff at ORNL participated in several technology-transfer activities.

   An article on the environmental issues associated with biomass production by Trimble et al. was published in Biomass. Dr. J. W. Ranney gave presentations to attendees of Southern Biomass Energy Conference and to the Minnesota Biomass Energy Coordinating Office on the topic of biomass production in SRIC systems. Judy Trimble gave presentations about the SRWCP to two groups visiting ORNL. An SRWCP

FY 1985 quarterly report was published as an ORNL Technical Manuscript. The biomass programs at ORNL were described in detail in a section of ORNL's Environmental Sciences Division Annual Progress Report. Complete references for all these technology-transfer activities can be found in the Technology Transfer section of this report.

6. One project site visit was conducted by L. L. Wright at Texas A&I University.

   A site visit was combined with attendance at the Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions at Texas A&I. Presentations by the principal investigator and all students associated with the Texas A&I project during the symposium, as well as field trips, offered an excellent opportunity to review the project. The field trips to two biomass trials established in south Texas demonstrated the effects of about a 254-mm difference in rainfall on growth of mesquite last year. One-year-old mesquite receiving 483 mm of rainfall was slightly larger than 2-year-old plants that received only 229 mm of rainfall during the second year of growth (rainfall during the first year was believed to be near normal or about 460 mm). Survival of the 2-year-old plants through the dry year of 1984 was 100%, and new growth was evident by April 1985.

Technical Accomplishments

1. Hybrid eucalyptus clones were planted by BioEnergy Development Corporation.

   Cuttings of ten hybrid eucalyptus clones were planted at two sites on the Island of Hawaii. The hybrids, selected for high fiber yield, disease resistance, and ease of vegetative propagation, were developed by researchers from Aracruz, Brazil. The hybrids will be monitored for adaptability to Hawaiian conditions.

2. Nursery stock of 28 species is being propagated by the Energy/Development International consortium.

   Two commercial nurseries and one university nursery are responsible for the propagation of most of the plants to be evaluated in the southwest species trials. All nurseries are using the 3.8-cm x 38.0-cm paper plant bands recommended by Michigan State University and Texas A&I University, but they are encountering a number of disadvantages such as increased labor requirements, fungus growth, and inability to easily check root growth. Propagation is on schedule, and planting will begin in mid-July at four sites: two in New Mexico, one in Arizona, and one in Texas.

3. Information on woody biomass production in Florida is being published by the University of Florida.

   A research paper was published in Biomass, and a report of the Cooperative Forest Genetics Research Program of the University of Florida was published this quarter. Six additional papers were reported to be "in press" or "accepted for publication" this quarter. The information relates to the genetic improvement of eucalyptus or other species for biomass production.

4. Coppice yields of European black alder were reported by Iowa State University.

   Results to date indicate that over 7.2 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ could be produced by improved selections of European black alder during the coppice cycle. This is based on estimated dry weight production of the best individual trees in a coppiced provenance (seed source) test. The ten best seed sources were estimated to produce 5.8 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ in the first year of coppice regrowth. Production was estimated according to an equation developed from the actual harvest and measurement of 39 trees. The coppice yields are about double the average annual first-rotation yields estimated at age 5.

5. Research plots were harvested for actual yield determinations by Kansas State University.

   A harvesting demonstration was held in March at the University's Sunflower research site east of Lawrence, Kansas. The demonstration was a cooperative effort sponsored by Kansas State University, the University of Kansas, and Northwest Missouri State University. Five acres of short-rotation intensive culture energy plantings were harvested, and the chips were transported to Northwest Missouri State University for use in their wood-fired boilers. Productivity rates for the harvested Siberian elm and silver maple are being determined. Differences between actual yields and yields estimated by regression were less than 2%, based on fresh weights.

6. Genetic test plantations of black locust and larch were established by Michigan State University.

   About 31,000 trees were established in 12 genetic test plantations of 4 sites in Michigan. These plantings include the approximately 400 seedlots of European black locust that have been collected by Michigan State University during the past 4 years. These plantations will be maintained by using strip weed control techniques.

7. A prototype SRIC harvester was tested on American sycamore plantations established by North Carolina State University.

   A prototype continuous feller-buncher manufactured by Hyd-Mech Engineering, Ontario, Canada, was used to harvest a 3-year-old American sycamore energy plantation in southern Alabama. The plantation was established on Scott Paper Company land in cooperation with the North Carolina State University Hardwood Research Cooperative. Cost analyses for the harvesting operation showed that delivered price for green chips from the energy plantation was less than the price for green chips from natural stands.

8. Hybrid poplar seedling-rotation yields of 4-year-old trees was reported by Pennsylvania State University.

   Seedling-rotation productivity rates varied from 4.8 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ to 10.7 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ in the trials comparing two sites and four management strategies and two planting years. The highest productivity rates were consistently achieved with the fertilizer and irrigation treatment. However, productivity from this combined treatment was only slightly higher than that from the fertilization treatment alone. For the four comparisons available (2 planting years and 2 sites), the productivity achieved by fertilization plus irrigation averaged only 0.7 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ higher than that of plots receiving fertilization alone. These results indicate that irrigation contributes very little to the increased productivity of the combined treatment.

9. An efficient methodology for <u>in vitro</u> micropropagation of elite genotypes of fourwing saltbush has been developed by Plant Resources Institute.

   The data indicate that a standard, Murashige and Skoog (MS), basal culture medium supplemented with 1.0 Mg/L BA (6-benzylaminopurine) as the growth regulator provided the best medium for multiplication of shoots. The system works well with both juvenile and adult material, and establishment of micropropagules into the greenhouse has been achieved.

10. A Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions was conducted by Dr. Peter Felker at Texas A&I University.

    The symposium was attended by nearly 100 people representing 20 nations, 12 states in the United States, and local Texas landowners. The conference clearly identified the importance of both mesquite and leucaena as both an energy source and a livestock food in semiarid regions of the world.

11. The effects of nitrogen fertilization on hybrid poplar clones on two different site types were reported by the USDA Forest Service, North Central Forest Experiment Station.

    On a sandy site, there was a maximum 400% increase in biomass in response to nitrogen fertilizer; while on the more fertile silt loam site, the maximum increase in biomass was only 50%. With the higher rates of fertilizer and irrigation, biomass yields from both sites were similar. For more information refer to pages 105 to 110 in the Appendix.

12. A new study to evaluate yield/density relationships was established by the USDA Forest Service, Pacific Northwest Forest and Range Experiment Station.

    The study to evaluate yield-density relationships of two hybrid poplar clones and two native black cottonwood clones was established with the cooperation of the Washington Department of Natural Resources in Yelm, Washington. This study will evaluate the effects of stand density, fertilization, and genotype on productivity rate. The stand densities being evaluated include the very tight spacings (three to ten plants per square meter) being advocated by some commercial hybrid poplar growers.

13. Breeding of black cottonwood was conducted this spring by the University of Washington.

    The number of successful crosses were lower than expected for nine cross combinations, and the number of apparently filled seeds per cross have been estimated at 50 or above. Because of greenhouse problems, another 7 cross combinations appear to have produced less than 50 filled seeds per cross. The more successful crosses included one of the clones that has shown exceptionally good form in current trials.

14. The crown geometry of plantation-grown American sycamore has been carefully evaluated and described.

    A PhD dissertation entitled "Crown Geometry of Plantation-Grown American Sycamore and its Simulation" was completed by John Schutt, a graduate student of the University of Tennessee working with J. W. Ranney, Field Program Manager of the SRWCP. The dissertation describes and simulates the limb development of young plantation-grown American sycamore trees. It shows that some aspects of limb development are genetically controlled while others are environmentally controlled. The study offers a conceptual basis for improving genetic selection strategy and for determining the best spacings required for improved yields. Additional research will be required to thoroughly address the effects of competition between trees on crown structure.

Planned Events/Accomplishments for Fourth Quarter FY 1985

1. The SRWCP Annual Contractors' Meeting will be held in Hilo, Hawaii, August 20-23, 1985.

2. A paper entitled "The Economic Evaluation of SRIC Energy Plantations" will be presented by R. O. Perlack at the Seventh Southern Forest Biomass Workshop, June 11-14, 1985, in Gainesville, Florida.

3. A presentation entitled "Need for Standardization in Short Rotation Energy Feedstock Research" will be presented by L. L. Wright at the Poplar Council of the U. S., 22nd Annual Meeting, June 25-27, 1985, in Lawrence, Kansas.

4. A final report on the status of forest-harvesting technology for SRIC systems will be completed.

5. At least five project-site visits are planned for the fourth quarter.

6. A representative from the SRWCP, Dave Dawson, will meet with the regional technical group of the Council of Great Lakes Governors to discuss future biomass-research plans for the region.

MILESTONES

Each of the milestones shown in Fig. 2 is listed below, and some indication of the status of the milestone or additional explanation is provided. These milestones were identified in the Annual Operating Plan of the SRWCP as major tasks which would be initiated or completed during FY 1985.

Task 1 - Species Screening and Genetic Improvement

1. Identify drought-tolerant F_1 hybrids of Populus trichocarpa x P. deltoides (March 1985).

   This milestone was met by the University of Washington in March 1985 with research results described in their annual report. Experimental data suggested that undersurface leaf color of Populus could be used as an indicator of drought tolerance. A correlation was demonstrated between the thickness of the spongy mesophyll (or "whiteness") of Populus trichocarpa x P. deltoides hybrids and their capacity to regulate stomatal control during a severe, short-term drought. Of the four hybrid families tested, two were identified as showing greater drought tolerance than either of the parents.

2. Report seedling-rotation productivity of 2-year-old mesquite (March 1985).

   This milestone was met by Texas A&I University, with research results reported in their annual report. Productivity of mesquite on a site that suffered severe drought in the second year after planting was very low. For seed-propagated Prosopis alba, the mean annual production after the second year was only 1.3 dry $Mg \cdot ha^{-1} \cdot year^{-1}$. About 90% of the growth occurred in the first year. It is very significant, however, that both seed-propagated and clonally propagated plants had 88 to 96% survival rates during that period. One of the hybrid clones had nearly double the production of the seed-propagated plants under the same conditions.

3. Start full-scale European black alder progeny tests in several locations (May 1985).

   This milestone will not be fully met until mid-June 1985. More than 70 hybrid crosses performed in spring of 1984 produced seed; however, only four of those crosses produced enough viable seed for field tests. Seedling growth has been slower than expected so the planting date has been delayed until mid-June. Seven seedlots from other sources will be added to make a total of 11 seedlots to be tested at 4 sites in Iowa.

FY 1985 MILESTONES

SPECIES SCREENING AND GENETIC IMPROVEMENT
- Identify drought-tolerant hybrids of cottonwood
- Report seedling-rotation productivity of mesquite
- Start full-scale black alder progeny tests
- Start evaluations of new collections of Populus spp.
- Summarize species/site relationships in the Southeast
- Summarize species/site trials in the Northeast

BIOLOGICAL EVALUATION OF SRIC ALTERNATIVES
- Report seedling-rotation productivity of eucalyptus
- Report seedling-rotation productivity of hybrid poplar
- Receive report on hybrid poplar management strategies
- Issue RFP for nonoculture viability tests

ECONOMIC EVALUATION AND HARVESTING
- Publish report on SRIC economics
- Do economic assessments of eucalyptus plantations
- Complete preliminary evaluation of SRIC harvesters
- Issue RFP for SRIC harvesting equipment
- Analyze woody biomass ootential in Virginia
- Assemble economic evaluation reports

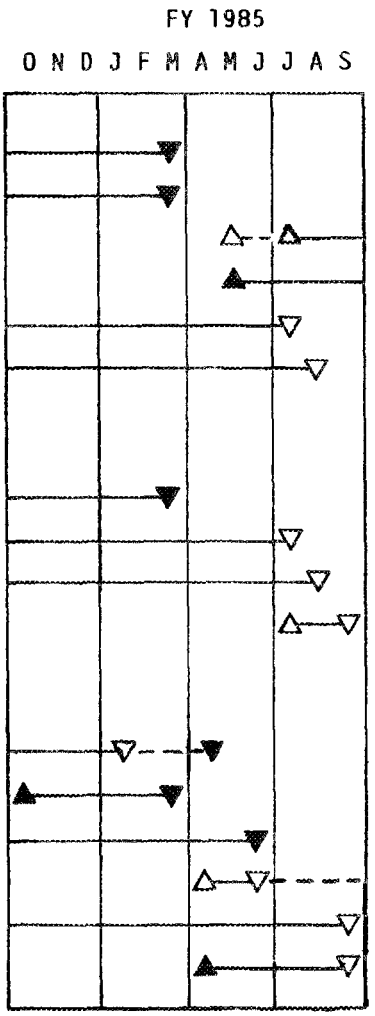


Fig. 2. Milestone chart for FY 1985.

FY 1985 MILESTONES (continued)

ENVIRONMENTAL EVALUATION

- Present 5-year results from whole-tree harvest sites
- Identify regrowth species on whole-tree harvest sites
- Publish report of whole-tree harvest effects (delayed)
- Determine nutrient drain of SRIC nbomass via uptake

PROGRAM MANAGEMENT

- Submit quarterly reports to DOE
- Submit draft technical progress report to DOE
- Submit draft TID plan to DOE
- Perform technical review of renewal proposals
- Submit draft multiyear plan to DOE
- Submit draft annual operating plan to DOE
- Submit project summary sheets to DOE
- Submit draft field task proposal/agreement to DOE
- Hold annual contractors' meeting
- Perform technical review of new proposals
- Complete renewals of subcontracts

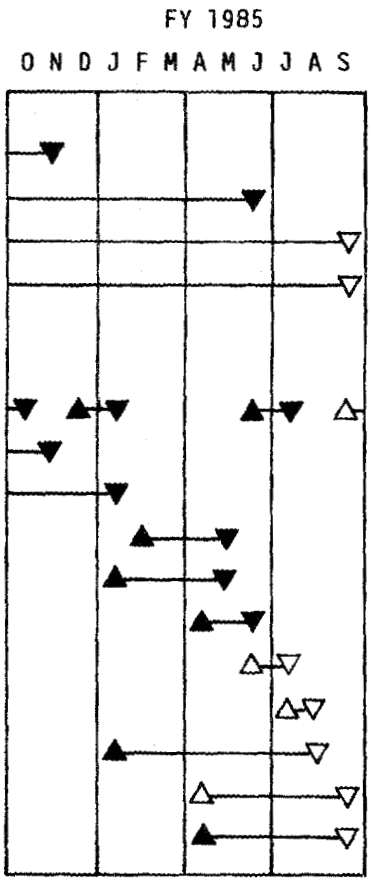


Fig. 2. (continued).

4. Start clonal tests of new collections of Populus species (May 1985).
   This milestone was met by work conducted at the USDA Forest Service North Central Forest Experiment Station. Stool beds for 200 clones of P. trichocarpa were established last fall at Harshaw Farm in Rhinelander, Wisconsin, and in East Lansing, Michigan, in cooperation with Michigan State University. New collections of P. deltoides (96 open-pollinated families) were outplanted this spring. New collections of P. balsamifera were recently completed. Site preparation is currently underway for establishment of replicated field tests at Harshaw Experimental Farm.

5. Summarize species/site relationships in the Southeast (July 1985).
   This milestone will be met next quarter, with the information being derived from research at North Carolina State University.

6. Summarize species/site trials in the Northeast (August 1985).
   This milestone is anticipated to be met next quarter, based on research data to be reported by the University of Vermont.

Task 2 - Biological Evaluation of Management Alternatives

7. Report seedling-rotation productivity of eucalyptus (March 1985).
   This milestone was met by the research results reported by the BioEnergy Development Corporation in their annual report. Actual seedling-rotation productivity rates for eucalyptus in Hawaii ranged from 6.7 dry $Mg \cdot ha^{-1} \cdot year^{-1}$ to 27 $Mg \cdot ha^{-1} \cdot year^{-1}$. These data were based on harvests of 3-year-old spacing trials. The results provide guidelines for selecting spacings that will result in high productivity levels.

8. Determine seedling-rotation productivity of hybrid poplar in central Pennsylvania (July 1985).
   This milestone will be met next quarter with a report on work conducted at Pennsylvania State University.

9. Receive final report comparing four hybrid poplar management strategies (August 1985).
   This milestone will be met next quarter with a report on work conducted at Pennsylvania State University.

10. Issue request for proposal (RFP) for initiation of monoculture viability tests (July 1985).
    No RFP will be released in FY 1985 due to the reduced FY 1985 budget. Plans are being made to release an RFP for this work in 1986, pending appropriate budget levels.

Task 3. - Economic Evaluation of Management Alternatives

11. Publish report on preliminary evaluations of SRIC economics (January 1985).
    A comparative economic assessment of seven SRIC systems was made in the paper presented by R. O. Perlack at the Institute of Gas Technology Symposium in January 1985. That paper is currently "in press." Similar information is contained in the SRWCP 1984 Annual Progress Report, which should be published by September 1985. The economic assessment work that has been conducted at ORNL is also highlighted in this quarterly report (pp. 35-41).

12. Perform economic assessments of Hawaiian eucalyptus plantations (March 1985).
    This milestone was met by information reported in the BioEnergy Development Corporation's annual report. A financial analysis was constructed for nine site conditions of eucalyptus plantations located on the Hilo-Hamaka coast and the Ka'u region of Hawaii. Financial analysis indicated that eucalyptus plantations in Hawaii have the potential for producing wood energy and earning more than 14% profit on many sites. After tax, the rate of return was 12.5% on forest land and 31.8% on high-yield caneland sites. This assumed
    yields of about 22 dry $Mg \cdot ha^{-1} \cdot year^{-1}$, which have been verified as possible for all sites considered.

13. Complete report providing a preliminary evaluation of innovative SRIC harvesting equipment (June 1985).
    This milestone will be met next quarter with a summary of work being performed by TVA.

14. Issue a request for proposals (RFP) for SRIC harvesting equipment (June 1985).
    No Request for Proposal will be released for this category of work because of budget constraints.

15. Complete analysis of woody biomass potential in Virginia (September 1985).
    Work toward this milestone is in progress at Virginia State University.

16. Assemble economic-evaluation reports from field projects (September 1985).
    Following receipt of the subcontractors' annual reports, which are expected to contain valuable new information on SRIC economics, R. D. Perlack will update ORNL's evaluation of SRIC economics and draft a report for program use and possible future publication.

Task 4. - Environmental Evaluation

17. Present five-year results from aboveground whole-tree harvest sites (November 1984).
    This milestone was completed and reported on in the SRWCP Quarterly Progress Report for the period September 1 to November 30, 1984.

18. Identify regrowth species on whole-tree harvest sites (July 1985).
    Work has been completed at ORNL that will meet this milestone. Results will be described next quarter.

19. Publish report on environmental effects of whole-tree harvesting (rescheduled).
    Publication of this report has been rescheduled as an FY 1986 milestone. The 1985 report will be a final report summarizing all work accomplished on this research.

20. Determine nutrient drain of SRIC biomass via uptake (September 1985).
    Work is in progress at ORNL. An evaluation of nutrient drain will be reported next quarter.

Task 5. - Program Management

21. Submit Quarterly Reports to DOE (October 31, 1984; January 31, 1985; and July 31, 1985).
    Quarterly reports covering work conducted in the first and second quarters of FY 1985 have been submitted. This report will meet the July 31 milestone deadline.

22. Submit draft Annual Technical Progress Report to DOE (November 15, 1984).
    The Annual Technical Progress Report, which summarizes the status of research in the SRWCP each year, was submitted to DOE for review on November 15, 1984.

23. Submit draft Technical Information Dissemination Plan to DOE (January 5, 1985).
    The Technical Information Dissemination Plan, which generally describes the types of efforts made by both the SRWCP field management staff and the SRWCP subcontractors to disseminate information to the public, was submitted to DOE on January 8, 1985.

24. Perform technical review of renewal proposals (April 30, 1985).
    Experts in the fields of silviculture, forest genetics, soil science, economics, and biotechnology were invited to Atlanta on March 20-22, 1985, to review the progress reports and proposals submitted by subcontractors to the SRWCP. Their reviews were summarized, and funding recommendations were presented to DOE on April 15, 1985.

25. Submit draft Multiyear Plan (MYP) to DOE (March 1985).
    The MYP was submitted to DOE on February 28, 1985. It represents a long-range planning effort and describes the research required to meet production goals set by the program.

26. Submit draft Annual Operating Plan (AOP) to DOE (June 1, 1985).
    The AOP, which is a detailed planning document describing specific programmatic and subcontractor milestones and accomplishments for FY 1986, is being prepared this quarter.

27. Submit project summary sheets to DOE (July 1, 1985).
    Project summary sheets will be prepared when requested by DOE.

28. Submit draft Field Task Proposal/Agreement to DOE (August 1, 1985).
    This agreement, which outlines the specific research and management milestones that will be tracked by DOE for the following fiscal year, is in initial stages of preparation this quarter.

29. Hold Annual Contractors' Meeting (August 1985).
    Plans have been finalized to hold the 1985 Contractors' Meeting in Hilo, Hawaii. The BioEnergy Development Corporation, which will host the meeting, has the largest SRIC plantings of any project in the SRWCP.

30. Perform technical review of new proposals (September 1985).
    No formal reviews of new proposals will occur during FY 1985 since no solicitations for proposals have been released. Unsolicited proposals will not be reviewed.

31. Complete renewals of subcontracts and interagency agreements.
    This work is initiated immediately following the annual review in April and continues until all planned renewals are completed.

PROCUREMENT STATUS

Procurements that have been or will be initiated during FY 1985 are indicated in Table 2. Placement of procurements was started in late April following the technical review and DOE's approval of ORNL's funding recommendations. As of May 31, four of the procurements required by June 1, 1985, were "in place" as scheduled, and one of the procurements was awaiting concurrence by the subcontracting institution. The two procurements planned for placement by July 1, 1985, are to be on schedule. The two USDA Forest Service interagency agreements were given no-cost extensions until SRWCP budgeting problems were resolved. Paperwork for renewal of those interagency agreements has been initiated and is expected to be "in place" by September. Discussions on work statements have been initiated with TVA and universities scheduled for renewal in August and September.

Table 2. Procurement status for the FY 1985 Short Rotation Woody Crops Program

Title	Contractor	Estimated amount (dollars)	Type procurement	Procurement date Planned/actual
Eucalyptus Plantations for Energy Production in Hawaii	BioEnergy Development Corporation	276,965	Renewal	Aug 1
Tree Species and Management Strategies for the Lake States	Michigan State University	50,000	Renewal	Jun 1/May 22
Species Selection and Silvicultural Systems for Producing Fuels from Woody Biomass in the Southeastern United States	North Carolina State University	70,300	Renewal	Jun 1/May 21
Breeding Alnus for Intensive Culture of Biomass for Energy	Iowa State University	50,000	Renewal	Jun 15/May 28
Tissue Culture of Elite Biotypes of Atriplex canescens as a Short Rotation Woody Biomass Crop	Plant Resources Institute	60,000	Renewal	Jun 1
Improvement of Woody Species for Energy Production in the Southwest	Energy/Development International	55,000	Renewal	Jun 1/May 30
Net Energy and Economic Analyses for Producing Populus Hybrid Under Four Management Strategies	Pennsylvania State University	136,000	Renewal	Jul 1
Production of Woody Biofuels from Mesquite (Prosopis spp.)	Texas A&I University	54,000	Renewal	Jul 1
Establishment of Populus Energy Plantations	USDA Forest Service, North Central For. Exp. Sta.	153,000	Renewal	Sep 1
Increasing the Biomass Production of Alder Plantations in the Pacific Northwest	USDA Forest Service, PNW For. and Range Exp. Sta.	150,000	Renewal	Sep 1
Biomass Harvesting and Field Handling	Tennessee Valley Authority	90,000	Renewal	Oct 1
Eucalyptus for Biomass Production in Florida	University of Florida	160,000	Renewal	Sep 1
Great Plains Energy Forest	Kansas State University	70,000	Renewal	Sep 1
Evaluation and Genetic Improvement of Black Cottonwood for Short-Rotation Coppice Culture	University of Washington	140,000	Renewal	Sep 1

INTERNATIONAL ACTIVITIES

Dr. David H. Dawson represented the United States and the SRWCP at a meeting of the International Energy Agency's (IEA) working group B, Forest Growth and Production, in January 1985. The meeting, held in Uppsala, Sweden, was organized for the purpose of preparing a program of work for the period 1986 to 1989. The IEA's Forest Growth and Production Group is undergoing reorganization to better coordinate joint research and information exchange. Primary activities of this meeting were to determine how to close or reorganize existing work to meet future needs and better fit reorganization goals. Fewer, more integrated projects are sought. In general, the subject areas of research for new activities remain unchanged, namely, genetic improvement, growth factors, production systems, and cost-effectiveness and evaluation. The major plant genera to be emphasized are Alnus (alder), Populus (poplar), and Salix (willow). The 1986-to-1989 program developed at the meeting was submitted to the Executive Committee of IEA for approval in April 1985. The proposed program was not approved and was sent back to working group B for further revision. Plans were made to meet in September to work on the revisions.

Dr. D. H. Dawson, consultant to the SRWCP, and Dr. E. A. Hansen, primary investigator on an SRWCP project, represented the United States at the Indo-U.S. Scientific Exchange Meetings held in early March 1985. Agreement was reached on a proposal for cooperative research on Populus selection and breeding as part of the Indo-U.S. Science and Technology Initiative. The proposed research, which will involve both U.S. and Indian scientists, will focus on selection, testing, and improvement of Populus species for energy. Field research using the same genotypes will be done in both countries. Planting materials, research data, and technical expertise will be shared. Principal investigators for research in the United States are Dr. D. H. Dawson, consultant to Oak Ridge National Laboratory; Dr. E. A. Hansen, USDA Forest Service; and Dr. R. Stettler, University of Washington.

TECHNOLOGY TRANSFER

This section summarizes technology transfer that occurred or was reported during the quarter. Publications, presentations, meetings attended, and tours given both by ORNL staff and by subcontractors to the SRWCP are listed.

Publications

1. Argent, R. M. 1985. Siberian elm: From windbreaks to wood energy. Trans. Kansas Acad. Science, 4. (abstract).

2. Flinchum, D. M., R. E. Goddard, H. R. Kok, P. A. Layton, C. H. McRae, G. L. Powell, and D. L. Rockwood. 1985. Coop. For. Gen. Res. Program 27th Prog. Rept., University of Florida, Sch. For. Res. and Conservation Res. Rept. No. 36. 20 pp.

3. Geyer, W. A. 1985. Climatological variation in energy forest yields in the Central Great Plains of the United States. IN Proceedings of the 1984 Southern Forest Biomass Workshop. USDA Forest Service, Southeastern Forest Experiment Station, Asheville, North Carolina.

4. North Carolina State University. 1985. Hardwood Research Cooperative Annual Report. 75pp.

5. Reighard, G. L., G. Howe, and J. W. Hanover. 1985. Effects of chemical weed control and seedling planting depth on survival and growth of aspen. Tree Planters' Notes, Winter 1985:3-7.

6. Rockwood, D. L. 1985. Genetic improvement potential for biomass quality and quantity. Biomass 6:37-45.

7. Trimble, J. L., R. I. Van Hook, and A. G. Folger. 1985. Biomass for Energy: The Environmental Issues. Biomass 6:3-13.

8. Van Hook, R. I., et al. 1985. Biomass Production. pp.71-83. IN Auerbach, S. I., et al., Environmental Sciences Division Annual Progress Report for the Period Ending September 30, 1984. ORNL-6140. Oak Ridge National Laboratory, Oak Ridge, Tennessee. 216 pp.

9. Wright, L. L., J. W. Ranney, J. L. Trimble, R. D. Perlack and C. R. Wenzel. 1985. Short Rotation Woody Crops Program Quarterly Progress Report for the Period September 1 to November 30, 1984. ORNL/TM-9540. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Popular Articles

1. Topeka Capital Journal Newspaper. April 26, 1985. "Study shows wood fuel can be cheaper than gas."

2. Lawrence World Journal Newspaper. March 30, 1985. "Timberrr! Trees fall in mechanical harvest."

3. Kansas City Times Newspaper. April 2, 1985. "Kansas wins acclaim for timber expertise."

4. Kansas State Collegian Newspaper. May 8, 1985. "Professor explains benefits of using wood chips as energy."

5. Oread. Univ. Kansas Newspaper. April 5, 1985. "Tree harvest yields chips for heating plant."

Presentations

1. Curtin, D. 1985. Video tape of SRIC plantation harvesting test. American Pulpwood Association Annual (APA) Meeting, March 17-19, 1985.

2. Curtin, D. 1985. Findings of plantation harvester test. American Pulpwood Association Southwide Energy Committee, April 24-25, 1985.

3. Dawson, D. 1985. National overview of short-rotation intensive culture research. Field-day seminar and demonstration of SRIC harvesting techniques, Lawrence, Kansas, April 12, 1985.

4. DeSousa, S. 1985. Influence of air temperature, light intensity, and photoperiod on rooting of Prosopis alba cuttings. Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions. Texas A&I University, Kingsville, Texas, April 29-May 2, 1985.

5. Dippon, D. R. 1985. Cost sensitivity analysis of Eucalyptus grandis. Third Southern Biomass Energy Research Conference, Gainesville, Florida, March 12-14, 1985.

6. Felker, P. 1985. Use of plant tissue mineral analysis to assess limitations of soil fertility on tree growth. Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions, Texas A&I University, Kingsville, Texas, April 29-May 2, 1985.

7. Felker, P. 1985. Influence of mechanical and chemical weed control on growth and survival of tree plantings in semiarid regions. Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions, Texas A&I University, Kingsville, Texas, April 29-May 2, 1985.

8. Tabone, T. 1985. Tissue culture propagation of Leucaena and Prosopis. Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions, Texas A&I University, Kingsville, Texas, April 29-May 2, 1985.

9. Hall, R. B. 1985. Alder - an agricultural alternative. Iowa Academy of Science. Pella, Iowa, April 27, 1985.

10. Hanover, J. W. 1985. Briefing on Michigan State University genetics and biomass research. NC-99 Tree Improvement Committee Meeting, St. Paul, Minnesota, March 12-13, 1985.

11. Hanover, J. W. 1985. Briefing on Michigan State University genetics research on biomass species. Leadership Dynamics Development Group, Grand Rapids, Michigan, March 29. 1985.

12. Miller, R. 1985. Overview and results of Michigan State University biomass plantation research. Soil Conservation Service Annual Regional Meeting, Lansing, Michigan, March 14, 1985.

13. Murray, M. 1985. Variation in tolerance of red alder families to soil waterlogging. Northwest Scientific Association Annual Meeting, Vancouver, British Columbia.

14. Ranney, J. W. 1985. Research on short-rotation woody crops in the South. Third Biomass Energy Research Conference, University of Florida, Gainesville, Florida, March 12-14, 1985.

15. Ranney, J. W. 1985. Research results of the Short Rotation Woody Crops Program. Symposium on Biomass Energy sponsored by the Bioenergy Coordinating Office at the University of Minnesota, April 26, 1985.

16. Reddy, K. V. 1985. Genetic improvement of Eucalyptus grandis for biomass production in Florida. Third Southern Biomass Energy Research Conference, Gainesville, Florida, March 12-14, 1985.

17. Reddy, K. V. 1985. Effect of inbreeding on estimates of genetic parameters in Eucalyptus grandis. Eighteenth Southern Forest Tree Improvement Conference, Gulfport, Mississippi, May 21-23, 1985.

18. Reighard, G. L. 1985. Genetic and cultural factors affecting growth performance of slash pine. Eighteenth Southern Forest Tree Improvement Conference, Gulfport, Mississippi, May 21-23, 1985.

19. Rockwood, D. L. 1985. Development of woody biomass cultural systems in Florida. Third Southern Biomass Energy Research Conference, Gainesville, Florida, March 12-14, 1985.

20. Schultz, R. C. and R. B. Hall. 1985. Growth and rooting characteristics of hybrid aspen and alder on a reclaimed mine site. Iowa Academy of Science, Pella, Iowa, April 27, 1985.

21. Sommer, H. E., H. Y. Wetzstein and N. I. Lee. 1985. Advances in the tissue culture of Liquidambar styraciflua L. Eighteenth Southern Forest Tree Improvement Conference, Gulfport, Mississippi, May 21-23, 1985.

22. Stettler, R. 1985. Biotechnology in the poplar program at the University of Washington. Meeting of chief executive officers of the Northwest pulp and paper industry, May 9, 1985.

23. Stettler, R. 1985. Biotechnology in the poplar program at the University of Washington. Meeting of staff at the Washington State Department of Natural Resources Research Branch, May 10, 1985.

24. Iorreano, S. J. and D. J. Frederick. 1985. A comparison of coppice and seedling biomass production with time and spacing on two sites in North Carolina. Paper presented at the Third Southern Biomass Energy Research Conference, Gainesville, Florida, March 12-14, 1985.

Meetings Attended

1. Geyer, W. A. International Meeting on Biomass 3rd ECC Energy Conference, March 1985, Venice, Italy.

2. Geyer, W. A. Field tour of coppicing hardwood trees in Italy by State Forest Resource Silviculture Institute of Italy and the University of Florence in Arezzo, Italy, April 1985.

3. Curtin, D. Participated in Underutilized Wood Steering Committee, sponsored by the Solar Electric Research Institute, March 4-5, 1985, Golden, Colorado.

4. Ranney, J. W. Eighteenth Southern Forest Tree Improvement Conference, May 20-23, 1985, Long Beach, Mississippi.

5. Rockwood, D. L. Eighteenth Southern Forest Tree Improvement Conference, May 20-23, 1985, Long Beach, Mississippi.

6. Wright, L. L. Eighteenth Southern Forest Tree Improvement Conference, May 20-23, 1985, Long Beach, Mississippi.

7. Wright, L. L. Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions, April 29-May 2, 1985, Kingsville, Texas.

Contacts and Tours

Bioenergy Development Corporation (BDC):

During the past several months BDC has discussed their research results with, and provided advice to, Bio Power Corporation, which is preparing to establish tree plantations to furnish biomass to the former Puna Sugar Company power plant. This will be a direct application of some of our research work to a commercial operation.

Dr. Larry Kulp, Vice-president in charge of technology strategy for Weyerhaeuser Company, visited BDC's Eucalyptus plantations in Hawaii.

University of Florida:

Don Rockwood hosted seven scientists from the Biomass Energy Research Conference to review his biomass research projects.

Iowa State University:

R. B. Hall and students met with Iowa Conservation Commission Foresters and Mr. Wayne Siegle of the Iowa Department of Corrections to discuss the possibility of converting the space-heating systems of one or more of the state penitentiaries to wood heat. They offered to supply materials for initial plantation trials.

R. B. Hall and students traveled to Creston, Iowa, to meet with representatives of the Soil Conservation Service, Forestry Section of the Iowa Conservation Commission, Multi-County Wood Utilization Committee, and the Southern Iowa Agricultural "Boosters." They toured potential planting sites and discussed the necessary steps to make wood biomass farming a practical alternative for southern Iowa.

Kansas State University:

Kansas Forestry staff visited the harvesting demonstration conducted on a 2.02-ha energy forest at Sunflower research planting site at DeSoto, Kansas (Lawrence area).

North Central Forest Experiment Station (NCFES):

Northern States Power Company consulted with scientists at NCFES on several occasions as they developed plans for a possible 500-MW wood-fired electric generating facility in Minnesota.

Ed Hansen and Dave Dawson visited India for a ten-day science exchange as part of the Indo-U.S. Science and Technology Initiative. The purpose was to identify planting sites for collections of Populus deltoides that will be sent to India in early 1986.

Oak Ridge National Laboratory:

A presentation on the Biomass Programs at ORNL was made by J. L. Trimble to new employees of ORNL's Information Resources Organization.

A presentation on the Short Rotation Woody Crops Program was given by J. L. Trimble to the Illinois Agricultural Leadership Program Group which visited ORNL.

Donna Fitzpatrick, Assistant Secretary for Conservation and Renewable Energy, visited ORNL on May 17, 1985. She was given a brief presentation by R. I. Van Hook, J. W. Ranney, and J. H. Cushman on DOE's Biomass Programs managed by ORNL.

Gary Schiefelbein, Don Stevens, and Daniel Anderson of the Pacific Northwest Laboratory (PNL) visited the SRWCP staff at ORNL to discuss potential areas for cooperation in biomass research between ORNL and PNL.

Pacific Northwest Forest and Range Experiment Station:

Dean DeBell attended a meeting concerning a hardwood research cooperative proposed by Oregon State University (OSU) for the Pacific Northwest. The meeting was initiated by OSU and held at Weyerhaeuser facilities in Centralia, Washington. Oregon State University, Weyerhaeuser Company, Goodyear-Nelson Company (an alder lumber manufacturer), and the Pacific Northwest Forest and Range Experiment Station were represented.

Tennessee Valley Authority (TVA):

Dennis Curtin toured harvesting operations and manufacturing plants in Sweden and Finland May 25-June 9, 1985.

Paul Barnett met with Jim Mattson and Ed Hansen in Rhinelander, Wisconsin, to gather data and information on plantations and perceived harvesting problems and opportunities. Initial plans were made for an IEA Workshop in September.

Paul Barnett met with scientists at Pennsylvania State University to collect data and discuss harvesting opportunities.

Texas A&I University

Peter Felker arranged tours of his mesquite biomass plantings as part of the Symposium on Establishment and Productivity of Tree Plantings in Semiarid Regions. About 80 people visited the sites.

ORNL RESEARCH AND PROGRAM SYNTHESIS ACTIVITY REPORTS

Nutrient Utilization Study (D. W. Johnson)

Data from the 1984 (third year) sampling of the short-rotation loblolly pine and yellow-poplar plantations have now been analyzed. Results show conclusively that there is no further benefit (and perhaps even a slight negative effect) from fertilizing quarterly (March, June, September, and December) with 25 $kg \cdot ha^{-1}$ urea nitrogen, as compared with annually (in March) at 100 $kg \cdot ha^{-1}$. Both loblolly pine and yellow-poplar trees fertilized annually had higher foliage nitrogen concentration ($\mu g \cdot g^{-1}$) and content ($g \cdot leaf^{-1}$) in August than quarterly fertilized trees. Unfertilized trees had the lowest biomass and foliage-nitrogen concentration and content in all cases.

Senescent leaves had very similar nitrogen concentration regardless of fertilizer treatment, indicating that fertilized trees efficiently conserved the fertilizer nitrogen they took up by translocating it to either older foliage (loblolly pine) or permanent tissues.

There was no evidence of any long-term increase (i.e., beyond the temporary increase in soil NH_4^+ and NO_3^-) in soil-nitrogen availability (measured by aerobic incubation and chemical fractionation) in fertilized plots, but there was a marked increase in both nitrification rate and nitrate leaching, especially in the quarterly fertilized plots.

These results suggest that nitrogen fertilization more frequently than annually benefits nitrifying bacteria in the soil more than the target organisms (trees), causing nitrate-nitrogen losses via leaching. There are attendant implications for the use of slow-release fertilizers, which may produce the same negative side effects as quarterly fertilization. Research plots comparing one-time-only urea vs slow release fertilization have now been established to test this hypotheses.

Whole-Tree Harvesting: Regrowth 4 Years After Whole-Tree and Sawlog Harvest (L. K. Mann)

Nutrient-budget estimates for an upland, mixed-hardwood forest in eastern Tennessee demonstrated that whole-tree above-stump harvest (WTH) removed much greater amounts of nutrients than a conventional sawlog harvest (SAW) (Johnson et al. 1982). Natural regeneration was monitored for 4 years after harvest to determine the effects of these two intensities of harvest on productivity and community composition.

Stump-sprout biomass, seedling biomass, number of stems, and tissue nutrient concentrations were determined for major species after both harvesting levels. Stump-sprout leaf-nutrient concentrations averaged 5% less nitrogen, 2% more phosphorus, 7% more potassium, and 13% more calcium after SAW than after WTH. Differences between leaf-tissue calcium and potassium were even greater in seedlings. Average total sprout biomass per stump was 15% greater, and seedling biomass was nearly 300% greater after SAW than after WTH. Only two species responded very differently to the two harvest intensities. Black cherry seedlings were more than twice as abundant and produced more than ten times as much biomass after SAW, compared to WTH. Very few blackgum stump sprouts survived after SAW compared with WTH, but blackgum root sprouts responded similarly to both harvest intensities. Although most species produced more biomass after SAW, several were more abundant after WTH.

Although these results are preliminary and based on only few samples, they indicate that differences between nutrients left on the site after harvest may affect tree growth. Growth differences at this early stage may be due to other factors such as microclimate effects of slash and differences between site disturbances during harvest. A detailed analysis of soil nutrients is planned to determine changes in nutrient availability.

Johnson, D. W., D. C. West, D. E. Todd, and L. K. Mann. 1982. Effects of sawlog vs whole-tree harvesting on the nitrogen, phosphorus, potassium, and calcium budgets of an upland mixed oak forest. Soil Sci. Soc. Am. J. 46:1403-1309.

Evaluation of SRIC Harvesting Equipment (D. T. Curtin)

The identification and documentation of existing prototypes of SRIC harvesting equipment is nearly complete. Only one working prototype was available in North America for physical evaluation, though several others are in various stages of construction and development. The prototype was tested February 18-22, 1985, through the following cooperative efforts:

1. North Carolina Hardwood Cooperative - Doug Frederick

2. Scott Paper Company - William Wharton

3. Hyd-Mech Engineering, Ltd. - Stan Jasinski

4. National Research Council of Canada - Ted Golob

5. USDA Forest Service, Southern Forest Experiment Station - Bryce Stokes

6. Tennessee Valley Authority - Dennis Curtin

The test indicated that the prototype harvester, HRCC FB7, can harvest trees up to 7 cm in diameter at a rate in excess of 1,000 trees per hour. Felling and bunching productivity averaged 14.7 green Mg per productive machine hour, and costs were predicted to be $2.24 per Mg. For the total system, felling through chipping, costs were projected to be between $8.24 and $9.5 per green Mg. The harvester had a number of mechanical breakdowns, which is characteristic of prototypes, but the engineering concepts are sound.

The draft topical report describing SRIC plantation harvesters and the draft final report have been submitted for review and are awaiting comments.

SRWCP Technical Data Base (L. L. Wright)

The design of the SRWCP technical data base was completed in March 1985. Upon completion of the design, data entry into the data base and the development of procedures to generate reports on the data in the data base was begun. To date, procedures to generate 12 different reports have been developed and tested. During the test phase of the procedures, new data requirements were discovered and incorporated into the data base design.

Entry of records into the data base proceeded this quarter. Data from Texas A&I University, Pennsylvania State University, North Carolina State University, and the University of Illinois were entered and can be accessed. Revisions were made and the reports were generated. Data from the University of Houston, Kansas State University, Utah State University, University of Vermont, University of Washington, and University of Georgia were extracted, converted, and compiled and are ready for entry into the system.

QUARTERLY HIGHLIGHT

The quarterly highlight aims to focus attention either on research being performed by the SRWCP or on analysis of the economic potential of the SRIC concept. This section presents the information in a format similar to that of a journal article. The highlight this quarter focuses on research being conducted at ORNL.

The Economics of Energy Plantations

R. D. Perlack
Energy Division
Oak Ridge National Laboratory

In this technical highlight, the economics of SRIC woody biomass plantations are demonstrated for a representative example constructed in part from a number of SRWCP field research projects. The purpose of this highlight is to illustrate the types of economic analyses that have been completed for the SRWCP and to indicate the extent of cost reductions and productivity improvements that will be necessary to make the SRIC concept ready for commercialization. A 5-year rotation, a 1.5-square-meter spacing (4000 trees/ha), two coppice harvests, and a productivity rate of 12 dry $Mg \cdot ha^{-1} \cdot yr^{-1}$ in the first rotation and 14.4 dry $Mg \cdot ha^{-1} \cdot yr^{-1}$ (20% increase over first rotation) in the subsequent coppice rotations are assumed. The energy content of the biomass is 19.7 GJ/dry Mg (17.0 MBtu/dry ton). The costs for this representative plantation are summarized in Table 3.

Perhaps a first question to resolve in evaluating the economics of wood-energy plantations is to analyze the sensitivity of the economically optimal rotation age to changes in important factors (e.g., the discount or interest rate). Because spacing determines to some extent the likely range of optimal rotation ages, only a limited number need to be examined. The minimum product price as a function of the real discount rate for three alternative rotation ages is shown in Fig. 3. These results confirm what one would expect: that the optimal rotation age is shortened by increases in the discount rate and lengthened with decreases in the discount rate. However, the results also indicate that the economics of a plantation are not affected a great deal by the choice of rotation age. That is, the minimum product price is not substantially different among the three rotation ages. The economics suggest that it is important to be within 1 year of the optimal rotation age, but being on the optimal rotation age is not critical. Similar results are found by varying productivity and price.

Table 3. SRIC energy plantation cost activities

Activity	Costs
Infrastructure development	$32/ha
Land rent	$80/ha/yr
Site preparation	$50/ha
Preplant weed control	$200/ha
Seedlings (4000 trees/ha)	$550/ha
Planting	$50/ha
Cultural management	
Fertilization	
Seedling yr 1	$75/ha
Seedling yr 2	$75/ha
Coppice yr 1	$75/ha
Weed control	
Seedling yr 1	$90/ha
Seedling yr 2	$90/ha
Pest control	
Seedling yr 2	$90/ha
Seedling yr 4	$90/ha
Coppice yr 2	$90/ha
Coppice yr 4	$90/ha
Administration	$30/ha/yr
Harvesting	$24/Mg
Transportation	$4/Mg

A 25% margin was added to the minimum product price to account for taxes and a return on investment.

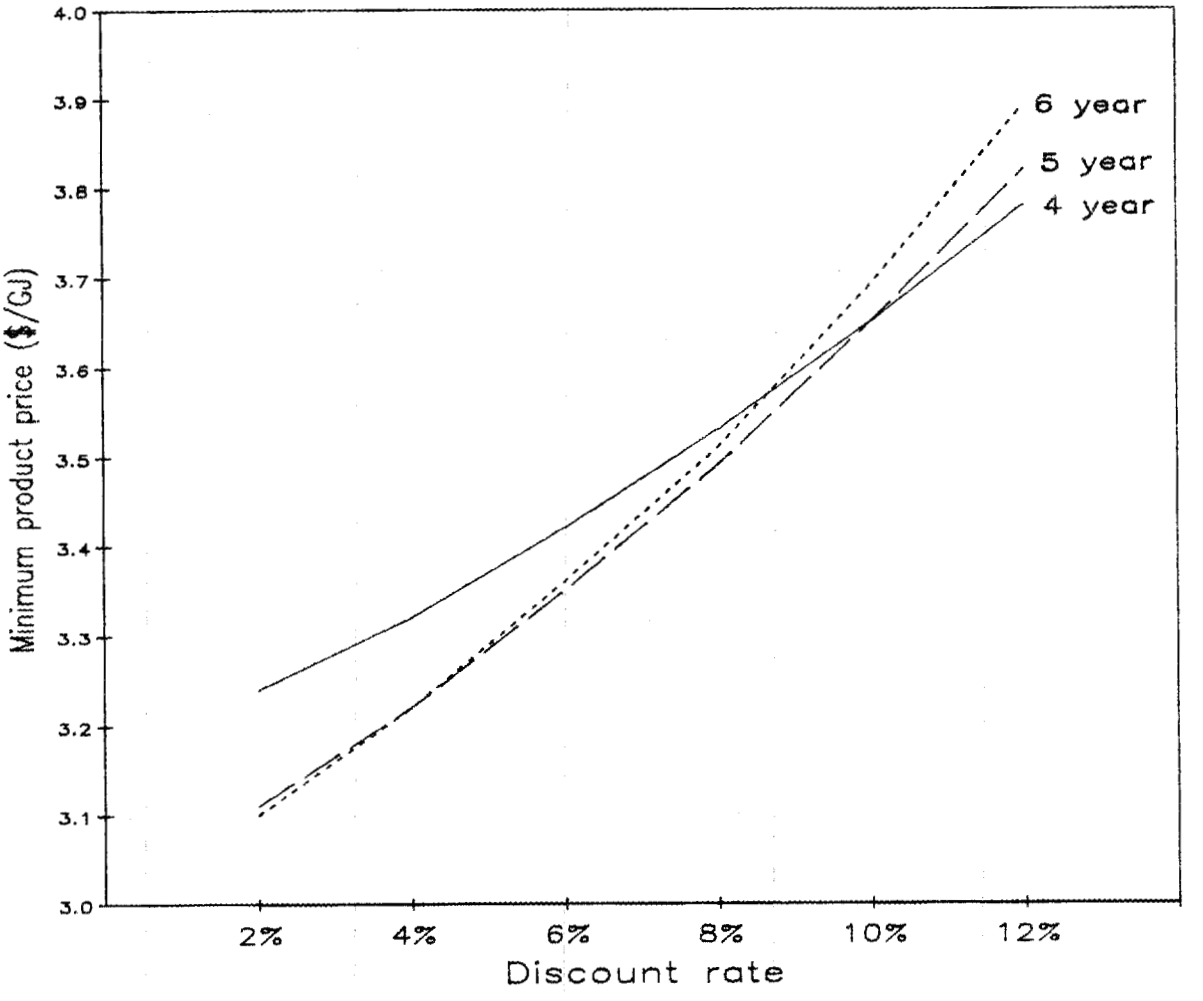


Fig. 3. Sensitivity of the optimal rotation to changes in the discount rate.

The importance of major cost activities and productivity rates on the economics of the representative plantation can be evaluated through sensitivity analysis. In Fig. 4, the results of the sensitivity analysis are summarized. The results from varying costs indicate that the minimum product price is affected most by harvesting costs. The costs of site preparation, planting, cultural management, and land rent are important, but relatively large changes in only one of these costs will not have a major impact on the economic viability of the plantation. The dominance of productivity on the economic viability of SRIC plantations is also shown in Fig. 4. The graph illustrates the diminishing impact of successive improvements in productivity. Productivity gains beyond, say, 60% do not provide a substantial reduction in product price. Conversely, Fig. 4 shows that losses in expected productivity can have disastrous effects on the economics of the plantation. For example, a 40% loss in productivity would increase the minimum product price by nearly $1.00/GJ. The sensitivity analysis shows quite obviously that increasing productivity and reducing harvesting costs are critical to the economic viability of the concept.

A key feature of SRIC plantations is the reliance on the coppicing ability of hardwood trees to regenerate succeeding stands at little or no additional expenses. In Fig. 5, the effects of coppicing on the economics of the plantation are demonstrated by varying the number of coppice harvests and the percentage increase in coppice productivity rate over that for the first rotation. A comparison of the calculated minimum product price for two coppice harvests and a 20% increase above th first rotation to no coppicing shows a difference of $0.97/GJ. Figure 5 also illustrates the trade-offs between the number of coppice harvests and the coppice productivity rate. For example, one coppice harvest and a 100% increase in productivity is nearly equal to two coppice harvests and a 40% increase in productivity. Further, one coppice harvest and a 40% increase in productivity is about equal to three coppice harvests and a 0% gain. Promoting high productivity rates throughout succeeding coppice rotations is necessary to ensure SRIC concept acceptance.

SRIC woody biomass plantations can be a significant source of new energy feedstock provided that research can reduce costs to approximately $2.00/GJ. Perhaps the greatest potential for cost reduction lies in genetics, which has the potential to increase productivity by as much as 100% in the next 10 years. The effect of a 40% productivity improvement in both the first rotation and succeeding coppice rotations would reduce the minimum required product price from $3.29/GJ to $2.85/GJ. A second major area of cost reduction could come from the development of a cost-effective SRIC harvesting system. If a 33% reduction in costs can be attained with the development of an innovative harvester, the effect would be to reduce the minimum product price to nearly $2.35/GJ, inclusive of the productivity

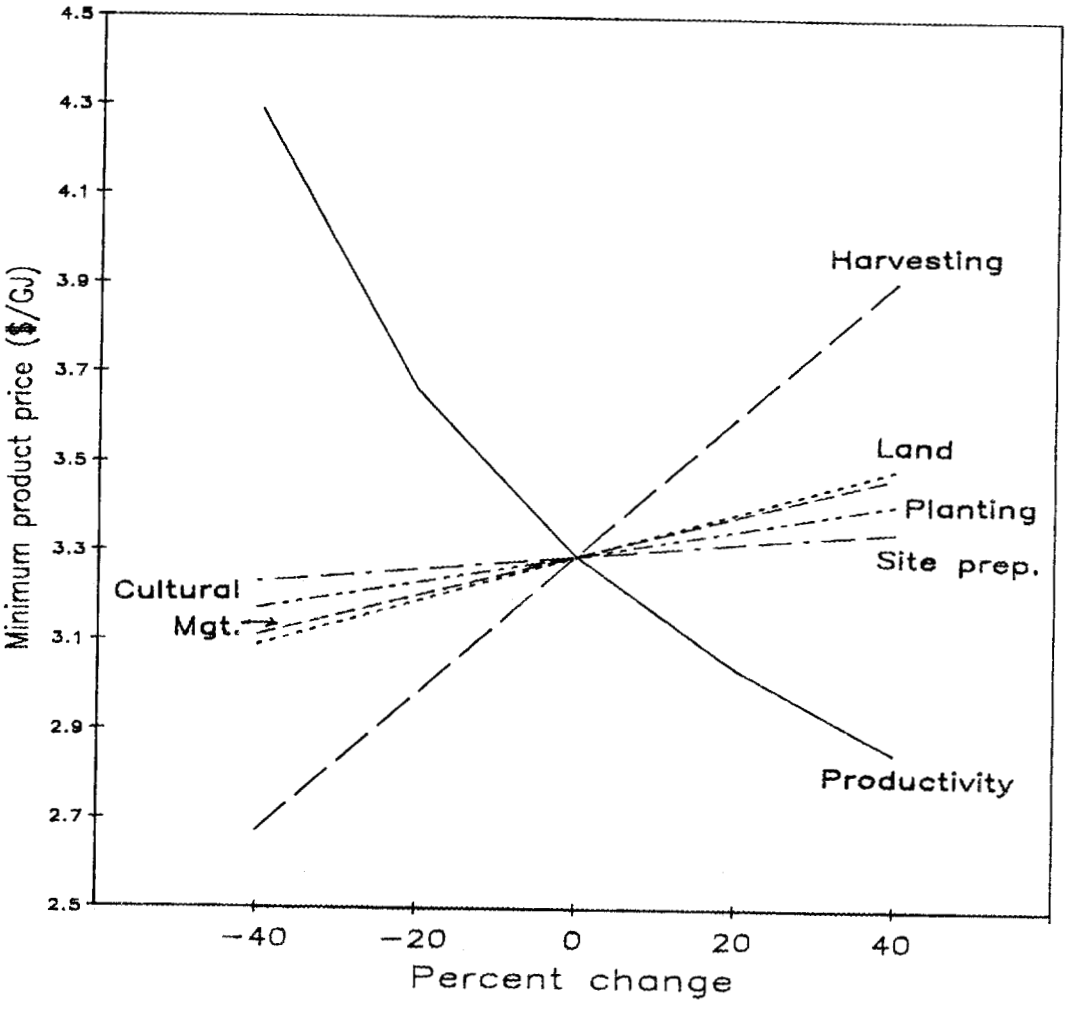


Fig. 4. Sensitivity of the minimum product price to changes in major cost activities and productivity rates.

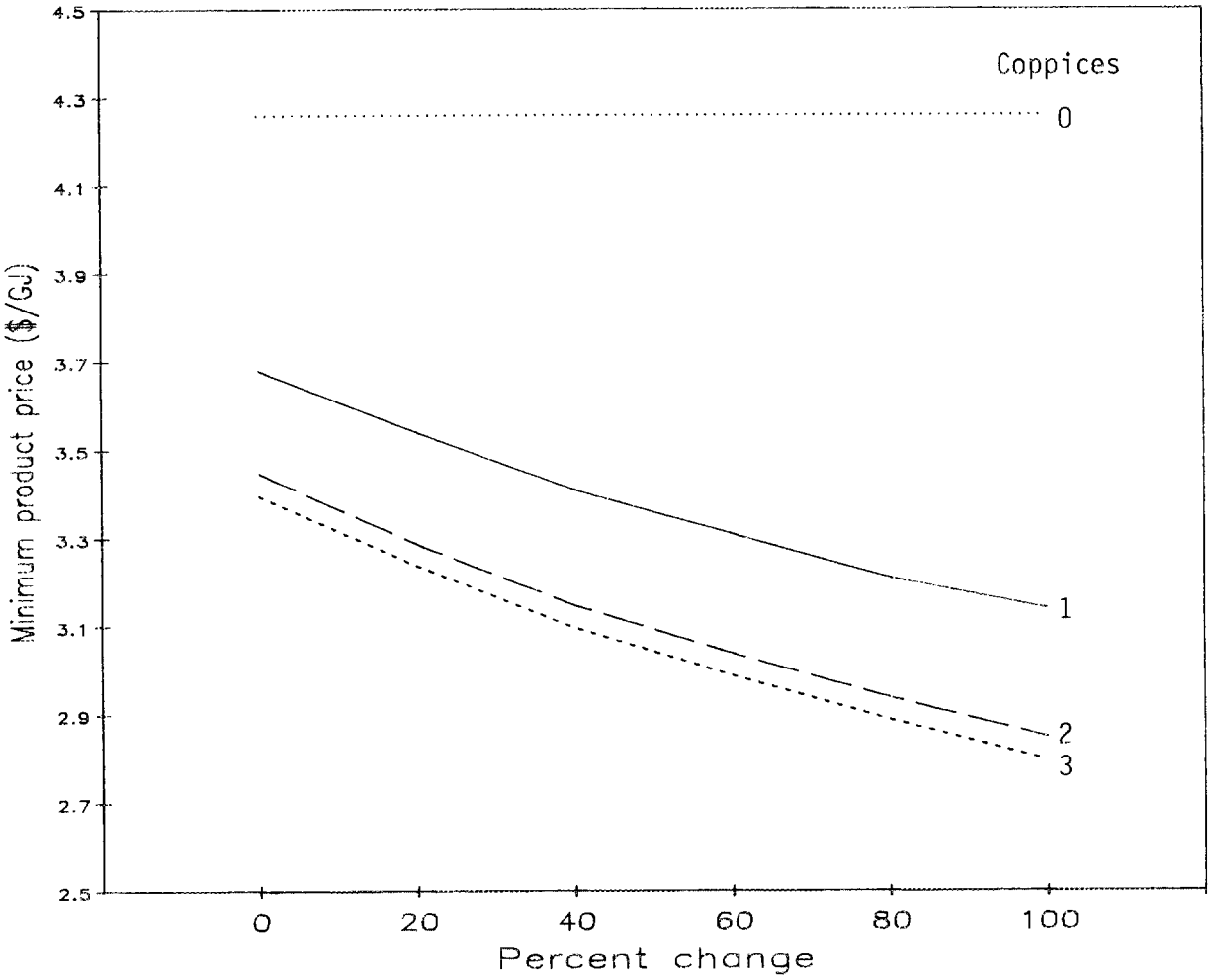


Fig. 5. Sensitivity of the minimum product price to changes in the coppice productivity rate and the number of coppice harvests.

increase. Significantly reducing plantlet costs through tissue culture research could further reduce costs by about $0.15/GJ. Continued research in promoting coppice-productivity increases, genetics to promote tree tolerance and site adaptability, and refinements in stand-management practices could contribute to competitive costs. To be sure, the ultimate test of concept feasibility will require demonstration in larger monocultural trials of the size of 20 to 40 ha so that risks, both biological and economic, can be evaluated. As is shown by the example, nonattainment of desired productivity rates greatly affects the economics of the concept.

APPENDIX: SUBCONTRACTED RESEARCH REPORTS

EUCALYPTUS PLANTATIONS FOR ENERGY PRODUCTION

Quarterly Report for the Period

March 1 to May 31, 1985

Thomas B. Crabb
Thomas H. Schubert

June 1, 1985

Report prepared by

Thomas B. Crabb
Thomas H. Schubert
BioEnergy Development Corporation
888 Kalanianaole Avenue
Hilo, Hawaii 96720

under

Subcontract 19X-09061C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

Current Activities

Major emphasis during the first part of March was devoted to completion of our 1984 Annual Report, and to preparation of our renewal proposal for 1985-86.

Research activities have been concentrated on scheduled remeasurement of our existing experiments. In terms of our research objectives, these remeasurements included:

1. Increase biomass production: Species Trials at Onomea V-05A, Kamae F26B and F25A, Amauulu, and Ka'u K451; E. robusta I and II Provenance Trials at Chin Chuck F30D, and E. tereticornis/E.camaldulensis Seed Source Trial at Kamae F26C.

2. Determine optional cultural requirements: NP Trial at Akaka, NPK Trial at Amauulu, and Osmocote Trial at Kamae F25B; Euc/Legume Ratio Test at Ka'u K765; Spacing Studies at Kamae F25C and Pepeekeo F69B, and Spacing & Rotation Study at Amauulu; Weed Control vs. None at Kamae F26A.

Also, trees in the Amauulu Erosion plots were remeasured and a new instrument shelter was installed there.

Additional research work included scheduled crop logging and refertilization in the Fertilizer Study at Pepeekeo F-69B, and refertilization in the Eucalyptus Thinning/Spacing Study at Kamae F26B and F27C. The Spacing Studies at Kamae F25C and Pepeekeo F69B were fertilized on an "area" basis, which means that the amount of fertilizer applied per tree was proportionally greater in the wide spacings, with fewer trees per hectare than in the narrower ones.

Because of the damage from the January, 1985 windstorm in the Ninole Valley area at Ka'u, the measurements in January, February and March of the Spacing Study at K755, the E. globulus Progeny Trial at K765, and the Euc/Legume Ratio Test at K765 will probably be the last ones in these experiments. Future observations will record coppicing in areas that were clear cut, and recovery of some of the damaged trees.

Summary of Research Results

No particular changes from past trends were noted. Eucalyptus saligna and E. grandis continue to be the two best species. The best of the E. robusta provenances were from Queensland and New South Wales in Australia. None of the E. tereticornis or E. camaldulensis seed lots have grown especially well.

The most effective fertilizer treatment appears to be at the medium level of applied nitrogen, with some added phosphorus. This level gave growth as good, or almost as good, as the highest levels of nitrogen and phosphorus.

Mixtures of 33% to 50% Albizia trees with Eucalyptus produce the best growth of the eucalyptus.

The narrowest spacing still has the tallest trees and the most biomass 3½ years after outplanting at Amauulu, but trees in this spacing are now growing only half as fast as those in the widest spacing.

Publications

Revised manuscripts on Species Trials, and on Eucalyptus/Legume Admixtures, have been sent to the Pacific Southwest Station editor, and hopefully will be published in time for the Biomass contractors' meeting in Hilo Aug. 20-23.

Highlights

Hybrid eucalyptus cuttings of ten clones were planted at the Pepeekeo F69B prime cane land site, and at Kamae F26E. These hybrids, selected for high fiber yield, disease resistance and good vegetative propagation potential, were developed by a research team at Aracruz in Brazil, and were obtained with the help of Dr. Charles Hodges of the U. S. Forest Service. If they prove to be adapted to our conditions, they will save us several generations of tree improvement research.

During the past several months, we have discussed our research results with, and provided advice to, Bio Power Corporation, who are preparing to establish tree plantations to furnish biomass to the former Puna Sugar Company power plant. This will be a direct application of some of our research work to a commercial operation.

SPECIES SCREENING AND GENETIC SELECTION AT SITES IN ARIZONA, NEW MEXICO, AND TEXAS

Quarterly Report for the Period

March 1 to May 31, 1985

Samuel Hale, Jr.
Energy/Development International

June 1, 1985

Report prepared by

Samuel Hale, Jr.
Bruce Ross-Sheriff
Energy/Development International
1015 18th Street, N.W., Suite 802
Washington, D.C. 20036

under

Subcontract 19X-89640C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U. S. Department of Energy
Contract No. DE-AC05-84OR21400

QUARTERLY REPORT FOR THE PERIOD
MARCH 1, 1985 - MAY 31, 1985
FOURTH QUARTER OF THE FIRST YEAR

TASK 1: Germplasm Acquisition

Final selection and acquisition of germplasm was completed during this reporting period. The current list of species to be tested at each site is appended to this report (Attachment 1). The species that will be planted at the sites supported by funding from NMERDI, the companion project, are also listed.

The rhizobia for inoculating the nitrogen-fixing leguminous seedlings was also obtained during this period.

TASK 2: Development of Propagation Techniques and Production of Nursery Stock

The nursery stock is being propagated at consortium members' nurseries. In line with our objective to stimulate commercial interest in this program, three of the nurseries are commercial operations while the fourth is at the New Mexico State University horticultural facilities. The Prosopis clone is being propagated at Texas A&I and the Utah Atriplex provenance is being propagated at the nursery of Native Plants, Inc. in Utah. The number of seedlings being propagated at each nursery is listed in Attachment 2.

All consortium members propagating seedlings are following uniform procedures and materials as outlined in the project's research operations manual. This manual also specifies the required record keeping during the nursery stage. Following the experience of the SRWC projects at Texas A&I and at Michigan State University, the accessions are being propagated in 1.5 inch diameter by 15 inch depth paper plant bands. The same potting soil formula has been used at all the nurseries, based on a formula in a SRWC report by Dr. Felker of Texas A&I University. Exceptions to this are the Quercus virginiana and the Atriplex canescens from Utah. These were started in other containers with slightly different potting soils before the paper plant bands were acquired.

The consortium members have generally not been pleased with the use of the plant bands. This may be influenced by the understandable preference for using their standard nursery containers with which they are both accustomed and better prepared to use. Some of the disadvantages of the planting bands expressed by the consortium members include:

1. More labor intensive; requires up to 3 times the time to prepare and fill.

2. There is a handling problem in that the seedlings cannot be sorted.

3. It is not possible to check the roots as an indicator for problems in propagation.

4. There are no ribs to direct the root growth.

5. They possibly enhance leaching of nutrients.

6. They do not dry out in the center.

7. A fungus tends to grow on the surface.

8. They are not reusable.

We will continue to monitor the use of these bands. If in fact they afford a 30 percent increase in survival due to the extra long root system, as they are purported to do, we may decide to continue the use of the bands despite the other perceived problems.

At this time the New Mexico State University nursery is modifying their watering schedule to longer intervals in order to assess whether or not the chlorotic aspect of the seedlings is due to oxygen deficiency.

Some of the selected species for trial have not been propagated commercially or little is known concerning their germination and nursery response. This is especially true of some of the exotic leguminous species. Therefore, techniques for seed stratification and scarification are being tested and developed for these less understood species. Generally these results show that the Leucaena species, Gleditsia tricanthos, and Acacia pennatula germinate best with scarification by H_2SO_4. The Acacia abyssinica should not be scarified or acid treated in any way or viability will be lost.

TASK 3: Establishment of Experimental Plots

The experimental design and plot layout has been completed for the Las Cruces plantation. This will serve as a model for the experimental design at the other sites. Each plot layout, however, will differ for each site in order to assure that blocks (reps) are established on homogeneous soils. Project managers Deardorff and Kirmse are personally coordinating this critical operation.

The basic design is a randomized complete block. There will be four blocks per site. Five accessions will be tested at each site which means there will be five plots (containing one accession) per block. This reduction in the number of species to be tested at each site is in accordance with the suggested changes offered by the reviewers of our annual report. Each plot will be planted in an 8 tree by 8 tree array at 6 ft. by 6 ft. spacing. The plots within each block will be randomized separately.

Also at each site additional species are to be tested in a simpler screen: 3 replicates of 10-tree line plantings. Attachment 1 indicates the species that will be tested by the RCB design and those that will be tested in line-plantings.

Plantings will begin in mid-July at all sites.

In accordance with the recommendations of the reviewers of our annual report to ORNL, we are presently determining the most efficient means to protect the seedlings from small mammals. Small mesh fencing or vexar tubes for rodent protection appear to be the best options.

TASK 4: Management and Evaluation of Experimental Plots

This task will begin after planting in August 1985.

Attachment 1

ACCESSIONS TO BE TESTED
AT FIRST THREE ORNL-SPONSORED SITES

I. Species to be tested in 4 complete replicates of 8 tree x 8 tree arrays (256 trees per accession per site. Test for survival and biomass production.)

II. Species to be tested in 3 replicated line plantings, 10 trees per replicate. (Test for survival and first indication growth potential.)

Glendale, Arizona Site

I.
- Acacia minuta
- Acacia nilotica
- Eucalyptus microtheca
- Prosopis alba
- Prosopis chilensis

II.
- Acacia abyssinica
- Acacia pennatula
- Casuarina equisetifolia
- Cupressus arizonica (Low Prov.)
- Cupressus arizonica (High Prov.)
- Dalbergia sissoo
- Leucaena diversifolia x leucocephala
- Leucaena leucocephala
- Pinus eldarica
- Prosopis alba clone B_2 V_{50}
- Quercus virginiana
- Ziziphus spina-cristi

Premont, Texas Site

I.
- Leucaena diversifolia x leucocephala
- Leucaena leucocephala
- Pinus eldarica
- Prosopis alba
- Quercus virginiana

II.
- Acacia abyssinica
- Acacia minuta
- Acacia nilotica
- Acacia pennatula
- Casuarina equisetifolia
- Dalbergia sissoo
- Prosopis alba clone B_2 V_{50}
- Prosopis chilensis

Alcalde, New Mexico Site

I.* Atriplex canescens (Utah Prov.)
Cupressus arizonica (High Prov.)
Cupressus arizonica (Low Prov.)
Elaeagnus angustifolia
Gleditsia triacanthos
Robinia pseudoacacia

II. Atriplex canescens (Var. Prov.)
Ailanthus altissima
Chrysothamnus nauseosus
Fraxinus velutina

---

* Only five accessions will be selected from this list depending on doubtful germination of Gleditsia. In addition, some species may be dropped from the line planting list depending on germination success or failure.

ACCESSIONS TO BE TESTED AT FIRST FOUR NMERDI-SPONSORED SITES

I. Species to be tested in 4 replicated blocks (test for survival and biomass production).

II. Species to be tested in replicated line plantings (test for survival and indication of growth potential).

Las Cruces, New Mexico Site

I.
- Atriplex canescens (Utah Prov.)
- Cupressus arizonica (High Prov.)
- Cupressus arizonica (Low Prov.)
- Pinus eldarica
- Prosopis alba

II.
- Atriplex canescens (Var. Prov.)
- Acacia abyssinica
- Acacia minuta
- Acacia nilotica
- Acacia pennatula
- Eucalyptus microtheca
- Leucaena diversifolia x leucocephala
- Leucaena leucocephala
- Prosopis alba clone B_2 V_{50}
- Prosopis chilensis
- Quercus virginiana
- Sambucus mexicana
- Sapium sebiferum

Los Lunas, New Mexico Site

I.
- Atriplex canescens (Utah Prov.)
- Cucurbita foetidissima
- Pinus eldarica

II.
- Ailanthus altissima
- Chrysothamnus nauseosus
- Gleditsia triacanthos
- Prosopis alba
- Prosopis alba clone B_2 V_{50}
- Prosopis chilensis
- Robinia pseudoacacia

Ghost Ranch, New Mexico Site

I.
- Elaeagnus angustifolia
- Robinia pseudoacacia
- Ulmus pumila

II.
- Ailanthus altissima
- Atriplex canescens (Utah Prov.)
- Atriplex canescens (Var. Prov.)
- Chrysothamnus nauseosus
- Gleditsia triacanthos

Armendaris, New Mexico Site

I. Atriplex canescens
(Utah Prov.)
Cucurbita foetidissima
Pinus eldarica

II. Casuarina equisetifolia
Cupressus arizonica
(High Prov.)
Cupressus arizonica
(Low Prov.)
Prosopis alba
Prosopis alba clone B_2 V_{50}
Prosopis chilensis

Attachment 2

WHAT NURSERY PROPAGATES WHICH SPECIES

Nursery	Species	Number Needed			Production Goal
NMSU	Acacia abyssinica	90	x 2.5	=	225
	Acacia pennatula	30			75
	Casuarina equisetifolia	90			225
	Cupressus arizonica (Low)	572			1,430
	Leucaena diversifolia x leucocephala	316			790
	Leucaena leucocephala	316			790
	Pinus eldarica	1,054			2,635
	Sapium sebiferum	30			75
	Sambucus mexicana	30			75
Plants of the Southwest	Ailanthus altissima	90			225
	Atriplex canescens (Var. Prov.)	630			1,575
	Chrysothamnus nauseosus	90			225
	Cupressus arizonica (High)	572			1,430
	Elaeagnus angustifolia	512			1,280
	Fraxinus velutina	30			75
	Gleditsia triacanthos	316			790
	Robinia pseudoacacia	542			1,355
Mountain States	Acacia minuta	316			790
	Acacia nilotica	316			790
	Dalbergia sissoo	60			150
	Eucalyptus microtheca	286			715
	Prosopis alba	828			2,070
	Prosopis chilensis	376			940
	Ziziphus spina-cristi	30			75
Storm Nursery	Quercus virginiana	316			790
Native Plants Inc.	Atriplex canescens (Utah Prov.)	1,054			2,635
Texas A&I	Prosopis alba clone B_2 V_{50}	150			375
NMSU-NMSERI	Cucurbita foetidissima -- Seed (direct seeded Herbaceous Perennial)	512			1,280

Attachment 3

ORNL SUBCONTRACT NO. 19X-89640C
"SPECIES SCREENING AND GENETIC SELECTION AT SITES IN ARIZONA, NEW MEXICO AND TEXAS"
LIST OF PUBLICATIONS

1. David C. Deardorff, "Site Descriptions -- Species Trial Sites -- Arizona, New Mexico, Texas," undated (approved August 1984).

2. --, "Species Screening and Genetic Selection of Southwestern U.S. Woody Plants for Biomass Production -- First Year Operations Manual," August 1984 and subsequent revisions.

EUCALYPTUS FOR BIOMASS PRODUCTION IN FLORIDA

Quarterly Report for the Period

March 1 to May 31, 1985

Donald L. Rockwood

June 1, 1985

Report prepared by

Donald L. Rockwood, Principal Investigator
C. W. Comer, Project Coordinator
D. R. Dippon

School of Forest Resources and Conservation
University of Florida
118 Newins-Ziegler Hall
Gainesville, Florida 32611

under

Subcontract 19X-09050C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

1. Description of New Research Activities and Research Results.

Task A. Selection in the Current Base Population of Eucalyptus grandis.

The effect of inbreeding on predicted gains for GPOP77 was studied and the inbreeding coefficients for the progenies of all possible matings among 50 families were calculated.

Task B. Screening of Eucalyptus Species for Frost Hardiness.

Survival measurements at age seven months of progenies of four species of Eucalyptus planted in Gainesville (Alachua County) were collected in April 1985.

Task C. Eucalyptus Species in Coppice Stands.

Quarterly measurements for Study 16 (Belle Glade) were made in February and March 1985. Data analyses are scheduled to be completed in the fourth quarter (June - August) 1985.

Seed was sown in April 1985 to produce plants for Studies 35 (Belle Glade) and 36 (LaBelle) for summer plantings. Arrangements for site preparation for Study 36 were made in May 1985. Site preparation for Study 35 will be done in July 1985.

Coppice growth for fertilizer tests in Study 7 (LaBelle) was removed in April 1985. Foliage and soil samples were collected from Study 7 fertilizer plots. Analyses of these samples will be completed in the fourth quarter (June - August) 1985.

Task D. Introduction of New Eucalyptus Sources.

Survival and growth measurements were made in February 1985.

Task E. Selection of Elite Eucalypts.

Fourty-six (46) plus-trees were selected from GPOP77 for scion and pollen collection in the fall of 1985.

Seed of Eucalyptus grandis was sown in April 1985 to produce seedlings to be used as rootstock for grafting.

Task F. Clonal Propagation and Testing of Eucalypts.

Growth and survival measurements for the Palmdale (Study GR1) were completed in May 1985.

Seed was sown in April 1985 to produce seedlings for planting at Bowling Green (Study MR7) in July 1985.

Task G. Economic Analyses of Eucalypts' Biomass Plantations.

Growth function estimations and simulation analysis were initiated using sand pine and slash pine data.

Task H. Systems Analysis for Biomass Production.

Model reevaluation was continued throughout the quarter (March - May 1985).

Task I. Pilot-scale Planting of Eucalyptus grandis.

No activities scheduled.

Task J. Fuel Characterization of Eucalyptus grandis.

Samples were prepared and inventoried in April 1985 for analysis.

Task K. Development of Other Species.

Analyses of slash pine data were completed in May 1985.

Soil and foliage samples for sand pine fertilizer tests at Study 13 (Chipola) and for slash pine fertilizer tests at Studies 10 (Alachua County) and 11 (Trenton) were collected. Analyses are scheduled to be completed by August 1985.

II. Technical Information Dissemination.

1. Presentations

Dippon, D. R. 03/12-14/85. Cost sensitivity analysis of Eucalyptus grandis. 3rd Southern Biomass Energy Research Conference, Gainesville, FL.

Reddy, K. V. 03/12-14/85. Genetic improvement of Eucalyptus grandis for biomass production in Florida. 3rd Southern Biomass Energy Research Conference, Gainesville, FL.

Reddy, K. V. 05/21-23/85. Effect of inbreeding on estimates of genetic parameters in Eucalyptus grandis. 18th Southern Forest Tree Improvement Conference, Gulfport, MS.

Reighard, G. L. 05/21-23/85. Genetic and cultural factors affecting growth performance of slash pine. 18th Southern Forest Tree Improvement Conference, Gulfport, MS.

Rockwood, D. L. 1985. 03/12-14/85. Development of woody biomass cultural systems in Florida. 3rd Southern Biomass Energy Research Conference, Gainesville, FL.

2. Visitors

Rockwood, D. L. - Woody biomass research in Florida.

03/13/85. Seven scientists from Biomass Energy Research Conference to review biomass research projects.

III. Publications.

*Flinchum, D. M., R. E. Goddard, H. R. Kok, P. A. Layton, C. H. McRae, G. L. Powell, and D. L. Rockwood. 1985. Coop. For. Gen. Res. Program 27th Prog. Rept., University of Florida, Sch. For. Res. and Conservation Res. Rept. No. 36. 20 p.

Dippon, D. R., D. L. Rockwood, and C. W. Comer. 1985. Cost sensitivity analysis of Eucalyptus grandis. Proc. 3rd South. Biomass Energy Res. Conf., Gainesville, FL. May 12-14, 1985. (accepted for publication).

Reddy, K. V., D. L. Rockwood, C. W. Comer, and G. F. Meskimen. 1985. Genetic improvement of Eucalyptus grandis for biomass production in Florida. Proc. 3rd South. Biomass Energy Res. Conf., Gainesville, FL. March 12-14, 1985. (accepted for publication).

Reddy, K. V., D. L. Rockwood, C. W. Comer, and G. F. Meskimen. 1985. Effect of inbreeding on estimates of genetic parameters in Eucalyptus grandis. Proc. 18th S. For. Tree. Imp. Conf., Gulfport, MS. May 21-23, 1985. (accepted for publication).

Reighard, G. L., D. L. Rockwood, and C. W. Comer. 1985. Genetic and cultural factors affecting growth performance of slash pine. Proc. 18th S. For. Tree Imp. Conf., Gulfport, MS. May 21-23, 1985. (accepted for publication).

*Rockwood, D. L. 1984. Genetic improvement potential for biomass quality and quantity. Biomass 6:37-45.

Rockwood, D. L. 1985. N.F.T. Highlights: Casuarina equisetifolia. Nitrogen Fixing Tree Assoc., Waimanalo, HW. (accepted for publication).

Rockwood, D. L., C. W. Comer, D. R. Dippon, and J. B. Huffman. 1985. Woody biomass production options for Florida. Florida Agr. Exp. Sta. Tech. Bull. (in press).

*(3 copies enclosed)

STUDIES ON THE TISSUE CULTURE OF HARDWOOD

Quarterly Report for the Period

March 1 to May 31, 1985

Harry E. Sommer and Hazel Wetzstein

June 1, 1985

Report prepared by

Harry E. Sommer and Hazel Wetzstein
School of Forest Resources
University of Georgia
Athens, Georgia 30602

under

Subcontract 19B-07860C-X02

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

1 b)

Protoplast cultures of black locust have been taken from the point of isolation, through cell wall formation and 1 or 2 cell divisions.

1 c) Stress and Culture Medium

In an experiment to check the interaction of proline concentration and agar concentration on the % hypocotyls producing buds and number of buds it was found in the absence of proline the number of buds produced and % producing buds was significantly greater at the 0.5% level on 0.5, and 1.0% agar then when agar was absent. However there was no significant difference between the results on 0.5 and 1.0% agar. If proline was present, no buds were produced.

In additional treatments based on 100 hypocotyl sections instead of 20, additional results of interest were obtained. Using 8 ml of medium petrie dishes were less productive than culture tubes at the 5% significance level. In culture tubes 8 ml and 20 ml were equivalent in productivity at the 5% significance level. The addition of 25 m Másparagine, 25 m M proline or 25 m M NH_4Cl to the media decrease próductiveness significant at the 1% level. The addition of 80 mg/1 adenine sulphate or 0.02 mg/1 ABA did not change the % of hypocotyl sections yielding buds (at 5% significance), but ABA did increase the average number of buds per hypocotyl at the 10% significance level.

2 a)

The following plantlets have been through rare in the hardening off chamber:

213 pines
683 sweet gum
26 yellow poplar

3 a)

From this spring's collection of post dormant buds, those from a 5 year old seedling have produced the greatest number of survivors with growing shoots. Multiplication from the axillary buds may be possible.

4 a)

The non-bud producing clumps of cells that were on modified Carlson's liquid medium have been transferred back to their normal bud proliferation medium with promising results. Many are now producing buds and shoots.

4 b)

Adventitious shoots were placed in Jiffy 7 plugs and Oasis blocks to attempt rooting *in vivo*. Within 48 hours all the shoots in Jiffy 7 plugs were dead while the majority of those in Oasis blocks were alive. After 1 month, 3 of those in Oasis blocks were alive and rooted.

4 c)

Evaluations of medium matrix on rooting and growth of Liquidambar shoots explants are continuing. Shoots placed on agar or liquid medium are being evaluated. Data for up to 6 weeks have been taken for leaf water potentials, osmotic potentials, and nutrient uptake. Histological preparations for light microscopy in paraffin, scanning electron microscopy, and transmission electron microscopy have been made to evaluate root initiation and development. Preliminary results to-date show greater root initiation and development in liquid versus agar cultures. Higher leaf water potential values are evidenced in agar culture, suggesting water relation factors may be influencing *in vitro* development.

BREEDING *ALNUS* FOR INTENSIVE CULTURE OF BIOMASS FOR ENERGY

Quarterly Report for the Period

March 1 to May 31, 1985

Richard B. Hall

June 1, 1985

Report prepared by

Richard B. Hall and Roger D. Hanna
Department of Forestry
Iowa State University
Ames, Iowa 50011

under

Subcontract 19X-43391C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

Progress on 1984-85 Work Plan

In the past three months we have completed our second year of controlled hybridization with selected parents and completed our estimates of one-year coppice yields. Results-to-date indicate that over 7.2 metric tons/ha/yr. could be produced by coppice of improved alder selections. At the same time large amounts of nitrogen can be made available in the soil for the growth of other species.

Interest in wood biomass for energy continues to mount in Iowa. A meeting was held with the Iowa Corrections Department which is cosidering converting one or more penitentiary sites to wood energy. On a much larger scale, a day long consultation and planning session was held with landowners and government agencies in southwest Iowa to begin developing strategies for growing and marketing wood fuels. Two papers were presented at the Iowa Academy of Sciences meeting concerning growth and yield of alder under different conditions.

Accomplishments this quarter and plans for the remaining work are listed categorically by work plan tasks/subtasks as follows:

Task 1. Breeding Program for Alder Species

Goal: Use the most promising selections available to breed for improved growth rate, climatic adaptability, and resistance to Phomopsis canker. With the aid of cooperators, test these progeny under a variety of site conditions.

Subtask 1a) Plant pilot-scale progeny test in June 1984 and establish guidelines for establishment of the full-scale progeny test.

This activity is complete, except for the final publication of an M.S. thesis and a short journal article based on this work. The two test sites are being maintained and will be used for growth measurements and budset observations this fall. Overwinter survival appears to be good.

Subtask 1b) Produce second cycle of crossings using selected parents in February - March 1985.

This activity is complete. We will continue to monitor strobili development over the summer and seed will be collected this fall under our new work plan.

Final numbers for our 1985 breeding effort were: 489 grafts on 180 stock plants allowing for 1516 pollination bags to be put on and 3979 strobili to be pollinated.

Table 1 indicates the crosses we intended to make and Table 2 summarizes the number of strobili actually pollinated/cross.

A comparison of Tables 1 and 2 emphasizes that difficulties are still being encountered in making all the desired crosses. Several trees chosen to be used as males were difficult or impossible to get pollen from this season. In spite of a number of experiments we ran this year, we still do not have the answer to producing pollen at will. Until these problems are solved it

will be necessary to start with a larger number of candidate males to achieve the number of actual males desired. Problems were also encountered again with graft failure due to dessication in the greenhouse environment. We think we have solved this problem by lowering temperatures, raising humidity, and, if necessary, applying an antitranspirent to the scions. Unfortunately, these solutions weren't arrived at this year until the scion material of some selections was depleted.

Table 1. 1985 mating design for the breeding project. Code numbers for male and female trees represent selections made in Illinois, Iowa and Wisconsin plantations. See Tables 2-4 of the Annual Report for more details on the parents. Within the tables X's indicate the crosses to be made.

		481 N13	221 N14	AI N19	221 I06	172 I07	962 I08	638 I30	962 S03	962 S04	118 S18
118	N05	X	X	X	X	X	X				X
AI	N12	X	X	X	X	X	X	X	X	X	X
481	N13		X	X	X	X	X				X
221	N14	X		X	X	X	X				X
521	N16	X	X	X	X	X	X				X
AI	N19	X	X		X	X	X	X	X	X	X
118	I05		X	X	X	X	X	X	X	X	X
221	I06		X	X		X	X	X	X	X	X
172	I07		X	X	X		X	X	X	X	X
962	I08		X	X	X	X		X	X	X	X
431	I25		X	X	X	X	X	X	X	X	X
511	I27		X	X	X	X	X	X	X	X	X
638	I30		X	X	X	X	X		X	X	X
962	S03		X	X	X		X	X		X	X
962	S04		X	X	X		X	X	X		X
962	S06		X	X	X		X	X	X	X	X
614	S07		X	X	X		X	X	X	X	X
614	S10		X	X	X		X	X	X	X	X
118	S18		X	X	X	X	X	X	X	X	

Table 2. Number of strobili pollinated per cross.

		481 N13	221 N14	AI N19	221 I06	172 I07	962 I08	638 I30	962 S03	962 S04	118 S18
118	N05	16	13	0	0	22	28	15			30
AI	N12	30	14	57	0	42	0	43	0	14	30
481	N13		17	0	0	0	21				0
221	N14	62		33	47	41	42				74
521	N16	19	13	0	13	19	0				16
AI	N19	54	50		0	57	51	49	0	51	52
118	I05	44	46	18	0	32	31	30	0	20	45
221	I06	10	104	0	0	40	25	31	0	0	0
172	I07	95	133	42	0		40	121	0	0	69
962	I08	14	71	0	0	49		34	0	18	0
431	I25	44	56	15	0	51	18	44	0	0	11
511	I27	59	68	28	16	32	29	55	0	15	20
638	I30	142	144	27	0	123	0		0	0	41
962	S03		57	0	0		56	62		77	63
962	S04		28	0	0		26	9	0		13
962	S06		0	0	0		0	0	0	16	9
614	S07		0	0	0		0	0	0	0	7
614	S10		0	0	0		0	0	0	0	26
118	S18	22	24	0	0	0	21	0	0	14	

As an alternative approach we did do some pollinations on trees in the field and successful grafts from previous years. The relative success of these pollinations will be compared to our grafting work this fall and appropriate adjustments will be made in 1986 breeding plans.

Subtask 1c) Harvest seed from first set of controlled crossings performed in 1983-84 using selected parents.

This activity is essentially complete as reported in the Annual Report. We are still waiting to evaluate the offspring from two interspecies crosses. We have 11 seedlings of two A. glutinosa x A. Rubra crosses and at least 15 seedlings of a putative A. glutinosa x A. incana cross. At this stage the seedlings only have a few true leaves so we have not tried yet to assess their hybrid characteristics to verify their makeup.

Subtask 1d) Start first full-scale progeny test in several field locations in May - June 1985.

Most of the detailed plans for completing this activity were explained in the annual report. Seedling growth has been slower than normal so the projected planting date for the study is now mid-June. One seedlot, the 1983 cross of 592-1-8 x 843-1-7, will have to be dropped from the study due to insufficient seedling survival. The remaining 11 entries (see Table 8 of Annual Report) will be planted in 7 replicated blocks at each of 4 sites.

Task 2. Analysis of Variation in Energy Traits

Goal: Use an existing provenance test of *Alnus glutinosa* to determine what traits contribute most to genetic variation in biomass energy content.

Subtask 2a) Continue collecting data on first year coppice growth over the 1984 growing season.

A system for estimating total coppice dry weight per stump was developed and applied to a sampling of our one-year-old coppice regrowth. To use the technique each sprout clump is catagorized into dominant, intermediate, and suppressed sprouts. The number of sprouts in each clump is tallied and the height and diameter are measured on the tallest sprout and an average (by inspection) intermediate sprout. Dryweight is then estimated by the equation:

$$DRY\ WT = 0.35 + (0.0014)(QD) + (0.0021)(QI) + (0.012)(SNO)$$

Where:

DRYWT = Total dryweight of sprout clump in kg.

$QD = (DNO)(DHT)(DDIA)^2$

$QI = (INO)(IHT)(IDIA)^2$

DNO, INO, and SNO = The numbers of dominant, intermediate and suppressed sprouts in the clump respectively.

DHT and IHT = Height in cm. of the tallest sprout and an average intermediate sprout.

DDIA and IDIA = Diameter at 1/2 height of the tallest sprout and the average intermediate sprout in inches.

This equation is based on actual measurements of 39 trees and has an r^2 of 0.79.

Using the equation to estimate dryweight production in this stand we estimated that the average production of the 10 best seed sources in the original provenance test was 5.8 metric tons/ha. Likewise, the production of the best individual trees could be over 7.2 metric tons/ha. in one year of coppice regrowth. This contrasts sharply with the first 5 years of seedling growth when yearly production averaged only 3.4 metric tons/ha.

Subtask 2b) Complete measurements of volume on best trees in Wisconsin and Illinois plantations by December 1984.

This activity is completed.

Subtask 2c) Determine caloric values and wood quality parameters for harvested trees. Complete by September 1984.

We are still moving slowly, but steadily along on this activity. We have now completed bomb calorimetry runs on all 736 samples that we had available to analyze. Table 3 is a revision of Table 9 in the annual report that reflects the new data. Detailed statistical analysis of this data and its biological interpretation have not yet been completed.

Table 3. Average caloric values of trees harvested from the Rhodes, IA provenance test and an adjacent species mixture trial in 1984.

Species/Provenance Group	----Calories/gm dryweight---- Stemwood	Branchwood
Alder provenances [a]		
100-British Isles	4715 (58)[b]	4874 (60)
200-Scandinavia	4745 (63)	4841 (66)
400-Germany	4781 (33)	4881 (32)
500-Poland, Czech., Hungary	4801 (59)	4920 (64)
600-France, Neth., Switz.	4727 (37)	4886 (38)
700-Yugoslavia, Bulgaria	4718 (37)	4877 (43)
800-Black & Caspian Sea, Asia Minor	4714 (16)	4781 (19)
900-Spain, Italy, Greece	4778 (44)	4891 (43)
Populus alba x *P. grandidentata*	4620 (6)	----
Populus x *euramericana*	4569 (7)	----
Acer saccharinum	4606 (6)	----
Plantanus occidentalis	4598 (5)	

[a] For further details on provenance numbering system see Table 1 of the Project Renewal Proposal.

[b] Numbers in parantheses are the number of samples on which the mean is based.

Task 3. Improvement of Selection Base for Alder

Goal: Establish large (greater than 1000 trees) population plantings of the most promising sources of *Alnus* germplasm on a variety of sites to serve as the basis for future cycles of selection and breeding.

Subtask 3a) Grow first set of selected large populations in nursery over the 1984 growing season.

As explained in the Annual Report we are a year behind on this activity. This week we are sowing our first large populations in the nursery. Eleven *A. glutinosa* and 23 *A. rubra* seedlots are being sown.

Task 4 Output of Improved Alder Stock

Goal: Provide the best available seed and clones of Alnus to other researchers for biomass studies and to applied tree growers for large-scale field use.

Subtask 4a) Begin cloning selected trees at Iowa plantation in June 1984 and make available a few limited clones.

This activity is also proceeding more slowly than planned. We do have 3 of our selected trees in tissue culture, 5 more have been established as stock plants in the greenhouse, and the remaining trees will be propagated as rooted cuttings by the end of June.

Subtask 4b) Maintain seed orchard established with selected trees from the Iowa provenance test.

This activity continues to proceed as the trees regain some health from the combined stresses of being moved just prior to a prolonged drought. It now appears that as many as 5 trees may have died and several others died back to ground level. The latter trees were cut and are now resprouting. Several of the trees are in relatively good health and will produce a seed crop this year. Three of the trees were used to duplicate controlled crosses we made in the greenhouse on grafted plants.

Related Research

In the summer of 1984 soil samples were collected in the alder plantation and comparison areas outside of the plantation. Analyses of soil nitrogen content were completed and then checked by duplicate runs through an independent soil testing lab. Figure 1 illustrates the difference in soil nitrogen after 5 years of alder growth on the site. This amounts to over 500 kg/ha/yr. of nitrogen accumulation in association with the biomass energy produced. With other work in progress on a mixture planting we hope to have some recommendations soon on mixture plantings that could take best advantage of alder's nitrogen fixing capacity while having growth compatability between species.

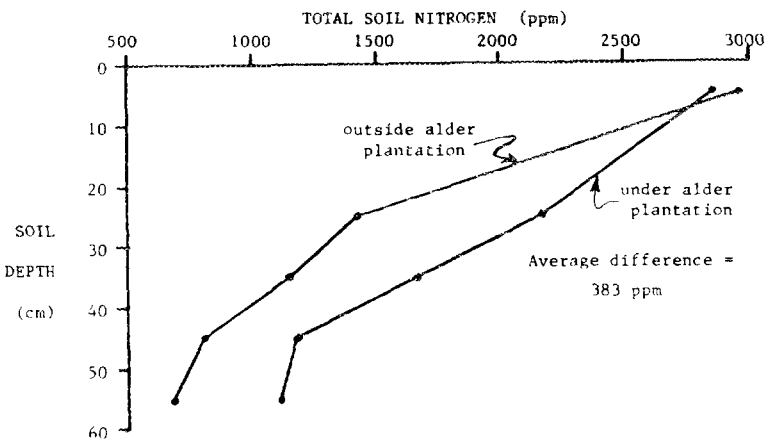


Figure 1. Profile of soil nitrogen content.

Another related research project was conducted under much different conditions and with very different results. In this project alder has been grown in pure plots and in mixture with hybrid aspen on a heavy clay soil on an upland site that was reclaimed after strip-mining for coal. In spite of the fact that the alder put down a very deep root system it frequently suffered drought stress on this site. Survival was poor and no nitrogen-fixing benefits were demonstrated. For this reason we are expanding our testing on upland/droughty sites to find selections that will perform better in such harsh environments.

Technical Information Dissemenation

On April 1, 1985 we met with Iowa Conservation Commission Foresters and Mr. Wayne Siegle of the Iowa Department of Corrections to discuss the possibility of converting one or more of the state penitentiary facilities to wood heat. The state will be doing a feasibility study of converting boilers and supplying biomass from state land. Initially, existing forests would be used, but a large acreage of bottomland on one of the prison farms would be a future candidate for planting to Populus, alder, silver maple, etc. energy plantations. We have offered to supply materials for initial plantation trials.

On May 22 we traveled to Creston, Iowa to meet with representatives of the Soil Conservation Service, Forestry Section of the Iowa Conservation Commission, Multi-County Wood Utilization Committee, and the Southern Iowa Agricultural Boosters. We toured potential planting sites and discussed the necessary steps to make wood biomass farming a practical alternative for southern Iowa. These government and citizen groups are developing markets for wood fuels and establishing research funds to study species, planting sites, yields, etc. Biomass farming is seen as a means of gaining economic returns from the land while protecting soil resources in this hilly, economically depressed portion of the state. We cooperated with the group this year in establishing site/spacing trials with hybrid poplars and silver maple. Alders will be included in these studies as soon as we have sufficient planting stock, probably next spring.

On April 27 we presented two papers at the Iowa Academy of Science meeting in Pella, Iowa. The first presented biomass yield and nitrogen accumulation data from our DOE alder genetics plots. The second delt with an earlier mixture trial with alder on reclaimed strip-mine land. The authors and titles for the papers were as follows:

Hall, R. B. Alder - An Agricultural Alternative.

Schultz, R. C. and R. B. Hall. Growth and Rooting Characteristics of Hybrid Aspen and Alder on a Reclaimed Mine Site.

Abstracts of the papers are enclosed with this report.

GREAT PLAINS ENERGY FOREST

Quarterly Report for the Period

March 1 to May 31, 1985

Wayne A. Geyer

June 1, 1985

Report prepared by

Wayne A. Geyer
and
Michael W. Melichar
Department of Forestry
Call Hall
Kansas State University
Manhattan, Kansas 66506

under

Subcontract 19X-07934C

for
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

GENERAL COMMENTS:

All 17 plantations were measured during the dormant season. Some are nine years old and showing the effects of close spacing with high mortality. Additional spouting studies were established in silver maple, Siberian elm, catalpa, and black locust plantings. A major harvesting demonstration was conducted. Maintenance of all plantings will continue during the 1985 growing season.

TASK: DETERMINE PRODUCTIVITY POTENTIAL

During the last week of March, a major harvesting demonstration was conducted on five acres of "energy forest" plantings at the Sunflower Research Area, east of Lawrence, Kansas. This was a cooperative effort between Kansas State University, the University of Kansas, and Northwest Missouri State University (NWMSU). Harvesting equipment and trucks were provided by NWMSU and chips were transported to their campus boilers.

This case study of harvesting eight-year-old trees planted at 4 X 9 ft. spacing allowed testing of whole-tree harvesting of small broadleaf trees. A Mor-Bell feller-buncher, logger, and Super Beever chipper were used. See attached map for schematic of cutting-study and Figure 1 for equipment break-even logging distances.

Yield in fresh tons/acre was 1.47 times greater for silver maple than for Siberian elm, primarily because the maple was taller. Feller-bunching and chipping was cheaper for maple. Elm was more difficult to handle in the feller-buncher operation because of extreme side branching which clogged the chipper.

Differences between actual yield and estimated yield from non-destructive D^2H tree measurements was less than two percent for silver maple. While these trees were cut at eight years, the Mean Annual Increment (MAI) for growth of maple was still increasing. Originally we estimated 10 years as being the approximate biological period for harvesting at a 4 X 9 ft. spacing.

An additional harvest operation was made at the Tuttle Creek planting site near Manhattan, Kansas. All nine wheels were measured, cut, chipped, and weighed for fresh weight-yield analysis. A weed control study was overlaid on this planting.

TASK: DETERMINE PRODUCTION COSTS

Selected areas in eastern and central Kansas were analyzed with the Oak Ridge Laboratory "Biocut" model. Silvicultural management strategies were essentially the same for all sites and species.

The net present values are shown in Table 1. The optimal management scheme for cottonwood on eastern Kansas sandy soil is seven years at a density of 1400 trees per hectare. An eight-year rotation with 7000 trees per hectare is best for eastern Kansas silty soils. The discounted average cost for energy wood in eastern and central Kansas runs between $1.56 and $1.77 per G.J.

TASK: EVALUATE HERBICIDE EFFECTIVENESS

This task continues to be a cooperative effort with numerous herbicide companies ($2000 annual support) and the KSU Department of Horticulture).

A total of three tree overspraying screening studies were initiated in 1983 and 1984. Additional spraying was conducted in April 1985 on these plots. The effects of individual and combination tank-mixes on weed control and seedling tree growth are being observed. Devrinol (87% weed control) provided better weed control than either Casoron (78%), Enide (69%), or combinations. Second-year tree height was greater with herbicide combinations than herbicides applied alone.

In May a new weed-control coppice study was implemented on the recently harvested Tuttle site (9 wheels--till, no weed control, and Devrinol plus Poast tank-mix).

TASK: DETERMINE COPPICE TECHNIQUES

Six additional coppice studies were initiated this winter. As a result of the Sunflower harvesting operation, two large studies were established on 3 1/2 acres of 8-year-old silver maple and 1 1/2 acres of Siberian elm. The main objective in both studies is to determine the effect of long-row disking versus no weed control treatment on coppice tree growth following logging/skidding. One-or two-year cultivation strategies will be compared to nontreated plots. Fertilizer tests will be overlaid on these sites next winter. These studies will supplement our previous coppice studies with these two species at Sunflower.

Four other studies on catalpa and black locust were initiated to test season of cut and stump height on subsequent coppice growth. Four species--silver maple, Siberian elm, catalpa and black locust--are being tested in this manner. To supplement our January, March, May, and July seasonal cuttings, additional trees will be cut in late August or early September.

PRESENTATIONS/PUBLICATIONS/TOURS/MEETINGS

1. Presentations
   a. W. A. Geyer. March. Biomass gains in coppicing trees for energy crops. 3rd European Community's Energy for Biomass Conference in Venice, Italy. POSTER.
   b. G. Naughton. March. Energy forest establishment and care. Woody Biomass and Energy Opportunities--Meeting (Harvesting Demonstration in Lawrence, Kansas.) TALK.
   c. R. M. Argent. March. Siberian elm: from windbreaks to wood energy. Kansas Academy of Science, Pittsburg, Kansas. TALK.
   d. T. Cable. January. Fuelwood use in Kansas. Annual Kansas Ag. Expt. Sta. Conference in Manhattan, Kansas. POSTER.

2. Publications
   a. Annual and quarterly reports for D.O.E.
   b. R. M. Argent. 1985. Siberian elm: from windbreaks to wood energy. Abstract. Trans. Kansas Acad. Science Vol. 4.

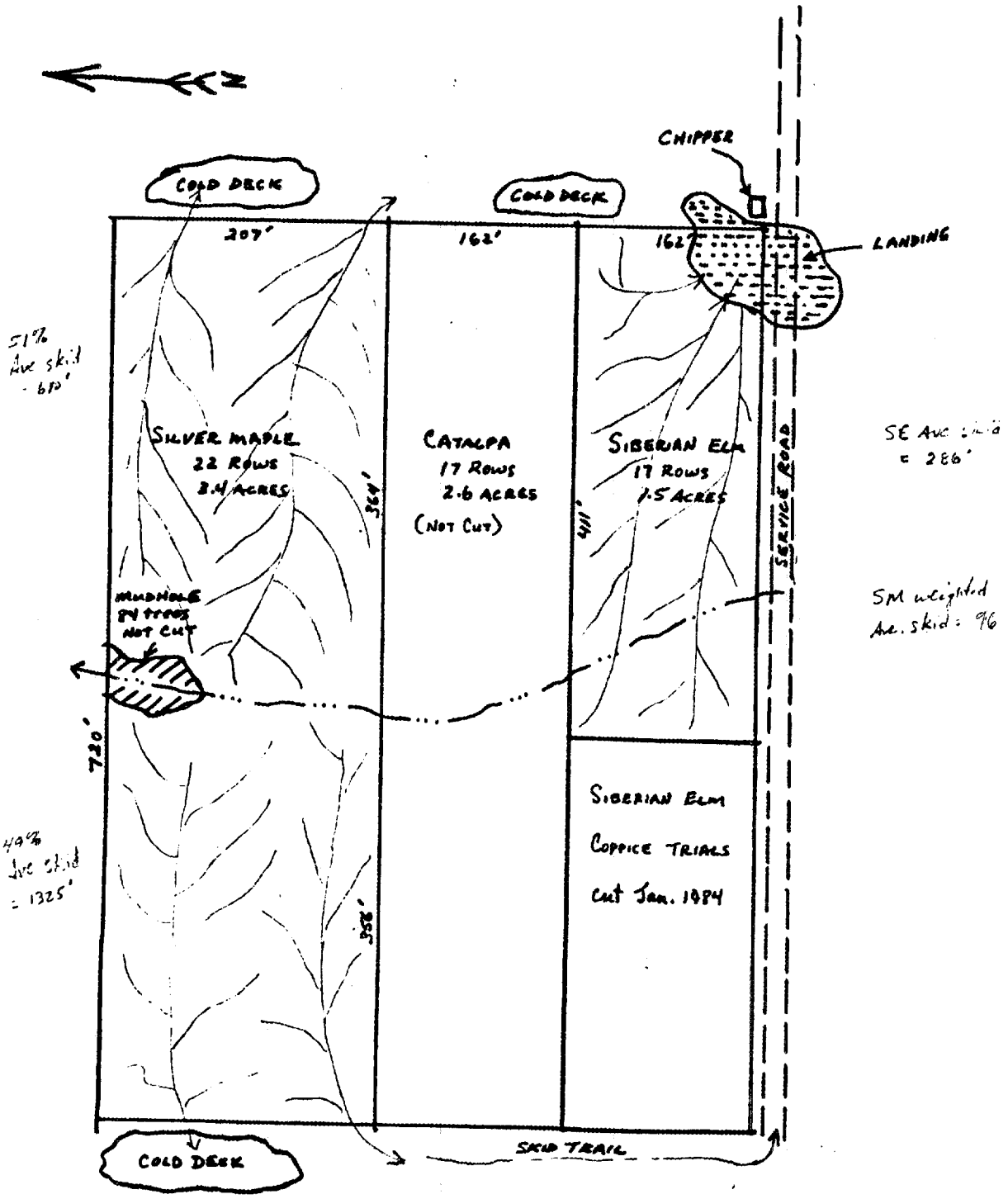
c. W. A. Geyer, G. Naughton and K. D. Lynch. 1985. Climatological variation in energy forest yields in the Central Great Plains of the United States. In Proceedings: 7th Annual Southern Forest Biomass Workshop. June 5-7. Athens, Georgia 121 p.
d. R. M. Argent. 1984. Outside storage effects on fuel potential of wood chip piles. Abstract. Trans. Kan. Acad. Sci. Vol. 3.
e. Topeka Capital Journal Newspaper. April 26, 1985. "Study shows wood fuel can be cheaper than gas."
f. Lawrence World Journal Newspaper. March 30, 1985. "Timberrr! Trees fall in mechanical harvest."
g. Kansas City Times Newspaper. April 2. 1985. "Kansas wins acclaim for timber expertise."
h. Kansas State Collegian Newspaper. May 8, 1985. "Professor explains benefits of using wood chips as energy."
i. Oread. Univ. Kans. Newspaper. April 5, 1985. "Tree harvest yields chips for heating plant."

3. Tours
   a. Forestry State Staff. Harvesting demonstration of five-acre energy forest at Sunflower research planting site at DeSoto, Kansas (Lawrence area).

4. Meetings
   a. W. A. Geyer. March. International Meeting on Biomass 3rd ECC Energy Conference, Venice, Italy.
   b. W. A. Geyer. April. Field tour of coppicing hardwood trees in Italy by State Forest Resource Silviculture Institute of Italy and the University at Florence in Arezzo, Italy.

ENERGY FOREST BLOCK PLANTING
SUNFLOWER RESEARCH CENTER
DESOTO, KANSAS.

G. NAUGHTON
20 MARCH 1985
1" = 100'



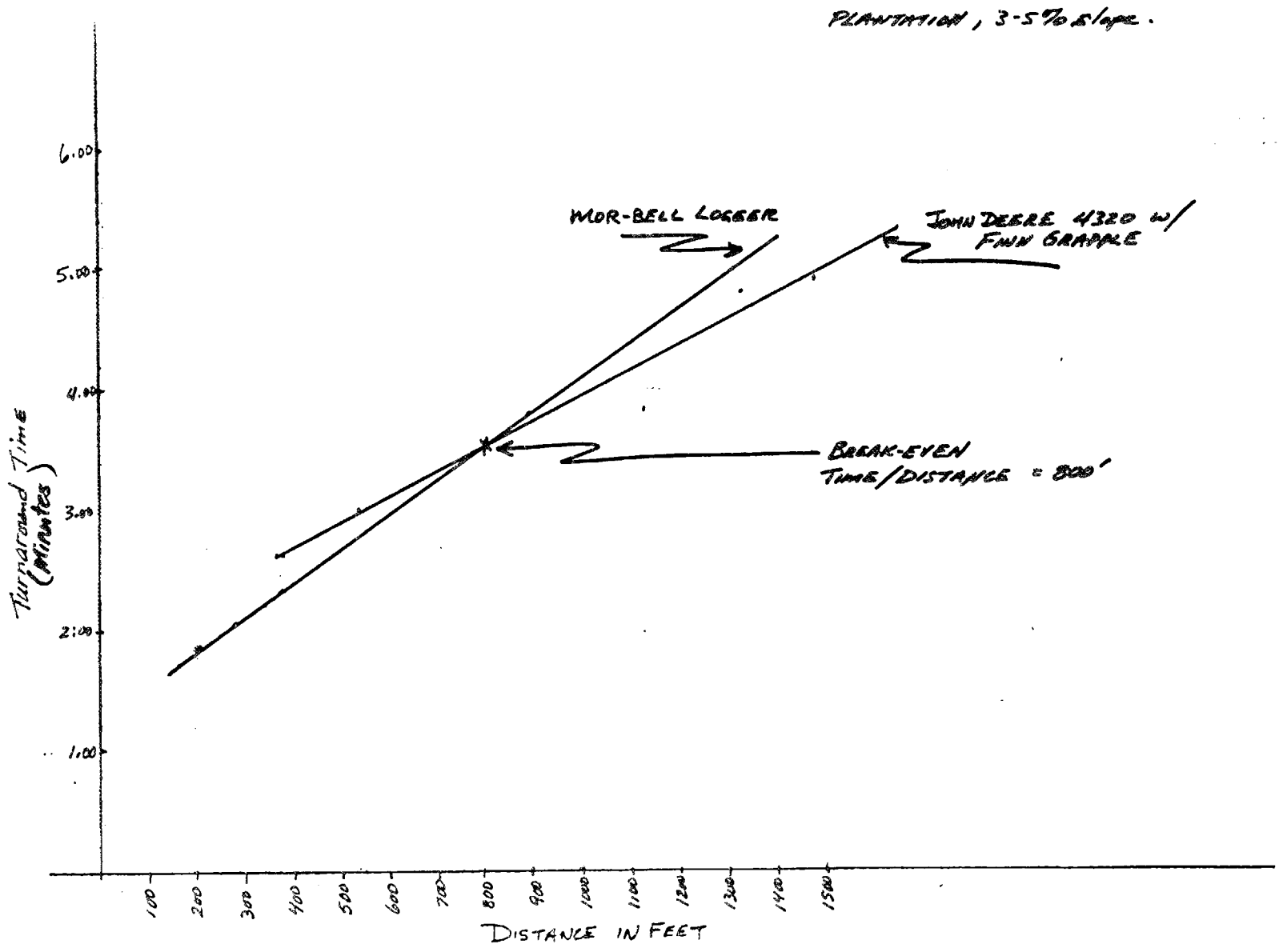

PLANTATION, 3-5% slope.
MOR-BELL LOGGER
JOHN DEERE 4320 w/ FWW GRAPPLE
BREAK-EVEN TIME/DISTANCE = 800'
Turnaround Time (Minutes)
6.00
5.00
4.00
3.00
2:00
1.00
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
DISTANCE IN FEET

Table 8. Great Plains Energy Forest Net Present Value for Alternative Spacings and Rotation Ages

Site/Species Spacing (trees/ha.)	Rotation Age (yrs.) 4	5	6	7	8
			($/ha.)		
Eastern Kansas					
Sandy Soil					
Cottonwood - 1400	- 449	177	553	562	*
- 3200	- 516	- 166	324	*	*
- 7000	*	*	*	*	*
Silty Soil					
Silver Maple - 1400	*	*	- 1152	- 879	- 682
- 3200	*	*	- 1123	- 891	- 613
- 7000	*	*	- 1270	- 740	- 273
Siberian Elm - 1400	*	*	- 1326	- 998	- 793
- 3200	*	*	- 1455	- 957	- 763
- 7000	*	*	- 1388	- 972	- 669
Central Kansas					
Sandy Soil					
Black Locust - 3200	- 273	- 264	*	*	*
Siberian Elm - 3200	- 532	- 22	*	*	*
Silty Soil					
Black Locust - 3200	-1040	- 74	10	*	*

Net present value is calculated at a price of $ 35 per dry tonne with a 0% real escalation rate.

TREE SPECIES AND MANAGEMENT STRATEGIES FOR BIOMASS PRODUCTION IN THE LAKE STATES

Quarterly Report for the Period

March 1 to May 31, 1985

James W. Hanover

June 1, 1985

Report prepared by

Raymond O. Miller and James W. Hanover
Department of Forestry
Michigan State University
East Lansing, Michigan 44824-1222

under

Subcontract 19X-09053C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U. S. Department of Energy
Contract No. DE-AC05-84OR21400

SHORT ROTATION WOODY CROPS PROGRAM
QUARTERLY REPORT

Name: James W. Hanover

Institution: Michigan State University

Project Title: Maximizing woody-biomass production through genetic selection, hybridization, and intensive culture.

Reporting Period: March 1, 1985 to May 31, 1985

Work this quarter was confined to completing the annual report and preparing for and conducting the spring plantings. 31,000 trees were planted in 12 genetic test plantations at four sites across Michigan. This immense undertaking took four weeks of preparation and six weeks of planting; an estimated 2,400 man-hours of labor. The tests established this spring are the culmination of work which began in 1981 and include the most extensive genetic studies of larches and black locust yet assembled anywhere in the world. These plantations will be maintained along with the other test plantings using strip weed control techniques. Preliminary survival and suitability data will be taken in these plantings in the summer of 1986.

The following is a summary of work completed for each task.

Goal I. Biomass Tree Improvement

1. Four plantations of rangewide black locust collections were established, two in southern lower Michigan, one in northern lower Michigan, and one in upper Michigan. Maintenance was begun on the southern-most plantings.

2. Aspens and aspen hybrids at an East Lansing site were scored for sex during the spring flowering period to facilitate breeding in the future. Also, some white poplar and hybrids were added to the breeding archives in Lansing with the establishment of a small planting this spring.

3. No action this quarter on hybrid pine.

4. Four plantations of larch species, provenances, and progeny were established adjacent to the black locust plantings mentioned above. Maintenance has also started on these plantations. Four smaller larch test plantations were also established this spring by project cooperators. The Michigan Department of Natural Resources planted one in northern lower Michigan and another in eastern upper Michigan. Mead Corporation established two plantings in central upper Michigan. These tests will serve to augment information from the four primary

tests installed by MICHCOTIP.

5. No action this quarter on ailanthus. We are still waiting the seed collection from China.

6. No work specified for this year. Two small plantations of European collections of English oak were established in lower Michigan. A single archive planting of honeylocust families with high pod production potential was also established in E. Lansing this spring.

Goal II Biomass Production Strategies

7. No action has been taken on spacing/rotation length tests. This project has been postponed indefinitely due to lack of funding.

8&9. Herbicides have been assembled and trees planted for the herbicide screening trials. Application of chemicals will be conducted within two weeks of this report date.

10. No action this quarter on clearcut species screening trials.

Goal III Commercial Biomass Plantations

11. In the last quarterly report (9-1-84 to 11-31-84) it was stated that "We anticipate that the work proposed...will provide the information needed to make these first large-scale plantations successful." Funding restrictions have eliminated our proposed study of spacing on yield and rotation length and genotype interaction with spacing. This is an absolutely critical element of any plantation prescription. Without these tests, one can only guess as to which spacing should be used. Without spacing/yield functions, a financial assessment of different management systems becomes mostly speculative. Planning for commercial plantations must be delayed as a result of this setback, but we continue to cultivate the interest of biomass fuel users in Michigan.

Presentations:

1. Overview and results of M.S.U. biomass plantation research. Presented by Ray Miller to Soil Conservation Service Annual Regional Meeting, Lansing, March 14, 1985.

2. Briefing on M.S.U. genetics and biomass research. Presented by James Hanover to NC-99 Tree Improvement Committee Meeting, St. Paul, March 12-13, 1985.

3. Briefing on M.S.U. genetics research on biomass species. Presented to Leadership Dynamics Development Group by James Hanover, Grand Rapids, March 29, 1985.

4. Research on tree improvement for short rotation biomass production. Presented by James Hanover to Alpha Zeta class, April 3, 1985.

Publications:

Reighard, G.L., G. Howe, and J.W. Hanover. 1985. Effects of chemical weed control and seedling planting depth on survival and growth of aspen. Tree Planters' Notes, Winter 1985:3-7.

SPECIES SELECTION AND SILVICULTURAL SYSTEMS FOR PRODUCING FUELS FROM WOODY BIOMASS IN THE SOUTHEASTERN UNITED STATES

Quarterly Report for the Period

March 1 to May 31, 1985

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

June 1, 1985

Report prepared by

D. J. Frederick
North Carolina State University
School of Forest Resources
Hardwood Research Cooperative
Raleigh, North Carolina 27650

under

Subcontract 19X-090543

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-840R21400

Task 1: Evaluating different silvicultural systems for short-rotation woody crops production and determining seedling and coppice production under variable plantation conditions

Current work in plantations in North Carolina, Georgia and Alabama includes routine maintenance and protection. Sampling is planned for fall, 1985 and winter, 1986. Currently, Scott Torreano, an M. S. graduate student, is summarizing all biomass yield, nutrient and energy data for all plantations. These data will be used for his thesis and for journal publication in the near future.

Task 2: Harvesting semioperational and operational energy plantations and determining yields, costs and efficiency

During the past quarter a final report was written and submitted to Oak Ridge on "Short-Rotation Biomass Harvesting System Evaluation." This report summarized our testing of a prototype continuous feller-buncher used for harvesting a 3-year-old sycamore energy plantation in Alabama. The machine was manufactured by Hyd-Mech Engineering, Ltd. of Woodstock, Ontario. Development was funded by the National Research Council of Canada. Coordination of the harvesting trials was arranged through Scott Paper Company, Hyd-Mech Engineering, U. S. Forest Service, Tennessee Valley Authority, and N. C. State University.

The trials included felling, bunching, skidding, chipping and hauling a 2-ha plantation. Costs and efficiency of each operation were computed and all operations were videotaped. A stump damage assessment was made for the felling and skidding functions.

The Hyd-Mech feller-buncher proved to have much potential for harvesting this size plantation which averaged 7 to 12 cm basal diameter and 7 m tall. Within-row spacing averaged 1.75 m. Production was greatly improved over alternative conventional methods and was better than last year's trials. The machine could bundle 3 to 10 trees at a time and lay them in piles, which facilitated skidding with grapple skidders. Two skidders were tested, a small Kubota 295 DL and a large Cat 518. There was a significant difference between the skidders in production rate but little difference in cost of the systems. However, several small tractors would be needed to keep a harvesting system balanced.

The feller-buncher could cut 850 trees/hour (including delays) or over 19 green tonnes/hour. Closer spacing of trees within rows would not allow the felling-bunching sequence to proceed without the machine slowing down. Therefore, this machine is best adapted to within-row spacing of about 2 m.

Several combinations of skidders, feller-bunchers and chippers were evaluated in the cost analyses. Costs for chips delivered roadside ranged from $9 to $10.50/green tonne with the Kubota tractors and a small chipper, and the Cat skidders and a large chipper, respectively. Delivery costs to the mill would be extra but still

totaled less than the current delivered price for green chips from natural stands. Increasing plantation growth rates and better machine matching to tree size should further improve the economics in future years.

A survey of stump damage showed little damage from the feller-buncher when it was operating properly. Most damage was by the large Cat skidder, but even this was minor.

The total biomass removed from the site was weighed directly and also estimated, using several techniques, and compared to the actual value. The actual value was 41.8 green tonnes/ha. This compared with 41.4 tonnes/ha, based on a 25-tree preharvest sample, and 48.0 tonnes/ha, based on a mean tree estimate. Currently other methods for estimating plantation biomass are being tested which could be easily used.

Task 3: Planting an operational-size energy plantation using optimal species, spacing and silvicultural systems

We are currently in the planning stages of this task and will be looking at sites during the summer and fall, 1985. Planting will be done during the winter, 1986.

Task 4: Installing detailed coppicing studies in several biomass plantations to better understand the dynamics of this regeneration method and provide recommendations to maximize yields

Results with sycamore indicate that on poorer sites, dormant season harvests result in coppice growth that is more productive than coppice originating from stumps cut during the previous growing season. Maximizing coppice productivity would therefore require dormant season harvesting. The demand for biomass for energy will be on a year-round basis. Therefore maintenance of coppice productivity harvested on a year-round basis will be critical. We have designed a study that will test harvesting during the dormant season with and without fertilization. Another study will test the effects of competition control on coppice development in various age class stands. Potential stands for both studies are being examined this summer, with planned installation during fall, 1985 or winter, 1986.

PUBLICATIONS AND PRESENTATIONS

Frederick, D. J., B. J. Stokes and D. T. Curtin. 1985. Field trials of a Canadian biomass harvester. Paper to be presented at the Seventh Ann. So. For. Biomass Workshop, Gainesville, Florida. June 11-14. 14 pp.

Megalos, M. A., D. J. Frederick, A. Clark, III and D. R. Phillips. 1985. Biomass and energy yields of Piedmont hardwoods. Proc., Third EC Conf., Energy from Biomass, Venice, Italy. PI/009.

North Carolina State University. 1985. Hardwood Research Cooperative Annual Report. 75 pp.

Stokes, B. J., D. J. Frederick and D. T. Curtin. 1985. Short-rotation biomass harvesting system evaluation. Final Report. Unpub. 43 pp.

Torreano, S. J. and D. J. Frederick. 1985. A comparison of coppice and seedling biomass production with time and spacing on two sites in North Carolina. Paper presented at the Third So. Biomass Energy Res. Conf., Univ. of Florida, Gainesville. March, 1985.

NET ENERGY AND ECONOMIC ANALYSES FOR PRODUCING POPULUS HYBRID UNDER FOUR MANAGEMENT STRATEGIES

Quarterly Report for the Period

March 1 to May 31, 1985

Paul R. Blankenhorn
Todd W. Bowersox
Charles H. Strauss

June 1, 1985

Report prepared by

Paul R. Blankenhorn, Todd W. Bowersox, and Charles H. Strauss
School of Forest Resources
Ferguson Building
The Pennsylvania State University
University Park, Pennsylvania 16802

under

Subcontract 19X-07928C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

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 liner 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 framework 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.

Current Quarter Activity

The major effort this past quarter has been the completion of the first rotation final report. The coppice growth and five year old production data have been obtained but have not been completely analyzed. These data will be reported in the next quarterly report.

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 consists of four treatment units (0.05 ha each for control, irrigation, fertilization, and fertilization/irrigation). Populus hybrid NE-388 cuttings have been planted in rows 0.8 meters apart and 0.6 meters between trees in a row for a $0.48m^2$ of growing space per tree. In each treatment unit, trees have been designated for annual destructive sampling and continuous inventory over a four year period. This task has been completed.

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. The plantations are fully operational. Records are

being maintained on the amount of water, fertilizer, herbicides, etc., added per treatment unit. These data will be incorporated into the linear programming model in Task 3.

Current Quarterly Activity

Trees planted in 1980 completed their first rotation in 1983, and were harvested. The first rotation treatment of control, irrigation, fertilization and fertilization/irrigation were continued for the first growing season of the second rotation.

The one year coppice growth of the 1980 planted and 1983 harvested trees has been measured and is being analyzed. Frequency of stump sprouting, growth and yield values will be reported when the analyses are completed. Second rotation yield values for wood, bark plus branches and total tree will be based on the one year old equations developed for the first rotation.

Trees planted in 1981 completed their first rotation in 1984. The growth and yield values for these trees have been combined with the values for the 1980 planted trees and have been included in the annual report (March 1985).

One destructive sample plot per each site-replication-treatment combination was permitted to grow for five years. The 1980 planted trees completed the fifth year in 1984. The 1981 planted trees will complete their fifth year in 1985.

Preliminary estimates of total tree yield for the five year old 1980 planted trees are 3.6, 3.9, 4.9 and 5.1 ODkg/m^2 for the control, irrigation, fertilization and fertilization/irrigation treatments, respectively. These estimates are averaged over both plantation sites. For each site-replication-treatment combination, each destructive sample plot (maximum of 20 measurement trees per plot) had the same border as the continuous inventory plots (maximum of 272 measurement trees per plot). However, five year old estimates derived from destructive sample plot measurements must be carefully evaluated since these values are derived from a much smaller data base than the continuous inventory four year old values.

Second rotation fertilization requirements (N, P, K, Ca and Mg) for maintaining non-limited nutrient conditions have been included in the annual report (March 1985). All nutrients for the 1985 growing season (first year coppice for the 1981 planted and second year coppice for the 1980 planted trees) have been applied.

Statistical analysis of the values for specific gravity, moisture content, heat of combustion, ash content, lignin content, extractive content, holocellulose content and alpha-cellulose content have been completed for the first rotation by management strategy and site. The data have been incorporated in the first rotation final report.

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 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.

Current Quarter Activity

With the securance of 4 year yield data from the Spruce Creek research biomass plantations, final estimates were developed on the financial and energy production costs per oven dry tonne. An accounting structure was then constructed to enumerate the functional steps involved in each of the sequential phases; production, harvesting, transit, storage and drying. This identified the financial and energy costs per oven dry tonne to the point of supplying biomass as an input to a final conversion phase.

Each functional step in the accounting process was further stratified in terms of the basic source of these expenses; i.e. labor, capital, land, fuel and material inputs and interest charges on such costs over time. This subsequent stratification provided a measure of the basic origin of these financial and energy costs within any given functional step. Furthermore, when the elements in each strata were summed over a series of steps, and phases, the process identifies the extent to which the composite of steps, or processes can be described as capital, labor, land or energy intensive.

Identifying the biomass system on an accounting basis and by basic source of such costs will facilitate the subsequent sensitivity analysis of the aggregate biomass system and also provide a basis for judging the ability or inability of changing such costs in the future.

TISSUE CULTURE OF ELITE BIOTYPES OF *ATRIPLEX CANESCENT* AS A SHORT-ROTATION WOODY BIOMASS CROP

Quarterly Report for the Period

March 1 to May 31, 1985

Cyrus M. McKell
Eve S. Wurtele
Manuel F. Balandrin

June 1, 1985

Report prepared by

E. S. Wurtele, M. F. Balandrin, C. M. McKell
Plant Resources Institute
417 Wakara Way
Salt Lake City, Utah 84108

under

Subcontract 19X-89638C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

INTRODUCTION

This is the 4th quarter report for "Tissue culture of elite biotypes of Atriplex canescens as a short rotation woody biomass crop." The research project is on schedule and making good progress. We are optimistic about the long-term implications for improved utilization of Atriplex as a result of project findings.

The objectives of this project are to establish a tissue culture system for the elite gigas form of Atriplex canescens that will allow rapid, low-cost, high volume propagation of plants for biomass production. Additionally, saponin content and variability within A. canescens will be analyzed to determine the feasibility of obtaining a valuable industrial compound from Atriplex biomass. To provide a source of plant materials for future study, an observation nursery will be established at University Research Park, Salt Lake City. Research activities are organized under four tasks.

A) DESCRIPTION OF CURRENT RESEARCH ACTIVITIES IN ALL TASKS IDENTIFIED WITHIN THE CONTRACTUAL WORK STATEMENT

Task 1. Collection of Plant Materials

No plant collections were scheduled for this season of the year. However, a late winter collection of plant materials was performed at the Nephi Field Station on February 28 to observe the condition of stems and leaves of A. canescens during the dormant period. The leaves appeared to be about one-third folded inward and somewhat contracted. Small stems were brittle and the subepidermal layer was deep green in color, in contrast to the gray-green appearance of the epidermis. Thirty-five samples were collected for chemical analysis. Inasmuch as tissue culture propagation was successful with samples collected during active growth, no stem segments were collected for tissue culture studies.

Task 2. Development of Tissue Culture Techniques

The methodology for a complete, efficient system of micropropagation has been developed. The effects of shoot quality and various hormonal supplements to the media on micropropagation have been evaluated. Although the numbers of shoots produced in the multiplication treatments were statistically different only in the case of the two BA concentrations (1.0 mg/l and 0.2 mg/l), we evaluated the quality of the shoots to be extremely poor for those produced on medium containing K, IAA, and GA_3. The poor quality vitreous-looking material was impossible to root and therefore no plants were established from these shoots.

When shoots of similar quality were transferred from the multiplication to the root-inducing medium, there was no difference in the frequency of rooting. However, larger numbers of plantlets were produced from shoots that had arisen on media supplemented with BA. When both rooted and non-rooted propagules were transferred to soil in the greenhouse, survival was poor for those which had arisen on the K, IAA, and GA_3 medium, while shoots from the two BA treatments established plants at similar rates.

The desirable end product of a propagation program is a vigorous plant which can be handled under conventional management practices. The data indicate that the MS medium supplemented with 1.0 mg/l BA is the best medium for the multiplication of A. canescens shoots to produce quality plants after the tissue culture phase of a micropropagation program.

2B. Adventitious Regeneration

A variety of media have been evaluated for potential to induce embryogenesis. MS medium supplemented with 0.5 mg/l BA and 0.5 mg/l 2,4-D, followed by the identical medium without the 2,4-D resulted in formation of globular embryoids. In one case, shoot formation occurred. We are pursuing further study of the conditions under which this shoot developed.

2C. Effects of Regeneration on Somaclonal Variation

Salt tolerance of plants, microshoots and callus was evaluated over a range of 0-1.0 M NaCl. Salt-tolerant microshoots and callus cells are now being obtained.

Task 3. Analyze for Saponin in Plant Materials collected from Field Populations of Atriplex canescens

Work is continuing steadily on the isolation, quantitation, and structure elucidation of the saponins from Atriplex canescens. A recent paper appearing in the Journal of Natural Products reports that the saponins of an Egyptian species of Atriplex have potent biological activity as molluscicidal agents. Thus, these compounds are useful in the eradication of schistosomiasis, a parasitic disease afflicting 200-400 million people worldwide. The structures of these compounds are very similar to those of the triterpenoid saponins from A. canescens. Our studies confirm that these structurally related pentacyclic triterpenoid saponins are similar to those occurring in many members of the Order Centrospermae, a group that includes Atriplex. Since saponins are used on a large scale commercially, our results further confirm that the saponins from Atriplex spp. will be useful in the surfactant markets which currently exist. A. canescens. gigas contains a diploid form, about double the concentration of saponins as regular polyploid A. canescens found in other locations.

Task 4. Establishment of an Observation Nursery and Production of Research Materials

A tract of land in the near vicinity of NPI's research laboratories was given spring preparation in April to receive plantlets of A. canescens from the Tissue Culture laboratory and greenhouse in June.

B) SUMMARIZATION OR SYNTHESIS OF RESEARCH RESULTS FOR SELECTED TASKS

Our most exciting results is that an efficient methodology for in vitro micropropagation of elite genotypes of A. canescens gigas has been developed. The system works well with both juvenile and adult material, multiplication rates are high, and efficient establishment of micropropagules into the greenhouse has been achieved.

C) TECHNICAL DISSEMINATION ACTIVITIES

No specific activities in technical dissemination were undertaken this quarter except for mentioning to vistiors that our work on Atriplex in vitro propagation sponsored by DOE was underway and doing well.

D) NEW PUBLICATIONS

No new publications this quarter. Two papers are in review for submission to journal editors in next period.

PRODUCTION OF WOOD BIOFUELS FROM MESQUITE (*Prosopis* spp.)

Quarterly Report for the Period

March 1 to May 31, 1985

Peter Felker

June 1, 1985

Report prepared by

Peter Felker, Soniade Souza, Tom Tabone, Edward Glumac,
Scott Wrightman, and Charles Wiesman

Caesar Kleberg Wildlife Research Institute
Texas A & I University
Kingsville, Texas 78363

under

Subcontract 19X-09066C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

INTRODUCTION

The major event this past quarter has been the "Tree Planting in semi-arid region symposium" held at Texas A&I from April 29 through May 3. Nearly 100 participants from Australia, India, Tanzania, Morocco, Sudan, Israel, England, France, Ghana, Chad, Zimbabwe, Burkina Faso(formerly Upper Volta), Haiti, Mexico, Venezuela, Brazil, Argentina, Chile, Peru, Costa Rica and Tennessee attended this symposium. A broad spectrum of papers were presented from rhizobia/mycorrhizae studies, to weed control, mineral nutrition, tissue culture, biomass estimation, genetic improvement and comparisons of the productivity of native and existing stands. Tree species dealt with included Acacia, Eucalyptus, Leucaena, Pinus eldarica and Pinus halepense, Prosopis, and Zyzphus.

Task 1 Fertility aspects of site characterizaton

Foliage samples have been taken for both Kingsville and Zachry Ranch sites and these samples have been dried and ground. Foliage samples have been taken for both locations for the second evaluation. Soil samples have been taken for all the plots and have been sieved and neatly stored. Analysis of the soil samples for sodium bicarbonate extractable phosphorus has been initiated.

Soil and plant analysis have been conducted for the 16 leucaena plots which varied in one year coppice regrowth from 2,500 kg dry matter/ha to 14,000 kg dry matter/ha. The most significant correlation was between leaf P and biomass production ($R = 0.71$, $P = 0.0019$). In contrast significant correlations did not exist between sodium bicarbonate extractable P ($R = -0.23$, $P = 0.38$) (recommended for semi-arid soils) or 1:10 water extractable P ($R = -0.32$, $P = 0.23$) of the soils and biomass production. However there was a significant negative correlation between soil pH at the deeper depths and biomass production ($R = -0.88$, $P = 0.0001$).

These data suggest that, for leucaena, leaf nutrient concentrations are more reliable indicators of plant productivity than soil test values. For a plant physiologist, this intuitively makes sense, since the leaf nutrient concentration is an an integration of all factors concerning nutrient availability i.e. concentration, changing concentration with rooting depth, and changing availability with regard to pH, and other nutrient interactions.

However, soil test values must be developed to indicate site potential and fertility requirements for plantings to be established. It goes without saying that soil test values are only useful if they are well correlated with plant growth.

We are currently experiencing mechanical difficulties with the atomic absorption unit and are seeking funds to have it repaired.

Task 2 Clonal comparisons of mesquite biomass production under 27 inch average annual rainfall conditions (Kingsville Prosopis alba B2V50 clonal plots)

These plots have been disked in both directions and solicam applied at 5 kg/ha. This has provided excellent weed control of all weed species including nutsedge. The trees are growing rapidly with recent spring rains.

Task 3 Clonal comparisons of mesquite biomass production under 18 inch average annual rainfall conditions (Zachry Ranch plots).

These plots were treated with solicam at 5 kg/ha but for unknown reasons, we have not achieved as good weed control as we have on the Kingsville clonal B2V50 plots. Fortunately these plots have recieved spring rains and as soon as the soil is dry enough mechanical weed control will again be performed on these plots.

Task 4 Compare seeding depths and herbicides for effectiveness in direct seeding of leucaena

In anticipation of a large scale direct seeding of leucaena planting in 1986, we established a direct seeding trial with leucaena. Four rates of herbicide were used i.e. 0.0, 0.5, 1.0, an 1.5 kg surflan per hectare and two seeding depths i.e. 1.5 and 2.0 inches. A randomized complete split-block design was used with 4 replicates(Herbicides were main treatment effects and seeding depth was the split plot).

Due to the large number of seeds required, scarification by hot water treatment (100 C) for 1 minute was employed as recommended by various authors. On a small trial this yielded 77 % germination.

A 2 row junior planter was used and the seeds were inoculated with a commercial rhizobia formulation. Fortunately 0.8 inches of rainfall occurred one day after planting and thus excellent survival should have been obtained. However, nearly 3 weeks later, very few of the seedlings have emerged. We suspect that in the scale-up to hot water scarify the seeds, we greatly decreased their germination potential. Four years ago at Texas A&I we used hot water scarification of leucaena (3 min at 80 C) and were very unhappy with the results as it only gave 50% emergence whereas mechanical scarification by hand usually gave greater than 95 % germination. Despite numerous reports in the literature on hot water scarification it apppears to depend too much on heat transfer rates as well as absolute temperatures with the result that time temperature results are unreliable.

Task 5 Native mesquite comparison trial.

These plots have been redisked and solicam applied. The weed control is excellent. These trees still need to be pruned.

Task 6 Seed Orchard maintenance and germplasm documentation

These plots were disked twice and karmex applied at 2 kg/ha the second week of April. With the advent of spring rains, bermuda grass, nightshades, and some perennial grasses have become a problem. Most of the trees flowered in the hot spring weather before the rains, but few trees set fruit, evidently because the rains came too early. When the spring rains cease in mid/late June, the trees may flower again, and perhaps set fruit if the remainder of the summer is hot and dry.

Task 7 Rooting of cutting research

The chemical compostion of cuttings and the rooting percentage of cuttings were measured after 5 successive harvests of heavily fertilized and non-fertilized stock plants. Correlations were examined between rooting percentage and leaf N, stem N, leaf carbohydrate, stem carbohydrate, and stem plus leaf phosphorus(N=79). There was no significant correlation between rooting percent, and leaf carbohydrate(P= 0.96), stem carbohydrate(P=0.87), and leaf plus stem phosphorus(P=0.31). The non-significant correlation between percent rooting and carbohydrates was negative(R= -0.018). However there was a significant positive correlation with stem nitrogen and percent rooting (P=0.009). There was an inverse correlation between stem nitrogen content and carbohydrate content(R= -0.167, P= 0.14).

We found the lack of correlation between leaf and stem carbohydrate and percent rooting surprising, as we had assumed carbohydrates were very important for rooting. The positive correlation between leaf N and rooting % indicates that unbalanced fertilizers, rich in N and low in P, K and other nutrients, might stimulate stem N percent and be successful in maintaining high rooting percentages from stock plants.

Task 8 Tissue culture research

This past 10 weeks we have achieved another major breakthrough in the tissue culture of Prosopis alba. When the concentration of stock A (ammonium nitrate) of the Murashige-Skoog media was varied it markedly influenced shoot production. However, since stock A contained nitrogen both in the form of ammonium and nitrate, it was not possible to determine which nitrogen source the effect was attributable to. Therefore we separately examined ammonium chloride, sodium nitrate, and glutamine. Glutamine was examined (a) since it is a source of organic nitrogen, (b)since it is first product of nitrogen fixation, and (c)

since it is the form in which nitrogen is transported from the nodules to the shoots in many legumes.

At the 28 day evaluation very few shoots were produced in the ammonium treatment but good shoot production occurred in both the nitrate and glutamine containing media(Table 1). After subsequent transfer on the same media, the shoot production was evaluated after 55 days(Table 1). Clearly glutamine was superior to both inorganic nitrogen sources in production of number and length of shoots. What cannot be seen from the table is that the explants on the nitrate media were yellow with considerable brown tip dieback. In contrast the shoots on glutamine still appeared quite healthy.

This is a rather unusual finding. It appears as if the requirements for Prosopis shoot multiplication are fundamentally different from other woody species such as pecan and walnut which respond positively to increased ammonium concentrations. It will be interesting to see if Prosopis has an obligate requirement for the organic nitrogen source that serves as the first nitrogen acceptor in nitrogen fixation and as the transport form of nitrogen from roots to shoots.

The key to economically viable tissue culture propagation is multiple shoot proliferation at each subculture. At this point we feel basic research on shoot multiplication is more important than to dabble in all phases of tissue culture propagation of Prosopis. When we get good shoot multiplication we will examine root production and hardening off.

Table 1. Effect of nitrogen source and concentration on development of Prosopis alba done B_2V_{50} after 28 days.

Nitrogen Source		Concentration (mM) 20	30	40	50	60
		Mean ± SD				
NH_4Cl	Shoot Number	0.60±0.51	0.53±0.52	0.26±0.46	0.20±0.41	0.13±0.35
	Shoot Length	0.60±0.51	0.53±0.52	0.26±0.46	0.20±0.41	0.13±0.35
$NaNO_3$	Shoot Number	0.93±0.26	1.13±0.35	1.47±0.52	1.13±0.52	1.33±0.49
	Shoot Length	1.13±0.52	1.33±0.49	1.33±0.62	1.07±0.46	1.33±0.62
Glutamine	Shoot Number	1.00±0.53	1.13±0.35	1.13±0.35	1.27±0.46	1.20±0.41
	Shoot Length	0.93±0.46	1.40±0.51	1.53±0.74	1.73±0.70	1.53±0.64

FINAL EVALUATION (55 days)

		20	30	40	50	60
NH_4Cl	Shoot Number	0.20±0.41	0.21±0.43	0.07±0.26	0	0
	Shoot Length	0.27±0.59	0.21±0.43	0.07±0.26	0	0
$NaNO_3$	Shoot Number	0.91±0.83	0.92±0.51	0.92±0.95	1.43±0.76	1.00±0.96
	Shoot Length	0.82±0.75	0.92±0.51	0.92±1.12	1.07±0.73	0.71±0.61
Glutamine	Shoot Number	1.78±0.67	1.46±0.52	1.77±0.73	1.89±0.33	1.63±0.52
	Shoot Length	1.56±0.73	2.38±1.33	2.31±0.95	2.22±1.30	2.13±0.64

ESTABLISHMENT OF POPLAR ENERGY PLANTATIONS*

Quarterly Progress Report for the Period

March 1 to May 31, 1985

Edward A. Hansen

and

Hans Nienstaedt

June 1, 1985

Report prepared by

Edward Hansen
Tom Crow
Dan Netzer
Don Riemenschneider

United States Department of Agriculture
Forest Service
Forestry Sciences Laboratory
P. O. Box 898
Rhinelander, Wisconsin 54501

Prepared for the

U. S. Department of Energy
Biomass Energy Technology Division
under
Interagency Agreement #DE-AI05-80OR20763

*Registered Trademark, Intertechnology-Solar Corporation

RESEARCH ACTIVITIES

Genetics:

New collections of Populus balsamifera have been completed. The area sampled was the native range of the species in Minnesota, Wisconsin, and Michigan. Sampling was done using a series of 7 North-South transects from longitude 94° 31' in northwestern Minnesota to longitude 84° 30' in the northern Lower Pennisula of Michigan. An attempt was made to sample 10 trees from each of 20 collection areas; however, due to scarcity of the species in two locations, it was necessary to sample an additional two locations to reach a total of 200 clones.

Propagation of hardwood cuttings via hydroponic rooting of softwood cuttings is proceeding although we have found Populus balsamifera to be significantly more difficult to root than Populus trichocarpa.

The new collections of Populus deltoides made through cooperative agreement with the University of Minnesota have been outplanted. The planting includes 96 open-pollinated families of P. deltoides collected from southeastern Minnesota and Iowa. Selections will be made from this replicated test for inclusion in future inter- and intra-specific mating designs.

Site preparation is currently underway for the establishment of replicated field tests at Harshaw Experimental Farm. A 10-acre old-field site at the Harshaw Farm was flagged and sprayed with the herbicide Roundup at a 2 lbs ai/acre rate. Further site preparation work will be done throughout the summer to prepare for planting of stock for Populus breeding trials in the spring of 1986.

We have noted significant winter damage on many clones of Populus trichocarpa that were established in stooling beds at Harshaw Farm in June 1984. Data on winter damage symptoms will be collected and used as an aid in selecting clones for future breeding work.

A modified agar-leaf disk screening test was used to screen 94 P. trichocarpa and 10 hybrid poplar clones. Approximately 18 leaf disks of each clone were inoculated with a spore suspension of Septoria musiva (Septoria canker). Data were analyzed to estimate the rate of leaf necrosis in response to the pathogen and the date at which 50% necrosis occurred. P. trichocarpa clones were classified into three groups based on the analysis: 1) resistant (>28 days to 50% necrosis), 2) intermediate (24 to 28 days for 50% necrosis), and 3) susceptible (<24 days for 50% necrosis). Most clones (69) appear to be susceptible to the pathogen while 15 appear intermediate and 10 appear relatively resistant. Future work will include a repeat of the in vitro screening and comparison of this data with observations from field plantings. Since Septoria canker is an important pathogen of hybrid poplars, and may be the limiting factor on some sites, resistance to this disease will be heavily weighted in selection of parental breeding stock.

Mid-rotation Management:

Nitrogen fertilizer test: This study objective is to develop alternative strategies for managing nitrogen nutrition in hybrid poplar plantations and to document the benefits of nitrogen fertilization. Selected trees were harvested,

dry weight determined, regression equations developed and total biomass calculated for each treatment. The data were summarized for the 5-year study and a manuscript written. The fifth-year measurements showed a maximum 400-percent increase in biomass in response to nitrogen fertilizer on the sand site; the highest fertilization rate (168 kg/ha/yr) resulted in the greatest biomass. There was a maximum 50 percent increase in biomass on the more fertile silt loam site. With higher rates of fertilization and irrigation, biomass yields from both sites were similar. A legume cover crop showed little effect on tree growth. Tree height on the silt loam site was generally increased by weeding but not by fertilization. On the sand site, tree height was increased by fertilization but not by weeding. Maximum biomass was associated with midsummer leaf tissue N concentration of 3 percent or greater.

Nutrient uptake study: This study is designed to identify fast growing hybrid poplar clones with low nutrient concentrations (if they exist). Three trees were harvested and analyzed from each of 15 clones at age 2 on a fertile and an infertile site. Preliminary analysis of nitrogen content shows significant clonal differences in N concentration between leaves, stembark, branchwood and branchbark on the fertile site, but for branches only on the infertile site (there was not sufficient leaf sample from the infertile site to test for nitrogen). Of those components that showed significant clonal differences in N content, the clones with the highest concentrations ranged from 38-58 percent higher than the clones with the lower concentrations. Also, clones with high concentrations of N tended to be high in all components, and vice versa. This suggests that there may be opportunity to select poplar clones with lower nutrient uptake and hence lower nutrient drain on the site. Further analyses will include calculating the total mass removal of N (perhaps clones with high concentrations are just slow growers), and analysis of other major elements. The plantations will be maintained another 2 years and harvested at age 5 to see if significant clonal differences still exist and if the pattern of nutritional differences between clones changes between ages 2 and 5.

Productivity Data:

Measurements were made on first rotation and coppice stands and the results were summarized in the FY 1984 Annual Report. Yields of hybrid poplar in large plots now exceed 10 t/ha/yr for the better clones.

Biomass production of two-year-old second coppice and four-year-old first coppice were measured and summarized. Coppice regrowth of various clones following dormant season harvesting was measured. Responses following growing season harvesting will be measured in August.

Physiology:

Research activities during the last quarter were directed at developing the photosynthate production and photosynthate distribution submodels of the ecophysiological growth model for juvenile Populus. The study objective is to relate these physiological factors to productivity.

Photosynthate Production Submodel - The leaf interaction module of this submodel determines the quantity of direct and indirect light incident on the adaxial and abaxial surfaces of each leaf present within the crown. Each leaf is projected on a plane to form a series of shadow polygons determined by the spatial relationship between the leaf and its light source. A hidden-surface algorithium

is then used to estimate mutual shading. Light intensity for the shaded leaf regions is calculated from an attenuation function. Light interception for unshaded leaves is calculated from the relationship between the intensity of the light and the angle between the light source and the leaf's normal vector. The diffuse and direct light are then summed for each leaf to provide a quantum flux that is used as an input to the photosynthate production submodel. This submodel computes hourly rates of photosynthesis as a function of quantum flux, leaf temperature, and leaf age.

Photosynthate Distribution Submodel - We have assembled the following information either as direct measurements or from the literature:

1) several daily photosynthate production traces that can be used as input to the distribution model;

2) photosynthate partitioning coefficients;

3) phenology of budbreak;

4) phenology of budset;

5) data on leaf initiation rates;

6) data on maximum internode lengths by clone;

7) average diameter to assume for internodes not fully expanded.

Using this input data, the submodel depicting photosynthate distribution is about 25 percent completed.

Other Research - In cooperation with the University of Washington, we established a plantation of 12 selected poplar clones from Stettler's collections. This plantation will be used for the purpose of studying the physiological aspects of growth and yield. In addition, these data will be used for an independent validation of the growth model. Related research funded by the Forest Service on carbon fixation and allocation, and on leaf morphology and orientation continues at the Rhinelander location.

Related Studies:

First-year results were obtained from a study designed to measure gains of hybrid poplar biomass due to research during the past 14 years. Total tree heights measured at the end of the first growing season show the following results:

treatment	tree height (cm)
old clone--1970 culture	57
old clone--1983 culture	95
new clone--1983 culture	174

These data show that the height gain due to cultural improvements during the past 14 years is 67 percent (from 57 to 95 cm). The height gain due to a better clone is 83 percent (from 95 to 174 cm). The "old clone--1970 culture" treatment is a duplication of the plot that Ek and Dawson established and reported a biomass yield of 15 t/ha/yr at age 4. The percentage gains reported

herein are at a maximum because they are based on 1-year-old tree data. They will decline substantially during the rotation as tree heights increase. Nevertheless, the implications are that substantial gains in biomass production have been achieved and that final yields (when mean annual production peaks) will probably be in excess of 15 t/ha/yr. The study duration is expected to be 4 years at which time the mean annual production will most likely peak.

Several different rates of the herbicides Verdict, Poast, and Fusalade were oversprayed August 20, 1984 on a 3-month-old hybrid poplar plantation. The plantation had been reinvaded with a dense stand of quackgrass. These herbicides are designed to control grasses without damage to broadleaf species. First results this spring indicate good grass control with Verdict at rates above 0.5 lbs ai/acre. Poast and Fusalade showed poor weed control at all rates tested. No damage to the hybrid poplars was noted with any of the rates or herbicides tested.

On April 29 Roundup was oversprayed on a 3-year-old hybrid poplar plantation containing blocks of 5 different clones. The oversprayed trees were in strips where no weed control had been done since the initial preplant herbicide had been applied and a dense stand of quackgrass had greatly suppressed tree growth. This test was done to see if tree growth stagnated by a heavy sod cover could be effectively released by a single treatment with Roundup.

Technology Transfer Activities:

Ed Hansen and Dave Dawson visited India for a 10-day science exchange as part of the US-INDO fuelwood energy program. The purpose was to identify planting sites for collections of Populus deltoides that will be sent to India in early 1986. Deltoides is the premier poplar in Uttar Pradesh, India and is widely planted in both pure plantations and under agro-forestry conditions. However, there has never been a systematic collection and testing program for P. deltoides in India.

Northern States Power Company consulted with us on several occasions as they develop plans for a possible 500 MW wood-fired electric generating facility in Minnesota. One of the many interesting scenarios they are exploring as a means to reduce costs is to batch-charge the fire chamber with whole trees (to avoid costly chipping) and to haul wood to the plant with very large (175 ton) trucks.

INCREASING THE BIOMASS PRODUCTION OF ALDER PLANTATIONS IN THE PACIFIC NORTHWEST

Quarterly Progress Report
for the Period

March 1 to May 31, 1985

Dean S. DeBell, Donald D. Hook, M. A. Radwan,
Donald L. Reukema, Robert O. Curtis

June 1, 1985

United States Department of Agriculture
Forest Service
Forestry Sciences Laboratory
3625 - 93rd Avenue, S. W.
Olympia, Washington 98502

Prepared for the

U. S. Department of Energy
Biomass Energy Technology Division
under
Interagency Agreement #DE-AI05-81OR20914

QUARTERLY REPORT

General

Work is mostly on schedule on the various aspects of our program. Progress during the quarter is summarized below.

Integrated Practices

Work on the poplar and alder research plantations at the DNR Tree Improvement Center (Yelm) has proceeded as planned with two exceptions. The drip irrigation system has not been installed; the delay was caused by contracting hurdles in the DNR organization. The plantations, however, are being irrigated via a movable overhead sprinkling system. The other exception to planned progress is associated with the unusually cold spring this year; four frosts have occurred since the poplar cuttings and alder seedlings began to leaf out. The last frost occurred on May 11 when temperatures dipped to 27° F. The cuttings have rooted very well but shoot development of the poplar has been unusually slow. Dula's D-01 clone has been far ahead of all other clones in phenological development. Foliage of most alder seedlings and the terminals of many alder seedlings have been killed; most appear to be resprouting from the base. If such regrowth of alder and shoot growth of poplar is not satisfactory, the plots can be replanted next spring with alder seedlings and poplar cuttings produced at the site. All herbicides and fertilizers have been applied as planned and initial height measurements were taken. Weeds are being controlled manually by tilling and hoeing in the alder plots.

Nitrogen and chlorophyll ('a' and 'b') analyses were completed for the 36 red alder families selected for the Dry Matter-Nutrient Relationships Study (Puyallup). Additional statistical analyses are being done to examine family differences and correlations among various growth traits. A manuscript on growth analysis of the families of this study is now in the second draft stage.

Nutrition and Fertilization

A manuscript has been drafted for a refereed journal on nutrient status of cottonwood and red alder in pure and mixed culture. This paper will present data on nutrient concentrations, nutrient contents, and efficiency of nutrient utilization for coppice shoots of these species obtained in two harvests (1979 and 1983). Two other manuscripts are planned from the original Lady Island study; one will report effects of 10 years of repeated harvesting on soil properties and the other will discuss stand dynamics throughout the five cutting cycles in the pure and mixed cottonwood and alder plantings.

The new crop rotation experiment at Lady Island is proceeding with few problems. Weeds developing over the winter were mowed; some hoeing was done around the trees; and the ground was sprayed with an herbicide mixture (Goal + Kerb) to prevent regrowth. The cottonwood trees are growing well in all treatments, and crown closure is expected to occur this growing season.

Genetics

A manuscript on variation among red alder families in tolerance to soil waterlogging was completed, and is now being edited for submission to a refereed journal. Results were discussed in our recent annual report.

Alan Agar and Susanne Brown are completing their theses on natural genetic variation and reproductive biology, respectively, at University of Washington under the guidance of Reinhard F. Stettler.

Productivity Prediction

Two manuscripts on this topic are now in the process of being published by the Pacific Northwest Forest and Range Experiment Station. One paper discusses development and use of the Red Alder Soil-Site (RASS) model; the other presents new height growth and site index curves for young red alder.

Other Items

1. Visitors

The following people visited the Yelm research plantation site this quarter:

Andrew Bryant, Herbicide Specialist, Hardwood Research Group, Crown Zellerbach Corporation, Wilsonville, Oregon

Reinhard Stettler, Professor of Forest Genetics, University of Washington, Seattle

Jud Isebrands, Tree Physiologist, North Central Forest Experiment Station, Rhinelander, Wisconsin.

2. Meetings Attended

a. Marshall Murray presented a paper on variation in tolerance of red alder families to soil waterlogging at the Northwest Scientific Association Annual Meeting in Vancouver, British Columbia.

b. Dean DeBell attended a meeting concerning a hardwood research cooperative proposed by Oregon State University (OSU) for the Pacific Northwest. The meeting was initiated by OSU and held at Weyerhaeuser facilities in Centralia, Washington. Oregon State University, Weyerhaeuser Company, Goodyear-Nelson Company (an alder lumber manufacturer), and the Pacific Northwest Forest and Range Experiment Station were represented.

A PROGRAM OF RESEARCH FOR THE PRODUCTION OF WOODY BIOMASS FOR FUELS AND CHEMICALS IN SOUTH CENTRAL VIRGINIA

Quarterly Report for the Period

March 1 to May 31, 1985

Donald L. Price

June 1, 1985

Report prepared by

Donald L. Price, Principal Investigator
Bureau of Economic Research and Development
Virginia State University
Petersburg, Virginia

under

subcontract 19X-43389C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

Report Abstract

This report summarizes the activities of Virginia State University as a participant in the Short Rotation Woody Crops Program under a subcontract (19X-43398C) managed by Oak Ridge National Laboratory for the U.S. Department of Energy. Project activities have included an overview of stand conditions found on nonindustrial private forest landownership in the study area, the identification of forest management practices found in the area, and the administration of a survey instrument to 1,500 selected landowners.

PROJECT TASKS STATUS - March 1, 1985 - May 31, 1985

Task One: Stand Condition Identification

The information for the overview of the range of stand conditions found on nonindustrial private forest landownerships in the five-county study area has primarily been obtained from the 1976 Virginia Forest Statistics published by Southeast Forest Experiment Station and also from Timberland Examination reports for landowners that were obtained from the county foresters in the study area. Highlights of the overview which have implications for the potential of SRIC production in NIPFL include: (a) Hardwood species are the predominant tree species in the study area. About one-half (51.3%) of all commercial forest land in the study area is in hardwood; 15% is in mixed pine-hardwood stands; and 33.7% is in pine (Loblolly-shortleaf). (b) On the average, 84% of the forest land in the study area falls in site classes 4 and 5, which means these sites have inherent capacity to grow crops of industrial wood (based on fully stocked natural stands at the rate of only up to 85 cubic feet/acre annually as compared to 165 or more cubic feet/acre for site class 1. In the 1976 Census Poletimber (39.6% of timberland acreage) was the most dominant stand-size class in the study area. The timber stands are natural rather than planted. Growth rates range from poor to fair. Average ages of mixed hardwood, pine-hardwood, and pine stands are 46 years, 42 years, and 37 years, respectively.

Since better quality land (site classes 1, 2, 3) is generally recommended to be planted in loblolly pine in Virginia, there is a substantial amount of land that has the potential to increase board-foot production per acre through intensive management. Stand density in each of the five counties is summarized in Table 3.

Task Two: Identification of Management Regimes

Management opportunities in the study area are as follows:

1. Regeneration with no site preparation - seed tree regeneration or planting pine seedling understory.

2. Regeneration with site preparation - removal of competing or undesirable vegetation followed by planting pine seedlings. Removal is accomplished by dozing, drum chopping, burning, or a combination of these operations. Site preparation is light, medium, or heavy.

3. Stand conversion - involves conversion of hardwood stands by clearcut harvesting, site preparation, and planting pine seedlings; removal of hardwoods from a pine-hardwood stand and allowing pine to grow through seed tree propagation or from planting an understory of pine seedlings.

4. Thinning - removal of some juvenile timber from a stand to allow for maximum growth by remaining stock; precommercial thinning (removal of an economic harvest of timber from a stand prior to clearcut of remaining growth at sawtimber stage).

5. No treatment.

6. Clearcut - total removal of all trees on a timber stand.

Based on a subsample of 115 returned mail surveys, it appears that the most common treatment is no treatment. One possible explanation can be seen in the responses to the question below:

How important are each of the following reasons for owning your woodland? (Circle one number opposite each reason)

	Very Important	Somewhat Important	Hardly Important	Not Important
Investment	1(28)	2(29)	3(13)	4(05)
Hunting	1(17)	2(26)	3(13)	4(21)
Other recreation	1(10)	2(19)	3(13)	4(23)
Protect against soil erosion	1(53)	2(16)	3(04)	4(09)
Watershed	1(29)	2(20)	3(07)	4(12)
Pasture for livestock	1(14)	2(19)	3(08)	4(29)
Commercial timber production	1(24)	2(16)	3(13)	4(18)
Source of wood products for own use	1(36)	2(29)	3(07)	4(13)
Esthetic enjoyment	1(35)	2(27)	3(06)	4(07)

One sees at a glance that environmental concerns (watershed maintenance and soil erosion control) and esthetics are more important than production of a commercial timber crop. The sample is composed of small farmers and rural landowners owning less than 400 acres who are not farming and oftentimes not residing in Virginia. There was little appreciation for cost-sharing programs. Landowners, when they do opt for timber management, opt for regeneration with no site preparation or only light site preparation. Discussions with county foresters reveals that NIPFL frequently decide against clearcutting a stand, favoring instead to think and plant an understory of pine seedlings or leave seed trees. Heavy site preparation, involving release of undergrowth through herbicide application, site fertilization, and irrigation is not used among the subgroup of NIPFL in our sample. The NIPFL ownerships in the 400-2,500; 2,500-5,000; 5,000-15,000; and 15,000-50,000-acre range were not sampled. Intensive timber production and improved management is common on these ownerships because wood is commercially grown.

Task Three: Determination of Growth, Yield, Costs, and Revenues

For each recommended management regime in the study area, estimates are being developed for costs of treatment, incremental yields, and revenues. The information for the estimation have been obtained from the Virginia Division of Forestry and will be supplemented by data from the Southern Timber Study (Economic Opportunities for Intensive Forest Management), prepared by Mike Vasievich and Peter Schroeder at Research Triangle Park, North Carolina.

Task Four: Determination of the Economic Feasibility of Various Management Options

An analysis of the costs and benefits of the various management regimes using appropriate investment criterion is being developed from the data gathered from the various secondary sources, and this will be supplemented by the survey data. We will use timber investment data from the Southern Timber Study (Economic Opportunities for Intensive Forest Management), prepared by Mike Vasievich and Peter Schoederr at Research Triangle Park, North Carolina.

Task Five: Land Owner Attitude Towards Improved Woodland Management

Socioeconomic data that would relate landowner attitude for improved woodland management is being collected through the administration of the structured questionnaire. A preliminary examination of a subsample of returned surveys indicates that woodland owners show only a slight propensity to manage their woodlands as an economic enterprise. At this point we can only speculate as to why, but it may be that the people in subsample (mainly older than 50) grew up in a small farm environment that did not emphasize the commercial management and marketing of a timber crop.

Table 1. Area of commercial forest land by stand size, class, and county 1976

County	All stands	Stand-size class			Nonstocked Areas
		Sawtimber	Poletimber	Sapling-Seedling	
Charlotte	207,387	48,484	108,791	50,112	-
Halifax	336,266	90,070	140,463	98,656	7,077
Pittsylvania	392,910	124,592	177,820	82,893	7,605
Brunswick	290,505	57,869	98,465	131,096	3,075
Southampton	263,927	121,040	65,244	74,216	3,427

Table 2. Area of commercial forest land by site, class, and county 1976

County	All classes	Site Class Longleaf 1	2	Loblolly 3	3	5
Charlotte	207,387	-	4,192	16,039	176,797	10,359
Halifax	336,266	-	-	34,942	259,506	41,818
Pittsylvania	392,910	-	-	59,275	293,374	40,261
Brunswick	290,505	-	-	42,774	232,451	15,280
Southampton	263,927	-	-	79,074	174,569	10,284

Table 3. Stand density (forest stocking)

County	Forest type		
	Pine	Pine-hardwood	Mixed hardwood
Brunswick	Fully stocked	Understocked	Understocked to fully stocked
Charlotte	Overstocked	Fully stocked	Understocked
Halifax	Fully stocked to overstocked	Fully stocked	Fully stocked
Southampton	Fully stocked	Understocked	Understocked
Pittsylvania	Fully stocked to overstocked	Overstocked	Fully stocked to overstocked

EVALUATION AND GENETIC IMPROVEMENT OF BLACK COTTONWOOD FOR SHORT-ROTATION COPPICE CULTURE

Quarterly Report for the Period

March 1 to May 31, 1985

R. F. Stettler

June 1, 1985

Report prepared by

R. F. Stettler and P. E. Heilman
University of Washington
College of Forest Resources
Seattle, Washington 98195

and

P. E. Heilman
Washington State University
Western Washington Research and Extension Center
Puyallup, Washington 98371

under

Subcontract 19X-43382C

for

Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831
operated by
Martin Marietta Energy Systems, Inc.
for the
U.S. Department of Energy
Contract No. DE-AC05-84OR21400

Task I - Field Trials 1a and 1b

These trials, now six years old, contain clonal materials collected from 50 black cottonwood trees (5 trees each from 10 source stands) representing the range of the species west of the Cascade Mountains from central Oregon to southern British Columbia. Three of the five replications in each of the two trials were harvested after four years and were then allowed to resprout. The second harvest will be made when the sprouts reach four years of age.

A scientific manuscript reporting on genetic and year-to-year variation in foliar nitrogen concentration was completed and submitted for publication. Field work for the quarter was primarily maintenance and repair of the irrigation system. Tensiometers removed during winter were reinstalled.

Task II - Field Trials 2, 2a, and 2b

These trials are mainly the repository for the seedlings produced in the breeding part of the project. Contrary to the annual harvesting in these trials in previous years, these trials were not harvested in 1984 but were allowed to grow for a second year. Work during the quarter was mainly in conjunction with maintenance of the irrigation system.

Task III - Field Trial 2c

Field Trial 2c is a test planting of some of the selected clones along with other clones we have obtained. It, too, was left to grow this year. As with the other trial, irrigation system maintenance has been the only work done during this quarter.

Task IV - Expanded Crossing Program

During this quarter, the actual crossing work was conducted of the second round in the expanded breeding program. Because of external circumstances the results turned out below the level we had expected to achieve. Key factor was the erratic spring weather with intermittent cold and hot spells. It led to occasional unexpected heat buildups in the greenhouses of our pollen suppliers as well as in our own and resulted in premature loss of floral branches. Thus, fewer crosses could be accomplished than had been planned. Most of the seed has been collected but is still in the cotton. For nine cross-combinations, the numbers of apparently filled seed per cross have been estimated at 50 or above, for seven, below 50. Among the more successful crosses were those involving our "Cottage Grove" clone, a black cottonwood with exceptionally good form.

Steps have been undertaken to improve greenhouse conditions for future efforts.

Task V - Field Trial 2d

Establishment of this trial was completed during the quarter. Materials in this trial are the seedlings produced in the first phase of the expanded crossing program which was conducted in early 1984. The seedlings

are growing well. An application of Assure was made last week to control a severe grass problem in the plantation.

Task VI - Field Trials 3a and 3b

These trials, located away from our Puyallup site, contain best material from each of the crosses we have made in our breeding program. Together with Trial 3c, they represent Phase 1 plantations to determine clonal ranking on several different soils/sites. Work during the quarter on Field Trial 3a at Pack Forest has consisted of continuing efforts to control both grass and the field mouse (Microtus) problems. This has involved using Poast within the plantation and Roundup around the perimeter. As yet this year we have not baited for the rodents.

Task VII - Field Trial 3c (Alger, Washington)

This plantation contains not only a set of our most promising production clones but, separately from them, a common-garden trial of ten geographical sources of black cottonwood and their progenies. This latter material offers a first opportunity to verify at a different location and at a greater genetic resolution the geographic trends identified in our Field Trial 1a. Several field inspections were made to prepare for a major collection of data during summer and fall, with emphasis on phenology and morphology.

Maintenance work during the quarter on this trial has consisted of adding lime to try to correct a few highly acid spots within the area.

Task VIII - Field Trial WC-2 (Herbicide Tolerance Trials)

Processing of the herbicide trial which utilized trees grown in pots of perlite continues. The dry weights were obtained for each tree; roots, shoots and cutting. Analysis of these data is in progress. In the fall, an early frost killed leaves of certain clones needed to complete the biochemical assay for herbicide resistance in chloroplasts of PRINCEP tolerant and intolerant clones. This resulted in inadequate replications of the experiment. To rectify this, a selected number of clones were grown in the greenhouse for a follow-up assay. Furthermore, it was of interest to determine whether or not chloroplasts were any more or less tolerant of herbicides in the spring than in the fall. Three clones of Populus trichocarpa, three clones of Populus deltoides and four hybrid clones were chosen on the basis of their performance in both field study and the perlite culture. In addition, leaves from field-grown trees of these clones were sampled.

Chloroplasts were isolated from fully-expanded sun leaves and submitted to herbicide treatments of PRINCEP, KARMEX and SILVEX. A number of rates ranging from 10^{-6}M to 10^{-4}M was utilized. Electron transport was observed using a chlorophyll fluorescence assay. All three of these herbicides bind to the QB protein in photosystem II, blocking electron transport and subsequently inhibiting photosynthesis. All clones showed a much higher degree of tolerance to PRINCEP than to KARMEX and SILVEX. A rate of 10^{-6}M KARMEX and SILVEX caused total inhibition of electron transport in all clones, whereas a dose of PRINCEP at 10^{-5}M or greater was

needed to achieve total inhibition in the same clones. Further analysis of fluorescence induction curves is in progress.

A small-scale field trial was conducted by one of our collaborators, Mt. Jefferson Farms, in Salem, Oregon, with the herbicide "Glean" (Chlorsulfuron). We are interested in this new chemical since a gene has been isolated in tobacco that confers tolerance to its carrier. In collaboration with other laboratories at the University of Washington, we are planning to introduce this gene into our hybrid material. It was, therefore, important to first make sure that a representative hybrid (Hyb. 11) was susceptible to "Glean". This was indeed found, even at low rates (1/8 oz a.i. per acre). Thus, the conceptual scheme for a gene transfer is justified and will be pursued; a grant for conducting this research is being submitted to the U.S.D.A. - Forest Service.

Task IX - Physiological Studies

This task concerns the comparative study of leaf anatomy of P. trichocarpa, P. deltoides, and hybrids. Our aim is to compare the anatomical structures both qualitatively and quantitatively in order to identify those elements that may correlate with growth and water relations of the intact plant. The leaf mesophyll is of primary concern since it shows consistent differences between the two species.

We have begun to gather data of leaf cross section relating to mesophyll of selected clones using an integrating dygitizer (Zeiss 'VIDEO PLAN'). All anatomical samples were preserved in FAA and embedded in paraffin. The following characteristics have been examined thus far:

a) Percent of cross-sectional tissue bearing chloroplasts; b) Percent "air space" per cross-section; c) Degree of compactedness of the mesophyll layers; and d) Differences in cell sizes among clones.

Task X - Clone Bank/Stool Collection

This clone bank contains the most promising individuals from all crosses made to date under the program. Considerable work was done during the quarter on this trial. Individuals found to be unsatisfactory were rogued from the trial and replaced with other individuals from the respective families. Additionally, the clone bank was expanded to include additional hybrids and P. deltoides and trichocarpa parental materials. After the needed cutting material was obtained from this planting, the entire area was uniformly cut back to provide for uniform sprouting. Weed control treatment was made using Goal and the irrigation system repaired for the coming season.

Delayed Component; Field Trial 4

In preparation for the Phase II plantations on a number of sites in western Washington and Oregon, we have established a nursery for increasing of planting stock. The nursery was planted with up to 120 cuttings each of 59 selected clones. The area was sprayed with "Goal" following planting and the plants are growing well. The agencies cooperating on this project are The Association of Soil Conservation Districts, United States Soil

Conservation Service, Washington State Department of Natural Resources and Washington State Cooperative Extension.

Tasks XI and XII - Ecophysiology Plantation

The ecophysiology plantation established in Puyallup, Washington as part of the SRWCP consists of 23 poplar clones representing a N-S gradient of P. deltoides and P. trichocarpa as well as several related hybrids. In April the first of a series of planned seasonal observations of morphological and physiological characteristics was initiated. Budbreak was species dependent and ranged from March 27 to April 25 according to latitudinal origin. Weed control with the herbicide "Goal" was necessary in early April when broadleaf weeds began overtopping the planted cuttings. In May permanent growth plots were established in each of the clonal subplots and solar radiation monitoring equipment was also installed. At the end of May the initial above and below ground biomass destructive harvests were made.

The same 12 clones were also grown during this quarter in a UW greenhouse in Seattle as part of a parallel study designed to observe the effects of leaf morphology and orientation on light interception. Leaf length, width and orientation varied widely among clones as did the light transmittivity through mature leaves. Considerable time was also spent securing the necessary approvals to conduct radioactive tracer experiments at Puyallup and UW. Permission for both locations was granted in late May.

Task XIII - Mechanisms of Drought Resistance

Our work over the past several months has involved observing the effects of exogenous Abscisic acid (ABA) on stomatal responses to leaf water stress in P. trichocarpa, a species found, in earlier work, to maintain open stomata well beyond the point of leaf wilting. When epidermal strips of P. trichocarpa were floated on solutions containing ABA, reductions in aperture were not observed while the strips remained in high water potential solutions. The effects of the ABA became apparent, however, when the epidermis was placed in a low water potential solution. Guard cell plasmolysis occurred at a higher water potential indicating that a reduction in cell solute concentration had resulted from the ABA treatment. It should be noted, however, that complete closure of P. trichocarpa stomata never did occur. The partial closure observed with loss of turgor in the guard cells occurred at a higher water potential with ABA treated strips than with the control strips.

The foliar application of ABA to developing shoots of P. trichocarpa appears to alter the response of stomata to leaf-water potential. Ten days after ABA application, stomata on both young and old leaves were open at high water potential. However, as the water potential of the leaf declined, the stomata on the younger leaves closed, while those of older leaves did not close.

Abscisic acid application to epidermal strips appears to lead to solute loss in P. trichocarpa guard cells, but the stomata remain open in spite of the loss of turgor in the guard cells. When ABA is applied to the foliage of P. trichocarpa, young developing leaves appear to acquire some

response to leaf water potential while older mature leaves do not. The stomatal response to low leaf-water potential in younger leaves seems to have been modified such that closure is effected when the leaf has lost turgor. The hypothesis that an ABA application will modify the development of stomata in expanding leaves is thus supported. However, further work is required on the role of ABA in stomatal development; especially the quantitative analysis of endogenous levels and how applications or changes in endogenous levels affect the development of stomata.

Publications

Heilman, P. E. 1985. Sampling and genetic variation in foliar nitrogen in black cottonwood and its hybrids in short rotation. Submitted to Canadian Journal of Forest Research. April 10, 1985.

Presentations

Two presentations were made by R. Stettler on the poplar program and its new biotechnology effort, one to a gathering of chief executive officers of the Northwest pulp and paper industry (May 9); the second to the staff at the Washington State Department of Natural Resources Research Branch (May 10).

INTERNAL DISTRIBUTION

1. S. I. Auerbach
2. R. S. Carlsmith
3-7. J. H. Cushman
8. J. L. Elmore
9. W. F. Furth
10. S. G. Hildebrand
11. D. W. Johnson
12. J. W. Johnston
13. L. K. Mann
14-18. R. D. Perlack
19-24. J. W. Ranney
25. D. E. Reichle
26. M. W. Rosenthal
27. M. S. Salk
28. R. B. Shelton
29-33. J. L. Trimble
34. A. F. Turhollow
35. R. I. Van Hook
36. D. C. West
37-41. L. L. Wright
42. Biology Library
43. Central Research Library
44-53. ESD Library
54-55. Laboratory Records
56. Laboratory Records-RC
57. ORNL Patent Office

EXTERNAL DISTRIBUTION

58. P. C. Badger, Southeastern Regional Biomass Energy Program, National Fertilizer Development Center, Tennessee Valley Authority, Muscle Shoals, AL 35660
59. David Bancroft, Council of Great Lakes Governors, 122 West Washington Ave., Suite 801A, Madison, WI 53703
60. B. J. Berger, Director, CE 32.1, Biomass Energy Technology Division, Department of Energy, Forrestal Building, Washington, DC 20585
61. P. R. Blankenhorn, School of Forest Resources, Pennsylvania State University, University Park, PA 16802
62. T. W. Bowersox, School of Forest Resources, Pennsylvania State University, University Park, PA 16802
63. J. Thomas Callahan, Associate Director, Ecosystem Studies Program, Room 336, 1800 G Street, NW, National Science Foundation, Washington, DC 20550
64. T. B. Crabb, BioEnergy Development Corporation, 888 Kalanianaole Avenue, Hilo, HI 96720
65. D. Curtin, Department of Forestry, Fisheries, and Wildlife, Tennessee Valley Authority, Norris, TN 37828
66. D. H. Dawson, 1835 North Stevens Street, P.O. Box 1321, Rhinelander, WI 54501
67. D. C. Deardorff, 601 W. San Mateo No. 98, Santa Fe, NM 97501
68. D. S. DeBell, USDA Forest Service, Forestry Sciences Laboratory, 3625 93rd Avenue, S.W., Olympia, WA 98502
69. L. S. Dolan, Seattle City Light, 1015 Third Avenue, Seattle, WA 98104
70. A. S. Fege, Northeastern Forest Experiment Station, 370 Reed Road, Broomall, PA 19008
71. P. Felker, College of Agriculture, Texas A&I University, Kingsville, TX 78363
72. J. A. Fisher, Fiber Fuels Institute, 310 Cedar Street, St. Paul, MN 55101

73. G. J. Foley, Office of Environmental Process and Effects Research, U.S. Environmental Protection Agency, 401 M Street, SW, RD-682, Washington, DC 20460
74. Pat Fox, Bonneville Power Administration, P.O. Box 3621, Routing EPG, Portland, OR 97208
75. D. S. Frederick, School of Forest Resources, North Carolina State University, Raleigh, NC 17650
76. W. A. Geyer, Department of Forestry, Kansas State University, Manhattan, KS 66506
77. C. R. Goldman, Professor of Limnology, Director of Tahoe Research Group, Division of Environmental Studies, University of California, Davis, CA 94616
78. A. Gyekye, Bureau of Economic Research and Development, Virginia State University, Petersburg, VA 23803
79. Alberto Goetzl, National Forest Products Association, 1619 Massachusetts Ave., NW, Washington, DC 20036
80. R. B. Hall, Forestry Department, 251 Bessey Hall, Iowa State University, Ames, IA 50011
81. J. W. Hanover, Department of Forestry, Michigan State University, East Lansing, MI 48824
82. E. A. Hansen, USDA Forest Service, Forestry Sciences Laboratory, P. O. Box 898, Rhinelander, WI 54501
83. P. E. Heilman, Western Washington Research and Extension Center, Puyallup, WA 98371
84. F. F. Hooper, School of Natural Resources, The University of Michigan, Samuel Trask Dana Building, Ann Arbor, MI 48109
85. J. W. Huckabee, Project Manager, Environmental Assessment Department, Electric Power Research Institute, 3412 Hillview Avenue, P.O. Box 10412, Palo Alto, CA 94303
86. George Y. Jordy, Director, Office of Program Analysis, Office of Energy Research, ER-30, G-226, U.S. Department of Energy, Washington, DC 20545
87. M. S. Joshua, Bureau of Economic Research and Development, Virginia State University, Petersburg, VA 23803
88. R. C. Kellison, Director, North Carolina State University Cooperative Programs, School of Forest Resources, North Carolina State University, Raleigh, NC 27650
89. F. Laing, Botany Department, University of Vermont, Burlington, VT 05401
90. R. Loose, Director, Office of Renewable Technology, CE 52, Department of Energy, 1000 Independence Avenue, Washington, DC 20585
91. Helen McCammon, Director, Ecological Research Division, Office of Health and Environmental Research, Office of Energy Research, MS-E201, ER-75, Room E-233, Department of Energy, Washington, DC 20545
92. C. M. McKell, Vice President Research, Plant Resources Institute, 417 Wakara Way, Salt Lake City, UT 84108
93. J. M. Peterson, New York State Energy Research and Development Authority, Two Rockefeller Plaza, Albany, NY 12223
94. Irwin Remson, Department of Applied Earth Sciences, Stanford University, Stanford, CA 94305

95. D. L. Rockwood, School of Forest Resources and Conservation, 118 Newins-Ziegler Hall, University of Florida, Gainesville, FL 32611
96. B. Ross, Energy/Development International, 1015 18th Street, N.W., Suite 802, Washington, DC 20036
97. H. E. Sommer, School of Forest Resources, University of Georgia, Athens, GA 30602
98-107. S. Sprague, Biomass Energy Technology Division, Department of Energy, Forrestal Building, Washington, DC 20585
108. K. Steinbeck, School of Forest Research, University of Georgia, Athens, GA 30602
109. R. J. Stern, Director, Office of Environmental Compliance, MS PE-25, FORRESTAL, U.S. Department of Energy, 1000 Independence Avenue, SW, Washington, DC 20585
110. R. Stettler, College of Forest Resources, University of Washington, Seattle, WA 98195
111. C. H. Strauss, School of Forest Resources, Pennsylvania State University, University Park, PA 16802
112. Leonard H. Weinstein, Program Director of Environmental Biology, Cornell University, Boyce Thompson Institute for Plant Research, Ithaca, NY 14853
113-117. C. R. Wenzel, Science Applications International Corporation, Oak Ridge, TN 37830
118. C. D. Whitesell, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, 1151 Punchbowl Street, Room 323, Honolulu, HI 96813
119. Raymond G. Wilhour, Chief, Air Pollution Effects Branch, Corvallis Environmental Research Laboratory, U.S. Environmental Protection Agency, 200 SW 35th Street, Corvallis, OR 97330
120. Frank J. Wobber, Ecological Research Division, Office of Health and Environmental Research, Office of Energy Research, MS-E201, Department of Energy, Washington, DC 20545
121. M. Gordon Wolman, The Johns Hopkins University, Department of Geography and Environmental Engineering, Baltimore, MD 21218
122. Office of Assistant Manager for Energy Research and Development, Oak Ridge Operations, P. O. Box E, U.S. Department of Energy, Oak Ridge, TN 37831
123-149. Technical Information Center, Oak Ridge, TN 37831