# EFFECT OF HARVEST SEASON AND SPACING ON COPPICED SWEETGUM BIOMASS YIELDS

B. G. McCutchan and E. L. Prewitt[1/]

Abstract.--Total green weight produced in 13.5 years from a sweetgum coppice plantation decreased with an increase in spacing, from 206.0 tonnes/ha[2/] at 0.3 x 1.2 m to 117.4 tonnes/ha at 1.2 x 1.2 m. The diameter of coppiced stems increased with spacing, 3.4 cm at 0.3 x 1.2 m to 4.7 cm at 1.2 x 1.2 m. Growth rates in the second coppice rotation were higher on plots that had been harvested as seedlings in January or April (dormant season), 21.3 tonnes/ha/yr, than on plots that had been harvested in July or September, 17.5 tonnes/ha/yr. Higher growth rate of dormant season seedling harvested plots compared to those harvested during the growing season is associated with higher stump survival and a larger number of coppiced stems per stump. Growth rate increased over rotations, 0.97 tonnes/ha/yr for the seedling rotation, 6.34 tonnes/ha/yr for the first coppice rotation, and 19.6 tonnes/ha/yr for the second coppice rotation.

Keywords: Biomass production, harvest season, spacing, *Liquidambar styraciflua* L.

## INTRODUCTION

Growing hardwoods at close spacings with intensive silvicultural practices, termed short-rotation intensive culture (SRIC), was introduced in the 1960's to help provide a continuous supply of raw material to pulp mills (McAlpine, *et al.*, 1966). Candidate species were those with rapid juvenile growth, coppicing ability and suitable wood qualities (McAlpine, *et al.*, 1966; Steinbeck, *et al.*, 1968). The venture has received less attention recently because of the high bark-to-wood ratio and the difficulty in separating bark from wood during the pulping process.

The type of plantation management envisioned for the silage cellulose concept was subsequently adapted for energy plantations. The objective of an energy plantation is to optimize or maximize biomass productivity of a species on a site. The biomass (woody aboveground material) would be burned in power plants or converted into chemical products (Williford, *et al.*, 1979). The North Carolina State University Hardwood Cooperative has embarked on an energy plantation project to determine species most appropriate for energy plantation use on various sites, optimum spacing and rotation lengths, and number of coppice rotations which can be obtained per cycle of planting (NCSU, 1981).

[1/] Graduate Research Assistant, School of Forest Resources, North Carolina State University, Raleigh, N. C., and Research Forester, Natchez Forest Research Center, International Paper Company, Natchez, Mississippi

[2/] tonne = metric ton = 1000 kg

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Studies established in the 1960's to test silvicultural practices suitable for SRIC provide plant material and potential information conducive to refining methods of silviculture to be used in energy plantations. A major benefit which can be derived is the response of several species, including sycamore (Platanus occidentalis L.) and sweetgum (Liquidambar styraciflua L.) to different spacings, rotation lengths and cultural practices (Saucier, et al., 1972; Steinbeck and Brown, 1976; Wittwer, et al., 1978). Sycamore has good potential for biomass productivity (Wittwer and Immel, 1978) but the species is very site-sensitive. Sweetgum does not grow as rapidly as sycamore during the juvenile years (Steinbeck and Brown, 1976) but the species is adaptable to a wide range of sites (Kellison, et al., 1979). That adaptability has elevated this species to a position of importance for biomass production in the South.

Data are available from an International Paper Company Silage Cellulose Study, established in 1968 in Decatur County, Georgia, to investigate the potential of sweetgum for biomass production. These data represent part of a larger study in which sycamore and yellow-poplar were also evaluated.

Sweetgum seedlings were planted in this study at various spacings to test the feasibility and growth potential of the close spacing concept (Hunt, 1976). Seedlings were harvested on a seasonal basis in 1970; the subsequent coppice crop was harvested in January, 1975.

The objectives of the study reported here were to:

1. Determine if trends observed in the seedling and first coppice rotation of sweetgum are found in the second coppice rotation, i. e., does green weight productivity decrease with increased spacing and does coppice regeneration resulting from a summer harvest remain inferior in diameter and height compared to that from a dormant harvest?

2. Assess root system vigor of sweetgum after repeated coppicing by comparing growth rates of the seedling, first coppice and second coppice rotations.

## MATERIALS AND METHODOLOGY

### Data Collection

The hardwood plantation established in January, 1968 occupies an upland Coastal Plain old-field site, which had originally supported longleaf pine. The soil is Orangeburg fine, sandy loam with an estimated site index of 26 m (50-year basis, loblolly pine). Seedlings of 1-0 stock were hand-planted at 0.3 x 1.2 m, 0.6 x 1.2 m, and 1.2 x 1.2 m assymetric spacings, in which pairs of rows were separated by 1.8 m and rows within pairs were separated by 0.6 m. Spacing within row was 0.3, 0.6 or 1.2 m, depending upon treatment. These spacings correspond to 26910, 13455 and 6726 seedlings per hectare, respectively. Each 22 x 20 m spacing treatment replicate consisted of nine double rows and was replicated three times on each of two adjoining areas (Figure 1a). High seedling mortality reduced survival over the six replications to 50, 52 and 50 percent for sweetgum at 0.3 x 1.2 m, 0.6 x 1.2 m and 1.2 x 1.2 m spacings, respectively (Hunt, 1976).

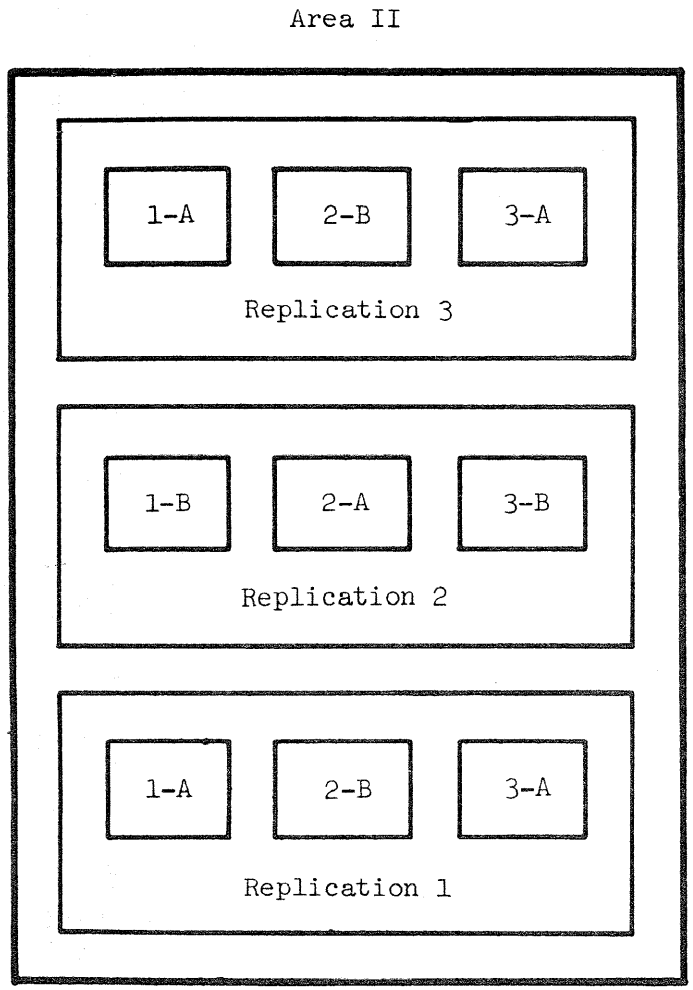



Figure 1a. Schematic diagram of one area of the spacing-harvest study; where spacing is either 0.3x1.2m (1), 0.6x1.2m (2) or 1.2x1.2m (3) and harvest is either January-April (A) or July-September (B)

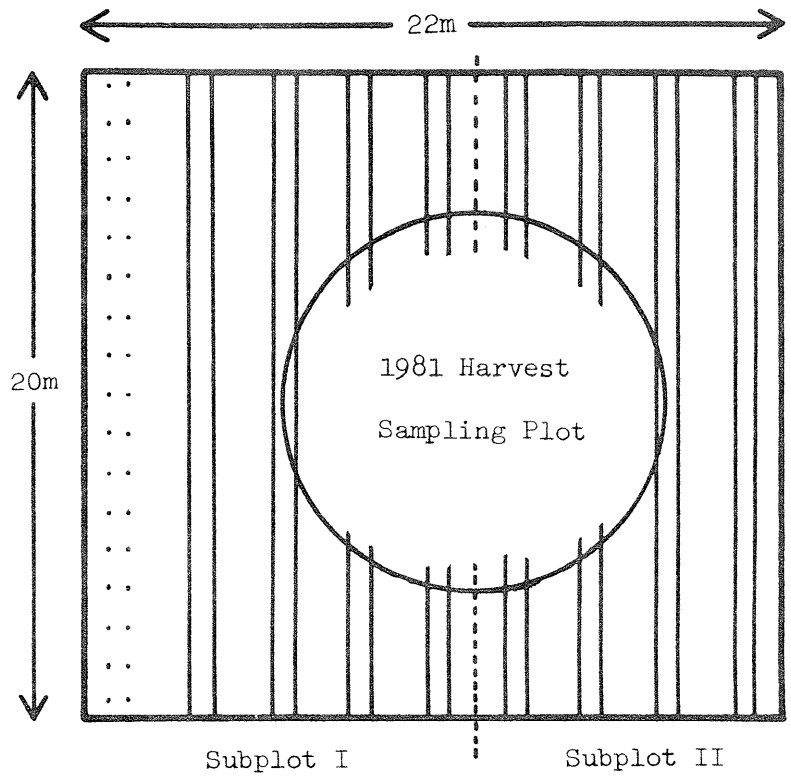



Figure 1b. Enlargement of a 1.2x1.2m spacing replicate containing nine double rows, subdivided into two harvest subplots

In 1970 the seedlings were harvested with seasonal treatments, January, early April, early July, and early September. Each spacing replicate was subdivided and either January-April harvests or July-September harvests were applied to the two subplots of the replicate (Figure 1b, Table 1).

Table 1. Number and spacing-harvest treatment replications by area

| Harvest (1970) | Spacing | | | | | |
|---|---|---|---|---|---|---|
| | Area I | | | Area II | | |
| | 0.3 x 1.2m | 0.6 x 1.2m | 1.2 x 1.2m | 0.3 x 1.2m | 0.6 x 1.2m | 1.2 x 1.2m |
| Jan.-April | 1 | 2 | 1 | 2 | 1 | 2 |
| July-Sept. | 2 | 1 | 2 | 1 | 2 | 1 |

Green weight was estimated from one double row per subplot. Reported weights reflect the green weight of aboveground woody biomass per unit area.

In January, 1975 all replicates of the coppice crop were harvested; woody green weight was estimated for each subplot by sampling one double row per subplot. In July, 1981 the second coppice crop was harvested and sampled for green weight productivity. A circular sample plot was harvested in each spacing replicate in Area II. Each circular plot sampled both seasonal harvest subplots, i. e., either January-April or July-September subplots (Figure 1b). Plot green weight (to the nearest 0.05 kg), plot moisture content, individual stem diameter at breast height (1.37 m) and total stem height were measured. All plot trees, including foliage, were whole-tree chipped. From the output, four 4-liter-sized doubled polyethylene bags were filled with chip samples and sealed. Moisture content was calculated for each bag and averaged for the plot: Percent moisture content = (green weight - oven-dry weight)/(oven-dry weight) x 100%.

## Data Analysis

Estimates of green weight yields from both the seedling and the first coppice rotations were averaged (over subplots) for each replication and then averaged by spacing and harvest season (January-April or July-September) over replications. Green weight data by spacing-harvest treatments for each of the first two rotations in Area II were added to the appropriate yields from the second coppice.[1/]

[1/] Since only Area II data are utilized in this analysis, deviations from results reported by Hunt (1976) sometimes may occur.

Growth rate was estimated by assuming constant growth during the growing season. The number of growing seasons for plots during the seedling rotation was dependent upon which seasonal harvest treatment was applied. The average number of growing seasons over the subplots (Table 2) was used to calculate growth rate.

Table 2. Number of growing seasons per rotation

| Rotation | Spacing | | | Harvest | |
|---|---|---|---|---|---|
| | 0.3x1.2m | 0.6x1.2m | 1.2x1.2m | Jan.-April | July-Sept. |
| Seedling | 2.3 | 2.6 | 2.3 | 2.1 | 2.8 |
| First coppice | 4.7 | 4.4 | 4.7 | 4.9 | 4.2 |
| Second coppice | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |

Stem height and diameter, stem density and plot moisture content are reported for the second coppice rotation only. The dependent variables were analyzed in an unbalanced cross-classified analysis of variance, unbalanced with respect to the number of spacing x harvest replications sampled in Area II (Table 3).

Table 3. Analysis of variance for an unbalanced cross-classified design

| Source | df | EMS |
|---|---|---|
| Replication | 2 | |
| Spacing | 2 | $\sigma_e^2 + hr_2\theta_S$ |
| Harvest | 1 | $\sigma_e^2 + sr_1\theta_H$ |
| Error | 3 | $\sigma_e^2$ |
| Total (corrected) | 8 | |

In this analysis, replication is considered a random effect, and spacing and harvest are considered fixed effects.

## RESULTS AND DISCUSSION

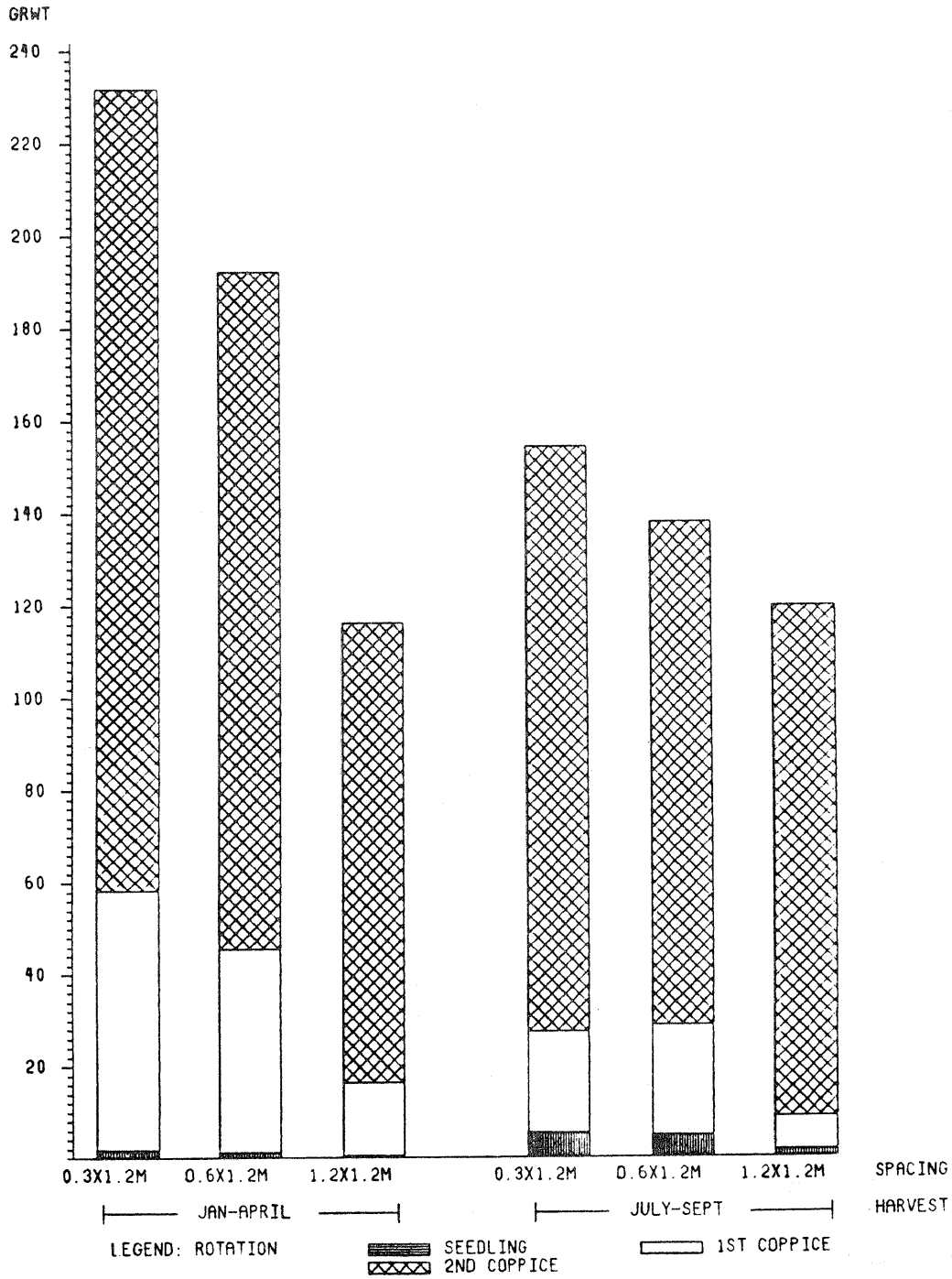
There were no significant relationships among dependent variables and effects analyzed, using the Generalized Linear Models Procedure (Barr, et al., 1979). Failure to discriminate may possibly be attributed to high plot-to-plot variation, unbalanced nature of the replications, and lack of treatment replication. Despite the absence of significant effects, trends were apparent in the data which bear discussion.

Stem diameter and height and biomass moisture content of the second coppice crop are reported in Table 4. Coppice stem diameter increased with spacing. This observation conforms with basic silvicultural principles (Smith, 1962) and with results from other SRIC studies (Saucier, et al., 1972; Wood, et al., 1976). Seasonal seedling harvest had no noticeable effect on the second coppice crop's diameter, contrary to increased diameter of dormant-harvested compared to summer-harvested plots observed in the first coppice rotation (Hunt, 1976). Total stem height increased with increased spacing, an effect also observed by Saucier, et al. (1972) and Steinbeck and Brown (1976). Coppiced stems on dormant harvested plots were taller than those on summer harvested plots, continuing the trend observed by Hunt (1976) in the first coppice rotation. Biomass moisture content did not differ significantly or vary in a clearly defined pattern with spacing or harvest season. Failure of moisture content to vary with spacing has been reported also by Kennedy (1980) and Saucier, et al. (1972).

Table 4. Mean stem diameter, total stem height, and biomass moisture content of a 6.5-year-old second-coppice sweetgum plantation

| | Spacing | | | Harvest | |
|---|---|---|---|---|---|
| | 0.3x1.2m | 0.6x1.2m | 1.2x1.2m | Jan.-April | July-Sept. |
| Number of Replications | 3 | 3 | 3 | 5 | 4 |
| Stem DBH (cm) | 3.4 | 3.8 | 4.7 | 4.0 | 3.9 |
| Stem Height (m) | 5.93 | 6.08 | 6.47 | 6.31 | 5.97 |
| Biomass Moisture Content (%) | 126 | 121 | 132 | 126 | 127 |

Green weight yields per hectare by rotation are depicted in Figure 2. These estimates of productivity represent approximately 50% seedling survival (Hunt, 1976), an important consideration if these results are to be compared to other studies of similar spacings and rotation lengths. Hunt (1976) reported that green weight yields decreased in the seedling rotation with an increase in spacing. This trend was also evident in the first and second coppice rotations.




Green tonnes per hectare

Figure 2. Mean green weight production by rotation of a 13.5-year-old sweetgum biomass plantation

The inverse relation between biomass yield and spacing with short rotations is well documented for sycamore (Belanger and Pepper, 1978; Saucier, et al., 1972; Wood, et al., 1976). Gibson and Sossaman (1977) report the change in this productivity trend with sweetgum as rotation length increases: growth rate at 1.5 x 1.5 m levels off after ten years, while at wider spacings growth continues to accelerate.

Summer-harvested seedling plots yielded more than dormant-harvested plots, which can be attributed to a longer third growing season (Hunt, 1976). In both subsequent coppice rotations, green weight yields were greater on dormant-harvested plots than on summer-harvested plots. In the first coppice crop, those plots with the dormant harvest had more growing seasons than those with the summer harvest. This age difference may partially account for the difference between harvest treatment yields. This reasoning fails to explain, however, the productivity difference with harvest treatment observed in the second coppice yields, where coppice was all the same age.

In Figure 3, productivity is compared on a growth rate basis to reduce the effect of growing season length. Green weight growth rate was decreased in both coppice rotations where seedlings had been harvested in the summer versus dormant season. Rootstocks were of comparable age at the end of each coppice rotation, so age could not be a causal mechanism for differences between harvest treatment yields.

The green weight productivity per tree stump varied directly with spacing in the second coppice rotation (Table 5); there was higher productivity per tree in the dormant harvest than the summer harvest. The decreasing trend in the number of trees per hectare with spacing was expected, based on the number of trees planted for each spacing. There was a consistently higher survival of tree stumps with the dormant harvest in contrast to the summer harvest treatment.

Table 5. Mean green weight growth (kg) rate and stocking density by tree and stem of a 6.5-year-old second-coppice sweetgum plantation

| | Spacing | | | Harvest | |
|---|---|---|---|---|---|
| | 0.3x1.2m | 0.6x1.2m | 1.2x1.2m | Jan-April | July-Sept. |
| Green weight (kg)/ tree/year | 1.88 | 2.21 | 5.04 | 3.31 | 2.71 |
| Trees/hectare | 16108 | 8572 | 3705 | 10226 | 8506 |
| Tree survival (%) | 60 | 64 | 59 | 64 | 57 |
| Green weight (kg)/ stem/year | 0.96 | 1.07 | 1.96 | 1.34 | 1.32 |
| Stems/hectare | 28752 | 17973 | 8645 | 19575 | 17059 |
| Stems/tree | 1.9 | 2.1 | 2.5 | 2.2 | 2.1 |

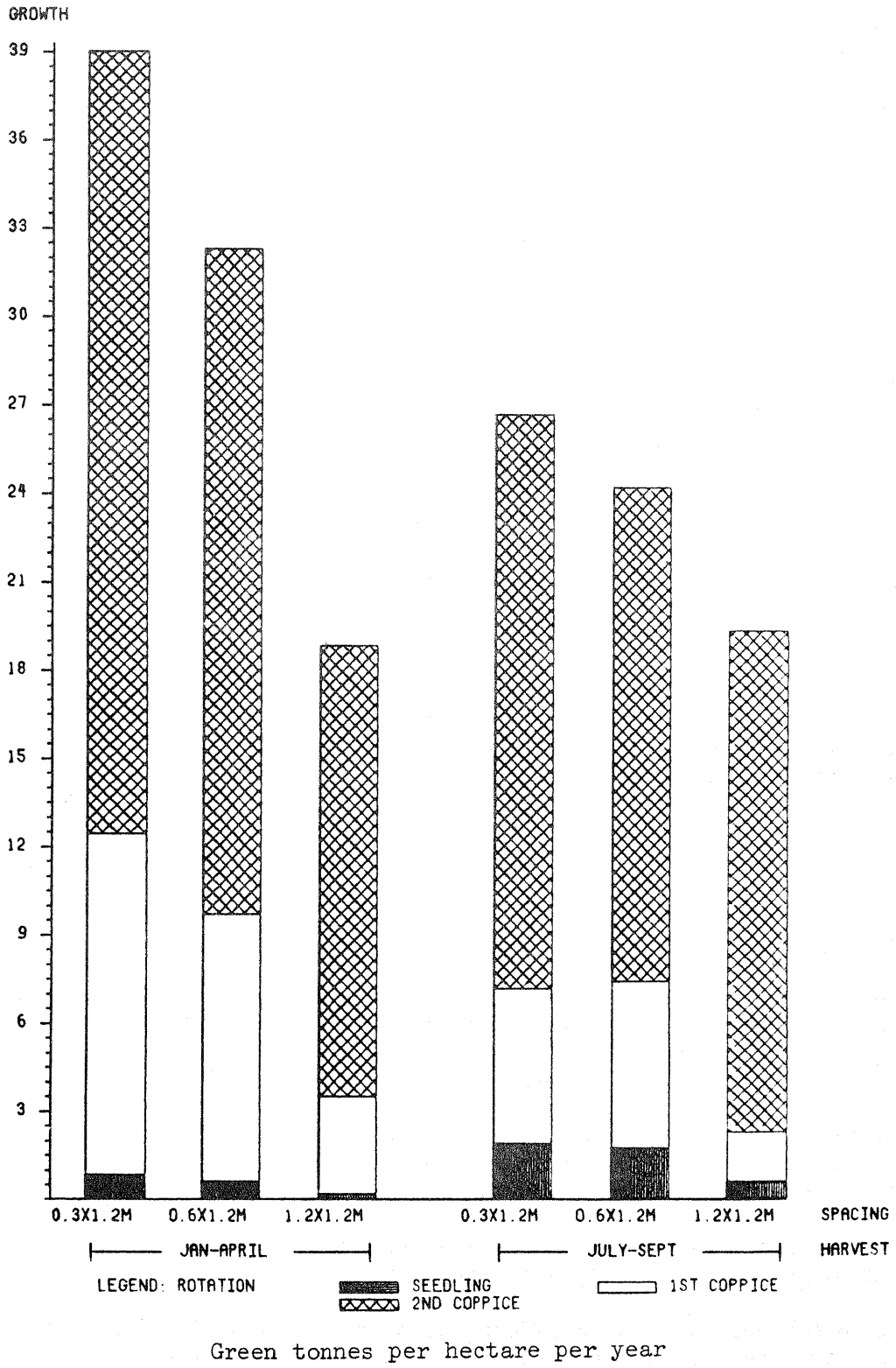



Figure 3. Mean green weight growth rate by rotation of a 13.5-year-old sweetgum biomass plantation

Growth rate per coppice stem increased with increased spacing, as did growth per tree; no effect of harvest was apparent. The number of stems per tree increased with spacing and was slightly higher with the dormant harvest compared to the summer harvest. Growth per tree stump is a function of the number of coppice stems and their growth. Since growth per stem is similar for both harvest treatments, the difference in tree growth rates for the two harvest treatments is probably due to the presence of more stems per tree with the dormant harvest as compared to the summer harvest. Belanger (1979) and Kellison (1981) report a greater number of heavier sprouts resulting from dormant harvest in contrast to a harvest in the growing season.

In general, growth differences between harvest treatments in both coppice rotations appear to arise mainly from differential tree stump survival and, to a lesser extent, number of coppice stems per tree stump. More stumps evidently survived a dormant harvest when carbohydrates were stored in root reserves, compared to the summer harvest of actively growing trees with low root reserves.

Growth rate increased over successive rotations (Figure 3). This increase in growth rate indicates that there is no detectable root degeneration resulting from repeated coppicing. The data, however, are confounded with increasing rotation lengths. Steinbeck and Nwoboshi (1980) report that growth rate increased with increased rotation length in short-rotation coppice silviculture.

## CONCLUSIONS AND SUMMARY

Data from the 13.5-year-old International Paper Company Silage Cellulose Study with sweetgum showed no statistically significant effects of spacing or harvest season. Trends in biomass yield and stand characteristics are consistent with results found with other species:

1. Green weight yields decreased with increased spacing in each of three consecutive rotations.

2. Diameter increased with increased spacing. Height increased with increased spacing as well, but to a lesser extent.

3. Harvest season of the seedling rotation influenced productivity of subsequent coppice crops; higher stump survival and slightly more stems per tree apparently contribute to the observed higher growth rate of dormant harvested plots compared to summer harvest plots.

4. Growth rate increased over successive rotations. Because of different rotation lengths, it is not possible to ascribe all the growth increase to increased vigor of the root systems.

5. Highest productivity in this study resulted from the 0.3 x 1.2 m spacing and dormant harvest, 231.9 tonnes/ha in 13.5 years.

Since the harvest season affects production in the first and in subsequent coppice rotations, the importance of dormant harvests needs to be stressed to insure coppice productivity. However, the increased productivity must be weighed against the practical implications of winter-early spring harvests, when harvesting conditions are usually poorest, and the need by the processing mills for a fiber supply across all seasons.

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