BIOMASS CHARACTERISTICS OF SYCAMORE COPPICE INFLUENCED BY PARENTAGE AND TYPE OF PLANTING STOCK

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Abstract.--Three years after clearcutting a six-year-old sycamore progeny test in northeast Mississippi, stem dry weight of coppice averaged 2.27 Mg/ha and represented 63% of the above-stump dry biomass. Stumps of trees established from unrooted cuttings produced fewer coppice sprouts, smaller sprouts, and 40% less coppice stem dry weight than stumps of trees established from seedlings. There were no differences between stumps originating from top-pruned and unpruned seedlings. Progeny families differed in survival, dry weight yield of five-year-old trees before the clearcut, and number and maximum diameter of coppice sprouts per stump. Small, positive correlations between stump diameter before clearcutting and the resulting coppice characteristics were found, and these relationships may differ among families.

Additional keywords: Coppice growth, genetic differences, Platanus occidentalis.

Growing American sycamore (Platanus occidentalis L.) in plantations under short coppice rotations for fiber has received much publicity as the "silage sycamore concept" (Georgia Forest Research Council 1973). The concept was originally advocated for pulp and paper production, but now has applicability to energy plantations. Age of tree, spacing, and season of cutting can influence coppicing ability and coppice yields (Kennedy 1975 and 1980; Kormanik et al. 1973). Objectives of the present study are to elucidate effects of parentage and type of planting stock on coppicing ability in a young sycamore progeny test and to compare coppice yields three years after clearcutting with stand yields prior to the clearcut.

MATERIALS AND METHODS

A nine-year-old open-pollinated sycamore progeny test in Oktibbeha County, Mississippi (33°18' North, 88°55' West) that was clearcut at age six to produce coppice was used for the study. Three types of planting stock were utilized to establish each of ten families in the test in June, 1974: (i) unrooted top cuttings from 1-0 seedlings, (ii) top-pruned 1-0 barerooted seedlings, and (iii) whole (unpruned) 1-0 barerooted seedlings. The first two types were obtained by clipping a seedling at 2.5 cm above the root collar to provide a complete top cutting and a detopped (top-pruned) root system. The ten families came from eight geographic seed sources in the Gulf South (Figure 1), with two families per source being used from sources "A" and "F" and one family per source from the other six. The test was arranged as a split-plot

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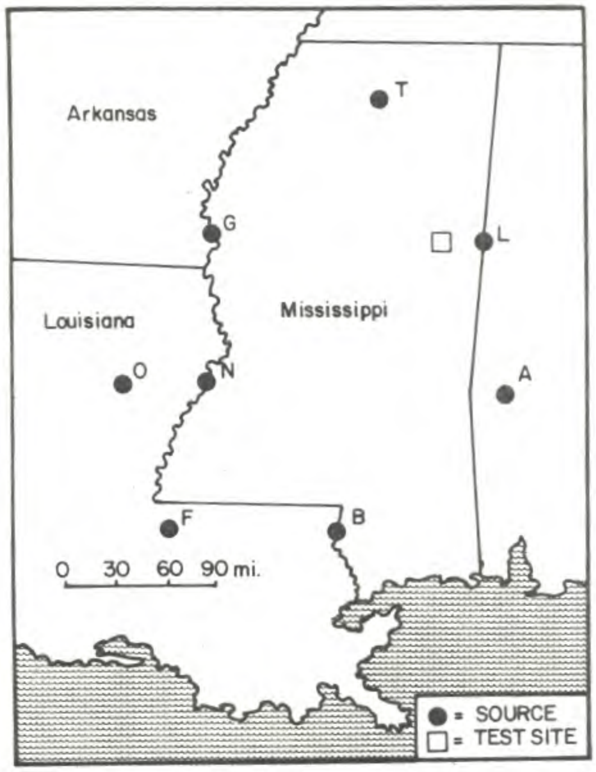

Figure 1.--Geographic locations of seed sources and test site for a sycamore progeny test used to study effects of parentage and type of planting stock on biomass characteristics of three-year-old coppice.

design with families as whole units and with four replications. Spacing was 3 x 3 meters, and each rep-by-family-by-stock-type plot contained five trees.

Stump diameters at 15 cm above ground, stem diameters at breast height (DBH), and tree heights were measured at plantation ages three and five. During the sixth growing season the test was clearcut, and at stump age nine the three-year-old coppice was measured for number of sprouts per stump, sprout diameter at 7.5 cm above stump, and sprout height above stump. Results of the fifth-year measurements before the clearcut have been reported by Land et al. (1981), but are expressed in metric terms in this paper for comparison with the coppice results.

A sample of 257 coppice sprouts from 36 stumps was measured for diameter and height during the fourth growing season of the coppice, and these sprouts were then destructively sampled for green and dry weights of stems, limbs, and leaves separately. Ratios of dry weight to green weight were used to obtain total dry weight of each component of each sprout, and the 257 records were utilized in developing dry-weight prediction equations for individual sprouts from regression on sprout diameter and height.

The above equations were applied to the three-year-old-coppice data to predict the dry weight of each sprout. Totals for all sprouts on a stump (kg/stump) were obtained and used as the basic records in analyses of variance for effects of families and types of planting stock. Survival times number of trees planted per hectare times dry weight per stump provided plot values for coppice yields in kg of dry weight per hectare.

RESULTS AND DISCUSSION

The 257 destructively-sampled coppice sprouts averaged 3.1 cm for diameter at 7.5 cm above stump and 3.5 m for height above stump. Minimum-maximum values were 1.3 cm to 8.9 cm and 1.2 m to 7.6 m, respectively. Dry weight/green weight ratios were 0.374 for leaves, 0.455 for limbs, and 0.451 for stems. The resulting means and ranges in dry weight per sprout for each component were 0.222 kg for leaves (0.004 to 1.874 kg), 0.229 kg for limbs (0.000 to 3.030 kg), and 0.833 kg for the stem (0.037 to 6.325 kg). The prediction equations derived from the samples (Table 1) should only be used on coppice within these size ranges.

Diameter squared times height (D^2H) was a better predictor of sprout dry weight than diameter squared (D^2), as indicated by smaller standard errors of estimate ($S_{y.x}$) and larger coefficients of determination (R^2) for D^2H than for D^2 in Table 1. The no-intercept models with D^2H were chosen for predicting dry weights in the three-year-old coppice, since these models did not greatly increase the $S_{y.x}$ values over those of the corresponding intercept models and since the no-intercept estimates for stem, limb, and leaf components can be added together to equal predicted total values.

The additive feature of the no-intercept predictions allows the calculation of predicted weights for other components if the predicted weight for one component is given. This feature also means that identical analysis-of-variance results and rankings of treatment means will be obtained for the predicted weights of the different components. Therefore, only the stem dry weights per tree (or per stump for coppice) and per hectare will be presented, and the other components' green and dry weights can be calculated from the conversion equations in Table 2 if desired.

Stem dry weight yield of the three-year-old coppice on nine-year-old stumps averaged 2.27 Mg/ha (1.0 tons/ac) and represented 63 percent of the above-stump dry biomass (Tables 2 and 3). These yield and percentage values are lower than those reported for other sycamore coppice studies (Kennedy 1975 and 1980; Kormanik et al. 1973), because of the wider spacing used here than in those studies. However, the three years of coppice growth produced approximately as much biomass as the first four years of tree growth in the progeny test, as indicated by a stem dry weight yield of 0.66 Mg/ha for the three-year-old progeny test and 5.75 Mg/ha for the five-year-old test. The average stump at nine years of age contained 3.9 coppice sprouts that were greater than 1.8-cm diameter at 7.5 cm above the top of the stump, and the largest sprout per stump averaged 4.42-cm diameter and 4.35 m height. No mortality of stumps occurred following clearcutting, so that the 80.5-percent survival of the nine-year-old stumps was the same as the survival of the three-year and five-year-old trees before clearcutting.

This investigation of effects of parentage and type of planting stock on coppice dry weight yields used the initial working hypothesis that stump survival, number of sprouts per stump, and size of the largest sprout per stump were the primary determinants of yield. It was also hypothesized that diameter of the stump when the trees were clearcut would influence these

Table 1. Equations for prediction of dry weights of stems, limbs, and leaves for five-year-old trees and three-year-old coppice in a sycamore progeny test in northeast Mississippi

Dependent Variable (= Y)	Prediction Equation[a/]	$S_{y.x}$	R^2
Five-Yr.-Old Trees			
Oven Dry Wt. (kg/tree)			
Stem	$Y = 0.1579(DBH)^2$	0.9480	
Limbs	$Y = 0.0808(DBH)^2$	1.0206	
Leaves	$Y = 0.0459(DBH)^2$	0.8800	
Total	$Y = 0.2846(DBH)^2$	2.1410	
Three-Yr. Coppice on 9-Yr. Stump			
Oven Dry Wt. (kg/sprout)			
Sprout Stem	$Y = -0.1345 + 0.00736(D^2)$	0.2680	0.957
	$Y = 0.0810 + 0.0108(D^2H)$	0.1939	0.977
	$Y = 0.0698(D^2)$	0.2880	
	$Y = 0.0111(D^2H)$	0.2058	
Sprout Limbs	$Y = -0.1094 + 0.0258(D^2)$	0.1908	0.843
	$Y = -0.0343 + 0.0038(D^2H)$	0.1778	0.864
	$Y = 0.0227(D^2)$	0.2093	
	$Y = 0.0037(D^2H)$	0.1799	
Sprout Leaves	$Y = -0.0348 + 0.0195(D^2)$	0.0977	0.922
	$Y = 0.0239 + 0.0028(D^2H)$	0.0945	0.927
	$Y = 0.0185(D^2)$	0.1014	
	$Y = 0.0029(D^2H)$	0.0965	
Total Sprout	$Y = -0.2787 + 0.1189(D^2)$	0.4920	0.945
	$Y = 0.0705 + 0.0174(D^2H)$	0.4012	0.963
	$Y = 0.1111(D^2)$	0.5387	
	$Y = 0.0177(D^2H)$	0.4050	

[a/] DBH = diameter at breast height in cm; D = diameter of sprout in cm at 7.5 cm above stump; H = height of sprout in m above stump.

determinants of yield, and this diameter would be subject to effects of parentage and type of planting stock.

Trees originating from unrooted cuttings produced significantly fewer coppice sprouts per stump, smaller diameters and heights for the largest sprout per stump, and less coppice stem dry weight per stump than did trees coming from seedlings, but there were no differences between pruned and unpruned seedlings (Table 3). The trees from cuttings also averaged smaller stump diameters at age five prior to the clearcut. Since stump diameter of the young trees may be an index of the size of the root system and thus of the absorption and storage capacity of the plant, analysis of covariance was used to adjust coppice means to equivalent stump diameters for each of the types of planting stock. The smaller size of the largest sprout per stump for cuttings than for seedlings was related to the effect of smaller stumps from cuttings since covariance adjustment removed the significant differences in sprou

Table 2. Distribution of green and dry weights among stems, limbs, and leaves of young sycamore trees and coppice sprouts, and conversion equations for calculating these components from stem dry weight

Trait	Percent Distribution in Tree or Sprout	Conversion Equations (Wts. in kg/tree, or Mg/ha)
Plantation Trees (3 & 5 Years Old)		
Stem Dry Wt. (= StDW)	56	StDW = given in Tables 3&5
Limb Dry Wt. (= LmDW)	28	LmDW = 0.5117(StDW)
Leaf Dry Wt. (= LvDW)	16	LvDW = 0.2907(StDW)
Total Dry Wt. (= TotDW)	100	TotDW = 1.8024(StDW)
Coppice Sprouts (3 Yrs. on 9-Yr. Stump)		
Stem Dry Wt. (= CStDW)	63	CStDW = given in Tables 3&5
Limb Dry Wt. (= CLmDW)	21	CLmDW = 0.3295(CStDW)
Leaf Dry Wt. (= CLvDW)	16	CLvDW = 0.2639(CStDW)
Total Dry Wt. (= CTotDW)	100	CTotDW = 1.5934(CStDW)
Stem Green Wt. (= CStGW)	61	CStGW = 2.2188(CStDW)
Limb Green Wt. (= CLmGWW)	20	CLmGW = 0.7214(CStDW)
Leaf Green Wt. (= CLvGW)	19	CLvGW = 0.7034(CStDW)
Total Green Wt. (= CTotGW)	100	CTotGW = 3.6436(CStDW)

sizes. Additional factors--such as stump vigor, root system arrangement, or response to clearcutting--that are not highly related to stump diameter may be more influential in determining number of sprouts per stump. Covariance analysis did not remove the significant difference between cuttings and seedlings for number of sprouts per stump.

Survival was lower for trees established from cuttings than for trees coming from seedlings (Table 3). This effect of planting stock occurred prior to plantation age three, and there was no stump mortality after clearcutting. Since coppice dry weight per stump was also lower for cuttings than seedlings, stumps from cuttings produced 40 percent less coppice stem dry weight per hectare (1.2 Mg/ha) than did stumps from seedlings (2.85 Mg/ha). In the five-year-old trees prior to clearcutting there was also a significant difference in stem dry weight yields between pruned and unpruned seedlings, but the difference was not present for three-year-old trees or three-year-old coppice.

The primary effect of parentage (family) on coppice characteristics was in number of sprouts per stump, although the maximum and minimum families for diameter of largest sprout per stump were also significantly different (Table 4). Stump diameter at age five differed significantly among some families, and when used as a covariate it removed the one significant family difference in diameter of largest sprout. Adjustment for stump diameter did not remove family differences in numbers of sprouts per stump, however. There were no significant family differences in coppice stem dry weight per stump or per

Table 3. Means and tests of significance for effects of type of planting stock on traits of 3-year-old trees, 5-year-old trees, and 3-year-old coppice in a 9-year-old sycamore progeny test

Trait	Overall Study Mean	Type of Planting Stock[a] Cuttings	Seedlings Top Pruned	Seedlings Whole	F-test Prob.[b]
Stump Diam. (cm) at Age 5	8.51	7.3	8.7	8.9	.0001**
No. Sprouts/Stump:					
Unadjusted[c]	3.9	3.3	4.0	4.2	.0001**
Adjusted	3.9	3.4	3.9	4.2	.008**
Diam. (cm) of Max. Sprout/Stump:					
Unadjusted	4.42	4.1	4.5	4.5	.001**
Adjusted	4.42	4.2	4.5	4.4	.243
Ht. (m) of Max. Sprout/Stump:					
Unadjusted	4.35	4.1	4.4	4.4	.001**
Adjusted	4.35	4.2	4.3	4.3	.759
Survival (%) at Stump Age 9	80.5	56	90	96	.0001**
Coppice Stem Dry Weight:					
kg/Stump	2.62	2.0	2.7	2.8	.0001**
Mg/ha	2.27	1.2	2.8	2.9	.0001**
Tree Stem Dry Weight:					
Age 3 (Mg/ha)	0.66	0.3	0.9	0.9	.0001**
Age 5 (Mg/ha)	5.75	3.0	6.6	7.7	.0001**

[a]Means underlined by same line are not significantly different at the .05 probability level.

[b]F-test probability level for "Types of Planting Stock" in analysis of variance.

./ Means unadjusted and adjusted for differences in age 5 stump diameter.

hectare, even though family differences in survival and dry weight yield of the five-year-old trees were detected prior to clearcutting (Table 5).

Relationships were examined between stump diameter and dry weight yields, number of sprouts per stump, and diameter of largest sprout per stump to elucidate the nature (or lack) of family effects on coppice production (Figure 2). Coppice stem dry weight, number of sprouts, and diameter of the largest sprout per stump all increased as stump diameter increased, but the percent of variation explained by regression (R

families, types of planting stock, and many non-measured variables (stump height, date cut, etc.), all contributed to the unexplained variation. The effects of families are illustrated by the plotted family means. Although family differences were not significant for stem dry weight at coppice age three, several interesting trends can be observed by comparing graphs. Family 'A2' is consistently a poor performer from tree age five through coppice age

Table 4. Means and tests of significance for effects of family on 3-year-old coppice characteristics in a 9-year-old sycamore progeny test

Trait	Family Rank[a/] #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	F-test Prob.[b/]
Stump Diam. (Age 5):											
Family	G1	F1	T1	L1	F2	A1	B1	N1	O1	A2	
Diam. (cm)	9.0	8.9	8.9	8.8	8.6	8.5	8.0	8.0	7.6	7.2	.145
No. Sprouts/Stump:											
Family	T1	B1	F2	G1	L1	A1	O1	F1	N1	A2	
Number (unadj.)[c/]	4.9	4.2	4.0	4.0	3.9	3.8	3.7	3.5	3.4	3.3	.003**
Family	T1	B1	F2	G1	L1	O1	A1	F1	A2	N1	
Number (adj.)	4.7	4.2	4.0	3.9	3.8	3.8	3.7	3.4	3.4	3.3	.002**
Diam. Max. Sprout/Stump:											
Family	L1	O1	G1	F1	A1	T1	F2	N1	B1	A2	
Diam. (cm) (unadj.)	5.0	4.7	4.5	4.5	4.4	4.3	4.2	4.1	4.0	3.8	.493
Family	L1	O1	G1	F1	A1	F2	N1	B1	T1	A2	
Diam. (cm) (adj.)	4.9	4.8	4.4	4.4	4.4	4.1	4.1	4.1	4.1	4.0	.504
Ht. Max. Sprout/Stump:											
Family	A1	L1	T1	G1	O1	F2	F1	B1	A2	N1	
Ht. (m) (unadj.)	4.8	4.7	4.7	4.5	4.4	4.2	4.1	4.0	4.0	3.9	.381
Family	A1	L1	O1	T1	G1	A2	F2	B1	F1	N1	
Ht. (m) (adj.)	4.7	4.6	4.5	4.5	4.4	4.2	4.2	4.1	4.0	3.9	.464

a/ Means underlined by same line are not significantly different at the .05 probability level.

b/ F-test probability level for 'Families' in analysis of variance.

c/ Means unadjusted and adjusted for differences in age 5 stump diameter.

Table 5. Means and tests of significance for effects of family on survival and stem dry weights of 3-year and 5-year-old trees and 3-year-old coppice on 9-year-old stumps in a sycamore progeny test

Trait	Family Rank[a] #1	#2	#3	#4	#5	#6	#7	#8	#9	#10	F-test Prob.[b]
Survival (Stump Age 9):											
Family	F2	G1	F1	L1	O1	A1	A2	N1	B1	T1	.152
%	98	93	83	80	78	78	78	75	70	70	
Coppice Stem Dry Wt.:											
Family	L1	T1	G1	A1	O1	F2	B1	F1	N1	A2	.512
kg/stump	3.5	3.4	3.2	3.2	2.4	2.1	2.1	2.1	1.8	1.7	
Family	G1	L1	A1	T1	F2	O1	F1	B1	N1	A2	.470
Mg/ha	3.3	3.0	2.9	2.6	2.3	2.1	1.9	1.8	1.5	1.4	
Tree Stem Dry Wt. (Age 3):											
Family	A1	N1	F2	G1	L1	F1	T1	O1	B1	A2	.668
Mg/ha	0.8	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	
Tree Stem Dry Wt. (Age 5):											
Family	F2	G1	F1	L1	A1	O1	N1	B1	T1	A2	.064
Mg/ha	7.5	7.3	6.6	6.5	6.2	5.0	5.0	4.7	4.6	4.2	

[a] Means underlined by same line are not significantly different at the .05 probability level.

[b] F-test probability level for 'Families' in analysis of variance.

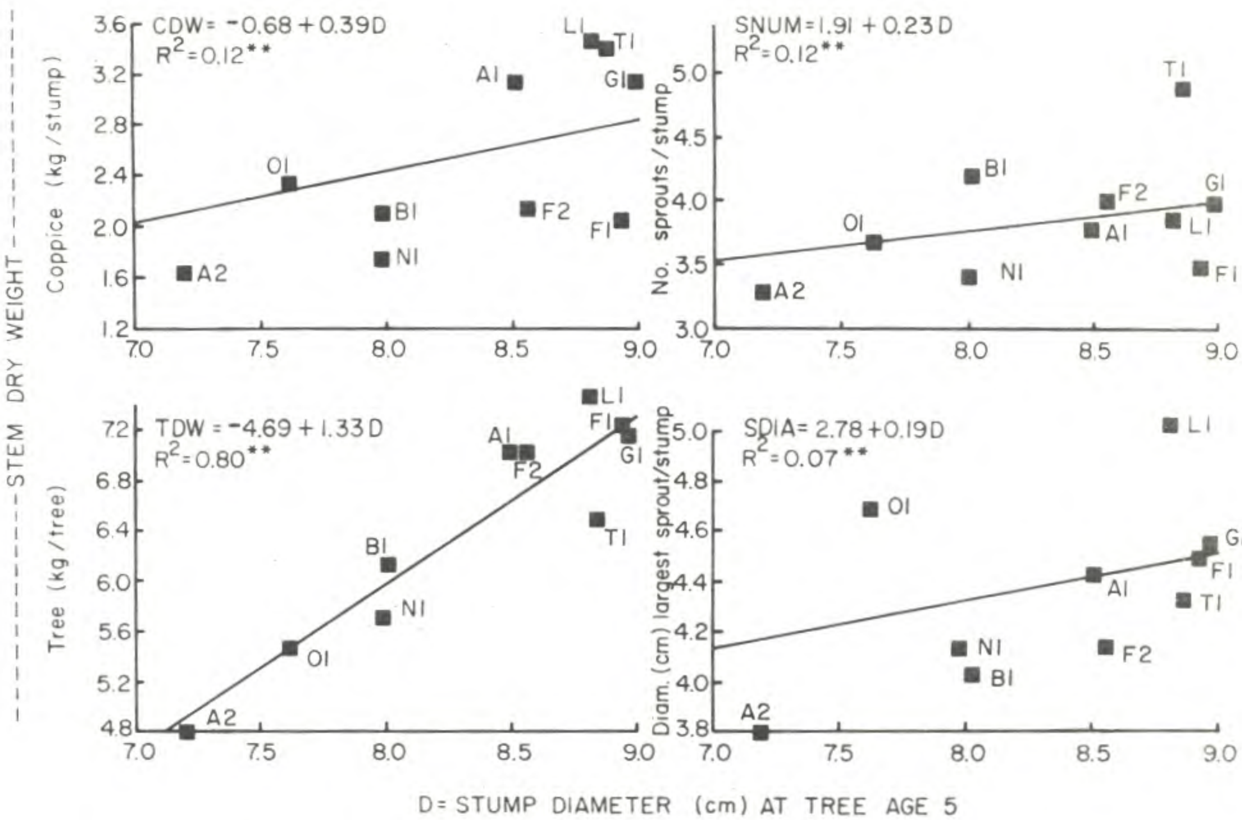

Figure 2.--Regressions and plotted family means for relationships between stump diameter at age five and (1) stem dry weight of tree at age five and (ii) characteristics of three-year-old coppice on nine-year-old stumps.

three. Families 'L1', 'T1', 'F1', and 'F2' illustrate contrasts in coppice dry weight production. All had large stump diameters at age five, and all but 'T1' had high stem dry weights at that age. Four years later the stem dry weight yields of the three-year-old coppice for 'F1' and 'F2' were well below their predicted values based on stump diameter, whereas 'L1' and 'T1' were well above the predicted values. The reasons differ between the two sets. 'L1' is high because of large diameter sprouts and average number of sprouts per stump, whereas 'T1' is high because of large numbers of sprouts and average sprout diameter. 'F1' is low because of low numbers of sprouts and average sprout diameter, whereas 'F2' is low because of small diameter sprouts and average number per stump. If these trends continue for older coppice, where family differences in coppice dry weight may be significant, the desirable families to breed for coppice production would be typified by 'L1': high biomass on a few, large sprouts per stump.

SUMMARY AND CONCLUSIONS

Dry and green weights of sycamore coppice sprouts ranging in size from one to nine cm in basal diameter and one to eight meters in height were reliably predicted from no-intercept linear regression equations presented in this paper with basal diameter squared times height as the independent variable. Using these equations, stem dry weight yield of three-year-old coppice on nine-year-old stumps in a sycamore progeny test planted at 3 x 3 m spacing in northeast Mississippi averaged 2.27 Mg/ha. This yield fell between the yields for the three-year-old and five-year-old trees in that test prior to clearcutting. Sixty-three percent of the above-stump dry coppice biomass was located in the stems. There was no mortality of stumps during the three years following clearcutting, probably because of the wide spacing used.1

Trees established from unrooted cuttings of seedlings' tops had poorer early survival and grew slower than trees established from pruned or unpruned bareroot seedlings. When the trees were clearcut, those from cuttings had smaller stump diameters and subsequently produced fewer and smaller coppice sprouts than those from seedlings. The end result was 40 percent less coppice stem dry weight produced on stumps of trees from cuttings than on stumps of trees from seedlings. Top pruning of bare-root seedlings before planting had no effect on coppice characteristics when compared with unpruned seedlings.

Families significantly affected survival and growth of trees during the first five years after planting. When the stand was cut at age six and allowed to coppice for three years, family differences were detected for number of sprouts per stump, but not for coppice stem dry weight per stump or per hectare. Small, positive relationships between stump diameter and coppice characteristics were observed, however, and family means varied around this relationship. Selection for families with the fastest growth rates during the first five years after planting, and thus the largest stump diameters when clearcut to produce coppice, may not always be the families that produce the most coppice biomass or the most biomass in the most acceptable form (few stems)

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