Top Pruning of Bareroot Hardwood Seedlings

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Abstract

There are two schools of thought (prune or no-prune) regarding top pruning bareroot hardwood seedlings. Those who recommend top pruning usually consider the economic advantages of top pruning. In some locations, the total cost of establishing hardwoods might be 7 percent lower for top-pruned stock compared with nonpruned stock. Top pruning can reduce the production of cull seedlings (e.g., those that are too tall for shipping), reduce the cost of lifting and shipping, decrease the chance of dieback, and increase growth after planting. Benefits of top pruning appear greater when nonpruned seedlings have low root-weight ratios (root dry weight to total seedling dry weight) and experience stress after planting. In most studies, height growth is stimulated so that, after 3 years in the field, top-pruned seedlings have caught up to the heights of nonpruned seedlings. This paper was presented at a joint meeting of the Northeast Forest and Conservation Nursery Association and Southern Forest Nursery Association (Kent Island, MD, July 20–23, 2015).

Introduction

Top pruning (also known as shoot clipping) has been used to improve the "transplantability" of hardwood seedlings for more than 300 years. John Evelyn (1677) gave a prescription of cutting 1-0 oak (*Quercus* spp.) seedlings in the nursery to a height of 3 cm. He also indicated that, after resprouting for 1 year, some growers recut the seedlings to a height of 15 cm. Two-hundred years later, Fuller (1884: p. 67) reported that "All kinds of forest trees may be, and nearly all should be pruned at time of transplanting." Brisbin (1888) observed that many planting failures could be explained by not pruning enough. Fernow (1910: p. 98) stated that "…pruning is to be done at the time of planting, when it is needful to restore the balance between the branch system and the root system, the latter often having been curtailed in the operation of transplanting the tree." Toumey (1916) stated that the more severely the root system is injured in lifting the trees, the greater the necessity for pruning the tops. Meginnis (1940: p. 35) said "… in horticultural practice, it is customary in transplanting deciduous trees to cut back part of the top in order to reduce transpiration losses pending the time that the root system becomes sufficiently established to restore water balance." Later, Duruz (1953: p. 125) commented that "Usually the amateur is disinclined to cut back a plant for fear of injuring it, but this pruning is essential in order to promote vigor, and better growth will follow." Koller (1977: p. 239) said that "…pruning is essential to the transplant operation" and that the minimum to be removed is "one-third of the growing stems." Kozlowski and Davies (1975: p. 4) said that "Probably the most useful, least expensive, and easiest way of assuring decreased transpirational loss of transplants is by pruning 15 to 40 percent of the bud-bearing branches."

Even though we have centuries of recommendations and decades of studies, there is a continued belief that top pruning will result in stunted growth (Meginnis 1940, Schnelle and Klett 1992), poor establishment (Chalker-Scott 2015, Schlarbaum et al. 1997), or poor stem quality (Dobkowski 1997), or that it will encourage animal depredation (Dey et al. 2006, Nugent 1974). Some claim that top pruning to reduce shipping costs is counterproductive (Schlarbaum et al. 1997). Others say that top pruning is not "natural." This assertion, however, is not entirely true, because various animals browse hardwood seedlings (Clark et al. 2009, Dey et al. 2006, Stanturf et al. 2000) and, on some sites, dieback occurs after planting. In addition, terminal bud abortion is a natural occurrence for many angiosperms (Romberger 1963). By contrast, proper top pruning has an economic justification, can increase seedling vigor (DesRochers and Tremblay 2009, Spetich et al. 2002), and, for some species, has no long-term effect on forking and stem quality (Briscoe 1969, Dierauf and Garner 1996, Jacobs 1969, Stout 1986, Thomas 2009).

Top-Pruning Methods and Application

Most managers top prune before lifting. They use a variety of tractor-powered top pruners, but two common types are rotary mowers and sickle bar mowers (figure 1) (Lowman et al. 1992, South 1996). In the past, a few managers pruned seedlings after lifting. When top pruning is conducted in the packing shed, paper cutters or hand shears have been used.

Timing

Some nursery managers top prune hardwoods two or three times during the growing season (Rentz 1997, Vanderveer 2005), while others top prune seedlings only once (table 1). The timing for top pruning depends on growing-season length. In some northern locations, the growing season is only 3 to 4 months long, with germination beginning in early May, allowing for top pruning in late summer. For example, at the Griffith State Nursery in Wisconsin, 1-0 northern red oak (*Quercus rubra* L.) seedlings are top pruned in September if they are taller than 43 cm (Storandt 2002). The growing season at this nursery is about 140 days with the first frost typically occurring about the third week of September. By contrast, the growing season in southern locations can be 6 to 7 months long. For example, at the Columbia Nursery in Louisiana, the growing season is about 230 days, and, therefore, top pruning (at 28 cm) begins when seedlings reach a height of 46 to

Figure 1. Top pruning *Quercus* seedlings using a sickle bar mower at the SuperTree Nursery (Shellman, GA). Only a few, well-replicated top-pruning trials have been conducted in operational hardwood seedbeds. (Photo by Robert Cross, 2008)

Table 1. Results from a 2006 nursery survey of hardwood nurseries (unpublished data collected by Amy Ross-Davis). Of the 26 returned questionnaires, 17 managers (65 percent) said they top pruned hardwood seedlings. Species, timing, pruning height, and reasons for pruning are listed in this table. The North region is between the 39th and 49th parallels and the South region is between the 49th and 25th parallels.

Species	Time of top pruning	Pruning height (cm)	Reason for top pruning
North region			
Quercus rubra L.	July 1–15	25	Increase root-weight ratio (RWR)
Populus and *Salix*	February	30–38	Reduce shipping cost
Liriodendron tulipifera L.	Several times	Increasing	Increase RWR; allow smaller seedlings to grow
Cornus sericea L.	Late June	25–28	Reduce shoot height
Alternate branched species	Late July	36–38	Decrease top growth
Quercus and *Prunus*	March–April	46	Reduce shipping cost
All hardwoods	Late fall to end of March	25–30	Increase RWR
Quercus, Fraxinus, and *Acer*	Early to mid-September	43	Facilitate packaging
All hardwood species	October	30–36	Reduce top height for packing
All shrub species	At harvest in April	15–30	Improve uniformity and force lateral growth
South region			
All hardwood species	Twice	30–61	Increase RWR
All hardwood species except *Fraxinus pennsylvanica* Marshall	August	47	Increase RWR
Quercus rubra L.	July 27	36	Increase RWR
All hardwood species except *Quercus*	Late October to December	30–46	Increase RWR; uniformity
Quercus	June—38 cm; Sept—58 cm	36–61	Improve root collar diameter
All hardwood species except *Juglans nigra* L. and *Carya*	July–August	61	Increase RWR

51 cm (Rentz 1997). A second top pruning (at 48 cm) is done in August, when the seedlings reach a height of 60 to 66 cm. The manager prefers not to top prune after August. At lifting, the final height may be about 70 to 76 cm. Thus, the second top pruning in Louisiana is about a month earlier than the first (and only) top pruning in Wisconsin.

Target Height at Lifting

The target height for hardwood seedlings at lifting varies by species, box length, and customer specifications. For oaks, recommended height at lifting varies from 15 to 20 cm (Dey et al. 2008, Johnson et al. 1986, Spetich et al. 2002) to 45 to 60 cm (McLeod 2000, Stanturf et al. 2000, Williams et al. 1993) and 60 to 120 cm (Allen et al. 2001, Kormanik et al. 1994). Differing opinions about economics, probability of dieback, and seedling "vigor" explain, in part, why the target seedling height varies among researchers. Although removing almost the entire shoot might achieve the desired results for a few species (DesRochers and Tremblay 2009, Meadows and Toliver 1987, Wightman et al. 2001, Williams 1974), this degree of pruning is rarely practiced by nursery managers.

A cull seedling can be defined, in part, as one that is either too short or too tall (Rose et al. 1990). Therefore, one simple way for nursery managers to increase the production of shippable seedlings is to top prune so that no seedlings exceed the maximum height limit. At some nurseries, maximum height is determined by the length of the shipping box or by the size of the tractor. Because tall, lignified stems can be injured when the tractor passes over the seedbed, top pruning allows for seedlings to pass under the tractor unscathed.

Effects of Top Pruning on Hardwood Seedlings

Top pruning is "improper" when it does not meet the objectives of the nursery manager (e.g., reducing seedling height so that all seedlings fit into a standard shipping box), reforestation manager (e.g., increasing seedling vigor), and landowner (e.g., reducing establishment cost per hectare). For example, removing only 1 cm of the shoot would be considered improper because it does not reduce shipping costs and may not reduce the percentage of cull seedlings (i.e., exceed a maximum height). Likewise, for some species, pruning to a final height of 15 cm would be considered improper when it results in a reduction in survival after outplanting.

Root-Weight Ratio

There are at least four definitions of shoot-root ratio. Some foresters define shoot-root ratio as the shoot length divided by taproot length (Weaver et al. 1982), but most researchers divide the shoot dry weight by the root dry weight (Bernier et al. 1995, Haase 2011, Thomas 2009). Some researchers avoid the drying process and calculate a shoot-root ratio based on fresh weights (Stoeckeler 1937, Wilde and Voigt 1949) or volume displacement (Haase 2011, Racey et al. 1983). I prefer the term root-weight ratio (root dry weight divided by total seedling dry weight [RWR]) because it is easy to understand, cannot be confused with ratios involving lengths or volumes, and has a slightly lower coefficient of variation than a shoot-root ratio (based on dry weights). An RWR of 0.6 simply means the roots make up 60 percent of a seedling's total dry mass.

Top pruning increases the RWR of hardwoods. For example, when a 130-cm-tall oak seedling has an RWR of 0.46, then removing one-half of the shoot mass with top pruning would increase the RWR to 0.63. In one study, removing one-third of the stem increased the RWR from 0.21 to 0.27 and delayed mortality in a greenhouse (Thomas 2009). It is unfortunate that few top-pruning studies report the dry mass of hardwood seedlings before and after clipping. Even so, top pruning (to increase RWR) might increase height growth in the field. Therefore, both greenhouse and field trials suggest that increasing the RWR may indeed reduce the amount of transplant shock and dieback.

Dieback After Outplanting

Top pruning can reduce dieback (Davies 1987). Under stressful field conditions, tall, nonpruned hardwood seedlings may die back during the first or second year after outplanting (Dey et al. 2006). For example, northern red oak seedlings (45 to 66 cm in height) exhibited dieback on three sites for 2 years after planting (Kaczmarek and Pope 1993a). On one site, the amount of dieback was equal to almost one-half the original height. In another study, 34 percent of tall (≈107 cm) northern red oak seedlings exhibited dieback 2 years after planting (Heitzman and Grell 2006).

Tall sweetgum (*Liquidambar styraciflua* L.) may die back when planted on sandy soils. When the initial height of grade 1 bareroot sweetgum seedlings averaged more than 100 cm, stem dieback ranged from 35 to 66 percent (Kormanik 1986). When average height was 84 cm (for grade 1 seedlings inoculated with *Glomus deserticola* Trappe, Bloss & J.A. Menge), however, dieback was only 18 percent. This and other findings (Jacobs et al. 2012) suggest that stem dieback is related to seedling height. Dieback is nature's way of letting foresters know they planted unbalanced hardwood seedlings.

Survival After Outplanting

Because of variations in pruning intensity, outplanting sites, rainfall amounts, and species, top-pruning effects on survival can be variable. Even so, I conducted a statistical test using survival data in table 2. Each treatment mean (pruned or nonpruned survival) was an observation, and each trial was a replication (n = 26). An ANOVA test revealed no overall top-pruning effect on survival ($p > F = 0.26$; least significant difference = 3 percent; $\alpha = 0.05$).

Table 2. Effect of top pruning of bareroot seedlings on field survival of hardwood seedlings. Treatments with less than 10 cm of stem remaining (after top pruning) are not included.

Genus	Years after outplanting	Survival (%)		Difference %)	Reference
		Not pruned	Top pruned		
Carya	5	94	83	– 11	Toliver et al. 1980
Eucalyptus	0.29	94	91	– 3	Thomas 2009
Prunus	1	80	78	– 2	Anonymous 1984
Quercus	1	100	99	– 1	Smith 1992
Liriodendron	2	69	68	– 1	Limstrom et al. 1955
Liquidambar	3	98	98	0	McNabb and VanderSchaaf 2005 (large stock)
Carya	3	91	91	0	Meadows and Toliver 1987
Carya	3	100	100	0	Wood 1996
Liriodendron	2	92	92	0	Dierauf and Garner 1996
Liriodendron	2	0	0	0	Kelly and Moser 1983
Quercus	3	87	87	0	Zaczek et al. 1993 (2-0)
Quercus	1	98?	98?	0?	Russell 1973
Juglans	5	74?	74?	0?	Russell 1979
Juglans	5	66?	66?	0?	Russell 1979
Fraxinus	3	96?	96?	0?	Woessner and van Hicks 1973
Liriodendron	1	> 90?	> 90?	0?	Sterling and Lane 1975
Liquidambar	3	90	93	+3	South 1999
Liquidambar	3	95	98	+3	McNabb and VanderSchaaf 2005 (large stock)
Robinia	2	79	82	+3	Meginnis 1940
Quercus	5	90	93	+3	Toliver et al. 1980
Quercus	5	64	69	+5	Stanturf and Kennedy 1996 (2-0)
Quercus	5	82	87	+5	Toliver et al. 1980
Betula	3	50	58	+8	Godman and Mattson 1971
Carya	3	85	94	+9	Meadows and Toliver 1987
Fraxinus	1	80	97	+17	Anonymous 1984
Carya	2	75	100	+25	Smith and Johnson 1981
	Average	**82**	**84**	**+2**	

? = values not reported by treatment.

When rainfall is adequate after outplanting and survival of nonpruned hardwood stock is greater than 90 percent, there appears to be no relationship between seedling survival and top pruning (Davies 1987, South 1998). Even so, six trials reported a survival benefit of 5 to 25 percent for top-pruned seedlings (table 2). The objective of increasing the RWR by top pruning is to increase the probability of survival after outplanting. When survival of nonpruned stock is less than 90 percent, top pruning may increase survival 45 percent of the time (table 2). In one study, top pruning 10 cm off the shoot reduced mortality, seedling moisture stress, and leaf area (Thomas 2009). Top pruning can reduce total water use for 5 weeks or more after planting (Abod and Webster 1990). For some hardwood species, top pruning to a height of 15 or 30 cm might increase new root growth (Kelly and Moser 1983). Reduced moisture stress and increased root growth have been attributed to increased field survival of hardwoods (Grossnickle 2011, Thomas 2009).

Weed competition and seedling size can affect the survival of top-pruned seedlings. In one study, seedlings were sorted into two size classes (initial diameter of 12 to 16 mm [large stock] or 4 to 8 mm [small stock]) and outplanted on a weedy site and a site with low weed competition (McNabb and VanderSchaaf 2005). The top-pruning treatments involved removing either 50 percent of the stem length (≈40 cm removed) or 94 percent of the length (≈75 cm removed). On both sites, the large stock had better survival and grew more than the small stock. Severe top pruning (i.e., leaving less than 6 cm of stem) reduced survival on both sites, which likely explains why nursery managers do not top prune sweetgum to a height of less than 20 cm. On the site with minimal weed competition, survival was high (more than 97 percent) and 50 percent top pruning had no overall effect on survival. On the weedy site, however, 50 percent top pruning reduced survival of the small stock by 10 to 12 percent compared with nonpruned seedlings.

Height After Outplanting

Top pruning typically stimulates height growth so that, after 3 years in the field, top-pruned seedlings equal the heights of nonpruned seedlings. For example, a study to examine top pruning of sweetgum (figure 2) was installed in January 1996 with seedlings grown at the Westvaco Nursery in South Carolina (South 1999). After 2 years of growth, there was no difference in height between nonpruned and top-pruned seedlings (table 3).

To provide additional evidence, a statistical test was conducted on height data from numerous top-pruning trials (table 4). This analysis included 22 trials (replications), with each replication containing two observations (pruned and nonpruned mean heights

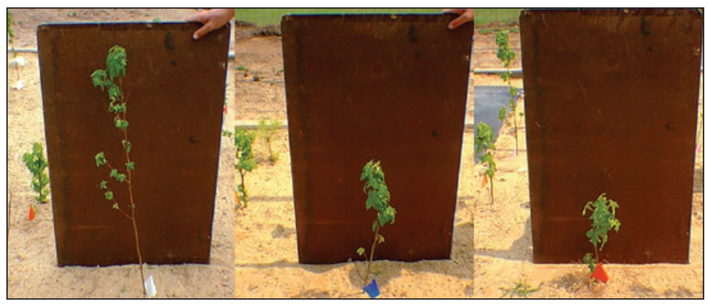

Figure 2. On average, tall, nonpruned *Liquidambar styraciflua* L. seedlings (left) grew only 112 cm during the 3 years after planting, whereas seedlings top pruned to 45 cm (middle) or 30 cm (right) in the nursery grew 144 cm or 157 cm, respectively. More details are provided in table 3. This photo was taken 5 months after planting. (Photo by David South, 1996)

Table 3. Effect of top pruning on seedling morphology and survival of sweetgum (*Liquidambar styraciflua* L.) (South 1999).

Treatment	April 1996 leaf-out (%)	November 1996 leaf length (mm)	Height (cm)				December 1998 groundline diameter (mm)	December 1998 survival (%)
			January 1996	September 1996	December 1997	December 1998		
None	49 a	55 c	81 a	86 a	162 a	193 a	26 a	90 a
Tip removed	62 a	61 b	73 b	75 b	157 a	192 a	26 a	92 a
45 cm	52 a	71 a	45 c	57 c	156 a	189 a	26 a	93 a
30 cm	28 b	71 a	30 d	49 d	159 a	187 a	25 a	93 a
(LSD)	(15)	(4.9)	(2.6)	(3.3)	(5.7)	(8.1)	(2.8)	(8.5)

LSD = least significant difference.
Note: Means in a column followed by the same letter are not statistically different ($\alpha = 0.05$).

2 to 11 years after outplanting). The ANOVA test found no difference between pruned and nonpruned heights ($p > F = 0.19$; least significant difference = 12.6 cm; $\alpha = 0.05$), indicating that height of pruned seedlings after several years in the field is, on average, no different than that of nonpruned stock. This finding suggests overall height growth was greater for the top-pruned seedlings, given that the initial height of nonpruned seedlings was significantly taller than that of top-pruned seedlings.

Economics

Top pruning might add $0.50 to the cost of producing 1,000 seedlings (table 5). Proper top pruning, however, not only reduces shipping cost, but it makes

Table 4. Effect of top pruning hardwood seedlings on subsequent height (cm) after 2 or more years in the field. Treatments with less than 10 cm of stem remaining (after top pruning) are not included.

Genus	Years after outplanting	Height (cm)		Difference (%)	Reference
		Not pruned	Top pruned		
Carya	5	121	147	+ 21	Toliver et al. 1980
Quercus	2	55	55	0	Smith 1992
Liquidambar	3	250	217	– 13	McNabb and VanderSchaaf 2005 (large stock)
Carya	3	75	81	+ 8	Meadows and Toliver 1987
Carya	4	400	380	– 5	Wood 1996
Liriodendron	2	103	106	+ 3	Dierauf and Garner 1996
Quercus	6	268	300	+12	Zaczek et al. 1997 (2-0 stock)
Quercus	5	134	134	0	Russell 1973
Juglans	5	183	201	+10	Russell 1979
Juglans	5	61	85	+39	Russell 1979
Fraxinus	3	320	328	+2	Woessner and van Hicks 1973
Liquidambar	3	193	189	– 2	South 1999
Liquidambar	3	224	218	– 3	McNabb and VanderSchaaf 2005 (large stock)
Robinia	2	92	81	–12	Meginnis 1940
Quercus	5	371	385	+4	Toliver et al. 1980
Quercus	11	719	744	+3	Stanturf 1995 (2-0 stock)
Quercus	5	336	321	– 4	Toliver et al. 1980
Betula	3	31	46	+48	Godman and Mattson 1971
Carya	3	52	56	+8	Meadows and Toliver 1987
Carya	2	197	309	+57	Smith and Jonson 1981
Quercus	2	85	77	– 9	Adams 1985
Quercus	6	131	122	– 7	Russell 1973
	Average	**200**	**208**	**+ 4**	

Table 5. An example of how top pruning in the nursery can reduce the cost per thousand planted hardwood seedlings. At this nursery, a bag contains either 100 tall seedlings or 200 top-pruned seedlings.

Treatment	Seedling height (cm)	Growing cost ($)	Lifting cost ($)	Bag cost ($)	Shipping cost ($)	Planting cost ($)	Total cost ($)
Not pruned	90	275.00	25	10	17.00	330	657
Top pruned	50	275.50	19	5	8.50	300	608

hand-planting easier, thereby increasing productivity and lowering planting costs. When considering all costs, planting nonpruned hardwood seedlings might increase overall costs by 8 percent when compared with planting top-pruned seedlings (table 5).

Shipping

The economic advantages of top pruning hardwoods vary by nursery. At some nurseries, shipping cost is based on weight, and top-pruned seedlings weigh less than nonpruned stock. In one trial, top pruning reduced seedling weights by 14 percent (McNabb and VanderSchaaf 2005). This reduction could save the landowner about $2.80 per thousand seedlings (assuming no savings in packaging or planting costs). At other nurseries, shipping cost is based on volume. Therefore, a longer box with 50 percent more volume to accommodate taller, nonpruned stock will cost the nursery 50 percent more to ship (plus the extra cost of the box). If it costs $8.50 per thousand seedlings to ship top-pruned stock and $17 to ship taller stock (table 5), then the savings to the landowner would be $8.50 per thousand seedlings.

Packing Materials

Top pruning also affects the cost of packing materials. At one nursery in Georgia, 200 top-pruned hardwoods can be placed in a bag that normally would hold only 100 nonpruned seedlings (Cross 2015). As a result, the cost of bags would be $5 per thousand for top-pruned stock and $10 per thousand for nonpruned stock.

Planting

Oak seedlings that weigh more (Spetich et al. 2009, Williams et al. 1993) and are taller than 90 cm (Allen et al. 2001) typically will take longer to plant by hand than shorter seedlings. Although small hardwood seedlings are easier to plant, top pruning late in the season typically does not increase the number of seedlings that can be carried by planters, because tree planters' bags are open and, therefore root mass, not height, is the limiting factor for carrying capacity (figure 3).

Tree-planting costs for hardwoods vary by region, species, and tree size. For some regions in the South, the cost of hand-planting a top-pruned hardwood seedling might be near $0.25 and the retail cost of a seedling might be $0.40. In other places, planting

Figure 3. Planting tall, hardwood seedlings in Issaquena County, MS. (Photo by Mike Oliver, 1999)

costs may exceed the cost of seedlings (Allen et al. 2001, Manatt et al. 2013). For example, a 20-cm-tall top-pruned 2-0 hardwood seedling might cost $0.65 to plant (Spetich et al. 2009) and a 90-cm-tall hardwood seedling might cost $0.70 to plant.

Seedling Price

Some nurseries base seedling prices on seedling height. For example, a horticultural nursery might have four different price classes for 1-0 seedlings. Tall seedlings may sell for $1.40 each and 50 cm seedlings may sell for $1.05 each (figure 4). When price is based on tree height, a manager would not top prune when demand is high for tall seedlings. In this example, removing 50 percent of the shoot would lower the profit by $0.35 per seedling. By contrast, in years when demand for 50 cm seedlings exceeds supply (and demand for taller stock is low), the manager might consider top pruning to increase seedling sales and avoid carrying unwanted stock over to the next year. Therefore, the economic incentive to top prune is driven, in part, by customer demand.

Future Research Needs

It is surprising that only a few published top-pruning studies (Dierauf and Garner 1996, Toliver et al. 1980) have been conducted in hardwood nursery beds (figure 1). Researchers typically top prune seedlings after lifting and before planting. Future research needs to determine if proper top pruning in hardwood nurseries will affect (1) the number of cull seedlings, (2) survival under moisture-limiting conditions, and (3) diameter growth of seedlings in the seedbed understory (i.e., those that are too short to be affected by the top-pruning equipment).

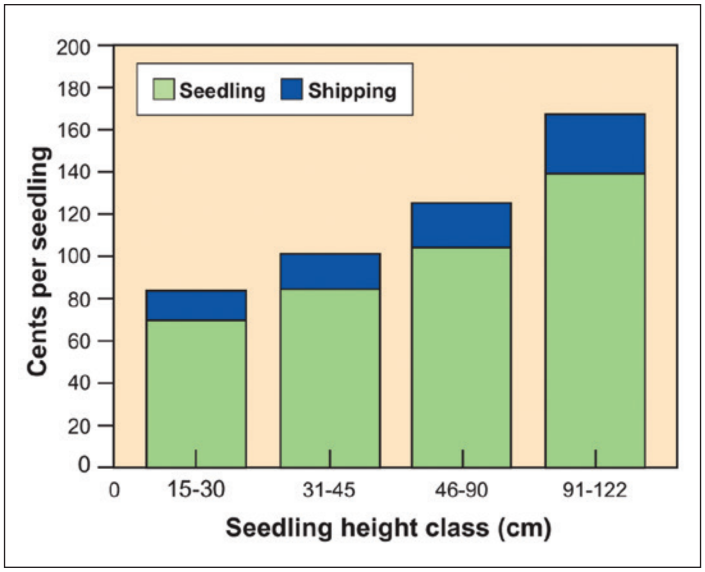

Figure 4. In this example, both shipping cost ($0.14, $0.17, $0.21, and $0.28 per seedling) and seedling price ($0.70, $0.85, $1.05, and $1.40 per seedling) increase with seedling height class.

Treatment plots should be designed to ensure that growth of nonpruned seedlings does not adversely affect the growth of adjacent top-pruned seedlings. It is very important to replicate treatments and to eliminate confounding (Haase 2014). In one study, top pruning was confounded with seedling age (Kaczmarek and Pope 1993b), which casts doubt on the researchers' conclusions regarding new root growth. In another study, a "suppression effect" was confounded with treatment (Kormanik et al. 1995) because rows of nonpruned seedlings were adjacent to rows of top-pruned seedlings. By mid-December, top-pruned seedlings were 3 to 6 cm shorter than the nonpruned stock, suggesting that the taller, nonpruned seedlings likely suppressed the growth of adjacent top-pruned seedlings. As a result, top-pruned seedlings were statistically smaller in height and stem diameter for the fastest growing family but not for the slower growing families.

The number of trees planted per treatment is also important (Haase 2014). In some tests, fewer than 40 nonpruned trees are planted per species (Crunkilton et al. 1992, Johnson et al. 1984, Shoup et al. 1981). This number is insufficient to test for treatment differences in survival. In fact, in some locations, even 100 (Stanturf and Kennedy 1996) or 200 trees per treatment (Meginnis 1940) were not enough to declare an 11-percent improvement in survival as statistically significant.

Because properly planted hardwoods have high survival when rainfall is adequate (table 1), researchers should consider using greenhouse trials when they investigate the effects of top pruning on survival. When rainfall is excluded, soil moisture levels can be controlled so that mortality rate can eventually reach 50 percent or more. In one greenhouse trial, 50 percent mortality of nonpruned seedlings occurred on day 25, whereas top-pruned seedlings did not reach that level of mortality until 10 days later (Thomas 2009). By contrast, field survival from both treatments was greater than 90 percent. Research efforts may be wasted when rainfall masks inherent differences in seedling quality.

Research conclusions need to be based on the scientific method. The scientific process follows a pattern: define the problem, review the literature, make observations and collect data, analyze data and form a generalization, formulate a null hypothesis, design a study to test the null hypothesis, draw conclusions, accurately report and publish results, and reevaluate the generalization. The null hypothesis is rejected only if data from a well-designed nursery study can be used to reject the hypothesis (Fisher 1971, Hurlbert 1984, Snedecor and Cochran 1978). For example, a null hypothesis can be stated as—top pruning sycamore seedlings has no effect on disease infection after planting. I know of no data that can be used to reject this hypothesis. Even so, some claim that top-pruned seedlings make an avenue for disease infection and encourage animal depredation. It is unscientific to reject a null hypothesis using only intuition and assumptions about top pruning (no matter how often the intuition is accepted as fact).

Conclusions

Top pruning hardwood seedlings has several benefits: reduced lifting, packaging, and shipping costs; increased RWR; reduced shoot dieback after outplanting; reduced planting time; and increased shoot growth after planting. In addition, top pruning in the nursery might increase survival on sites with limited rainfall. Unless customers are willing to pay more for taller seedlings or unless nonpruned seedlings are below a critical height, nursery managers may realize economic benefits from proper top pruning of seedlings.

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