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INCREASING THE BIOMASS PRODUCTION OF SHORT ROTATION COPPICE FORESTS
Progress Report

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ABSTRACT

Two biomass plantations, one in the Coastal Plain, the other in the Piedmont province of Georgia, have been established. *Platanus occidentalis*, *Liquidambar styraciflua*, *Alnus glutinosa* and *Robinia pseudoacacia* were planted in pure and mixed plots. Differences in the growth at the end of the first growing season were attributed mostly to weed competition in the Coastal Plain. *Robinia* grew remarkably well in the Piedmont, averaging more than 2.2 m tall in irrigated plots. A fungus tentatively identified as belonging to the genus *Botryosphaeria* is causing heavy *Alnus* mortality in the Coastal Plain.

Progress in the genetic improvement phase of the project included a collection of *Platanus* seedlots from throughout Georgia to identify promising provenances and the production of *Liquidambar* and *Robinia* plantlets in tissue culture.

Differences in the calorific content of young sprout material from nine hardwood species (unit oven dry weight basis) were found to be small. Other studies dealt with the effects of different harvesting cycles on the size and carbohydrate contents of sycamore rootstocks.

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 silvi- culture. 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.

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(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.

PROGRESS REPORT

Increasing the Biomass Production of Short-Rotation Coppice Forests

The Plantations: The focal points of this project are the two 50 acre plantations in which American sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua*), European black alder (*Alnus glutinosa*) and black locust (*Robinia pseudoacacia*) were planted in pure and mixed plots. Lack of seedlings prevented completion of plantation establishment in 77/78, therefore approximately half were planted February 1979. Both plantations are now complete. Their physical and statistical design is shown in Figure 1 for the Coastal Plain (Tatnall County) and Figure 2 for the Piedmont (Putnam County).

There was considerable variation among species in seedling size (Table 1) at planting. Sycamore and alder seedlings were taller in both years than sweetgum and locust. Planting speed of the single row, modified wildland planter we used averaged about 900 seedlings per hour. This included turn around time, seedling loading, breakdowns etc. When the fields were too wet to be machine planted, we hand planted some areas

Table 1. Heights and root collar diameters of seedlings at planting.

Planting Season	Species							
	Sycamore		Sweetgum		Alder		Locust	
	Ht.	Dia.	Ht.	Dia.	Ht.	Dia.	Ht.	Dia.
	cm							
1978	60	1.3	45	0.7	72	0.6	--	--
1979	86	1.5	41	0.6	58	0.7	32	0.8

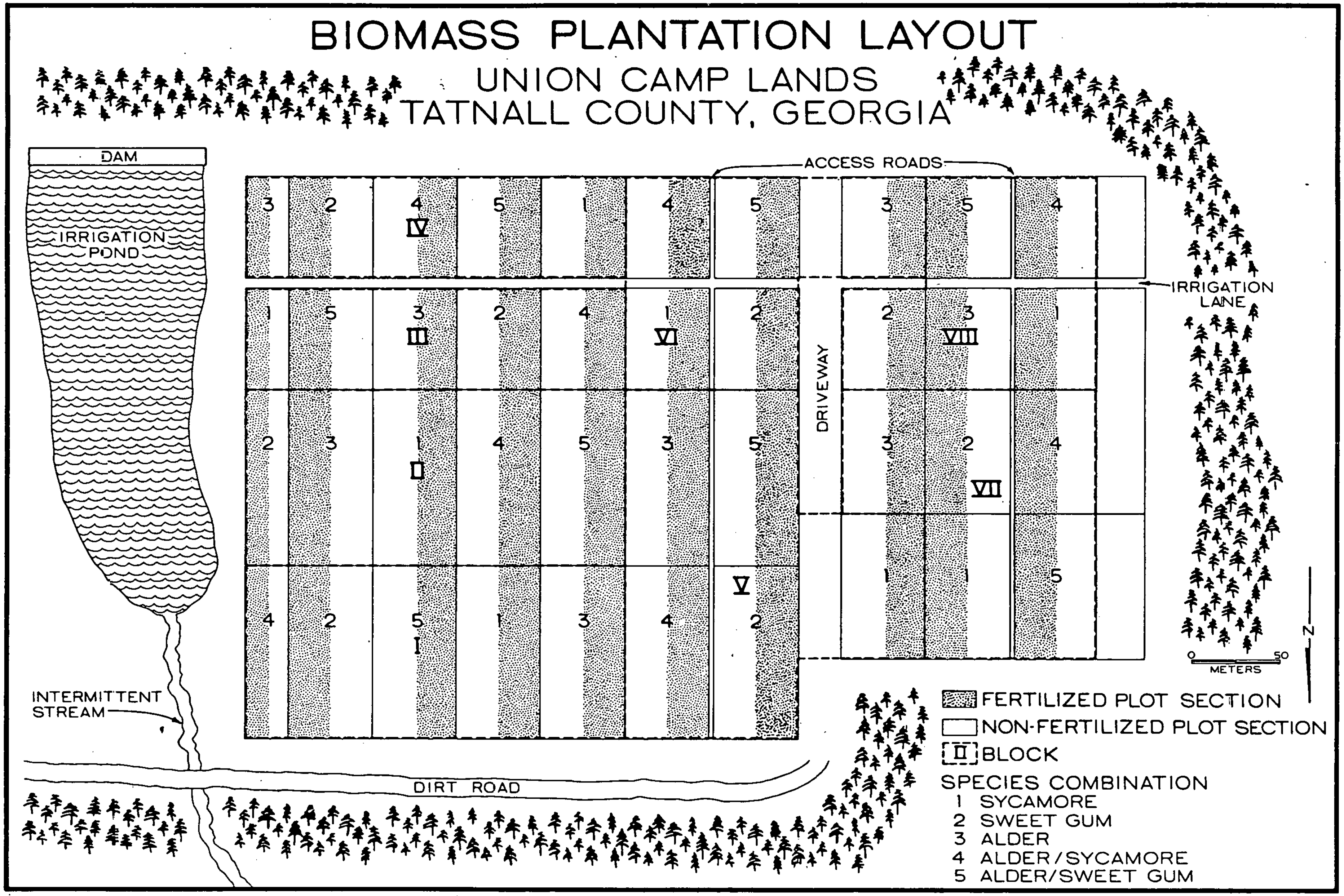
BIOMASS PLANTATION LAYOUT
UNION CAMP LANDS
TATNALL COUNTY, GEORGIA
DAM
IRRIGATION POND
ACCESS ROADS
IRRIGATION LANE
DRIVEWAY
INTERMITTENT STREAM
DIRT ROAD
METERS
N
FERTILIZED PLOT SECTION
NON-FERTILIZED PLOT SECTION
BLOCK
SPECIES COMBINATION
1 SYCAMORE
2 SWEET GUM
3 ALDER
4 ALDER/SYCAMORE
5 ALDER/SWEET GUM

FIGURE 1.

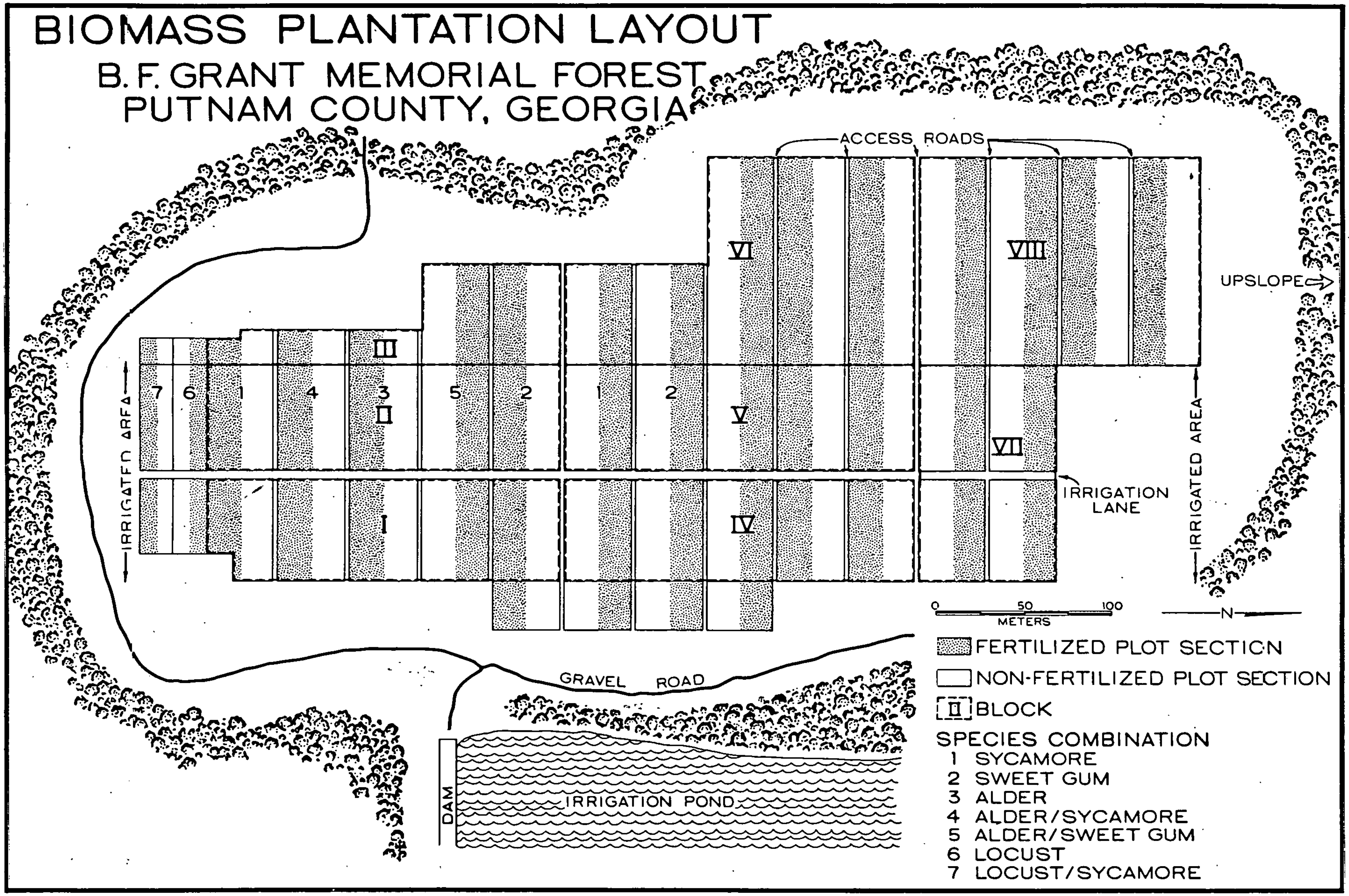
BIOMASS PLANTATION LAYOUT
B. F. GRANT MEMORIAL FOREST
PUTNAM COUNTY, GEORGIA
ACCESS ROADS
VI
VIII
UPSLOPE
III
7
6
1
4
3
5
2
1
2
II
V
VII
IRRIGATED AREA
IRRIGATED AREA
IRRIGATION LANE
I
IV
0 50 100
METERS
N
GRAVEL ROAD
DAM
IRRIGATION POND
FERTILIZED PLOT SECTION
NON-FERTILIZED PLOT SECTION
II BLOCK
SPECIES COMBINATION
1 SYCAMORE
2 SWEET GUM
3 ALDER
4 ALDER/SYCAMORE
5 ALDER/SWEET GUM
6 LOCUST
7 LOCUST/SYCAMORE

FIGURE 2

and averaged about 500 seedlings per man day.

Those portions of the plantations established in 77/78 were limed to raise soil pH to about 6.0 and <u>fertilized</u> with 800 pounds of 10-10-10 per acre in July, 1978. The latter was banded over the rows in 3-foot wide strips. One half of each plot received a banded top-dressing of 120 lbs/acre of elemental nitrogen in the Piedmont (Sept. 78) and 80 lbs/acre of elemental phosphorus in the Coastal Plain (Sept. 78). These top-dressings occurred too late to affect growth in 1978, but should become noticeable in the coming growing season.

The Piedmont plantation was <u>irrigated</u> (layout shown in Fig. 2) seven times (.99 inches of water applied each time) during the droughty summer of 1978. The Coastal Plain was not watered because the irrigation pond never contained enough water due to the drought and possibly also a leaky bottom. We recorded <u>energy inputs</u> by noting the amounts of diesel necessary to run the irrigation pump and tractors. Irrigation resulted in small height and diameter growth increases, but did not affect survival in any consistent way among species (Table 2). The portable irrigation system functioned well. The gun threw water in a circle with a 400 foot diameter and covered about 14 acres/8 hours. Water distribution across the watered circle was not uniform, therefore we measured trees only in 100 foot sections on both sides of the irrigation lane that did receive uniform amounts (Figs. 3 and 4).

TATNALL COUNTY SITE

LAYOUT OF IRRIGATION PLOT

A SYCAMORE/ALDER MIX IS SHOWN

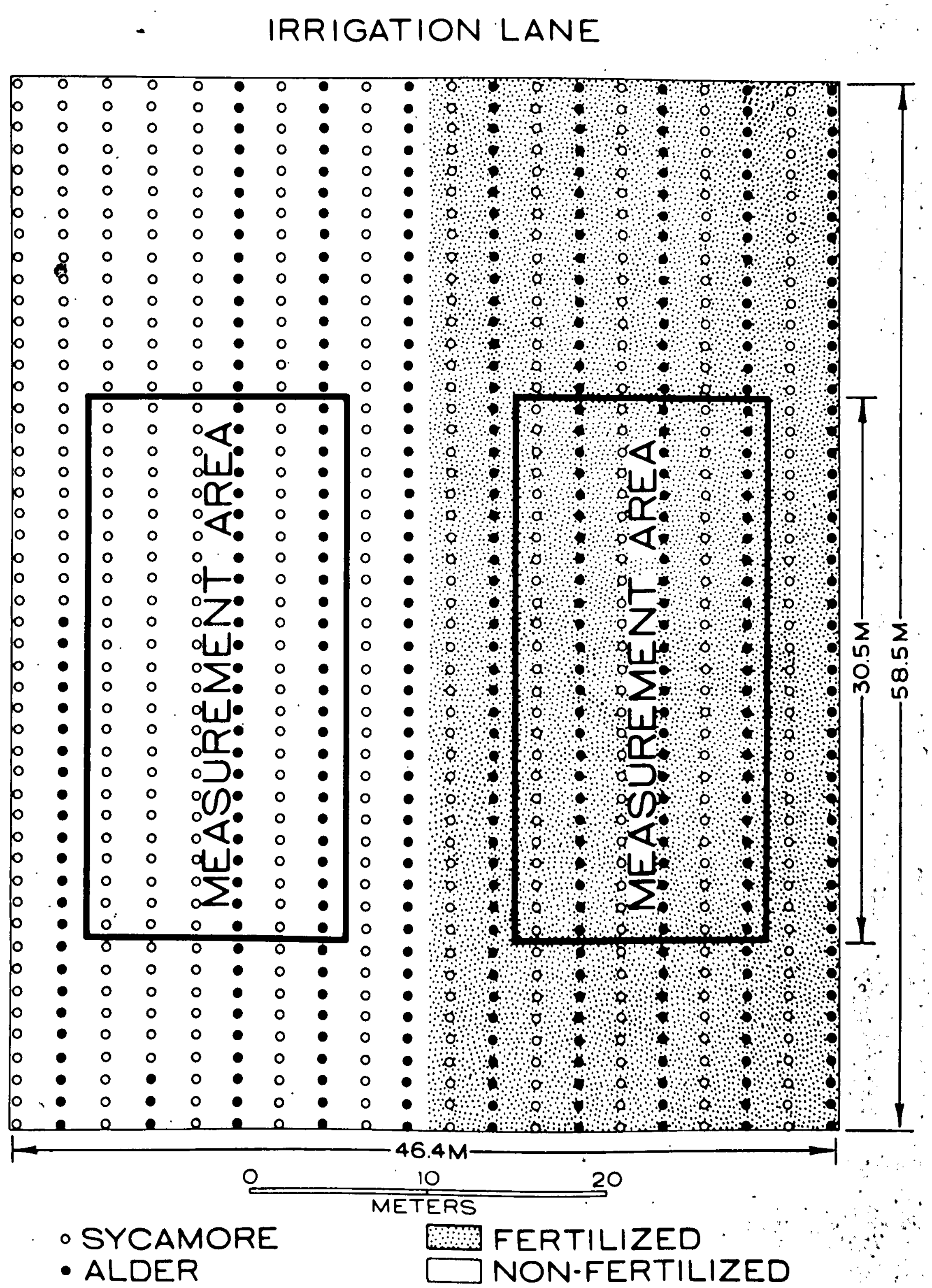

FIGURE 3

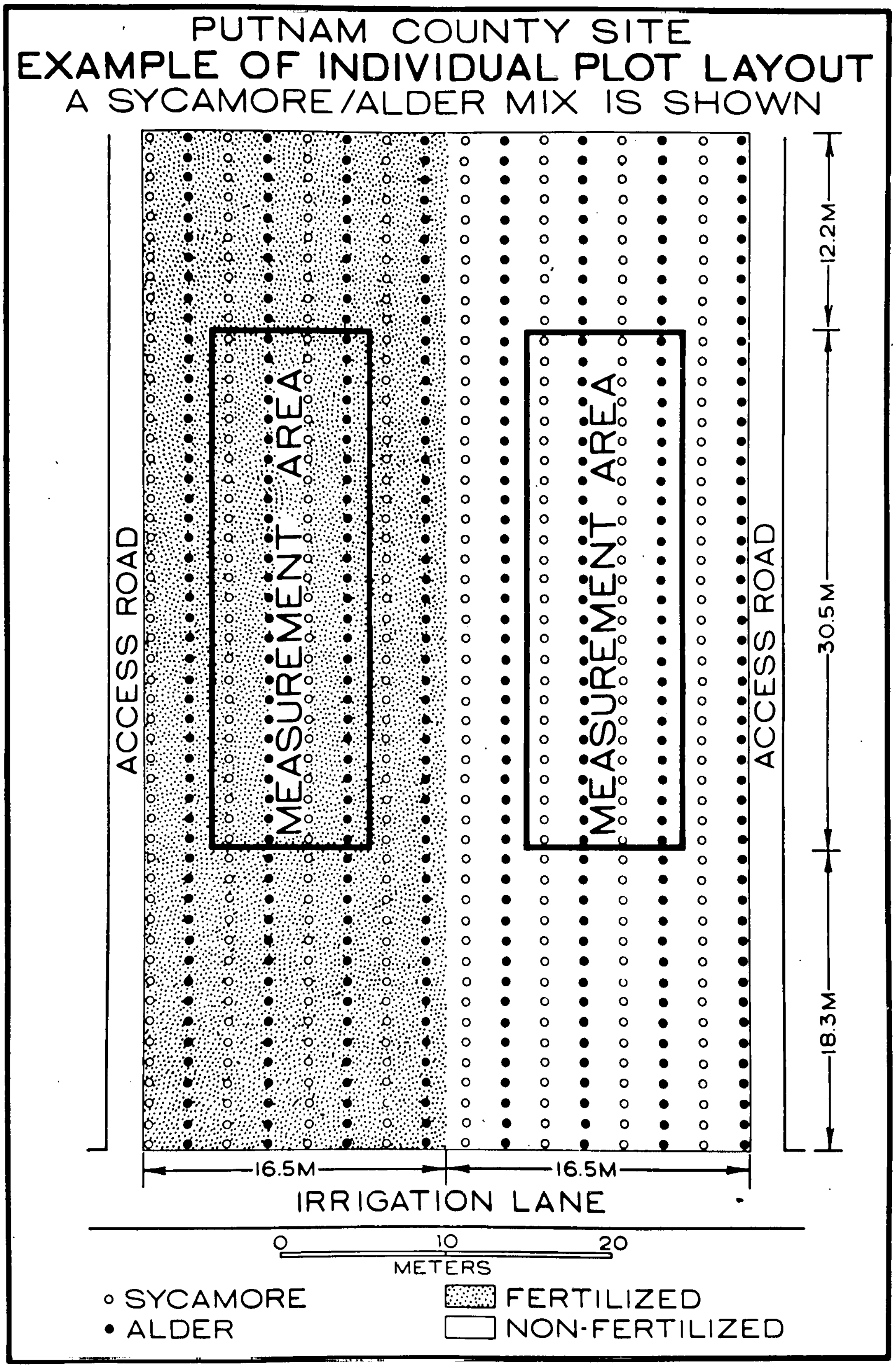
PUTNAM COUNTY SITE
EXAMPLE OF INDIVIDUAL PLOT LAYOUT
A SYCAMORE/ALDER MIX IS SHOWN
ACCESS ROAD
MEASUREMENT AREA
MEASUREMENT AREA
ACCESS ROAD
12.2M
30.5M
18.3M
16.5M
16.5M
IRRIGATION LANE
0
10
20
METERS
SYCAMORE
ALDER
FERTILIZED
NON-FERTILIZED

FIGURE 4

Table 2. Average heights and diameters of the trees at the end of the first growing season.

Site	Sycamore* Sur.	Ht.	Dia.	Sweetgum Sur.	Ht.	Dia.	Alder Sur.	Ht.	Dia.	Locust Sur.	Ht.	Dia.
Piedmont												
Non-irrigated	83	130	1.8	87	52	1.1	81	73	1.1	86	186	2.0
Irrigated	80	133	2.0	77	59	0.9	84	76	1.2	84	221	2.7
Coastal Plain												
Non-irrigated	70	71	0.8	69	49	0.5	50	100	1.3	--	--	--

*Survival in percent living, sizes in cm.

Of special interest in Table 2 is the excellent growth of the black locust. It grew from the smallest tree at planting to the tallest at the end of the first year in the field. Even though one should not place much faith in the results of only one year, we have planted a higher proportion of the Piedmont planting to locust in 1979. Black locust will probably perform well in the Piedmont of Georgia and points north, areas within its natural range. We have planted a few hundred locust seedlings in the Coastal Plain planting, an area south of the natural range of locust.

All species grew less in the Coastal Plain than they did in the Piedmont. This was mostly due to the intense competition from ragweed and grasses, including Johnson grass. Our efforts at mechanical control failed to keep the weeds in check. We estimate that the site produced 3.3 tons of oven dry ragweed per acre! Before the seedlings leaf out in 1979 we will spray this site with simazine, a preemergence chemical. It has been tried with fair success by Dr. Fitzgerald on our faculty and by

International Paper Company foresters in the South. Hopefully it will provide some control until August. By then the trees should have grown above the weed competition.

European alder survived poorly in the Coastal Plain. Especially in those portions of the plantation on areas which had previously been planted to Christmas trees, the alder was hard hit by a fungus tentatively identified as Botryosphaeria. Alders that were planted in an old soybean field were almost free of the fungus. We have no plans to control the fungus.

Genetic improvement: Sycamore seedlots from various stands in Georgia were collected in order to identify provenances with desirable characteristics. These and other seeds will be sown in an experimental nursery, about one acre in size. Land clearing and leveling for this nursery will get under way as soon as the weather permits. Seeds from this collection and from other species will also be sent to the General Electric thin-film growth facility in Syracuse, N.Y.

Seeds from five, half-sib families of both Eucalyptus grandis and and E. robusta were obtained from U.S.F.S. experimental plantings at Lehigh Acres, Florida. Seeds from two families of each species were surfaced sterilized and grown in vitro to obtain sterile material for studying bud and root differentiation. Explants were taken from cotyledons, hypocotyls, stem segments, leaf axils, and shoot tips and placed on five different culture media previously used in other systems for bud and/or root formation leading to embryoid or plantlet formation. So far no plantlets have been obtained in Eucalyptus, although observations on initial bud formation look promising and these studies are being continued.

Plantlets of sweetgum and black locust (root and bud differentiation) were obtained in tissue culture. We are currently developing techniques for mass cloning in liquid cultures to produce numerous plantlets in single containers. These will then be transplanted and grown to plantable sizes in either greenhouse, lath-house or nursery beds.

The Visiting Scientist in 1978 was Dr. M. Neenan from the Agricultural Institute in Carlow, Ireland. Dr. Neenan is in charge of short-rotation forestry research for Ireland and is assessing the feasibility of substituting wood for peat in Irish electric generating plants. He stayed from June through August, 1978 and became familiar with our project. While here, he investigated the calorific content of young sprouts (most about 8-10 years old) from nine hardwood species (Table 3). There were only small differences among the energy values (on a dry weight basis) of the species. The general conclusion, therefore, was that species should be chosen for their suitability for particular sites rather than their differences in energy content. The differential in tonnage of biomass produced per acre by the most suitable species will likely outweigh the higher energy values for a less adapted species. A manuscript detailing these results has been submitted to FOREST SCIENCE.

Rootstock development under various harvesting cycles is one of the keys to sustained high yields in coppice forestry. In order to determine effects of 1-, 2-, and 7-year rotations, sycamore rootstocks which had been planted nine years ago and harvested continuously on these cycles since then, were excavated. Rootstock spacing varied from 1 x 4 to 2 x 4 and 4 x 4 feet. The root mass (oven-dry) on plots harvested every year averaged only 15.2 tons/ha, significantly lower than the 22.3 and 24.2 tons/ha rootstock weights for the 2- and 7-year rotations, respectively. The difference

Table 3. Calorific values (oven-dry weight basis) of nine species of hardwoods, collected in mid-summer.

Species	Xylem	Bark	Branches	Twigs	Leaves
Green ash	4768 b[1]	4618 e	4857 f	4818 i	5119 k
Black cherry	4766 b	4948 d	4841 f	4866 i	5232 k
Box elder	4894 a	4321 e	4881 f	4838 i	5028 k
Redbud	4864 a	4631 e	4738 g	4736 j	5088 k
Red maple	4808 b	4557 e	4760 g	4770 i	4976 k
Sweetgum	4721 c	4569 e	4684 h	4702 j	4658 l
Sycamore	4756 b	4779 e	4856 f	4872 i	5171 k
Water oak	4777 b	4622 e	4756 g	4818 i	5084 k
Yellow poplar	4819 b	4631 e	4800 g	4782 i	5067 k
Mean	4777	4631	4797	4800	5047
S.E.	34	16	23	91	80

[1] Entries followed by different letters differ significantly at the 5% level of confidence.

between the latter two was not significant statistically. It appears, therefore, that annual harvests lead to inferior rootstock development and, therefore, lower yields. But rotation ages beyond two years (and probably less than 10 years) do not affect rootstock development differentially. Thus, the regrowth potential of rootstocks cut every two years should be the same as that of stocks cut every four or five or eight years.

Table 4. Total number excavated, survival percentages and dry weights (kg) of sycamore root systems grown at three spacings and coppiced on various rotations in Georgia.

Rotation (years)	Spacing									
	0.3 x 1.2 m			0.6 x 1.2 m			1.2 x 1.2 m			Average
	No.	Sur.	Wt.	No.	Sur.	Wt.	No.	Sur.	Wt.	total (tons/ha)
1	127	88	71.0	68	94	82.0	31	86	83.0	15.2
2	135	93	107.0	64	89	119.3	35	97	121.1	22.3
7	144	100	144.4	66	92	115.5	34	94	117.3	24.2
Average total wt/ha (tons)			20.7			20.4			20.7	

1/ Values are totals for 51.84 m^2 areas (3 replicate plots of 17.28 m^2 each).

Spacing did not affect total root mass per acre after these rootstocks had been in the field for nine years (Table 4). Even though the number of rootstocks per unit area varied by a factor of four, the total rootstock mass supported by a unit area was the same. Apparently there is a maximum of about 20 tons/ha of sycamore rootstock mass that can be supported at this age. A manuscript dealing with rootstocks is in peer review and will be submitted for publication soon.

In another study dealing with rootsystems, Blum, and M.S. candidate supported by this project, investigated changes in root carbohydrate levels over time. He found no significant differences in the starch levels of rootstocks cut annually and those harvested every two years, nor did the fluctuation patterns for the two harvesting treatments differ from one another between September and April (Fig. 5). When the starch level results are interpreted in light of the root mass results reported above, the following hypothesis appears plausible. The concentrations of carbohydrate reserves in rootstocks coppiced on one-and two-year rotations do not differ significantly, but the size of the rootstocks does. Therefore, the total amount of carbohydrates available for resprouting is larger on the longer rotation. A manuscript dealing with these carbohydrate relationships is in review.

Another graduate student supported by the project (Thackston) determined the leaf area indices of sycamore sprout stands in which the stumps were spaced at 1 x 4 and 4 x 6 feet. The leaf area indices did not differ significantly with spacing and were 2.6 and 2.4, respectively.

Seed handling and nursery practices for various alders are being studied by Cook, another MS candidate. Results to date are incomplete.

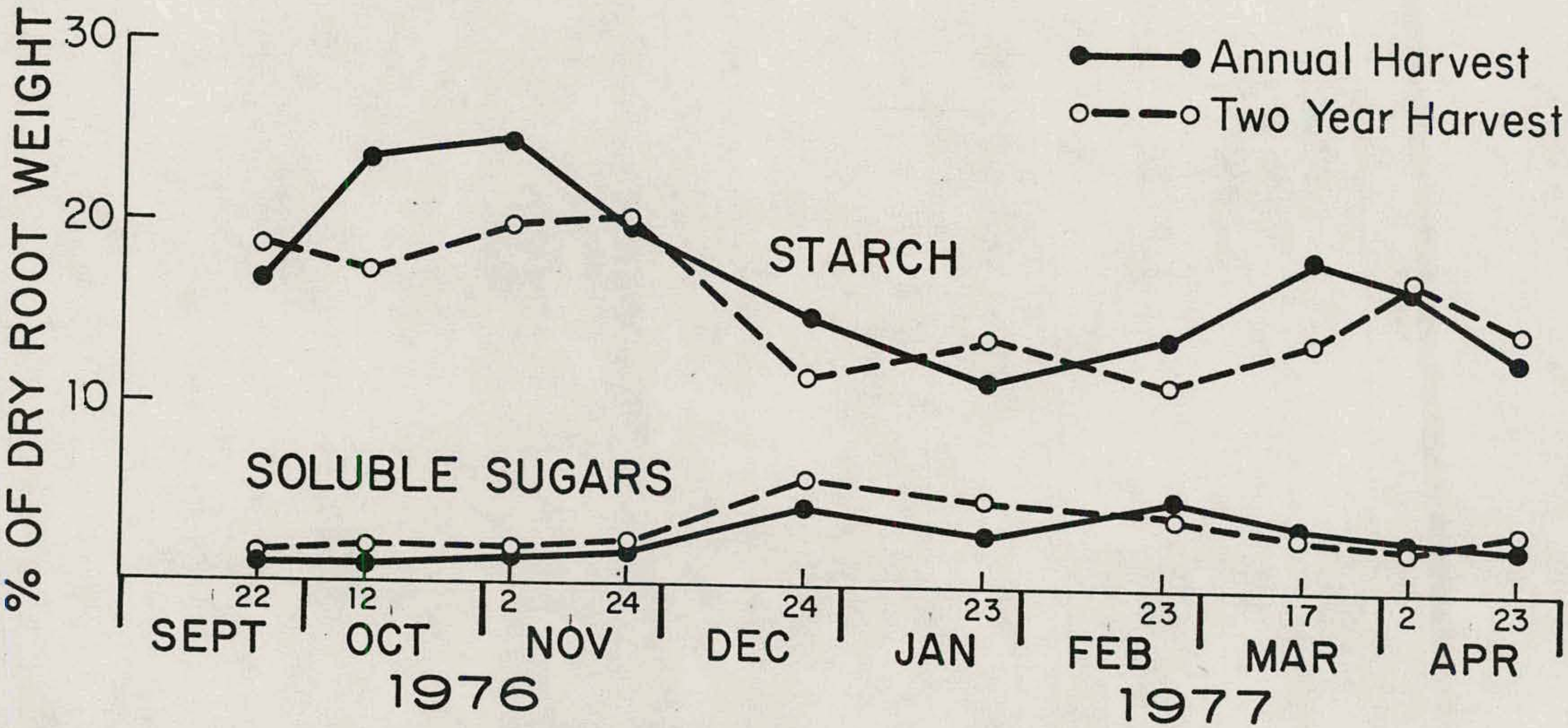

Figure 5. Winter starch and sugar levels in sycamore rootstocks harvested annually and every two years.