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. 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 of cutting oak (Quercus sp.) seedlings in the nursery to a height of 3 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. Later, Duruz (1953) said "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." Kozlowski and Davies (1981) said that "Probably the most useful, least expensive, and easiest way of assuring decreased transpirational loss of transplants is by pruning 15 to 40% of the bud-bearing branches." 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[1] 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. This paper 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 with loblolly pine were also included. Survival data from these studies were used to develop regression equations for loblolly and longleaf pine. For most studies, one mean was obtained for top-pruned seedlings and one mean was acquired for non-pruned seedlings. When tests involved multiple years, or multiple sites, a mean was derived for each site/year combination. In studies where various top-pruning treatments were applied, the more typical treatment was selected. For example, data for an extreme 10 cm (pruning height above ground) treatment for loblolly pine would be excluded in favor of a more typical 25 cm treatment.

Although 15 hardwood studies were from southern forest nurseries, two additional studies from Canada and the United Kingdom were also included. Insufficient data were available to develop a regression equation for any single hardwood species. Therefore all hardwood studies were combined to develop one equation. In most of the hardwood studies, a single top-pruning was applied at the end of the growing season. Details of the individual studies were reported previously (South 1996).

RESULTS AND DISCUSSION

Effect on Survival

Twenty comparisons with loblolly pine were obtained from published reports (Dierauf 1976, Dierauf and Olinger 1982, Barnett 1984, Stanley 1986, Blake and South 1991, South and Blake 1994, Dierauf and Chandler 1995). In general, seedling survival of loblolly pine was increased by top-pruning (Figure 1). Average survival of top-pruned seedlings was 86 percent while non-pruned seedlings averaged 79 percent. In tests where survival of non-pruned seedlings was high, there was little or no increase in survival. However, as environmental stresses at the planting site increase, top-pruning increased the probability of survival. On one piedmont site in Virginia, top-pruning increased seedling survival by 43 percentage points (Dierauf 1976). For the 13 planting chances where survival of non-pruned seedlings was less than 80 percent, top-pruning increased survival by 16 percentage points.

Twenty data sets were derived from reports with longleaf pine (Allen and Maki 1951, Allen 1955, Shipman 1958, Derr 1963, Shoulders 1967 Parker and others 1981). In one study (Shipman 1958) pruning caused a large decrease in survival. Other studies showed top-pruning increased survival (Figure 2). Overall, survival of non-pruned seedlings was 48 percent compared to 59 percent for top-pruned seedlings. For the 16 comparisons showing a survival benefit to pruning, top-pruning increased survival by an average of 14 percentage points. Wakeley (1954) warned against "close" pruning of longleaf needles and this might have accounted for the negative results reported by Derr (1963) who top-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 (Duryea 1990, Barnett 1984).

Effects of top-pruning on hardwoods were previously reported (South 1996). Due to short heights (< 0.5 meter) and high survival (>79 percent survival) of most non-pruned seedlings, top-pruning increased average survival by only 5 percentage points. Therefore, for hardwood seedlings less than 0.5 meters tall, there was no relationship between survival of pruned and non-pruned seedlings (Figure 3). However, out of a total of 18 comparisons, only in 3 studies was survival lower for top-pruned seedlings. There was a 17 percentage point increase in survival for 6 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). Data from both Alabama (Larsen and others 1986), Georgia (Rowan 1987), and Arkansas (Barnett and others 1984) suggest that a proper balance between roots and shoots is important for good survival of loblolly pine. At lifting in December, a RWR within the range of 0.27 to 0.35 is preferred to a ratio less than 0.25 (Figure 4). On some droughty sites, an increase in RWR from 0.2 to 0.3 could increase seedling survival by 26 percentage points.

Top-pruning can improve the RWR of planting stock. In one study, top-pruning increased the RWR of loblolly pine seedlings from 0.14 (non-pruned seedlings) to 0.18 (for single clipped seedlings) (Sung and others 1994). In an unpublished study conducted by the Auburn University Southern Forest Nursery Management Cooperative, top-pruning 3 times resulted in 0.26 RWR (as compared to 0.21 for non-pruned seedlings). For slash pine (Duryea 1990), top-pruning increased the RWR to 0.23 (RWR = 0.20 for non-pruned seedlings).

In the 1930's when genetically improved seed were not available and when nursery irrigation was minimal, a 12 cm tall loblolly seedling with a RWR of 0.3-0.4 could be achieved without top-pruning (May 1933, Huberman 1940, Andrews 1941). There was little need to top-prune pines during the first half of this century when seedlings were short. However, with advances in genetics and nursery management, the RWR of seedlings has gradually decreased with time (Mexal and South 1991). Some believe that genetic improvement programs now favor genotypes that grow relatively more shoots than roots. In some cases, 9- month-old, genetically improved seedlings can exceed 45 cm in height (Boyer and South 1988, Kormanik and others 1992). In some studies non-pruned seedlings had a RWR as low as 0.1 (Sung and others 1994). Kormanik and others (1995) say that with current nursery practices, anything approaching a RWR of 0.33 is attainable only with top-pruning.

Improper and Proper Top-pruning

Top-pruning is a general term that refers to any removal of foliage, branches 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, Haach 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 (South and Blake 1994, Dierauf 1976). 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 3 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 seeldings 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.

For conifers, some recommend top-pruning several months prior to lifting when stems are succulent (Stockey 1975, DeYoe 1986, Dierauf 1997). In one early report, pruning pine immediately before planting reduced survival, but the next year pruning in July to a height of 20 cm resulted in 95 percent survival (Anonymous 1939). Pruning during the growing season allows the stem to develop new buds and seedling appearance at lifting looks better to uninformed customers. For loblolly pine, pruning several months prior to lifting can increase freeze tolerance (South and others 1993). However, as evidenced by simulated browsing studies with several conifers, pruning woody stems once (after planting) appears to have little or no adverse effects on long-term growth or survival (Lewis 1980).

Support for the belief that succulent tissue should be pruned is not as great for hardwoods. In fact, most researchers top-prune hardwoods at lifting or at the planting site (South 1996). Some recommend pruning a woody stem to a height of 20 cm two weeks before planting (Johnson and others 1986). The practice of top-pruning at lifting might be based on the observation that terminal bud abortion occurs in nature for a number of hardwood species (Romberger 1963). Even so, several managers top-prune hardwoods two or more times during the growing season, when stems are succulent (Rentz 1997). Although shoot pruning at the planting site can reduce dieback (Davies 1987) and can improve survival (Johnson 1984; South 1996), it does not reduce lifting and shipping costs.

The difference between "proper" and "improper" top-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 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 (Thames 1962, Stanley 1986). 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 (Larsen and others 1989). 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 1. 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, Bailey (1986) indicated that under certain assumptions a 10% increase in survival of slash pine would be worth $40 to $50/ha. Assuming seedlings in an hectare of nursery can be used to plant 1,000 ha of woodlands, increasing seedling survival by 10% on all planting sites would increase crop value by $40,000 to $50,000/ha. Even when top-pruning increased survival by 10% on only 5 percent of the sites, crop value would increase by $2,000 to $2,500/ha. Either case would easily justify the cost of top-pruning (about $40/ha/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 (South 1987). 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 (Haach 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 small 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/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 (Table 1). 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 2 or 3 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, heights of top-pruned seedlings after 2 growing season 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 3 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 1). 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 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 (Romberger 1963).

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.

Meginnis (1940) advised against top-pruning black locust (Robinia pseudoacacia L.) and claimed the concern for a balance between roots and shoots at planting has been greatly overemphasized. Others agree and state that a RWR of 0.12 by November has not reduced outplanting survival of loblolly pine (Kormanik and others 1995). Some point to studies in Canada (Racey and others 1983, Bernier and others 1995) that show no relationship between survival and seedling balance. A lack of a relationship can be expected when researchers obtain high outplanting survival. Researchers typically achieve higher survival rates than operational planting crews (Rowan 1987). However, a significant relationship is more likely when some seedlings die due to unfavorable environmental conditions (Figure 4).

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 (Johnson and others 1979).

One year at the Ashe Nursery in Mississippi, brown spot needle blight (Mycosphaerella dearnessii) was observed after top-pruning (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 (Kais 1989). Pruning avoids forming a dense mat of needles and allows a uniform application of fungicides (Shoulders 1967). 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.

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 cm 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 (Dobkowski 1997). 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 spp.) and yellow poplar (Liriodendron tulipifera L.)report no problems with tree form (Johnson and others 1986, Dierauf and Garner 1993, van Sambeek 1996). 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 (Duff 1956). The height of 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 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 (Shoup and others 1981; Duryea and Omi 1987; Dierauf 1997), 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. Many researchers know that 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 frequently the intuitions are generally accepted).

CONCLUSIONS

A large number of research studies indicates 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 three years in the field, there typically is no difference in total height between non-pruned and top-pruned seedlings.

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FOOTNOTES

1. Root weight ratio 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 some practitioners believe the shoot/root ratio involves shoot height and taproot length.

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FIGURE CAPTIONS

Figure 1--Comparison in survival between top-pruned and non-pruned loblolly pine seedlings. The dashed line represents the regression equation (n= 28). The solid diagonal lines represent equal performance of the two treatments. Points above the solid line represent cases where top-pruning increased survival.

Figure 2--Comparison in survival between top-pruned and non-pruned longleaf pine seedlings. The dashed line represents the regression equation (n= 20). The solid diagonal lines represent equal performance of the two treatments. Points above the solid line represent cases where top-pruning increased survival.

Figure 3--Comparison in survival between top-pruned and non-pruned hardwood seedlings. The dashed line represents the regression equation (n= 17). The solid diagonal lines represent equal performance of the two treatments. Points above the solid line represent cases where top-pruning increased survival.

Figure 4--Relationship between outplanting survival of loblolly pine seedlings and root weight ratio (root dry weight/seedling dry weight) for 20 nurseries (adapted from Larsen and others 1988).

Table 1--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