EFFECTS OF TOP-PRUNING ON SURVIVAL OF SOUTHERN PINES AND HARDWOODS

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Abstract—Two schools of thought exist regarding top-pruning bareroot seedlings. One school favors top-pruning due to the economic advantages. Top-pruning can reduce the production of cull seedlings (increase crop value) as well as increase the chance of survival after outplanting. Published studies suggest that top-pruning can increase overall survival of loblolly pine and longleaf pine by 7 and 13 percentage points, respectively. Pruning various hardwood species (mainly after lifting) increased average survival by 5 percentage points. The benefits of top-pruning appear greater when seedlings experience stress after planting and when non-pruned seedlings have low root-weight ratios (root dry weight/total seedling dry weight). On some droughty sites, a seedling with a 0.3 root-weight ratio might have a 26 percentage point higher chance of survival than a seedling with a 0.2 root weight ratio. In most studies with hardwoods or multinodal pine species, height growth is stimulated so that after 3 years in the field, pruned seedlings have caught up to the heights of non-pruned seedlings.

One school advises against top-pruning in the nursery. Some believe the concern for a balance between roots and shoots at planting has been greatly overemphasized. Others believe that top-pruning is not natural and that cutting the shoot will anthropomorphically hurt the seedling. A few believe top-pruning will result in forked trees at harvest (with the fork just above ground level). Those who advise against top-pruning tall seedlings usually do not give justifications that are based on economics or field performance.

INTRODUCTION

Nursery managers have been improving the "transplantability" of bare-root seedlings by top-pruning for over 300 years. John Evelyn (1679) gave a prescription for cutting oak (*Quercus sp.)* seedlings in the nursery to a height of 3 centimeters (cm). After resprouting, some growers applied a second pruning at a 15-cm height. Two hundred years later, Fuller (1884) 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) 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. Today, more than 90 percent of nursery managers in the Southern United States and Australia top-prune seedlings (Duryea 1986, Duryea and Boomsma 1992). Most managers apply this practice to improve the root-weight ratio[2] of both bare-root seedlings and rooted cuttings.

Even though it has been practiced for centuries, two schools of thought have evolved regarding top-pruning. Some believe that top-pruning is not beneficial and should never be practiced. Others believe top-pruning increases the chances of survival and increases crop value. This review paper summarizes top-pruning studies mainly from southern forest nurseries and was written in hopes of clarifying some of the differences in philosophy between the two schools.

METHODS

Published studies were compiled for loblolly pine (*Pinus taeda* L.), longleaf pine (*Pinus palustris* Mill.), slash pine *(Pinus elliottii* Englm.), eastern white pine (*Pinus strobus* L.) and various hardwood species. Eight unpublished studies on loblolly pine were also included. Survival data from these studies were used to develop three regression equations relating survival of pruned seedlings (Y) to survival of non-pruned seedlings (X).

RESULTS AND DISCUSSION

Effect on Survival

Survival of loblolly pine was increased by top-pruning (table 1). In tests where survival of non-pruned seedlings was high, there was little or no increase in the survival rate.

Table 1—Overall effect of top-pruning on seedling survival of loblolly pine, longleaf pine, and hardwood species

		Survival rate	
Species	Number of tests	Pruned	Non-pruned
		- - - - - *Percent* - - - - -	
Loblolly pine	28	86	79
Longleaf pine	20	59	48
Hardwoods	17	90	85

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[2] Root-weight ratio (RWR) is determined by dividing the dry weight of the root system by the dry weight of the total seedling. The term is inherently easier to comprehend than the root-shoot ratio. The RWR is also less confusing, since many practitioners believe the root-shoot ratio compares shoot height with taproot length.

However, as environmental stresses at the planting site increased, top-pruning increased the probability of survival ($Y = 16.9\ X^{0.375}$; $R^2 = 0.80$). On one piedmont site in Virginia, top-pruning increased seedling survival by 43 percentage points (Dierauf 1976). For this species an increase in survival may result, in part, from an increase in freeze tolerance (South and others 1993). For the 13 tests where survival of non-pruned seedlings was less than 80 percent, top-pruning increased survival by 16 percentage points.

For longleaf pine, pruning increased overall survival of seedlings by 11 percentage points (table 1). For the 16 comparisons showing a benefit to clipping needles, survival increased by 14 percentage points ($Y = 5.2\ X^{0.64}$; $R^2 = 0.90$). Wakeley (1954) warned against "close" pruning of longleaf needles and this might have accounted for the negative results reported by Derr (1963) who pruned needles back to 13 cm.

Top-pruning of eastern white pine had no effect on seedling survival (Dierauf 1997). Data from two studies with slash pine show no statistically significant effect of top-pruning on survival after outplanting (Barnett 1984, Duryea 1990).

Effects of top-pruning on hardwoods were previously reported (South 1996). Due to short heights (< 0.5 meter) and a high survival rate (>79 percent) of most non-pruned seedlings, top-pruning increased average survival by only 5 percentage points (table 1). Therefore, for hardwood seedlings less than 0.5 meters tall, there was no relationship between survival of pruned and non-pruned seedlings ($Y = 75.8 + 0.16X$; $R^2 = 0.05$). However, out of a total of 18 comparisons, only in three studies was the survival rate lower for top-pruned seedlings. There was a 17 percentage point increase in survival for six studies exhibiting a benefit from top-pruning (ranging from +3 to +42 percent).

Importance of Restoring the Balance Between Roots and Shoots

The increase in survival due to top-pruning results from planting seedlings with a higher root-weight ratio (RWR) (i.e., a better "balanced" seedling). A proper balance between roots and shoots is important for good survival of loblolly pine (Larsen and others 1986). At lifting in December, a RWR within the range of 0.27 to 0.35 is preferred to a ratio of less than 0.25 [initial survival = 157.6 + 64.7 ln (RWR); $R^2 = 0.54$]. On some droughty sites, an increase in RWR from 0.2 to 0.3 could increase seedling survival by 26 percentage points. The main reason nursery managers top-prune bare-root seedlings is to improve the RWR.

Improper and Proper Top-pruning

Pruning is a general term that refers to any removal of the foliage, branches, terminal bud, or stem of seedlings. This often vague term includes both "proper" and "improper" pruning. Proper top-pruning meets the objectives of the nursery manager (which might include reducing seedling height at planting, increasing the RWR at planting, increasing seedling uniformity, increasing seed efficiency). Likewise, improper top-pruning fails to meet management objectives. As an example, in some cases a single top-pruning will fail to meet the objective of reducing heights of pines in the nursery (Mexal and Fisher 1984, Haack 1988, Blake and South 1991). When compared to non-pruned seedlings, taller, improperly top-pruned seedlings might exhibit lower outplanting survival (Blake and South 1991). However, proper top-pruning of southern pine seedlings (involving a series of clippings) can reduce seedling height at lifting and this can result in a dramatic increase in field survival (Dierauf 1976, South and Blake 1994). It is now accepted that single top-pruning of loblolly pine or slash pine in the month of August is "improper" since it will likely have no effect on increasing RWR in December. Multiple top-pruning (typically involving three or more clippings) as described by Dierauf (1997) is much more likely to meet management objectives. The first clipping is typically conducted about August 1 and cuts about 10 to 20 percent of the seedlings. The second clipping cuts about 50 percent of the seedlings and is conducted in the last week of August. The third clipping occurs in mid-September about 3 or 4 weeks later (cutting perhaps 33 percent of the seedlings). In years with unusually rapid growth after the equinox, a fourth clipping may be required.

The difference between "proper" and "improper" pruning of pine seedlings depends on the degree of pruning. In some situations, moderate top-pruning (reducing shoot height by 17 percent) can improve survival of loblolly pine by 20 percentage points. However, removal of one needle will have no effect on reducing seedling height and would not result in increased survival. Top-pruning only the terminal bud will have no effect on the root growth potential of loblolly pine (Williams and others 1988). On the other hand, removing the entire shoot (increasing the RWR to 100 percent) will likely kill a loblolly pine seedling. Even removing all but 10 cm of stem (above the root-collar) can greatly increase mortality. Removal of all foliage by hand (leaving an intact stem) will reduce survival of longleaf pine and slash pine (Wakeley 1954). Removing too much foliage will decrease survival since new root growth of pines depends on needle biomass. Therefore, conifer seedlings should not be top-pruned to such an extent as to reduce new root growth or to check shoot growth (Brisbin 1888). However, several hardwoods are quite tolerant of severe top-pruning, and planting of "stumps" is an accepted practice in many tropical countries. This agrees with Toumey (1916) who stated that "On the whole, broadleaved species withstand pruning better than conifers."

Reasons to Top-Prune

Reasons for and against top-pruning are listed in table 2. Individuals in favor of top-pruning usually are so for economic reasons. The primary economic justification for top-pruning in the nursery is to increase field survival. For example, a 10 percent increase in survival might be worth $40 to $50 per hectare (ha). Assuming seedlings in a hectare of nursery can be used to plant 1,000 ha of woodlands, increasing seedling survival by 10 percent on all planting sites would increase crop value by $40,000 to $50,000 per ha. Even when top-pruning increased survival

Table 2—Reasons for and against top-pruning of bare-root seedlings

Stated reasons for top-pruning
It increases the chance of survival.
It increases the root/weight ratio.
It increases crop value by increasing seed efficiency.
It increases seedling uniformity.
For some species, it increases freeze tolerance.
For some species, it increases initial growth after outplanting.
For some top-blights, it reduces the disease symptoms at lifting.
For some species, it reduces shipping costs.
For longleaf pine, it permits lateral root pruning.
For some hardwoods, it reduces injury to workers during lifting.
Top-pruning allows managers to fertilize and irrigate to produce large root systems.
Stated reasons against top-pruning
It is not natural.
The balance between root and shoot is not important for survival.
It causes a wound.
It increases seedling uniformity.
It alters seedling biochemistry.
It causes forked seedlings.
It makes culling of small seedlings difficult.
It might increase disease.
For some species, it reduces the probability of having a terminal bud at lifting.
Top-pruning is not needed when short seedlings with small diameters are produced by withholding fertilization and irrigation.

by 10 percent on only 5 percent of the sites, crop value would increase by $2,000 to $2,500 per ha. Either case would easily justify the cost of top-pruning (about $40 per ha per clipping).

Another economic justification for top-pruning involves increasing seed efficiency. Seed efficiency is defined as the number of plantable seedlings produced per pure live seed. When increasing seed efficiency, top-pruning has a dual benefit. First, multiple top-pruning reduces the number of tall seedlings that exceed the culling limit. In one case where seedlings were top-pruned only once, 77 percent of the crop exceeded a cull limit of 33 cm (Haack 1988). Reducing the number of tall seedlings can be a major economic benefit when tall seedlings end up on the culling room floor. Second, top-pruning tends to reduce the growth of the dominants in the seedbed and allows some of the smaller seedlings to grow into a plantable grade. For pines, this “release” effect occurs mainly when multiple top-pruning is practiced. For example, with one pruning the smaller diameter seedlings might be decreased by 2 percentage points (Mexal and Fisher 1984) but with two prunings, a decrease of 5 percentage points might result (Duryea 1990). Assuming 1.5 million seedlings could be produced without top-pruning, an additional 30,000 to 75,000 plantable seedlings would increase crop value by $1,000 to $2,500 per ha.

Improving outplanting survival will allow some organizations to lower target outplanting densities. Planting fewer trees will not only reduce regeneration costs but will also allow the best genotypes to be planted over more hectares. Nursery managers may also benefit from reduced lifting, culling, and shipping costs. Although safety is sometimes mentioned as a reason to top-prune hardwoods (due to a reduction in eye injuries during hand lifting), this is typically not a driving factor. However, seedling uniformity can be important. In some cases, a nursery with uniform nursery beds will attract and retain more customers. In years with a regional seedling surplus, this will convert to a distinct economic advantage.

An improvement in seedling growth after outplanting is often observed for top-pruned seedlings. Typically the increase in growth allows pruned seedlings to catch up to the heights of non-pruned seedlings at the end of two or three growing seasons (Zaczek and others 1997). For some oaks, the probability of achieving dominance in the canopy is increased by top-pruning (Johnson 1984). For some species, the top-pruning increases the rate of bud flushing and stimulates “free growth” (Colombo 1986). In a few cases, top-pruned seedlings after two growing seasons were taller than non-pruned seedlings (Smith and Johnson 1981, McCreary and Tecklin 1994). However, in one study with white pine, seedlings top-pruned twice were still 15 cm shorter than controls after three growing seasons (Dierauf and others 1995).

Reasons Not to Top-Prune

Students of the “no top-pruning” school can provide several reasons why nursery managers should not top-prune seedlings (table 2). Most of these reasons are not based on economics but are based on feelings instead. One reason given for not top-pruning is that it is not “natural.” However, this is not entirely true since deer, moose, cattle, and rabbits often top-prune both pine and hardwood seedlings. The terminals of many pines are killed in nature by insects. In some areas, 50 percent of the terminal buds of conifers die after outplanting (Colombo 1986). Some believe a live terminal bud is important at time of planting. However, terminal bud abortion is a natural and common occurrence for many angiosperms.

A few believe top-pruning is bad in that it produces a uniform seedling crop. A uniform seedling crop makes it more difficult to cull the bottom 25 percent of the population. With pines and some hardwood species, top-pruning does increase the number of seedlings with forks (Dierauf 1997) and some customers do not like forked trees. However, forks at time of planting affect appearance rather than long-term growth or survival.

Some who advise against top-pruning claim the concern for a balance between roots and shoots has been greatly overemphasized. For example, Kormanik and others (1995) say that a RWR of 0.12 is typical in November and has not affected survival of loblolly pine. Some point to studies in Canada that show no relationship between survival and seedling balance (Racey and others 1983, Bernier and others 1995). A lack of a relationship can be expected when researchers obtain high outplanting survival. Researchers typically achieve higher survival rates than operational planting crews. However, a significant relationship is more likely when some seedlings die due to unfavorable environmental conditions.

Some fear that top-pruning will increase disease. Toumey (1916) was concerned about the introduction of disease since "every cut produces a wound through which spores of fungi may gain access..." As a result, he said, "as little pruning should be done as is necessary to maintain a proper balance between root and shoot." The concern about top-pruning increasing seedling diseases persists today. If some unidentified disease is observed late in the growing season, top-pruning is sometimes suspected of having increased susceptibility to the pathogen.

One year at the Ashe Nursery in Mississippi, brown spot needle blight (*Mycosphaerella dearnessii*) was observed after pruning longleaf pine (Kais 1978). Top-pruning in July and November spread infected needles over the nursery. Even so, periodic clipping of needles during the growing season is recommended as a means to reduce the incidence of brown spot in the nursery. Pruning avoids forming a dense mat of needles and allows a uniform application of fungicides. Some managers who grow longleaf pine apply fungicides both before and after clipping. For drill-sown longleaf, clipping allows managers to do a better job of lateral root pruning which increases survival.

Top-pruning will not increase fusiform rust (*Cronartium quercuum f. sp. fusiforme*) in the nursery since spore flight occurs several months before the first clipping in August. However, Stanley (1986) reported an increase in rust on 3-year-old trees that had been severely top-pruned in the nursery. It seems likely that top-pruning to a height of 10 to 15 cm in the nursery stimulated height growth (and succulent foliage mass) the year after planting. The increase in rust galls at age 3 likely resulted from infection during the year after outplanting (above the 15 cm height). Other management practices that increase seedling growth also increase fusiform rust; these include fertilization, soil cultivation, and use of herbicides for weed control.

Some are concerned that top-pruning in the nursery will affect wood quality when the tree is harvested after 30 years. A similar concern was expressed by Toumey (1928) who stated that "Poor bole form, particularly crookedness, is very commonly caused by damage to the leading shoot or to the terminal bud." He adds that "The loss of the terminal bud very frequently causes double top in pine, spruce, balsam fir and larch." He said the double top causes great loss in the quality of the timber. These statements could lead some to conclude that injury to the terminal bud in the nursery always results in a permanently crooked or forked tree. However, there are no published data to support this belief. Long-term top-pruning studies with oak (*Quercus sp.*) and yellow poplar (*Liriodendron tulipifera* L.) report no problems with tree form. For Monterey pine (*Pinus radiata* D. Don), a fork low to the ground does not affect average tracheid length, spiral-grain angle, average density, or late-wood ratio (Nicholls and Brown 1974). In fact, total volume can be slightly greater for a forked tree. A fork caused by pruning seedlings to a 25 cm height would not be higher than 25 cm from the ground (few pines exhibit permanent forks this close to the ground). Likewise, a fork 1 meter above the ground would not be caused by top-pruning a hardwood back to a 50 cm height in the nursery. Although top-pruning will cause some seedlings to be forked in the year after planting, this fork is ephemeral and certainly does not move up the stem as the tree ages. After the seedlings are outplanted and reach a height of 2 meters, most people cannot tell the difference between a top-pruned and non-pruned loblolly pine. Although a harvested tree with two stems originating 25 cm above ground will produce different amounts and quality of lumber, there are no data to show that top-pruning increases the frequency of these (low forked) trees in a plantation.

Scientific Method

At this point I will digress and touch briefly on the scientific method. The scientific process follows a pattern: define the problem; 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; reevaluate generalization. The null hypothesis is rejected only when data from a well-designed study can be used to reject the hypothesis. In the case of lumber quality, the null hypothesis can be stated as: top-pruning in the nursery has no effect on lumber quality. I know of no data from a top-pruning study that can be used to reject this hypothesis. Since researchers cannot prove a null hypothesis, it remains the responsibility of those who reject the null hypothesis (e.g., claim that top-pruning does affect wood quality) to publish data to support their claims. In other words, it is unscientific to reject a null hypothesis using only intuition and assumptions (no matter how often the intuition is accepted by the public).

CONCLUSIONS

A large number of research studies indicate that proper top-pruning is a beneficial nursery practice. It can benefit nursery managers by increasing both crop value and seedling uniformity. For the consumer or forest landowner, seedlings that have been properly top-pruned will have a higher RWR and a greater chance of survival. Proper top-pruning increases growth after planting so that after 3 years in the field, there typically is no difference in total height between non-pruned and top-pruned seedlings.

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