Development of Water Tupelo Coppice Stands on the Mobile-Tensaw River Delta for Five Years After Precommercial Thinning and Cleaning

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ABSTRACT: *Three 4-yr-old stands (or locutions) were selected for treatment. Treatment consisted of two components: (I) thinning water tupelo* (Nyssa aquatica *L.) stump sprouts and (2) cutting all stems of Carolina ash* (Fraxinus caroliniana *Mill.) and black willow* (Salix nigra *Marsh.) (cleaning). Contrary to results in other areas, survival ofwuter tupelo coppice was very high and was not affected by the treatments. Cleaning had little or no positive effect on the individual tree or stand-level variables we measured. Thinning sprout clumps significantly increased diameter growth of water tupelo; the effect of thinning was considerably largerfor one locution. Stand basal area growth was decreased by thinning sprout clumps. However, quadratic mean diameter was increased by thinning, particularly at one locution. Although thinning decreased basal urea 5 yr after treatment, the increase in quadratic mean diameter was sufficient for there to be no significant effect of thinning on total volume 5 yr after treatment. Because of this, and in anticipation of imminent natural thinning of the unthinned plots, we suspect that the thinned plots will eventually have significantly greater standing volume than the unthinnedplots, at least for the location where density of large sprouts was initially the highest. Rotation age will be decreasedfor that stand because stems will achieve merchantable size sooner. Thus we consider precommercial thinning of sprout clumps to be a potentially effective practice in stands with a high density of large water tupelo sprouts. South. J. Appl. For. 25(4):165–172.*

Key Words: Bottomland hardwoods, intermediate practices, silviculture, stand density.

Water tupelo stands tend to be denser than other bottomland hardwood stands (Putnam et al. 1960, Goelz 1995). After clearcutting, young coppice stands are also dense, with many sprouts arising from each stump. Most of these sprouts die before they are harvested, thus their growth is lost to mortality. Carolina ash or black willow, often abundant in these young stands, are not desirable species on these sites; if they hinder the preferred water tupelo, their removal in a cleaning operation may be warranted.

Mature water tupelo stands in the Mobile-Tensaw River Delta are often harvested with helicopter systems, a method too expensive to use for thinning. Permanently flooded conditions often preclude using rubber-tired or tracked equipment for thinning. As commercial thinning may not be practical in these stands, we became interested in conducting precommercial thinning and cleaning to achieve a merchantable size (currently, 3 in. top diameter) at an earlier age, thereby reducing rotation length, as well as minimizing unsalvageable losses of growth to mortality. Water tupelo is harvested for pulp; most mature stands being harvested in the area are 60 to 80 yr old.

Previous studies have indicated that thinning is not particularly beneficial for water tupelo stands. Kennedy (1983) found that thinning mature water tupelo stands in the

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Atchafalaya Basin of Louisiana did not increase diameter growth. In McGarity's (1979) study of 60-yr-old muck swamp forests, thinning increased growth of individual trees, but unthinned plots had greatest volume growth.

Although mortality of individual sprouts is expected as each stump undergoes self-thinning, previous studies have indicated that mortality is high for entire stumps of water tupelo. DeBell(197 I) reported high survival for water tupelo stump sprouts 1 yr after harvesting; however, at age 4, 45% of the stumps with sprouts had died. Kennedy (1982) reported that because mortality of young water tupelo sprout clumps was high, tupelo coppice would not comprise an important component of the mature stand. After 6 yr, only 9% of the stumps cut in May and 18% of the stumps cut in November had live sprouts. In contrast, Aust et al. (1998) reported high survival of water tupelo coppice in the Mobile-Tensaw River Delta, and attributed it to the 3 to 4 in. of sedimentation the area receives per decade.

In this article we intend to determine: (1) whether diameter and height growth rates of water tupelo stump sprouts respond to thinning; (2) whether stump-sprout thinning will improve survival of the remaining sprouts; (3) whether cutting all Carolina ash and black willow (cleaning) will improve growth and survival of tupelo stump sprouts; and (4) how stand basal area, stems per acre, and stand volume of the preferred species, water tupelo, are affected by thinning and cleaning over the 5 yr period following treatment.

Initial results from this study (Goelz et al. 1993, Goelz et al. 1998, Goelz and Meadows 1999) indicate that thinning stump sprouts increases annual diameter growth by 20 to 45% over unthinned plots 3 yr after treatment, although cleaning does not improve growth. Unlike previous observations in other studies, mortality of tupelo stump sprouts was negligible.

Methods

Study Site Description

Three locations were chosen on Kimberly-Clark (formerly Scott Paper) Corporation land on the delta of the Mobile and Tensaw Rivers in southern Alabama (approximately 88"W long., 31°N lat.). The Mobile-Tensaw River Delta is a deltaic plain formed below the confluence of the Alabama and Tombigbee Rivers. The area has a warm temperate to subtropical climate with a nearly 9 month growing season. Rainfall is fairly uniformly distributed during the growing season and averages 63 in./yr (O'Neil and Mettee 1982). In wet years, the beginning of the growing season is initiated by recession of the floodwater, which is highest in late winter, rather than by increasing temperatures. The native water tupelo stands on these locations were clearcut in the 1986-I 987 dormant season and four seasons of growth occurred before this study began; clearcuts were 40-60 ac. Harvest was completed prior to the 1987 growing season for all locations. All stems over 2 in. dbh were felled when the stands were clearcut. The locations are good for water tupelo and are densely stocked to water tupelo, Carolina ash, baldcypress (*Taxodium distichum* [L. | Rich.), and black willow, with other species present.

Stems per acre before and immediately after treatment are presented in Table 1. Before treatment, the locations had

Table 1. Number of stems per acre at study initiation. Other hardwood are primarily Carolina ash and black willow. Stems less than 2.5 in. dbh are 3.0 ft or taller. Stems at least 2.5 in. dbh were not permanently tagged until after treatment. "Pre" and "post" refer to before or after treatment. Stands were located in the Mobile-Tensaw River Delta and were treated in autumn of 1990.

Treatment	Water Tupelo <2.5 in.	Water Tupelo ≥2.5 in.	Other hardwood <2.5 in.	Other hardwood ≥2.5 in.	Baldcypress <2.5 in.	Baldcypress ≥2.5 in.	Total
	(dbh)						
Location 1							
Control	3,066	140	3,672	0	629	48	7,555
Clean(pre-)	2,025	117	2,963	5	356	68	5,534
Clean(post-)	1,900	100	104	0	379	64	2,547
Thin (pre-)	2,842	105	3,121	2	570	25	6,801
Thin (post-)	1,025	53	2,729	0	537	35	4,379
Clean and thin (pre-)	3,437	143	4,128	0	252	5	7,965
Clean and thin (post-)	1.476	77	232	0	183	5	1,973
Location 2							
Control	1,448	291	4,006	3	203	2	5,953
Clean(pre-)	3,108	231	2,629	3	185	5	6,173
Clean(post-)	2,645	283	383	3	161	7	3,482
Thin (pre-)	2,208	283	4,481	0	166	5	7,143
Thin (post-)	676	143	4,484	2	226	8	5,539
Clean and thin (pre-)	3,069	315	1,962	0	131	3	5,488
Clean and thin (post-)	733	138	187	0	99	3	1,312
Location 3							
Control	5,600	86	4,249	0	491	16	10,442
Clean(pre-)	3,896	89	3,963	0	680	3	8,631
Clean(post-)	2,893	86	259	0	414	3	3,631
Thin (pre-)	3,162	119	4,984	0	552	10	8,837
Thin (post-)	1,232	36	4,154	0	397	8	5,827
Clean and thin (pre-)	4,791	69	5,173	3	365	2	10,403
Clean and thin (post-)	1.164	36	101	0	229	3	1,533

5,000 to 10,000 stems per acre over 3 ft high. Note that we did not tally trees less than 2.5 in. dbh in our most recent measurement; these data are presented to describe the stands at the time of treatment. In Table 1, "other hardwood" is dominated by Carolina ash and black willow; location 3 has much more willow than locations 1 or 2. All three locations have high densities of water tupelo. However, location 2 has a much higher density of sprouts over 2.5 in. dbh, and a lower density of smaller sprouts, than do locations 1 and 3. Location 2 also differs greatly from locations 1 and 3 in that water tupelo stumps were smaller, and there were more stumps per acre (personal observation). Average diameter of the trees of adjacent intact stands appears to be smaller at location 2 than locations 1 and 3 (personal observation). As there are more stumps per acre at location 2, it follows that large gaps between sprout clumps are rare at that site, although they are common at the other two locations. Location 1 is located on the Tensaw River, locations 2 and 3 are on the Middle River. Location 2 is within 3 aerial miles northwest of location 1, and location 3 is within 3 aerial miles northwest of location 2.

Experimental Design

A 2 x 2 factorial design with two randomly selected replications at each location was used. The first factor consists of two treatments: thinning or not thinning water tupelo sprout clumps. For the thinning treatment, all water tupelo stumps were thinned to one or two best sprouts, where "best" was defined as the largest well-formed sprout that originated low on the stump. When two well-spaced sprouts of good form and low origin were present, both were left. If only one good sprout was present, that one sprout was left.

The second factor consists of two treatments: cleaning or not cleaning the Carolina ash and black willow. All ash and willow were cut as close to the ground as possible with a chainsaw. These factors provide four treatment combinations:

1. No thinning, no cleaning (control).
2. No thinning, cleaning.
3. Thinning, no cleaning.
4. Thinning and cleaning.

Eight 0.786 ac treatment plots were placed in each location. As the soils near the riverbank are much different from the rest of the stand, all treatment plots were at least 800 ft from the river. Treatments were applied in the autumn of 1990.

Measurements

The measurement plot (0.304 ac) was in the center of each treatment plot. Stems at least 2.5 in. dbh were permanently numbered, and the following measurements were taken: dbh (to the nearest 0.1 in.), species, origin (seedling or sprout), number of sprouts on stump, and crown class (Kraft's tree class) (Daniel et al. 1979). Total height was measured with a telescoping height pole (to the nearest 0.01 ft) on 25 randomly selected trees per plot, unless fewer than 25 stems were present that were at least 2.5 in. dbh These trees were remeasured 1, 3, and 5 yr after the study began. At years 1, 3, and 5, after treatment, 5 trees were randomly selected from among the stems that had become at least 2.5 in. dbh since the last measurement; height was also measured on these trees in subsequent years.

Individual tree volume at year 5 was calculated by: (I) fitting a dbh to height regression equation, specific for locations and treatments and species; (2) estimating total height with this equation for those trees whose height was not measured; (3) using equations given in Clark et al. (1991) to calculate inside bark diameter at stump height, at breast height, and at 17.3 ft; (4) using Smalian's formula to calculate cubic foot volume between stump and breast height, between breast height and 17.3 ft, and calculating volume above 17.3 ft as a cone to total height. Thus volume estimates are for total volume, inside bark, to the tip of the tree. Volume was only calculated for trees 4.0 in. dbh and greater. The equation of Clark et al (1991) was based on trees 5.0 in. dbh and greater; thus, in addition to representing a merchantability limit, we chose a4.0 in. minimum dbh to decrease the amount of extrapolation. This procedure for calculating volume overestimates merchantable volumes for smaller trees proportionally more than it overestimates merchantable volume for larger trees. However, we used it since there are no available equations for water tupelo coppice to a 3 in. top diameter.

Statistical Analysis

Analyses were by analysis of variance or covariance. The design is a 2 x 2 factorial with two levels for thinning, two levels for cleaning, and three locations with two replications per location. Effect of location was considered fixed. For plot-level data where we considered multiple measurements over time, we applied a repeated measures design (Neter et al. 1990). For individual-tree characteristics, such as diameter growth and height growth, analysis was by analysis of covariance, with plot error used to test for plot-level effects and individual tree error used to test for significance of covariates and treatment-by-covariate interaction terms. As tree level data is unbalanced, due to different numbers of trees on each plot, this analysis of covariance was conducted by fitting full and reduced models and obtaining sums of squares attributed to that source as the difference between full and reduced models (Netcr et al. 1990). For height growth, we only used data from water tupelo trees that were dominant or codominant at all measurements. We were more interested in height growth as an indicator of site quality or of vigor of the sprout, rather than merely describing average stand height. Survival data were analyzed by using log-linear models applied to the cross-classified categorical data, with the likelihood ratio statistic, G^2, as the test statistic (Fienberg 1980). Survival was analyzed independently for the periods 199 1 to 1993 and 1993 to 1995. As water tupelo is the preferred species on these sites, some of our analyses were run for "all species," and again for only water tupelo. All significance tests were conducted at an α level of 0.05.

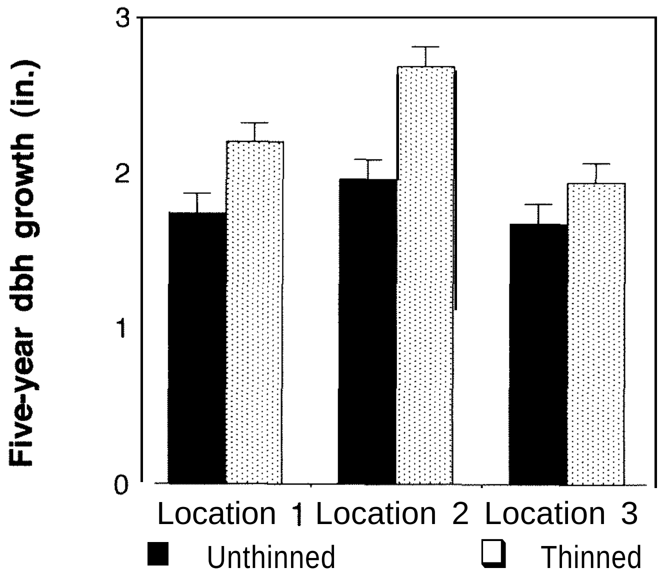

Figure 1. Mean dbh growth of water tupelo fat least 2.5 in. dbh) 5 yr following thinning.

Results and Discussion

Mean Five-Year Diameter Growth of Water Tupelo Sprouts

Thinning, location, and the thinning-by-location interaction terms significantly affected plot-mean diameter growth. Means for thinned and unthinned plots at each location are presented in Figure 1. The effect of thinning ranges from 0.26 in., for location 3, to 0.72 in. for location 2, or a 16 to 37% increase over the unthinned treatment.

The effect of numbers of sprouts on a stump is shown in Figure 2 (adjusted R^2 is 0.16), for trees on unthinned plots. The slope of the line increases with number of sprouts. Thus, initial size is more critical to subsequent growth when a sprout has many competitors on the stump than when it only has one. For trees greater than the average (around 2.9 in.) the more sprouts, the greater the diameter growth. This might not be expected, but the stumps that produced many sprouts tended to be more vigorous, either due to greater carbohydrate reserves or to the absence of significant pathogens in the stump.

Five-Year Height Growth of Dominant and Codominant Water Tupelo

Location, thinning, cleaning, and the thinning-by-cleaning, location-by-thinning, and location-by-cleaning interaction terms all significantly affected height growth 5 yr after treatment (Figure 3). Thinning or cleaning decreased height growth from that of the controls; however, thinning and cleaning together did not decrease height growth more than either treatment by itself. The effect of cleaning was negligible on location 2 (where, by chance, plots with the fewest ash and willow were assigned the cleaning or thinning and cleaning treatments). Apparently, thinning sprout clumps or cleaning produces trees that become bushier and grow less in height than in the control plots. Although angiosperm trees typically possess a decurrent branching pattern, this is typically expressed more fully when the tree is open grown, or more generally, lacks competitors (Kramer and Kozlowski 1979). For the control plots, there were only small differences among locations in height growth.

Survival of Water Tupelo

Survival of water tupelo sprouts was very high across all locations and treatments, averaging 0.995 during the period of 1991-1993 and 0.993 during the period of 1993-1 995. These correspond to annual survival rates of 0.997, and 0.996, respectively. Treatments did not significantly affect survival in either period. Personal observation suggests that most of the mortality was due to damage by beaver ***(Castor** canadensis* Kuhl), although some mortality was undoubtedly

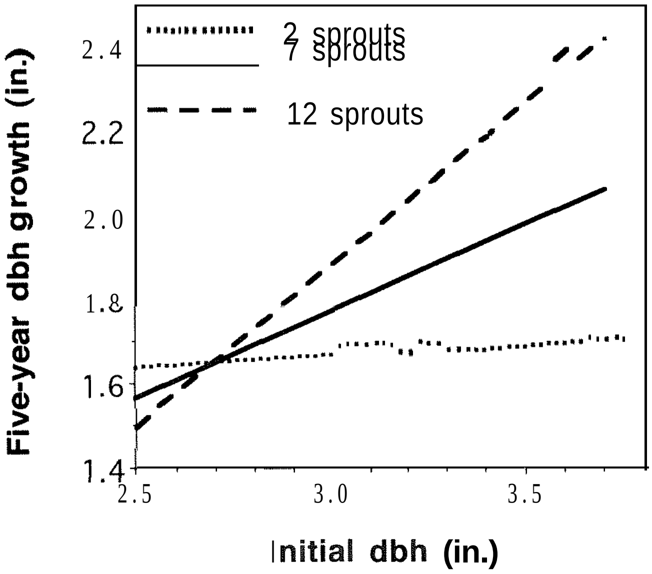

Figure 2. Lines describing dbh growth of unthinned water tupelo (at least 2.5 in. dbh) from a regression equation using initial diameter and initial number of sprouts, and their interaction, as predictors.

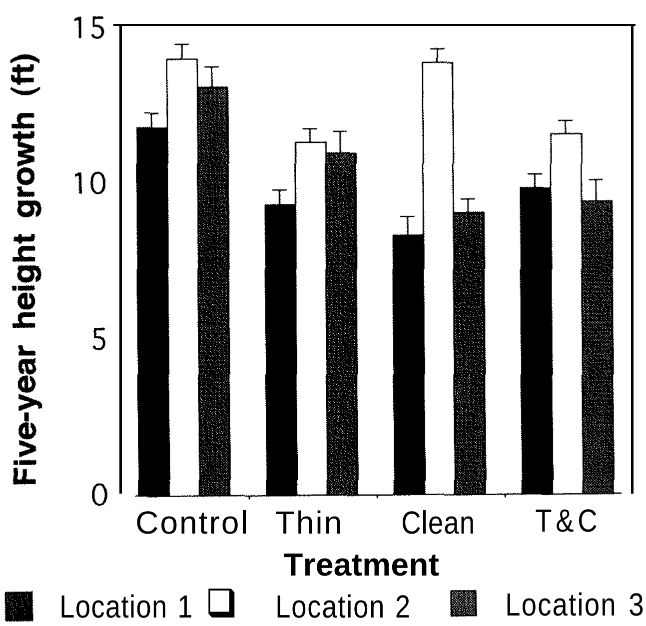

Figure 3. Height growth of individual dominant or codominant water tupelo trees for 5 yr following treatments.

due to natural thinning of sprout clumps and also to deterioration of the stump before the sprout developed an independent root system. The high survival found in this study contrasts markedly with the results of coppice tupelo in other regions (DeBell 197 1, Kennedy 1982). Unlike those areas, we believe that overstory of the mature stand will be comprised primarily of coppice water tupelo. Aust et al. (1998) found high survival of water tupelo coppice as well in the Mobile-Tensaw Delta. They attributed high survival to high deposition of sediment (3-4 in./decade). We suggest an additional factor may also be important: the hydrological processes of the Mobile-Tensaw River Delta has been negligibly altered by man while the study sites of DeBell (1971) and Kennedy (1982) represent more highly affected ecosystems.

Stand Basal Area of All Species

The development of stand basal area (ft^2/ac) over time is presented in Figure 4. Location, thinning, interaction of location and thinning, interaction between location and cleaning, and year, all significantly affected stand basal area. For location 2, cleaned plots have more basal area than control plots and thinned and cleaned plots have more basal area than thinned-only plots. We believe this is merely a coincidence-that the plots that were cleaned had a greater capacity to grow than the uncleaned plots. There were relatively few ash and willow trees that were removed in the cleaning at this location. Location 2 had the greatest basal area for all treatments. For location 3, thinned plots diverge from cleaned plots from yr 3 to yr 5 after treatment. This is primarily due to ingrowth of seedling willow into the stand. In the cleaned plots, the willow was set back sufficiently that few stems became greater than 2.5 in. dbh in the 5 yr of the study, while considerable willow became greater than 2.5 in. dbh on the thinned plots.

Stand Basal Area of Water Tupelo

The development of water tupelo basal area over time is presented in Figure 5. Location, thinning, location-by-thinning interaction, and year are the only significant factors. Cleaning did not affect stand basal area of water tupelo. Again, location 2 has the greatest basal area, as well as the greatest treatment effect. The unthinned plots for location 1 and 3 are very similar in tupelo basal area; however, there is a greater difference between treatments for location 3. The difference between treatments is increasing over time.

Stems Per Acre of All Species (2.5 in. dbh or Larger)

The changes over time of stems per acre of all species are depicted in Figure 6. Location, thinning, thinning-by-location interaction, location-by-cleaning interaction, and year are all significant. The patterns are very similar to Figure 4, describing basal area development. However, differences in treatment effect are much greater for trees per acre than for stand basal area at location 2. Increases of trees per acre seem to be slowing down while the corresponding figure for stand basal area is very linear, at least for locations 1 and 3. This is expected since trees continue to grow after reaching the 2.5 in. dbh threshold, and thus, basal area is not linearly related to number of stems. At location 2, it seems that plots are approaching their maximum number of stems per acre for all

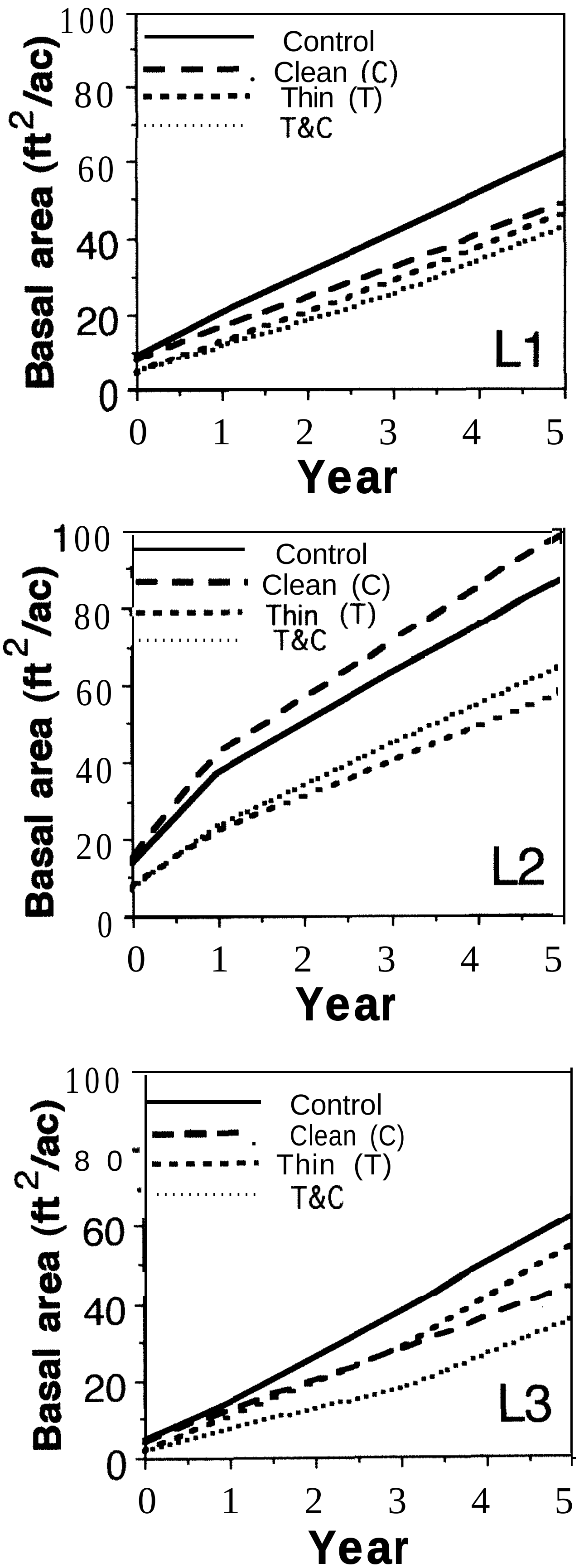

Figure 4. Stand basal area development of the total of all species (at least 2.5 in. dbh) for the four treatments on: location 1 (L1); location 2 (L2); and location 3 (L3). Year 0 represents data at study initiation, after treatment.

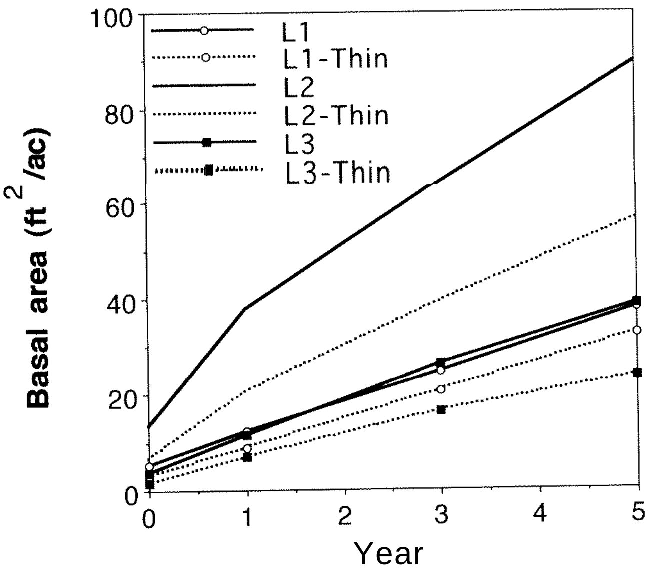

Figure 5. Stand basal area development of water tupelo (at least 2.5 in. dbh) for the thinned and unthinned plots on: location 1 (L1); location 2 (L2); and location 3 (L3). Year 0 represents data at study initiation, after treatment.

treatments; we expect natural thinning to then decrease number of stems over time.

Stems Per Acre of Water Tupelo (2.5 in. dbh or Larger)

The changes over time of stems per acre of water tupelo are depicted in Figure 7. Thinning, location, thinning-by-location interaction, and year are significant factors. Similar to the corresponding figure for stand basal area, Figure 5, location 2 has the greatest treatment effect, as well as the greatest number of trees for all treatments. The unthinned plots seem to be diverging from the thinned plots over time. This suggests two things. First, thinning sprout clumps removed many stems that were initially smaller than the 2.5 in. dbh threshold for measurement, and thus these stems never grew into the 2.5 in. class. Second, stumps did not resprout so vigorously that those new sprouts attained the 2.5 in. threshold for measurement. As the slopes for thinned plots appear to be getting flatter as time passes, and continue to be flatter than those for unthinned plots, it appears that few resprouts will survive and grow past the 2.5 in. threshold. Thus, thinning did effectively and permanently reduce stems per acre.

Quadratic Mean Diameter of Water Tupelo

In an even-aged stand, quadratic mean diameter will increase over time, and certainly merchantability of a stand is determined by the diameter of the constituent trees. Thus, we view quadratic mean diameter as an index of stand maturity. The change in quadratic mean diameter over time is graphed in Figure 8. Location, thinning, location-by-thinning interaction, location-by-cleaning interaction. thin-by-cleaning interaction, location-by-thin-by-cleaning interaction, and year were all significant, In spite of all those significant factors, the effect of the treatment was small. except for the effect of thinning (with or without cleaning) at location 2. At location 1, the control treatment had a greater quadratic mean diameter than the quadratic mean diameter of either the thinning

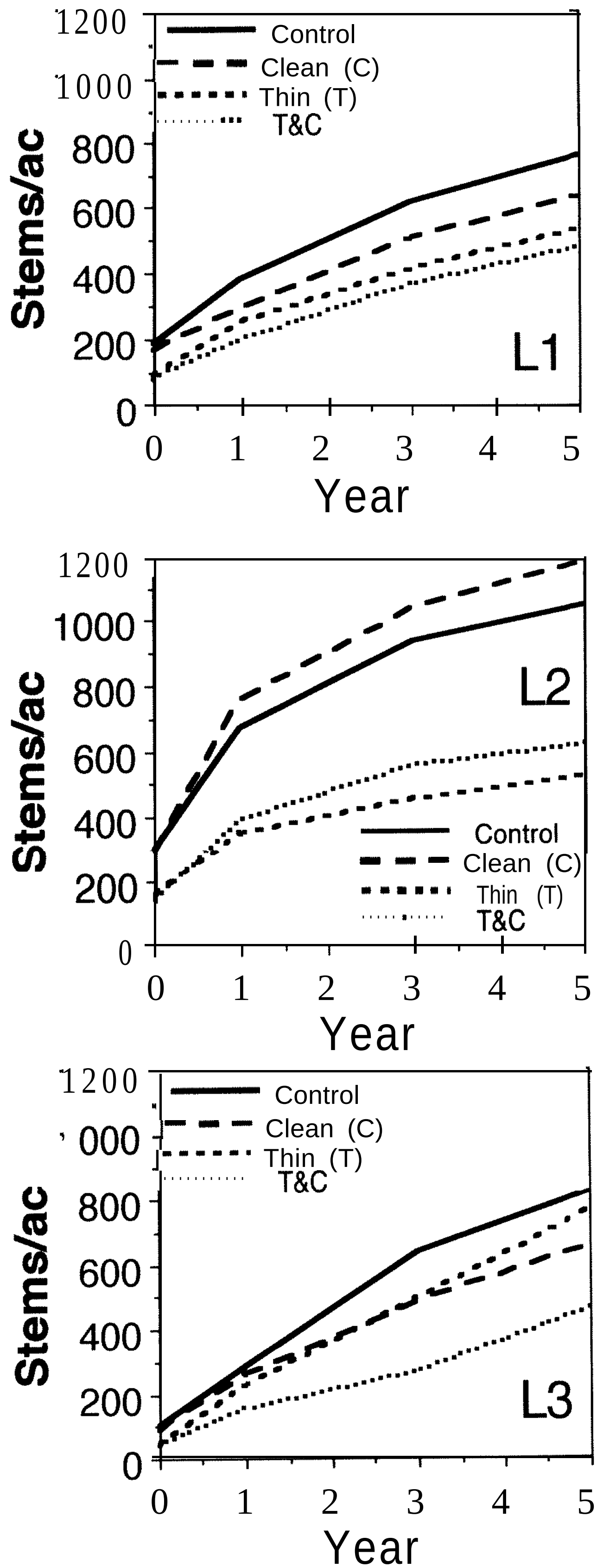

Figure 6. Development of stems per acre for the total of all species (at least 2.5 in. dbh) for the four treatments on: location 1 (L1); location 2 (L2); and location 3 (L3). Year 0 represents data at study initiation, after treatment.

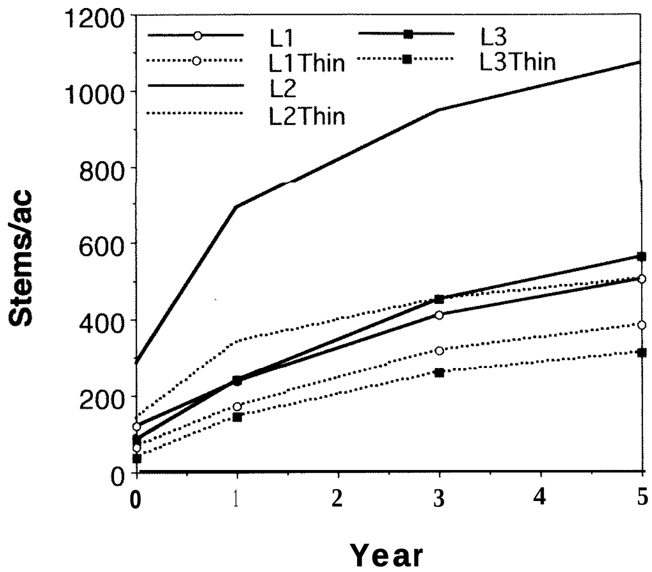

Figure 7. Development of stems per acre for watertupelo (at least 2.5 in. dbh) for the thinned and unthinned plots on: (L1) location 1; (L2) location 2; and (L3) location 3. Year 0 represents data at study initiation, after treatment.

or cleaning treatments. At location 3, the thinning treatment was almost the same as the control. One of the objectives of thinning the sprout clumps in this study was to reduce rotation age. As we suggest quadratic mean diameter is an index of stand maturity, it appears the ultimate rotation age was really only reduced at location 2. So, unless the effect of thinning becomes more noticeable in the future for locations 1 and 3, this goal of thinning will not be fulfilled at those sites. As noted, location 2 initially had a greater density of large water tupelo sprouts and a greater density of stools (personal observation). This may reflect that location 2 was a younger stand at time of harvest.

Stand Volume of Water Tupelo

Total volume (ft^3/ac), 5 yr after treatment, for each treatment and location, is graphed in Figure 9. Only location was a significant factor. Treatments and interactions of treatments and locations were not significant. Since unthinned plots had more stems than thinned plots, and since most of the trees initially at least 2.5 in. dbh have grown past the limit of merchantability for the volume calculation ($\geq$ 4.0 in. dbh), these results are unexpected. These results may suggest that the treated plots have already caught back up to the control plots within 5 yr of treatment (since thinning would have produced an immediate reduction in standing volume). This further suggests that at some point in the near future, the thinned plots will surpass the unthinned plots in stand volume. We believe that it is inevitable that thinned plots will possess more stand volume at some point in the future, because mortality will be greater among thinned plots.

Summary and Conclusions

Cleaning had little or no positive effect on individual tree or stand level variables we measured. While we generally suggest that cleaning is not beneficial, we do so with the caveat that it does not appear to be beneficial within 5 yr of

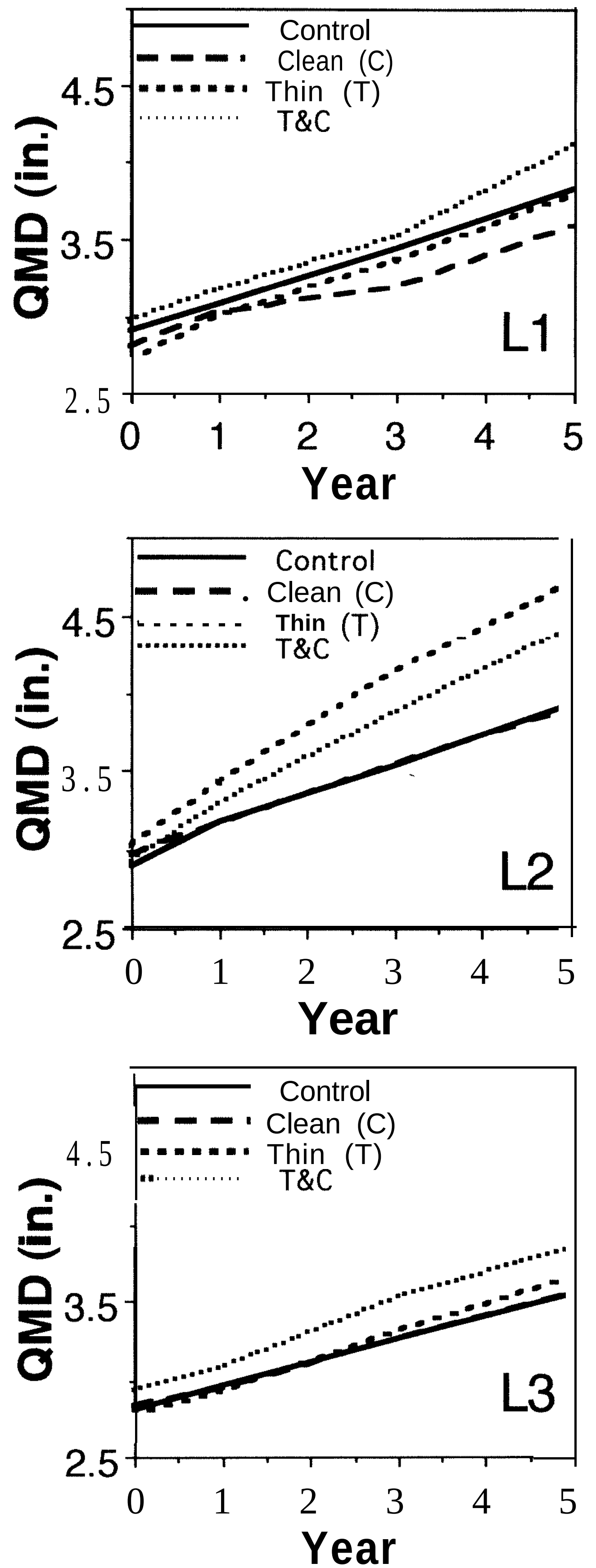

Figure 8. Quadratic mean diameter (QMD) development of all species (at least 2.5 in. dbh) for the four treatments on: location 1 (L1); location 2 (L2); and location 3 (L3). Year 0 represents data at study initiation, after treatment.

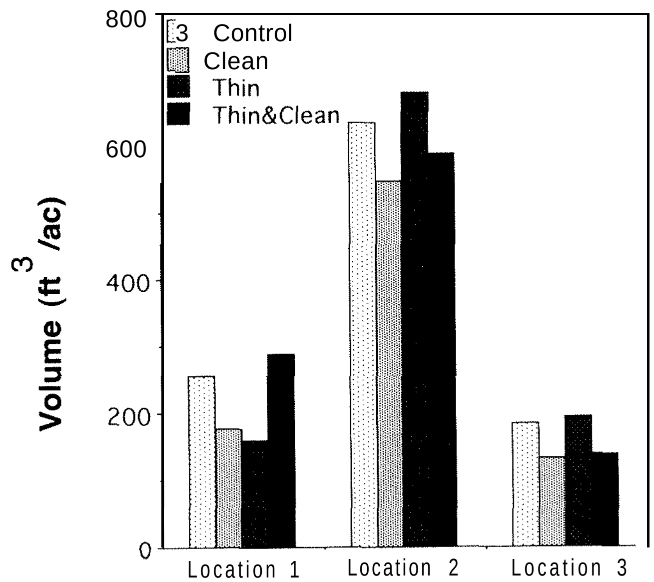

Figure 9. Total inside-bark volume (ft^3/ac), in trees at least 4.0 in. dbh, for four treatments on three locations, 5 yr after treatment.

treatment. However, on location 3, plots that were not cleaned have volume of willow approximately equal to volume of the preferred water tupelo. Within the 5 yr period of our measurements, presence of willow has not significantly adversely affected growth of water tupelo, but it might in the future. Willow seedlings became established primarily in relatively large gaps between tupelo sprouts. Thus, willow and tupelo have not interacted much yet, but they might in the future as individual trees of each species grow and develop larger crowns. The willow seedlings were initially shorter than the dominant water tupelo at study initiation; however, the willow are as tall as the tupelo 5 yr after treatment (where they weren't cleaned). We are much more confident that Carolina ash does not provide any important negative influence on water tupelo coppice; Carolina ash were quickly outgrown and dominated by water tupelo. Coppice-origin water tupelo quickly asserts dominance over ash. Carolina ash were initially shorter than water tupelo. and this difference increased greatly over the course of the study. Thus, stands where willow is numerous might be candidates for cleaning; abundant sprouts of Carolina ash are inconsequential. Locution 3 averaged over 1000 willow stems per acre over 3 ft tall at age 3. before treatment; cleaning may be considered where willow is similarly abundant.

Thinning sprout clumps significantly increased diameter growth of water tupelo, and this difference was greatest for location 2. Basal area growth was decreased by thinning, and the difference between thinned and unthinned plots seems to be increasing. However, quadratic mean diameter was considerably increased by thinning at location 2: thinning did not consistently increase quadratic mean diameter at the other locations. Although thinning decreased basal area, increase in quadratic mean diameter was sufficient for there to be no significant effect of thinning on total volume. Because of this, we believe that the thinned plots will soon have significantly greater standing volume of water tupelo than the unthinned plots. at least at location 2. It is possible that this difference will be increased and much more of the growth will be harvestable at the end of the rotation, because natural mortality will reduce stem density of the unthinned plots. Although thinning clearly wouldn't increase biomass production, less will be lost to mortality and more will be harvestable. Furthermore, we believe that thinning sprout clumps will reduce rotation age considerably, at least on location 2. Thus, we consider thinning to be a potentially effective option on stands similar to our location 2. For comparison to other stands, at age 4, prior to treatment, the plots on location 2 averaged nearly 300 stems/ac over 2.5 in. dbh, and about 2500 sprouts/ac over 3.0 ft in height (Table 1). In addition, there were few large gaps between stools at location 2. We consider thinning to be a viable option for similar stands.

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