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INCREASING THE BIOMASS PRODUCTION OF SHORT ROTATION COPPICE FORESTS
Progress Report

Klaus Steinbeck
Claud L. Brown

School of Forest Resources
University of Georgia
Athens, Georgia 30602

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CONTENTS OF PROGRESS REPORT

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AEC CONTRACT NO.

SUPPORTING DIV OR OFFICE DOE - Solar Techology - Fuels Biomass

NAME & ADDRESS OF CONTRACTOR OR INSTITUTION: (State the division, department, or professional school, medical, graduate or other, with which this project should be identified.)

School of Forest Resources
University of Georgia
Athens, Georgia 30602

TITLE OF PROJECT:

Increasing the Biomass Production of Short Rotation Coppice Forests

NAMES, DEPARTMENT, AND OFFICIAL TITLES OF PRINCIPAL INVESTIGATORS AND OTHER PROFESSIONAL SCIENTIFIC PERSONNEL. (not including graduate students) engaged on the project, and fraction of man-year devoted to the project by each person.

Dr. K. Steinbeck, Associate Professor
Dr. C. L. Brown, Professor
Dr. H. E. Sommer, Assistant Professor
Mr. R. S. Sinclair, Assistant Forest Resource Manager

NO. OF GRADUATE STUDENTS ON PROJECT: 1 NO. OF GRADUATE STUDENT MAN-YEARS 1/3 year EFT

SUMMARY OF PROPOSED WORK: (200-300 words, omit Confidential Data). Summaries are exchanged with government and private agencies supporting research, are supplied to investigators upon request, and may be published in AEC documents. Make summaries substantive, giving initially and for each annual revision the following: OBJECTIVE; SCIENTIFIC BACKGROUND FOR STUDY; PROPOSED PROCEDURE; TEST OBJECTS AND AGENTS.

The objective of the project is to increase biomass yields from coppice forests by admixing tree species (Alnus glutinosa, Robinia pseudoacacia and others) to plantations of Platanus occidentalis and Liquidambar styraciflua. Yield increases due to intensive cultivation, especially fertilization and irrigation, will be documented. A genetic improvement program of promising candidate species both through the identification of superior genotypes and mass cloning with tissue culture is also included.

Results to date:

Three plantings have been established successfully to screen candidate species on various sites and to test the effects of weed control, fertilization and irrigation on short rotation forests. Two plantations in Ga. are in their 2nd and 3rd growing seasons while one in S.C. is in its 1st growing season. A two acre plantation has been established to test development of geographic seed source material for sycamore. A nursery is in operation to develop seedling production methods for new species and to grow and maintain genetic material. Mass cloning of selected material by tissue culture techniques has produced material for testing in outplantings.

BUDGET PRIMARY SECONDARY

PROGRAM CATEGORY NO.

Klaus Steinbeck Clark L Brown
Signature of Principal Investigator

DATE: 6. Aug. 1980.

INVESTIGATOR - DO NOT USE THIS SPACE

DISCLAIMER STATEMENT

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ABSTRACT

Two biomass plantations have been established in Georgia, one in the Coastal Plain (Tattnall Co.) and one in the Piedmont (Putnam Co.). Half of each plantation has gone through three and the other half through two growing seasons. Sycamore (Platanus occidentalis) and Sweetgum (Liquidambar styraciflua) are the main species under test, either in pure plots or in admixture with Black alder (Alnus glutinosa) and Black locust (Robinia Pseudoacacia). The best growth has been made by black locust in the Piedmont where it averaged over 4 m in height at two years of age in both irrigated and non-irrigated plots. Sycamore averaged 2.8 m in height in comparable plots. Growth of all species in the Coastal Plain was less than that in the Piedmont due to soils and to heavy weed competition the first year.

There is some evidence that species grown in admixture grow significantly differently from the same species in a pure stand. Alder survival is disappointingly low.

A 10-acre planting on the Savannah River Project near Aiken, South Carolina was established in Jan.-Feb. 1980 to test the effectiveness of a fertilizer application in the bottom of the slit made by the mechanical tree planter at time of planting. As of this report (Aug. 1980) there is no evidence of fertilizer injury to any of the five species being screened.

A two acre plot near the 10-acre planting mentioned above and a smaller plot in Putnam Co., Ga. have been established to test the performance of geographic seed sources of sycamore and sweetgum. The sweetgum seedlings came from 27 stands east of the Mississippi. The sycamore selections came from Georgia and adjacent states. During the two year 1978-79 period sycamore seed was collected from 243 half-sib families in 82 stands.

The tissue culture studies involve the growing of cell material in sterile culture with varying hormonal and nutrient concentration. Over 50,000 cultures were established and maintained over a 12 month period. Complete plantlets have been derived from hypocotyl sections from sweetgum. A trial with 2683 sections produced 261 that developed shoots on shoot growth medium. These shoots could be traced to 87 different seedlings. It appears possible to multiply clones of sweetgum material with relative ease, using media and techniques currently available.

During the past winter 25 black locust plantlets and 50 Paulownia tomentosa plantlets were planted in a test plot on the Whitehall Forest. These represent the first mass-produced plantlets of these species.

OVERVIEW OF PROJECT

PROJECT TITLE: Increasing the Biomass Production of Short Rotation Coppice Forests

School of Forest Resources, University of Georgia, Athens, Georgia

OBJECTIVE: To determine ways of increasing the biomass production of short rotation hardwood forests.

PROCEDURE:

(1) Species Screening: Plant a variety of hardwood species amenable to short-rotation forestry on such soils as might be available for energy or fiber production. Selected species will (a) have rapid juvenile growth rates, (b) sprout from the stump and grow well in plantations, (c) resist wildlife damage as well as insect and disease attacks.

(2) Cultural Treatments: Intensive cultural practices such as cultivation, mechanical and chemical weed control, fertilization and irrigation will be evaluated. This involves the establishment of test plantations on several sites and data collection over at least a five year period.

(3) Genetic Improvement: (a) Superior individuals and geographic seed sources of the most promising species will be selected and propagated. Selection will be based on biomass production rates, adaptability to a variety of site conditions, pest resistance and ease of multiplication. (b) Tissue culture techniques for mass cloning of hardwoods will be developed. The main thrust of this phase will be the development of practical systems for the vegetative multiplication of genetically select material and rapid assessment of the growth potential of clones.

(4) Species Mixtures: The energy input-output balance of plantations might be more favorable with reduced fertilizer inputs. Therefore, the biomass production of nitrogen fixing, woody species grown either in pure or mixed stands will be determined.

(5) Ecological Assessment: Changes in soil fertility and organic matter status under pure and mixed stands will be followed.

(6) Education: Provide graduate assistantships to attract students in hardwood silviculture. This will help ease the current shortage of foresters versed in hardwood plantation establishment and management.

PROGRESS First year Fiscal 1978 - EG-77-5-09-1015

(1) Two sites were selected for the large scale field plantings in Georgia; one a 50 acre Piedmont site on the B. F. Grant Memorial forest in Putnam Co., belonging to the School of Forest Resources, and the other on a 50 acre Coastal Plain site in Tatnall County on Union Bag-Camp Corporation land. Both areas were site-prepared and irrigation ponds constructed nearby. Because of a shortage of seedlings only half of each site could be planted. The extremely dry weather following planting, and the shortage of water that developed at the Tatnall site, compromised survival and growth but at the same time furnished insight on the problems that can be expected in large scale operations. Weed control, fertilization and cultivation were carried out during the growing season. The general conclusion is that satisfactory stands were produced on both sites despite the adverse weather conditions.

(2) Soil samples were taken on both sites prior to planting; these have been analyzed for soil nutrient levels; additional samples were taken after fertilization and later in the season to monitor nutrient losses or gains. These samples were analyzed in part during the fiscal year or are in the process of being analyzed. Soil nutrient changes will be followed during the five year period planned for these studies.

(3) Soils were sampled on both sites prior to planting; these have been analyzed for soil nutrient levels; additional samples were taken after fertilization and later in the season to monitor nutrient losses or gains. These samples were analyzed in part during the fiscal year or are in the process of being analyzed. Soil nutrient changes will be followed during the five year period planned for these studies.

(4) Experience with black alder seed demonstrated the need for greater information on stratification, storage and treatment of such seed in order to obtain a satisfactory supply of seedlings. Hence, laboratory experiments were conducted to determine the proper handling of such material prior to actual planting.

(5) Good success was obtained with bud and root differentiation of several hardwoods using tissue culture techniques. However, the use of solid media with tissue explants grown in single tubes restricted the amount of material that could be handled at one time under laboratory conditions. Hence, a study was initiated on the feasibility of mass cloning in liquid culture to bring about controlled differentiation of numerous embryoids (young intact plants) in single containers.

PROGRESS

Second year Fiscal 1979 - EG-77-5-09-1015

(1) Since the main thrust of this project is to study the biomass production of short rotation hardwoods as influenced by cultural practices, fertilizer and irrigation, emphasis was placed on the completion of the Coastal Plain and the Piedmont plantings. These plantings will be the source of data beginning in 1981 and continuing beyond the 5 year period now planned for the project.

The plantings are under way as of Jan. 1, 1979 and that half of each 50 acre plot not completed in 1978 will be finished by Mar. 1, 1979. Also replaced plantings were made where skips existed in the 1978 plantings.

(2) Tree growth data for the 1978 plantings is in hand. Later on this year we will collect leaf samples and analyze their nutrient content. This will provide baseline data for foliar analysis as a diagnostic tool to assess the nutrient status of plantations. It will also help in assaying nutrient cycling and nutrient losses at harvest. Soil and leaf analysis should also record the effects of interplanted nitrogen fixing tree species.

(3) Soil samples to monitor soil nutrient changes were taken in the fall of 1978 and will be taken again in 1979. These samples are analyzed for the common soil nutrients and the data will be used to give a profile of the changes under short rotation plantings as related to different cultural practices.

(4) The site for a one-acre tree nursery was selected and cleared on an experimental forest (Whitehall) near campus. It will provide an opportunity to develop growing techniques for the non-traditional species used in short-rotation forestry.

(5) A seed collection program from various geographic locations has been initiated for American sycamore and sweetgum. We hope to identify populations with superior biomass production potential and pest resistance. These seeds also will be sown in the experimental nursery. Older short-rotation plantings also have been screened for vigorous individuals. The genetic improvement of hardwoods by both vegetative and sexual means is a long-term approach to improving biomass yields which requires concentrated efforts over a period of years.

(6) Past research on plantlet formation for cloning hardwood species in quantity served as the basis for dealing with sycamore, sweetgum, locust and other species. Since tissue culture methods offer the promise of short-cutting the process whereby superior strains can be grown in quantity. research on the application of tissue culture technqiues to biomass production is a quick method of getting high yielding strains of hardwoods into use after such strains have been isolated and identified.

(1) The short rotation plantings in Tattnall and Putnam Counties, Georgia are successful. Survival averaged 87 and 75% respectively. Weed control and fertilization have followed the planned schedules. Irrigation was possible only on the Putnam Co. planting. Some interesting growth reactions are becoming apparent in the species admixtures which should become more pronounced as the trees continue competition.

(2) So far the plantings are too young for experiments in harvesting, chipping and chip storage. It is hoped that a satisfactory harvesting machine can be acquired soon. Dr. Steinbeck has viewed harvesting equipment in England to see if currently engineered machines could be used, or modified as an interim solution. A hydraulically driven circular saw mounted with an articulated boom on a small farm tractor holds promise. A unit is on order and will be tested during the winter of 198C.

(3) Levels of sugar and starch in root systems coppiced at different seasons of the year showed some variation in relation to growth demands. Levels are highest in roots before growth starts in the spring and gradually builds up again later in the season.

(4) Tree improvement efforts based on geographic selections of sycamore and sweetgum resulted in a two acre planting of selected material on the Savannah Plant and one near the Putnam Co., Ga. site.

(5) Tissue culture research continues with emphasis on improvement of cultural media and hormonal requirements for production of shoots and roots from callus formed from shoot and embryo cells. Sweetgum is relatively easy to propagate in pure culture but sycamore is difficult because of the contaminating organisms present in seed coats and shoot tips.

(6) A 10-acre planting established on the Savannah River Plant in Jan.-Feb. 1980 has been designed to test a method of fertilizer application in the slit made by the planting machine. Hopefully fertilizer applied in this fashion will not burn the roots of newly transplanted seedlings and allow for more efficient utilization of the fertilizer by the trees. This method of applying fertilizer could result in a significant energy input saving.

(7) The completion of a one acre nursery at Whitehall makes possible the development of seedling production methods for new candidate tree species as well as the production of sufficient seedlings for outplantings. The species used in the project are often considered weeds by traditional foresters and are therefore not available commercially.

PROGRESS BY TASKS 1979-1980

The tasks which outline the nature of the research operation according to the DOE Contract for Fiscal 1980 are:

1. Maintain plantations
2. Monitor plantations
3. Genetic improvement
4. Cooperation with other interested parties
5. Storage properties of chip piles
6. Seasonal harvesting effects
7. 10 acre species screening trial
8. Graduate education

1. Maintain plantations

The plantings in Putnam and Tattnall Counties, Georgia are on different soil types and the locality differences and soil conditions are reflected in the nature and the amount of required maintenance. The objectives of the maintenance are to maintain optimum conditions for biomass production to determine if such operations significantly affect wood yields.

The Putnam County plantation is on a heavy Piedmont soil. Because of drought conditions and high temperatures over the past year the plots were irrigated 7 times between April 1979 and August 1980. A 10-10-10 fertilizer was applied at the rate of 800 lbs/A in June 1979 and ammonium nitrate at 120 lbs/A in August 1979. The plots were harrowed or bush hogged for weed and grass control 4 times during the year.

The Tattnall County planting supported a heavy growth of grass and herbaceous plants requiring continual control efforts. This plot was harrowed 7 times during the season and Simazine was applied in March 1979 and March 1980. Fertilizer at the rate of 800 lbs/A of 10-10-10 was applied in July 1979.

Considerable weed control proved necessary on the Savannah River Project planting made in January and February 1980. Harrowing and hand application of Simazine was necessary in May and further harrowing and hand hoeing in June 1980. A third harrowing was necessary in July.

Most of the plots in the older plantings have closed ranks making further machine harrowing unnecessary since herbaceous weeds are being discouraged by shade and competition from the trees.

2. Monitor Plantations

Growth measurements over a two year period for the Piedmont and Coastal Plain plantings are given in the following table.

As reported last year, black locust still ranks highest in height and diameter. Next tallest is sycamore which rivaled locust in diameter growth. All species at least doubled in both height and diameter during the second growing season. The largest increment of height growth was exhibited by black locust which grew 2.43 and 2.16 meters for non-irrigated and irrigated respectively. The next largest height growth was by sycamore in the Coastal Plain which grew 1.63 meters in height and 2.5 cm in diameter. Alder grown in the Coastal Plain was taller than that in the Piedmont but slowed its growth during the second growing season in the field. Otherwise all species grew faster on the Piedmont site. The excellent growth of both locust and sycamore may be partly due to crown closure for these species which resulted in the shading out of the weed competition. Sweetgum is off to its typical slow start and has not yet achieved full site occupancy.

Survival averaged 77% overall in 1978 and decreased to 70% at the end of the 1979 growing season. Alder in particular continued to die, especially in the Coastal Plain where it is now down to an unacceptable 38% survival rate. Irrigation continued to have no discernible effect on survival in the Piedmont.

When sycamore and sweetgum were grown in mixture with alder, they generally grew more slowly than they did in pure plots. On the Coastal Plain site, for example, all three species grew less in height and diameter in the mixtures. The trend was less pronounced in the Piedmont, there sycamore and alder averaged less in diameter and only

Table 1. Average heights and diameters of the trees at the two sites.

Site	End of season	Species											
		Sycamore			Sweetgum			Alder			Locust		
		Sur.(%)	Ht.	Dia.	Sur.(%)	Ht.	Dia.	Sur.(%)	Ht.	Dia.	Sur.(%)	Ht.	Dia.
Piedmont													
Non-Irr.	'78	83	130	1.8	87	52	1.1	81	73	1.1	86	186	2.0
	'79	80	282	3.8	70	109	1.8	71	157	2.2	80	429	4.0
Irrigated	'78	80	133	2.0	77	59	0.9	84	76	1.2	84	221	2.7
	'79	74	280	3.9	72	117	2.0	76	150	2.2	78	437	4.2
Coastal Plain													
Non-Irr.	'78	70	71	0.8	69	49	0.5	50	100	1.3			
	'79	66	234	3.3	61	91	1.8	38	167	2.7			

All heights and diameters (15 cm above ground line) in cm.

sycamore grew less in height in the mixed plots. This is the opposite of the hoped for result of species mixing. Obviously future developments will be most interesting. Sycamore has recently been reported to be allelopathic and this may be evident in the mixed plantings.

The soil nutrient levels are determined annually in both plantations (Table 2). No differences in available nutrients due to fertilization appear in Putnam County, but in the Coastal Plain in Tattnall County, the unfertilized plots averaged higher in all soil nutrients which we analyzed than the fertilized ones. Any attempt at explanation would be pure speculation at this point.

Table 2. Soil Nutrients (ppm) and pH in June, 1979.

Nutrient, pH	Piedmont		Coastal Plain	
	Fert.	Non-Fert.	Fert.	Non-Fert.
pH	6.1	6.1	6.0	6.1
Phosphorus	7.7	6.3	21.5	23.8
Potassium	62.5	62.0	25.7	29.6
Calcium	582	594	141	161
Magnesium	87.9	91.9	15.0	15.7

3. Genetic improvement

Two field plantings were made to test the performance of seedlings from geographic seed sources of sycamore and sweetgum. A two acre plot on the Savannah River Plant area adjacent to the 10 acre species screening performance test was planted to 702 sycamore seedlings and 648 sweetgum exclusive of the border trees. The other planting on the B. F. Grant Forest in Putnam Co., Ga. was planted with 432 sweetgum selections and 100 sycamore. The weather turned dry and the remaining sycamore have not been planted and held in storage.

The sweetgum seedlings under test came from four individual trees from each of 27 stands east of the Mississippi River. Nursery results indicate that many traits vary with latitude. Northern seed source seedlings were shorter, set bud earlier and lost their leaves earlier than those from seed of more southernly origin. On the average stem diameters were approximately equal regardless of latitude of parent trees. There was sufficient variation between stands within a region and families with stands to suggest that selections at these levels will produce genetic gains for nursery expressed traits.

Survival for outplanted sweetgum was nearly 100 percent in both plantings. Biomass data will be taken at the end of three years.

The sycamore selections came from Georgia and adjacent parts of neighboring states. For the two year period 1978-79, seed was collected from 243 half sib families in 82 stands. In the spring of 1980 seed from all families were sown in seven replications in the nursery at Whitehall. Variations in height for Georgia collections were equally divided among latitude, stand within latitude and family within stand. Diameter variations were confined to families within stands.

The tissue culture facility at the School of Forest Resources has the capability of handling approximately 10,000 cultures in the main culture room at any given time. An additional 2,000 cultures can be handled in rigidly controlled incubators programmed for differences in day and night temperatures and/or photoperiod. Five hundred tissue culture flasks for liquid suspension cultures can be operated at any given time.

Most of the cloning and organogenesis research the past year was carried out with short rotation hardwoods including sweetgum, sycamore, black locust, red and European alder, honey locust, catalpa, Paulownia, red maple, and river birch. Over 90% of the effort was devoted to sweetgum, black locust, and alder.

During an average week of activity with one technician and 2-3 part-time student help about 500 cultures are established for studying bud or root differentiation. Over the period of one year approximately 25,000 new cultures are developed. The turn over rate per culture varies from 30 days to 6 months depending upon the material and conditions being studied. In some studies many of the original explants are later subcultured as much as 12 times each year, others less frequently, i.e., every 90 days. Over 50,000 cultures are established and maintained during a twelve month period. Most of these cultures are examined individually (some cursory, others in considerable detail) at least 3-5 times during their maintenance. In a period of twelve months a total of 250,000 observations may be made and a large number of these recorded in a daily log book.

The nutrient media currently used involves 5 different basal media that is, 5 major stock solutions of inorganic salts to which

as many as 8-36 different combinations of organic growth factors (hormones mostly) are frequently varied. This alone permits as many as 180 different media for any given species at any given time.

During the past winter 50 Paulownia tomentosa and 25 black locust explants were planted in a test plot on the Whitehall Forest. These represent the first mass-produced plantlets of these species. At the time of planting these plantlets averaged 45 cm in height.

In order to produce sweetgum plantlets for a one acre plantation sterile seedlings were grown from 5 half-sib bottomland sweetgum seedlots. The hypocotyls of 299 seedlings were cut into 3-4 mm sections and placed on 12.5 ml of bud induction medium in a 50 mm petri dish. Three to 4 sections were placed in each dish. A total of 697 petri dishes containing 2683 hypocotyl sections were used. To date 261 shoots have been obtained and placed on a shoot growth medium. The origin of these shoots can be traced to 87 different seedlings. Additional shoots are still being formed on the bud induction medium.

4. Cooperation with other interested parties

Armstrong Cork is interested in large scale plantings of short rotation hardwoods in Georgia. Steinbeck conferred with them on planning such plantings and in the evaluation of 600 acres of proposed planting sites. Buckeye Cellulose in Florida is also interested in establishing short rotation forests.

Steinbeck also participated in a training program for scientists from developing nations on alternate energy sources held at the University of Florida.

Sommer gave a Seminar for the Pioneering Research Group of the Campbell Soup Co. near Camden, N. J. on July 11, 1980. He participated in discussions on tissue culture and trees and application of techniques to tomato genetics.

Steinbeck presented an invitational paper on Short Rotation Forests for Energy Production at the National Meeting of the American Chemical Society held in Aug. 1980 in San Francisco. A non-technical summary of this paper was requested for distribution to the news media.

Steinbeck was interviewed by Station WXYZ in Detroit for their News Maker Program in regard to short rotation energy plantations as the result of an article entitled "Quickie Trees from a Tree Pantry" that appeared in the Technology section in the May/June 1980 issue of NEXT magazine.

The magazine "The Mother Earth News" contained a brief note and picture of a Georgia biomass plantation in its July/August 1980 issue.

5. Storage properties of chip piles

Activity on this task is related to plantation age; the trees are too young for cutting and chipping trials.

A search is being conducted for suitable existing equipment to handling field harvesting of short rotation systems. Steinbeck visited Hydrocut Ltd. in Sudbury, England June 17-18, 1980 for a demonstration of their harvesting system engineered around a tractor with a front-mounted circular saw. This equipment has possibilities for adaptation to the short rotation systems and should be tested under production conditions.

6. Seasonal harvesting effects

Sprouting in coppice forestry is in part influenced by the amount and kind of carbohydrates stored in stump and root tissues. Since the amount of stored sugars varies with the season of the year, the time of coppicing may be important in the regeneration of new sprout growth.

A sycamore planting in Wilkes Co., Ga. planted in 1967 and arranged in replicated plots at 2' x 2' and 4' x 4' spacings afforded material for a root carbohydrate study in relation to season of cutting. This planting was first coppiced in 1970. In 1979 selected areas at both spacings were coppiced again at monthly intervals over the period of one year except for October and December 1979 and February 1980. The root samples were taken in both the growing period and the dormant season.

Certain trends were noted in 1979. Sugar levels for the March to August period ranged from 1.4% to 0.8% of the fresh weight. All plots showed a rise in starch levels in March. Starch levels declined through April and May as the result of new growth. Root starch levels in all plots increased in June and July.

There was no significant difference in either starch or sugar levels at the 2 x 2 and 4 x 4 spacings for any month sampled.

Rootstocks cut long enough for sprouts to develop had starch levels comparable to that in the roots of the uncut controls or those sampled at the time of cutting.

Dickson's method of measuring starch by enzyme action was compared with the perchloric ($HCLO_4$) method used in earlier tests. The Dickson method showed 2.7 times the amount of starch suggesting greater sensitivity. This method was also easier to use. Earlier results with the

perchloric method was converted to expected Dickson values by multiplying by 2.7

7. 10 acre species screening trial

A 10 acre plot located on the Savannah River Plant area was prepared and planted in Jan. & Feb. 1980 (Fig. 1). The objective of this planting is to study the effects of applying fertilizer at the time of planting in the bottom of the slit made by the planting machine. If this method of fertilizing seedlings proves practical it would reduce the need for broadcast fertilization early in the seedlings growth period. The 5 species under test are: sycamore, sweetgum, red maple (Acer rubrum), black locust and European black alder. Each species is being tested in separate sub-plots replicated four times.

Initial conditions were satisfactory for survival and growth, however data on growth and survival will not be taken until the end of the growing season.

Figure 1. A species screening/planting slit fertilizer application trial was established in the winter of 1979/80. Ten acres in size, it contains five species replicated four times in randomized complete blocks. Planted on a Troup sandy loam it is located in Barnwell County near Aiken, S. C. on the Savannah River Plant. The site is level with slopes of less than 2%. Previously this area supported a slash pine plantation which had been clearcut. The remaining unmerchantable vegetation as well as the pine stumps were pushed into windrows by a bulldozer. Access to the Savannah River Plant is controlled by the Department of Energy and DuPont.

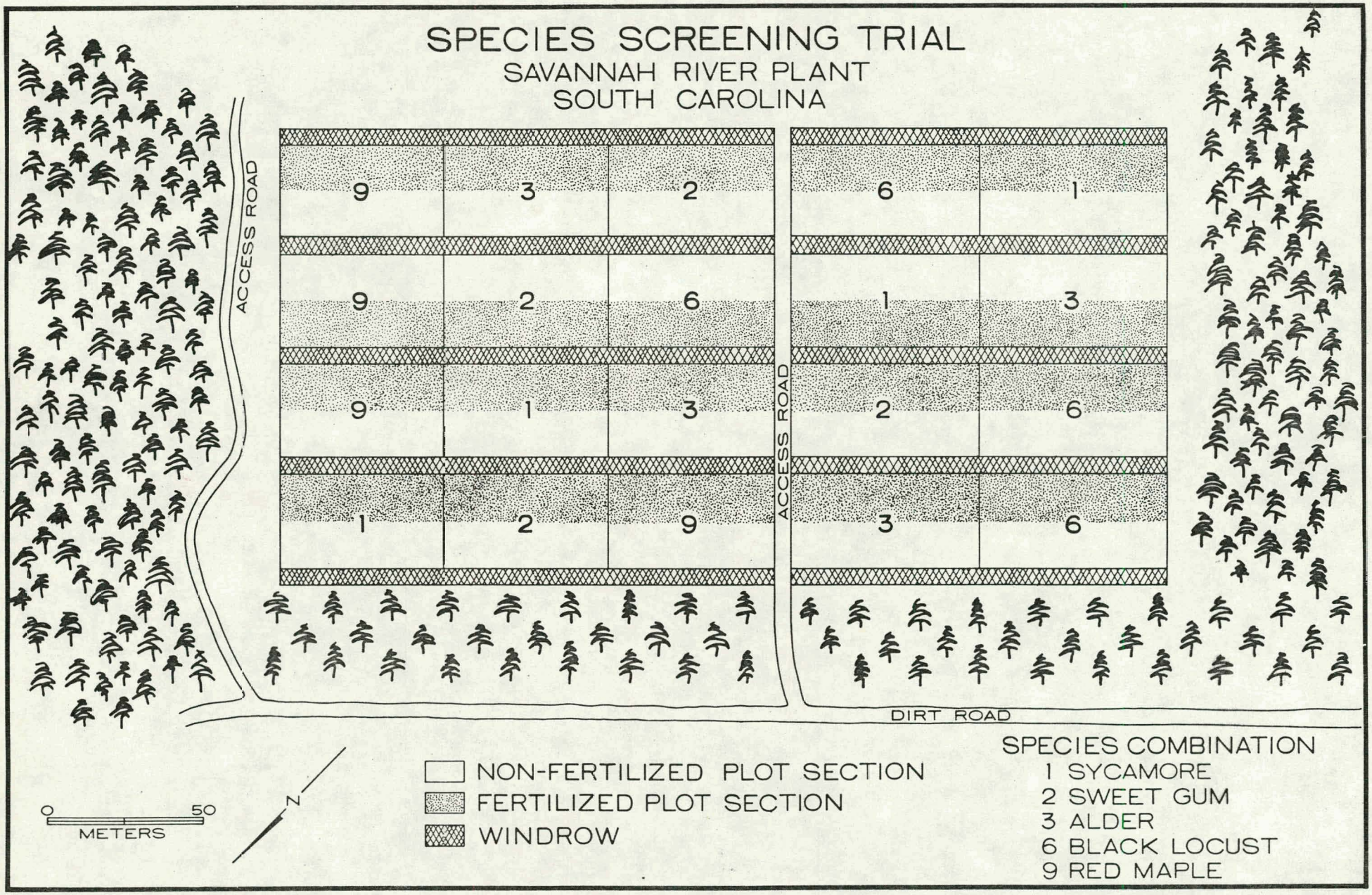
SPECIES SCREENING TRIAL
SAVANNAH RIVER PLANT
SOUTH CAROLINA
ACCESS ROAD
ACCESS ROAD
DIRT ROAD
9 3 2
6 1
9 2 6
1 3
9 1 3
2 6
1 2 9
3 6
NON-FERTILIZED PLOT SECTION
FERTILIZED PLOT SECTION
WINDROW
SPECIES COMBINATION
1 SYCAMORE
2 SWEET GUM
3 ALDER
6 BLACK LOCUST
9 RED MAPLE
0 50
METERS
N

Figure 1

8. Graduate education

Michael H. Renfroe is working on the controlled organogenesis of sweetgum in culture in vitro for his doctorate research supported by the DOE project. Hypocotyl explants from eight-week-old sweetgum seedlings were grown on media prepared with various combinations of naphthaleneacetic acid (NAA) and benzylaminopurine (BAP). While some of the explants developed roots and/or shoots, many formed only callus. In the search for a more satisfactory medium the cultures were placed on media with various concentrations of NAA and BAP and other substances. Seventeen percent of cultures with shoots formed roots. Callus cultures developed roots in 56 percent of the transplants. Apparently at the phytohormone concentrations tested the stock callus lines expressed morphogenic capacity for roots more readily than for shoots.

Tests were also conducted on the stratification period required for satisfactory germination of sweetgum seed. It was found that this period could be reduced by half without significantly affecting germination.

It is difficult to obtain sterile cultures from sycamore seed. The seed must be given special treatment to eliminate fungal contaminants and even under the most effective routines the percentage of sterile cultures so derived remains low. Organogenesis with sycamore is more difficult than with sweetgum and the search is continuing for effective concentrations and kinds of phytohormones.

European Black Alder is difficult to grow in pure culture and suitable phytohormones, their concentrations, and ingredients in culture material will require numerous trials to determine workable cultural conditions.

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Fig. 2. American sycamore beginning its third growing season after planting in Putnam Co., Ga., spacing 4 x 8 feet. No further weed control needed. The crowns are beginning to occupy the site completely.

Fig. 3. General view of the Putnam Co., Ga. planting along the irrigation lane. Three-year-old black locust in foreground.

Fig. 4. Sowing the experimental nursery at the Whitehall Forest. All for naught - the seeds failed to germinate.

Fig. 5. Sycamore x alder mixture beginning its second growing season in Tattnall Co., Ga. in the Middle Coastal Plain. The Simazine spray is still controlling the weeds.

Fig. 6. Sweetgum and alder mixture on the same site as Fig. 5.

Fig. 7. Planting at the Savannah River Plant (SRP) in South Carolina in the Upper Coastal Plain.

Fig. 8. One objective of the SRP planting was to test the feasibility of applying fertilizer in the planting silt. Custom-built fertilizer hopper at the right of the man planting the seedling.

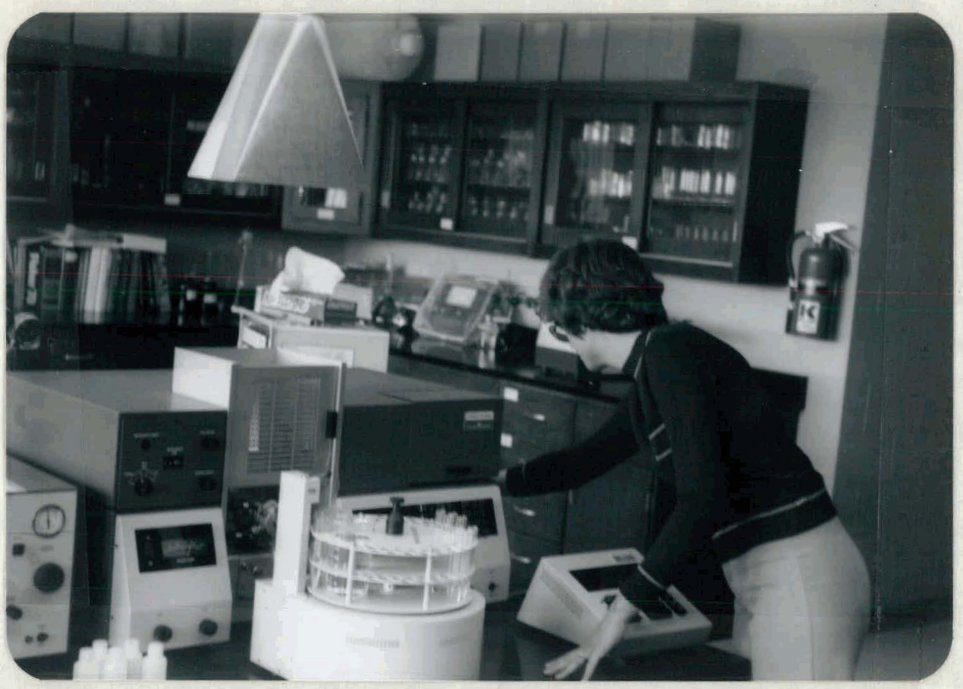

Fig. 9. Soil and plant analysis for nutrients with atomic absorption unit.

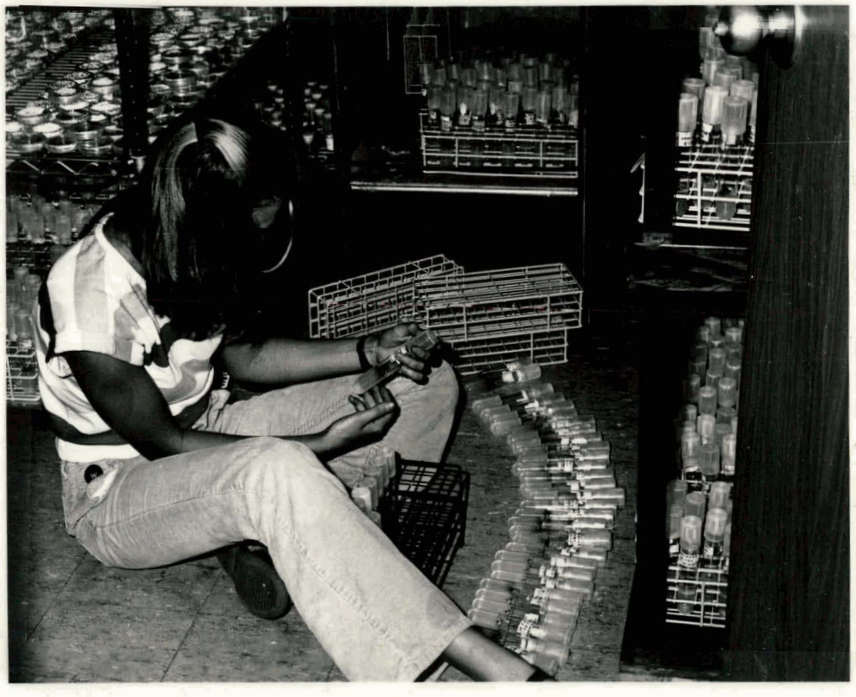

Fig. 10. Thousands of test tubes need to be prepared and later cleaned in tissue culture work.

Fig. 11. Bud initiation from shoot tip of sweetgum on chemically defined agar medium X 1.

Fig. 12. Sweetgum plantlet produced by embryogenesis in liquid culture then transferred to agar medium for growth and normal development X 3.