Effect of Initial Root Collar Diameter On Survival and Growth of Yellow-Poplar Seedlings Over 17 Years

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A nursery study was installed to test the effects of seedbed density and top-pruning on field performance of bareroot yellow poplar (Liriodendron tulipifera *L.) seedlings. Seedlings were grown at a density of either 9.5 or 16.3 seedlings/ft^2 (102 or 175/m^2) and half were top-pruned in August to a height of about 10 inches (25 em). Outplanted seedlings were measured for heights at ages 2, 9, and 17 years. Survival and growth were positively related to initial root collar diameter. Neither top-pruning nor seedbed density had a lasting effect on growth.* Tree Planters' Notes 47(1):30-33; 1996.

This study was installed at the Virginia Department of Forestry's Augusta Nursery, in the Shenandoah Valley, in the summer of 1971. We wanted to look at the effect of the following 3 treatments on the size and per formance of yellow-poplar *(Liriodendron tulipifera* L.), also know as tuliptree, seedlings:

1. Bed densities of 10 and 20 seedlings/ft^2 (107 and 215 / m^2)
2. Top-pruning once during the growing season vs. no top-pruning
3. Root-pruning once during the growing season vs. no root-pruning

The 3 treatments were applied in all combinations, resulting in a 2 × 2 × 2 factorial, yielding 8 treatment combinations. These 8 treatments were replicated 5 times, in 5 adjacent seed beds, for a total of 40 plots. The individual plots were 5 feet (1.5 m) long.

We thinned the plots to the target density of 10 and 20 seedlings /ft^2 (107 and 215/m^2) on July 19 and 20. Seedlings were still very small, none of them over 6 in (15.2 cm) tall. Stocking was erratic and sparse, in places, on all plots. We had hoped to leave either 10 or 20 seedlings on each square foot of each 5-foot-long plot, but many individual square feet had fewer than 20 seedlings. Actual densities left after thinning averaged 9.5 and 16.3 seedlings /ft^2 (102 and 175/m^2). We toppruned to about a 10-inch (25 cm) height on August 23. Many seedlings were not tall enough to be pruned.

We did the root-pruning on September 17, attempting to keep the under-cutter at about a 10-inch (25 cm) depth. Soils at the Augusta Nursery are very heavy and contain a lot of small rounded rocks, and the root-pruning did not go well at all. We ended up dragging a lot of seedlings, and decided to drop this part of the study, which reduced the 8 treatment combinations to just 4 (those that included just seedbed density and top-pruning).

Lifting and Grading

We lifted the seedlings on March 21, 1972. We discarded 1 of the 5 seedbed replications because of excessive variation related to soil differences. From the remaining 16 plots (4 replications × 4 treatment combinations), we lifted a 40-seedling sample across the center of each plot.

We separated the seedlings from each sample by root collar diameter into 1/16-in (1.6-mm) size-classes. Seedlings less than 5/32 in (3.9 mm) were discarded, and the remaining trees were counted by root collar diameter class. We grouped them into 2 size classes for planting in the field: the small size class included the 3/16-in (4.8-mm) and 4/16-in (6.4-mm) seedlings and the large size class included 5/16-in (7.9 mm) and larger seedlings.

Planting in the Field

We planted the seedlings on the Lesesne State Forest, which is in Nelson County, east of and at the foot of Three Ridges Mountain, one of the tall mountains that form the crest of the Blue Ridge in central Virginia. The soil is deep and rocky, developed in colluvium from the mountain above, which is largely composed of granodiorite. These soils are typically good hardwood sites.

Before planting, the area supported a stand dominated by black locust *(Robinia pseudoacacia* L.) and ailanthus *(Ailanthus altissima* (Mill.) Swingle), with some dogwoods *(Corpus florida* L.) and scattered apple trees *(Malus* spp.*),* and a moderate ground cover of honeysuckle *(Lonicera japonica* Thunb.). We harvested the stand during the winter of 1970-71, using the locust for posts. We piled the brush and burned the piles in the spring of 1971. Stumps sprouted vigorously and the

honeysuckle grew rapidly. In the late summer of 1971 we sprayed the area with 2,4-dichlorophenoxy acetic acid and then in the early fall, after the honeysuckle had cured, we burned the area. Even with this intensive site preparation, hardwood sprouts again became a serious problem, especially the locust and ailanthus. Consequently, in the spring of 1974, after the poplar seedlings had been through 2 growing seasons, all competing hardwoods were basal-sprayed.

The seedlings were planted on March 28, 1972, using a spacing of 6.6 × 6.6 ft (2 m× 2 m). Even though the seedlings were grouped into small- and large-diameter classes, we noted on a map the diameter of each individual seedlings; in other words, within the small-diameter class, we knew which seedlings were 3/16 in (4.7 mm) and which were 4/16 in (6.3 mm). As seedlings were planted, the top length of each seedling was measured and recorded.

The field planting, therefore, included 8 treatments, the 4 original seedbed treatments each with 2 size classes. These 8 treatments were replicated 3 times in randomized blocks, with a 20-seedling row of each treatment in each block.

Measurements

Seedling heights were measured at ages 1 and 2. At age 9 we measured the diameter at breast height (DBH) of each surviving tree. At age 17 we measured the DBH of each surviving tree and the total height of 60% of the surviving trees. Before we took our measurements at age 17, the trees had suffered considerable top breakage from at least 1 severe ice storm. The trees on which we measured heights were, for the most part, trees that had sustained the least breakage. Many of the badly broken trees became suppressed by more fortunate neighbors. The 3 replications were installed side by side with the 20-seedling rows running approximately north and south

Seedbed Results

Seedlings grown at 10/ft2 (102/m^2) were slightly taller (7%) and slightly larger in diameter (13%) than seedlings grown at 20/ft^2= (175/m^2=) (table 1). Top-pruning reduced top height substantially; top-pruned seedlings were 33% shorter. Top-pruning also had a slight effect on diameter; top-pruned seedlings were 8% smaller.

Survival

The seedbed treatments— low and high bed densities and top— pruning-had no significant effect on survival (table 2). Root collar diameter, on the other hand, had an important effect on survival that increased with age (table 3). After age 2, the slower height growth of smaller diameter seedlings resulted in more of them dying of suppression.

Table 1—*Average root collar diameter (in 16ths of an inch) and shoot height when seedlings were lifted, by seedbed treatment*

Treatment	Height* ft	Height* m	Diameter† (# of 16ths in.)
Low density, top-pruned	1.02	0.31	4.11
Low density, not pruned	1.53	0.47	4.79
High density, top-pruned	0.97	0.29	3.90
High density, not pruned	1.42	0.43	3.96

Low-density seedlings were raised 10/ft^2 (107/m^2); high-density seedlings were raised at 20/ft^2 (215/m^2).
* Based on 120 seedlings for each treatment, measured as they were planted.
† Based on 160 seedlings for each treatment, 40 from each of 4 seedbed plots.

Table 2—*Average survival at ages 1, 2, 9, and 17 years by seedbed treatment*

Treatment	% survival 1 yr	2 yrs	9 yrs	17 yrs
Low density, top-pruned	96	92	82	74
Low density, not pruned	92	92	84	68
High density, top-pruned	93	92	84	68
High density, not pruned	94	93	82	71

Low-density seedlings were raised 10/ft^2 (107/m^2); high-density seedlings were raised at 20/ft^2 215/m^2).

Table 3—*Average survival at ages 1, 2, 9, and 17 years by initial root collar diameter (RCD)*

RCD in.	RCD mm	No. planted	% survival 1 yr	2 yrs	9 yrs	17 yrs
3/16	4.8	120	82	81	62	45
4/16	6.3	120	96	94	87	73
5/16	7.9	119	98	98	89	82
6/16	9.5	59	100	98	93	81
7/16	11.1	29	100	100	97	86
8/16	12.7	8	100	100	100	88
9/16	14.3	2	100	100	100	100
Totals		457				

Note: An analysis of variance was performed on survival at age 2 by grouping the 6/16 to 9/16th-inch seedlings. This provided 120, 120, 119, and 98 planted seedlings in the 3/16-, 4/16-, 5/16-, and 6/16-in and larger diameter classes. Survival percentages were first transformed to arc sine percentages. The overall F for initial diameter was statistically significant (probability of a larger F=0.014). Using Duncan's new multiple range test, the only significant differences (at both the 0.05 and 0.01 levels) were that both 5/16-in and 6/16-in and larger seedlings survived better than 3/16-in seedlings.

Height Growth

At age 2, the initial reduction in top length caused by top-height had disappeared; in fact, top-pruned seedlings were actually taller at age 2 (table 4). The small initial height advantage, when lifted, of seedlings grown at the lower density, had not increased, and on a percentage basis had decreased from 7 to 3%.

Heights at age 2 were strongly related to initial root collar diameter. An analysis of variance was performed, and the overall difference between large and small seedlings— 3.96 ft (1.21 m) compared to 2.91 ft (0.89 m)— was significant (probability of a larger F = 0.000009). Average heights at age 2, by initial 1/16-inch(1.6-mm) diameter classes, are presented in table 5. Average heights at age 17 are presented in table 6 by initial root collar diameter.

Table 4—*Average height by treatment at age 2*

Treatment	Height	
	ft	m
Low density, top-pruned	3.56	1.08
Low density, not pruned	3.42	1.04
High density, top-pruned	3.42	1.04
High density, not pruned	3.35	1.02
Low density, top-pruned, small	3.12	0.95
Low density, top-pruned, large	4.00	1.22
Low density, not pruned, small	2.87	0.87
Low density, not pruned, large	3.96	1.21
High density, top-pruned, small	2.96	0.90
High density, top-pruned, large	3.88	1.18
High density, not pruned, small	2.70	0.82
High density, not pruned, large	4.00	1.22

Note: Low-density seedlings were raised 10/ft^2 (107/m^2); high-density seedlings were raised at 20/ft^2 (215/m^2).

Table 5—*Average height at age 2 by initial root collar diameter (RCD)*

RCD		# of Trees		Average height	
in.	mm	Planted	Measured	ft	m
3/16	4.8	120	97	2.5	0.76
4/16	6.3	120	113	3.3	1.01
5/16	7.9	119	116	3.7	1.13
6/16	9.5	59	58	4.3	1.31
7/16	11.7	29	29	4.4	1.34
8/16 & 9/16	12.7 & 14.3	10	10	4.5	1.37
		457	423		

Diameter Growth

Average diameters at ages 9 and 17, by initial root collar diameter class, are presented in table 7. Diameter at base height (dbh) increased with increasing initial root collar diameter, reaching a maximum for 6/16-in (9.5-mm) and 7/16-in (11.1-mm) seedlings, and then fell off for 8/16-in (12.7-mm) and 9/16-in (14.3-mm) seedlings. We have no idea why DBH decreased for the largest seedlings, but the sample size was only 10 and 9 seedlings (at ages 9 and 17), so the difference may be a random effect. An average stand table at age 17, combining all initial root collar diameter classes, is presented in table 8.

Conclusions

Seedling size has a profound impact on both survival and growth of bareroot yellow-poplar seedlings. Although top-pruned seedlings were initially about 6 in (15 cm) shorter, growth during the first 2 years after outplanting was increased enough so there were no height differences between treatments at age 2.

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Table 6—*Average heights at 17 years, for all trees and just dominant and codominant (D&CD) trees, by initial root collar diameter (RCD)*

Initial RCD			All trees measured for height				D&CD trees measured			
					Height				Height	
in	mm	No. surviving	No.	%*	ft	m	No.	%*	ft	m
3/16	4.8	54	35	65	52.0	15.8	18	33	62.2	19.0
4/16	6.3	88	53	60	56.5	17.2	28	32	61.1	18.6
5/16	7.9	98	55	56	55.8	17.0	25	26	62.5	19.1
6/16	9.5	48	34	71	56.5	17.2	21	44	62.5	19.1
7–9/16	11.1–14.3	34	16	41	58.7	17.9	11	32	62.3	19.0
Averages				60	55.7	17.0		32	62.0	18.9
Totals		322	193				103			

* Number measured as a percentage of number surviving.

Table 7—*Average diameter at breast height (DBH) by initial root collar diameter (RCD) at 9 and 17 years*

Initial RC		9 yrs			17 yrs		
			DBH			DBH	
in	mm	No.	in	cm	No.	in	cm
3/16	4.8	74	2.44	6.20	54	5.13	13.03
4/16	6.3	104	3.26	8.28	88	5.98	15.19
5/16	7.9	106	3.50	8.89	98	5.78	14.68
6/16	9.5	55	3.98	10.11	48	7.04	17.88
7/16	11.1	28	3.90	9.91	25	6.80	16.51
8 & 9/16	12.7 & 14.3	10	3.34	8.48	9	5.78	14.68
Averages			3.32	8.43		5.99	15.21
Totals		377			322		

Table 8—*Average density of trees at age 17 by diameter class (diameter at breast height, DBH)*

DBH			
in	cm	Trees/ac	Trees/ha
1/16	2.5	25	62
2/16	5.1	38	94
3/16	7.6	58	143
4/16	10.2	88	217
5/16	12.7	71	175
6/16	15.2	73	180
7/16	17.8	135	333
8/16	20.3	73	180
9/16	22.9	56	138
10/16	25.4	38	94
11/16	27.9	10	25
12/16	30.5	6	15
Totals		671	1,657