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# Effects of Different Amounts of Codominant Stem Subordination on the Growth and Aesthetics of *Acer rubrum* 'October Glory'

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**Abstract.** Background: Codominant stems are a common condition of concern on landscape trees. Understanding the impact of varying degrees of stem reduction can assist practitioners in making informed pruning decisions. Methods: To determine this, a single reduction or removal cut was made on each pair of codominant stems on medium-aged *Acer rubrum* 'October Glory' at approximately 25%, 50%, 75%, and 100% of the diameter relative to the basal diameter at the shared union or left as nonpruned controls. Changes in stem diameter ratio, trunk diameter growth, sprout production, wound closure, and aesthetics were documented for 4 years starting in 2020. Results: Stem diameter ratio was significantly reduced in codominant stems pruned to a relative diameter of 50% or 75% after a single growing season. The 75% treatment reduced growth for 2 growing seasons. There were no significant differences in change of stem diameter ratio with any treatment after 3 growing seasons. Larger pruning cuts resulted in the growth of more sprouts and more exposed wood after 3 years. Aesthetics of trees following pruning were acceptable for nonpruned, 25%, and 50% treatments in all years but were rated as not acceptable or moderately acceptable for 75% and 100% treatments after 2 growing seasons. Trees with the 75% treatment became aesthetically acceptable after 3 growing seasons. Conclusions: Pruning codominant stems of *A. rubrum* 'October Glory' with a cut that is 50% or 75% the diameter of the basal diameter at the shared union is appropriate at reducing stem diameter ratio, minimizing exposed wood, and maintaining overall aesthetic appearance after 2 to 3 years.

**Keywords.** Pruning Specifications; Sprouts; Stem Diameter Ratio; Structural Pruning.

## INTRODUCTION

Codominant stems are where 2 or more stems of similar diameter originate from the same union (American National Standards Institute 2017). Codominant stems are inherently weak points of attachment that require significantly less load (e.g., wind, ice) to cause failure as compared to branches that are smaller than the parent stem (Gilman 2003; Smiley 2003; Kane et al. 2008). This greater likelihood of failure is compounded by the occurrence of included bark (Gilman and Grabosky 2006) which can reduce the strength of the attachment by 14% to 20% relative to codominant stems without included bark (Smiley 2003).

When codominant stems fail, there may be damage to nearby targets and within the tree, and the exposed wood may desiccate, discolor, and decay (Shigo and Hillis 1973). In addition, codominant stems are more likely to have connections to the pith of the parent stem, which when exposed can result in a greater volume of discoloration, leading to decay (Gilman and Grabosky 2006). The lack of a branch protection zone in codominant stems also allows for more internal stem damage and decay than branches with small stem diameter ratio that possess a branch protection zone (Shigo 1990; Eisner et al. 2002; Gilman and Grabosky 2006).

Formative or structural pruning is an important practice for trees of all ages, especially trees that have codominant stems (Lilly et al. 2019). By pruning one codominant stem in a pair or multiple pairs of codominant stems, the stem diameter ratios of codominant stems can be reduced over time (Downer et al. 1994; Gilman and Grabosky 2009; Gilman 2015). By reducing the stem diameter ratio of the 2 codominant stems with pruning, the likelihood and severity of a future failure should be reduced (Downer et al. 1994; Eisner

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et al. 2002; Smiley 2003; Kane et al. 2008; Gilman and Grabosky 2009; Gilman 2015). Structural pruning is especially important for tree species with opposite branching such as maples (*Acer* spp.) and ash (*Fraxinus* spp.) where codominant stems are common (Smiley et al. 2017).

The ANSI A300 standard for pruning trees specifies that objectives should be identified and should consider species, age, and pruning system (e.g., natural, espalier, etc.). These objectives should drive specifications for the cut type (i.e., reduction, removal, or heading), size, number, and location (American National Standards Institute 2017). Specifications of severity of pruning cut can be subjective based on species and the practitioner's experiences and can also be derived from multiple perspectives (e.g., percent length, cut diameter). Few studies have focused on determining the effects of pruning cut type (i.e., removal, reduction, or heading)(Downer et al. 1994) or severity (Gilman and Grabosky 2009; Gilman 2015) on reducing the stem diameter ratio of codominant stems in shade trees, and to our knowledge none have investigated this on medium-aged red maples (*Acer rubrum* L.). The purpose of this study was to determine the effects of different degrees of codominant stem reduction or removal on tree aesthetics, stem growth, sprouting, and wound closure, to inform decisions in the development of pruning specifications and pruning intervals.

## MATERIALS AND METHODS

### Study Trees and Experimental Design

We used 56 even aged and sized (24.5 cm [SE 0.4 cm]) *Acer rubrum* 'October Glory' planted in rows on approximately 6-m centers for this experiment. The study was conducted in Charlotte, NC, USA, which is in USDA Hardiness Zone 8a, and maples were grown in soils that ranged from a CECIL sandy clay loam (CeD2) to a DAVIDSON sandy clay loam (DaB)(Soil Survey Staff 2019).

Trees were fertilized with a granular slow-released fertilizer (30-0-12) annually at a rate of 0.5 kg N/$m^2$ within a circle centered on the trunk with a radius of 5× the DBH. Trees had minimal pruning in the past and were chosen based on having at least one pair of codominant stems off the central main leader. When measured just above the union, codominant stems had an average basal diameter of 13.9 cm (SE 0.4 cm) and a stem diameter ratio of 0.86 (SE 0.02). The dominant stem (larger of the 2 stems) was retained intact, while the smaller stem was pruned by making one reduction or removal cut. Each tree was randomly assigned to 1 of 5 pruning cut severity treatment groups: nonpruned controls, light, medium, heavy, and complete removal, in a completely randomized design. The specification of each pruning cut severity treatment was defined based on the size of the pruning cut relative to the basal diameter of the pruned stem and are called hereafter: nonpruned controls (nonpruned), low severity (25%), moderate (50%), heavy (75%), and removal (100%). To comply with the ANSI A300 standard, the exact location of each cut was made at the location of the nearest lateral branch or trunk (American National Standards Institute 2017). All reduction cuts were made just above (distal to) the closest lateral branch, which was within the margin of error equaling 4.8% of our targeted relative diameter cut size. Pruning treatments were made and initial measurements taken on 2020 May 13 and 14. Data collected were: (1) diameter of each codominant stem just above the union; (2) trunk diameter at 1.4-m above grade (DBH); (3) length and diameter at cut of pruned section of stem; (4) fresh mass of pruned section of stem (in full leaf); and (5) visual aesthetic rating determined from consensus of 3 ISA Certified Arborists® based on knowledge of a typical client's perspective where 1 = not acceptable, 2 = moderately acceptable, and 3 = acceptable (Figure 1). Since these were averaged across all trees in a given treatment, ranges were evenly assigned to each of the categorical ratings as follows: 1.0 to 1.66 (not acceptable), 1.67 to 2.33 (moderately acceptable), and 2.34 to 3.0 (acceptable).

### Effects of Pruning Severity over Time

For the next 3 years, measurements were repeated on 2021 May 19, 2022 May 4, and 2023 May 10. Data included the initial measurements as previously described except the length and mass of pruned stem, which was measured at time of pruning. Additionally, in all 3 years postpruning, the number of sprouts and basal caliper of the 5 largest sprouts within 30 cm of the cut were counted and measured. Lastly, in 2023, the presence of woundwood was noted and measured. The percent wound closure was measured from photographs taken of the pruning cut face with a scale bar using the program Assess 2.0 (APS, St. Paul, MN, USA) by measuring the cross-sectional

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**Figure 1. Photographic representation of visual aesthetic ratings defined for each tree based on a consensus rating of 3 ISA Certified Arborists® where 1 = not acceptable, 2 = moderately acceptable, and 3 = acceptable.**

**Table 1. Exact pruning cut sizes and relative sizes based on basal diameter for the approximated specifications for each pruning severity cut treatment group, where the number in parentheses represents the standard error of the mean for each parameter. Nonpruned trees had no cuts made in this study. NA (nonapplicable).**

| Pruning treatment | *N* | Cut size (cm) | Basal diameter (cm) | % Basal diameter | % Length reduced | Mass removed (kg) |
|---|---|---|---|---|---|---|
| 25% | 11 | 4.3 (0.5) | 13.3 (0.8) | 32.5 (3.4) | 37.8 (2.9) | 7.3 (2.5) |
| 50% | 12 | 7.9 (0.6) | 13.6 (0.8) | 58.3 (2.4) | 63.2 (3.3) | 31.9 (5.8) |
| 75% | 12 | 10.1 (0.7) | 12.7 (1.0) | 80.5 (3.1) | 79.8 (3.6) | 53.0 (9.9) |
| 100% | 10 | 12.7 (0.7) | 12.7 (0.7) | 100.0 (0.0) | 100.0 (0.0) | 88.4 (10.7) |
| Nonpruned | 11 | NA | NA | NA | NA | NA |

area (CSA) of woundwood and dividing by the CSA of the initial cut surface. This was done by calibrating each photo with a scale bar at the plane of the cut surface, manually "drawing" around the perimeter of the woundwood in each photograph in the program, and then using the initial cut face cross sectional area for relative surface area.

## Statistical Analyses

All statistical analyses were conducted in JMP® 16 (JMP Statistical Discovery LLC, Cary, NC, USA), and significance was determined at alpha *P*-value of 0.05. Linear regressions were calculated to determine predictive model equations for pruning cut size and percent length removed of pruned section, as well as mass of pruned stems after removing the nonpruned controls from the data set. Since cuts were made to the closest lateral branch, exact pruning cut sizes across all the cut severity treatments (nonpruned controls were excluded) can be found in Table 1.

A one-way analysis of variance (ANOVA) was calculated for the stem diameter ratios of each pair of codominant stems for all years after pruning independently for all treatment groups, excluding the removal treatment. A one-way ANOVA was calculated for the average change in DBH (cm) for all years after pruning independently across treatment groups in addition to the total change in DBH (cm). The number of sprouts produced each year and the average caliper (cm) of sprouts were log ($x$ + 1)

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transformed to normalize variance before analyzing with a one-way ANOVA for all treatments in each year independently. The wound closure data were log ($x$ + 1) transformed prior to analyzing with an ANOVA to normalize variance, and the CSA of exposed wood was analyzed with ANOVA without transformation. A chi-square analysis was conducted for the presence or absence of woundwood across pruning cut severity treatments, and the Pearson probability is presented. For all one-way ANOVAs, means were separated with Tukey's HSD when significance was observed in the model. Since the visual aesthetic ratings were based on categorical, noncontinuous data, we used a nonparametric Wilcoxon test, with means separation using Wilcoxon pairwise comparisons to determine differences with this parameter across each time point independently.

## RESULTS

### Pruning Severity Relationships

There was a significant ($P < 0.0001$), positive linear relationship ($R^2 = 0.682$) of pruning cut diameter to percent length removed where the percent length could be predicted with the equation *percent length removed (Y) = 22.21 + 5.439 × pruning cut diameter (X)*(Figure 2A). Similarly, there was a significant ($P < 0.0001$), strong ($R^2 = 0.975$) positive and exponential relationship of pruning cut diameter to the total mass of the pruned piece of stem where mass could be predicted with the equation *mass of pruned piece (Y) = 1.819 – 2.002 × pruning cut diameter (X) + 0.6758 × pruning cut diameter² (X²)*(Figure 2B).

### Change in Stem Diameter Ratio over Time

The stem diameter ratio was significantly reduced ($P = 0.0037$) after the first full growing season (2020 to 2021) for the 50% and 75% pruning cut severity treatment but not for the 25% treatment relative to the nonpruned controls (Table 2). After the second full growing season (2021 to 2022), the 75% pruning cut severity treatment continued to be significantly reduced ($P = 0.0137$), while the 25% and 50% pruning cut severity treatments were no different than the nonpruned controls. After the third full growing season (2022 to 2023), there was no longer any influence of the pruning cuts on the change in the stem diameter ratio across any treatment; however, the actual stem diameter ratio of the 75% pruning cut severity treatment was significantly different than the control (Figure 3).

### Change in Tree DBH over Time

Although after the first full growing season (2020 to 2021) there was no statistical difference in growth rate of the trunk influenced by pruning cut severity, the 75% and 100% pruning cut treatments trended to have the *slowest* trunk diameter growth rates, namely

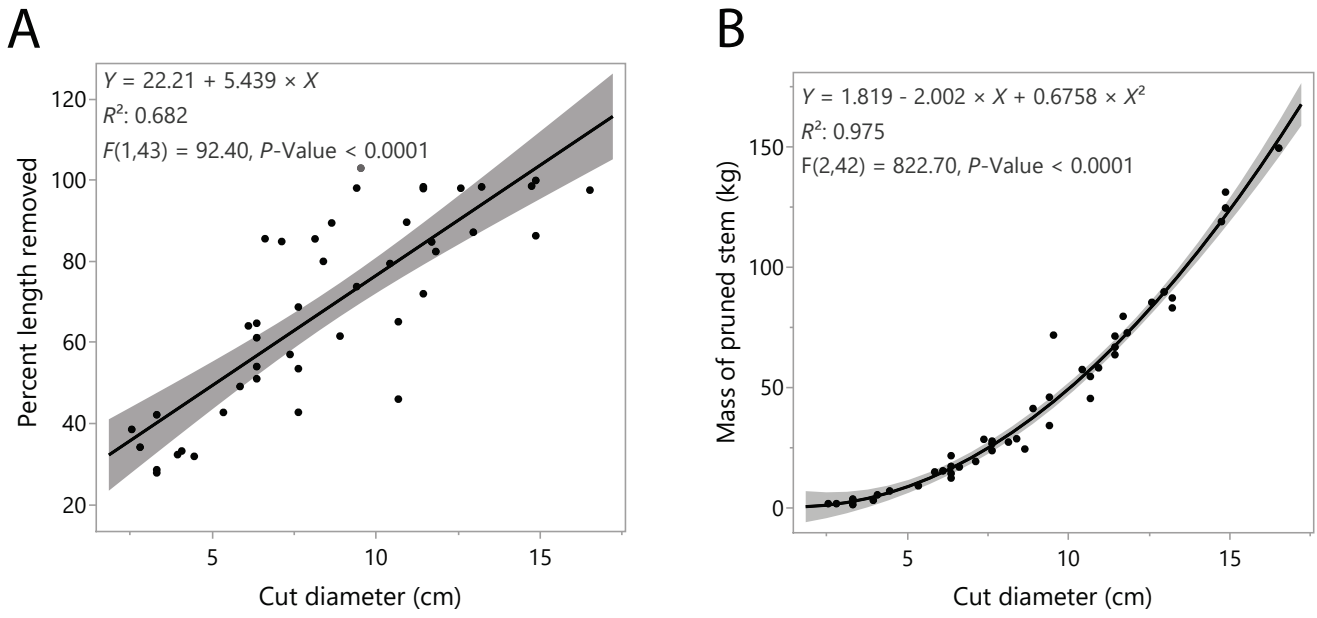


**Figure 2. Predictive relationships between pruning cut size and percent length removed (A) and pruning cut size and mass of pruned stem (B).**

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53% and 29% slower growth rate than the nonpruned controls, respectively (Table 3). Surprisingly, in the second full growing season (2021 to 2022), there was significantly ($P = 0.02$) less trunk growth in the trees pruned at the 25% pruning cut severity (having grown only 59% as much as the nonpruned controls), while

**Table 2. Change in stem diameter ratio of codominant stems across pruning severity cut treatments over time.**

| | | Δ Stem diameter ratio over time[1] | | | |
|---|---|---|---|---|---|
| **Pruning severity[2]** | ***N*** | **2020–2021** | **2021–2022** | **2022–2023** | **Total (2020–2023)** |
| Nonpruned | 11 | 0.001 (0.005) a[3] | –0.004 (0.007) a | –0.001 (0.006) a | –0.004 (0.008) a |
| 25% | 11 | –0.011 (0.008) ab | –0.022 (0.013) ab | –0.004 (0.011) a | –0.036 (0.013) ab |
| 50% | 12 | –0.046 (0.014) b | –0.010 (0.006) a | –0.001 (0.008) a | –0.057 (0.015) ab |
| 75% | 12 | –0.041 (0.010) b | –0.058 (0.018) b | –0.002 (0.011) a | –0.097 (0.026) b |
| *P*-value | | *0.0037* | *0.0137* | *0.9805* | *0.0042* |

[1] Average change in stem diameter ratio as a relative change in size of the diameter of the pruned stem to the retained stem where the standard error of the mean is in parentheses.
[2] Pruning cut severity relative to the basal diameter of the stem being pruned and total.
[3] Different letters indicate significant differences between pruning cut severity treatment means for each growing season independently.

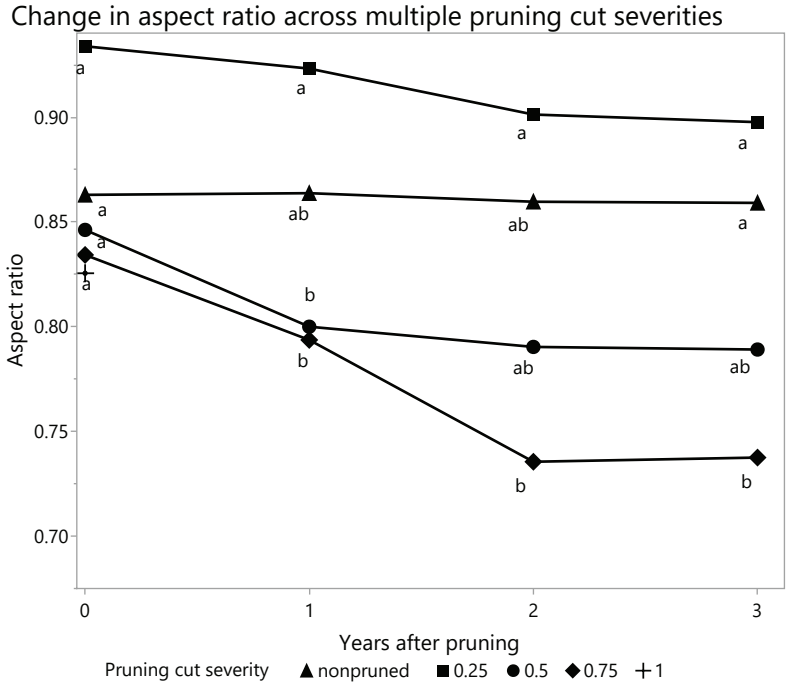


**Figure 3. Change in stem diameter ratio (aspect ratio; relative ratio of pruned stem to retained stem in a codominant pair) in all pruning cut severity treatments over time where different letters indicate significant differences calculated with Tukey's HSD within each time point postpruning.**

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the other treatments were no different than the non-pruned controls. However, the 75% treatment had on average 41% slower trunk growth than the non-pruned controls. In the final growing season (2022 to 2023), there was no effect of the pruning treatments on trunk growth rates, and there were no obvious trends (Table 3).

## Pruning Effect on Sprout Production and Size over Time

In every year, there were statistically significant effects of pruning cut treatment on the number of sprouts produced (Table 4). The mean frequency of sprout production 1 year after pruning was 0 (non-pruned controls), 0.36 (25%), 0.83 (50%), 0.75 (75%),

**Table 3. Average change in trunk DBH (cm) across different pruning cut severity treatments and years. DBH (diameter at breast height).**

| | | Average change in DBH (cm) over time[1] | | | |
|---|---|---|---|---|---|
| **Pruning severity[2]** | ***N*** | **2020–2021** | **2021–2022[3]** | **2022–2023** | **Total (2020–2023)** |
| Nonpruned | 11 | 1.26 (0.20) | 1.29 (0.20) a | 0.44 (0.06) | 2.99 (0.15) |
| 25% | 11 | 1.21 (0.31) | 0.53 (0.08) b | 0.79 (0.10) | 2.53 (0.32) |
| 50% | 12 | 1.11 (0.18) | 0.91 (0.15) ab | 0.57 (0.15) | 2.59 (0.18) |
| 75% | 12 | 0.59 (0.25) | 0.76 (0.12) ab | 0.72 (0.12) | 2.07 (0.24) |
| 100% | 10 | 0.90 (0.28) | 1.10 (0.24) ab | 0.56 (0.15) | 2.55 (0.42) |
| *P*-value | | *0.2885* | *0.0206* | *0.2751* | *0.2085* |

[1] Average change in trunk DBH (cm) over time where the standard error of the mean is in parentheses.
[2] Pruning cut severity relative to the basal diameter of the stem being pruned.
[3] Different letters indicate significant differences between pruning cut severity treatment means for each growing season independently.

**Table 4. Average number of sprouts and caliper of produced sprouts across pruning cut severity treatments over time.**

| | | Average number of sprouts over time[1] | | | Average caliper of sprouts (cm) over time[2] | | |
|---|---|---|---|---|---|---|---|
| | | Years after pruning[3] | | | Years after pruning | | |
| **Pruning severity[4]** | ***N*** | **1** | **2** | **3** | **1** | **2** | **3** |
| Nonpruned | 11 | 0.0 (0.0) b | 0.0 (0.0) b | 0.0 (0.0) c | — | — | — |
| 25% | 11 | 1.0 (0.6) b | 1.9 (0.9) ab | 1.2 (0.5) bc | 0.2 (0.1) | 0.3 (0.1) | 0.5 (0.2) |
| 50% | 12 | 4.3 (1.2) a | 4.9 (1.3) a | 2.7 (0.6) ab | 0.4 (0.1) | 0.5 (0.1) | 0.6 (0.1) |
| 75% | 12 | 4.2 (0.9) a | 4.4 (0.9) a | 3.2 (0.6) a | 0.3 (0.1) | 0.8 (0.4) | 0.6 (0.1) |
| 100% | 10 | 2.6 (1.2) ab | 1.9 (0.8) ab | 1.3 (0.6) bc | 0.2 (0.1) | 0.7 (0.3) | 0.3 (0.1) |
| *P*-value | | *0.002* | *< 0.0001* | *< 0.0001* | *0.0861* | *0.4443* | *0.1040* |

[1] Average number of sprouts produced for each treatment group over time where the standard error of the mean is in parentheses.
[2] Average caliper of sprouts produced for each treatment group over time where the standard error of the mean is in parentheses.
[3] Different letters indicate significant differences between pruning cut severity treatment means for each growing season independently.
[4] Pruning cut severity relative to the basal diameter of the stem being pruned.

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and 0.5 (100%). Similarly, at 2 and 3 years after pruning, the frequency of sprouts produced were 0 (nonpruned controls), 0.45 (25%), 0.92 (50%), 0.83 (75%), and 0.5 (100%); and 0 (nonpruned controls), 0.54 (25%), 1.0 (50%), 0.83 (75%), and 0.4 (100%), respectively (Figure S1). There were no sprouts produced in any year in the nonpruned controls, and although the 25% and 100% pruning cut severity produced sprouts, the number of sprouts was low. In all 3 years after pruning, the 50% and 75% pruning cut severity treatments produced the greatest number of sprouts. Since there were no sprouts produced in the nonpruned controls, these were excluded from the sprout caliper analysis. In the trees that produced sprouts, there was no statistically significant difference or trend in any year for the caliper (cm) of sprouts produced (Table 4).

### Wound Closure Response to Pruning Cut Severity

The amount of wood exposed by pruning wounds was greatest in the 100% (removal) treatment with CSA of 116.2 $cm^2$. This was followed by 75% treatment with 79.3 $cm^2$, 50% with 47.9 $cm^2$, and 25% with 12.9 $cm^2$.

Not all pruning cuts formed woundwood. The frequency of woundwood production was 0.67 (25% treatment), 0.75 (50%), 0.75 (75%), and 0.9 (100%), respectively, although not significant ($P = 0.64$) based on chi-square analysis.

Three years after pruning, pruning treatment had a significant ($P = 0.0141$) effect on the mean percent of wound closure (Table 5). Woundwood was greatest on the 25% treatment, closing 33% of the CSA. There was considerably less closure in the 50% and 75% treatments, where woundwood closed 9% and 8% of the CSA, respectively. The 100% (removal) treatment was no different than any of the other treatments, with woundwood that closed 12% of the CSA.

### The Effect of Pruning Cut Severity on Overall Aesthetics over Time

Immediately after pruning (0 years after pruning), the visual aesthetic rating of trees pruned at 25%, 50%, and nonpruned controls were acceptable (> 2.34 rating). With the 75% treatment they were moderately acceptable (1.67 to 2.33), and not acceptable (1.0 to 1.66) for 100% (removal) treatment (Figure 4). After 2 full growing seasons, these trends persisted in the visual ratings. After 3 years, on average, the 25%, 50%, 75%, and nonpruned treatments were visually acceptable, while the complete removals were moderately acceptable (Figure 4).

## DISCUSSION

In this study, we were able to show the effects of making a single reduction cut (25%, 50%, 75% pruning cut severity) or removal cut (100% pruning cut severity) on red maples. We found positive correlated and predictable relationships between pruning cut size (cm) and length of pruned stem ($R^2 = 0.682$) as well as mass of pruned stem ($R^2 = 0.975$). This was in concordance with Grabosky et al. (2007), who found that the CSA of the base of a branch was related and could predict the length of *Quercus virginiana* 'Cathedral' branches. These relationships are important in driving specifications of pruning for practitioners because as an arborist you can more easily and definitively measure pruning cut diameter within a tree compared to the percentage of length to remove.

**Table 5. Effects of pruning cut severity treatment on the presence of woundwood, percent wound closure, and CSA of exposed wood after 3 growing seasons following pruning cuts, where numbers in parentheses represent the standard error from the mean for each parameter. CSA (cross-sectional area).**

| Pruning severity | Presence (%) | % Wound closure | Exposed CSA ($cm^2$) |
|---|---|---|---|
| 25% | 66.7 | 33.4 (11.4) a | 12.9 (3.9) c |
| 50% | 75.0 | 9.0 (2.7) b | 47.9 (7.6) b |
| 75% | 75.0 | 7.8 (2.6) b | 79.3 (12.1) ab |
| 100% | 90.0 | 11.9 (3.2) ab | 116.2 (15.0) a |
| *P*-value | *0.6736* | *0.0141* | *< 0.0001* |

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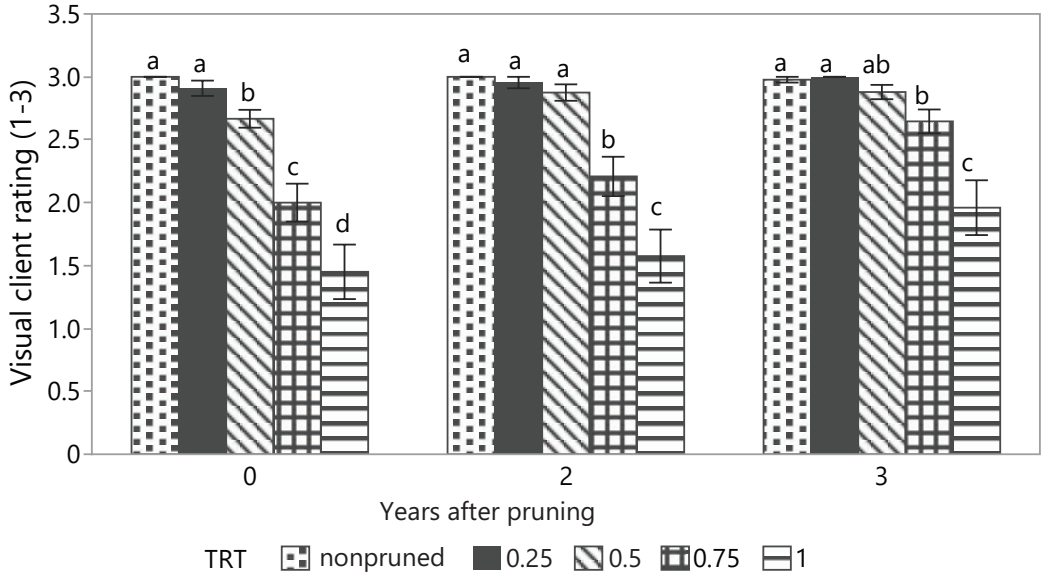


**Figure 4. Visual aesthetic ratings, which were based on a consensus by at least 3 arborists 0, 2, and 3 growing seasons postpruning. Visual ratings were assigned as follows: 1 = not acceptable, 2 = moderately acceptable, and 3 = acceptable. These were averaged across all trees in a given treatment (TRT), and ranges were evenly assigned to each of the categorical ratings as follows: 1.0 to 1.66667 (not acceptable), 1.66667 to 2.33334 (moderately acceptable), and 2.33334 to 3.0 (acceptable). Each error bar is constructed using 1 standard error from the mean. Different letters indicate significant differences calculated with Tukey's HSD within each time point postpruning.**

However, length reduction is often an easier visual specification for clientele than pruning cut diameter. Since we show they are related in *A. rubrum* 'October Glory,' cut size can be calculated from desired length reduction easily and should be investigated for other species. In addition, we found that the mass of the branch in full leaf was exponentially related to the pruning cut diameter, which could be important in determining amount of load removed when pruning or rigging branches based on the cut diameter.

Similar to other studies (Downer et al. 1994; Gilman and Grabosky 2009; Gilman 2015), we were able to show that codominant stem subordination can reduce the size ratio of codominant stems for at least 2 years by making a single cut if that cut diameter is at least 75% of diameter of the stem. Downer et al. (1994) showed that thinning by 50% or heading back to a 10-cm stub of one stem in a codominant pair reduced the growth rate of the pruned branch in *Quercus agrifolia.* Similarly, Gilman and Grabosky (2009) showed that by pruning one stem of a codominant stem pair in *Quercus virginiana* by removing 50% or 75% of the photosynthetic canopy volume, you could significantly reduce the stem diameter ratio of the codominant stems in 3 years. Gilman (2015) showed that by pruning multiple codominant stems within an individual tree, similar principles apply, and by removing 50% or 75% of the photosynthetic tissues from one stem within a codominant pair across multiple branches in a tree, you could significantly reduce the stem diameter ratio of the codominant pair for 3 to 5 years. While these studies made multiple cuts on one stem of a codominant pair, we made a single reduction cut in the 25%, 50%, and 75%, or a single removal cut (100%). We showed that with only 1 pruning cut, after 3 growing seasons, the stem diameter ratio was reduced by 0.5%, 4%, 7%, and 12% in the nonpruned controls, 25%, 50%, and 75% treatments, respectively. The change in stem diameter ratio was greatest after the first growing season for the 50% and 75% treatments. After 2 growing seasons in the 50% treatment, growth of both stems was the same, but the growth impact remained significant in the 75% treatment. After 3 growing seasons, stem diameter ratios were no longer affected. This was unlike previous studies that saw at least 3 years of reduction in stem diameter ratio (Gilman and Grabosky 2009; Gilman 2015). It is likely that this is due to the fast-growing nature of red maple.

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Like previous studies investigating the effects of pruning severity on trunk diameter growth (Gilman and Grabosky 2009; Gilman 2015), we saw little to no effect of any pruning treatment on the trunk DBH over the course of the study. We did detect a reduction in trunk diameter growth rate of the 25% pruning cut severity treatment after one full growing season compared to the control, where previous authors had seen a slight increase at light pruning severity treatments. Similar to Gilman (2015), we found that more severe pruning treatments resulted in a trend of slower trunk diameter growth rates, although not statistically significant.

The overall aesthetics of the trees in this study were significantly influenced by pruning cut size. Since pruning objectives define pruning specifications (American National Standards Institute 2017) and structure and aesthetics are probably the main objectives in natural pruning style, practitioners should consider aesthetics in making these prescriptions. The 75% and 100% pruning cut severity treatments resulted in moderately acceptable and not acceptable rating ranges after 2 full growing seasons, respectively, and would displease clients due to large gaps in the canopies following pruning. However, these canopies filled in these gaps after 3 full growing seasons and on average became acceptable (75%) and moderately acceptable (100%) after 3 years.

Since pruning reduced the stem diameter ratio of the codominant stems, especially in the 50% and 75% pruning cut severity treatment, the branches and attachments in theory should be stronger and have a lower likelihood of failure than the nonpruned controls (Gilman 2003; Smiley 2003; Kane et al. 2008; Smiley et al. 2017). It is also possible that, in time, especially if subordination pruning was repeated, a branch protection zone could form, reducing the potential for decay spread and development into the parent stem (Eisner et al. 2002; Gilman and Grabosky 2006). Furthermore, by making 25%, 50%, and 75% reduction cuts, we were able to reduce the amount of exposed wood by 89%, 59%, and 32%, respectively, relative to the removal cut (100% treatment) at the union of the codominant stems. By making smaller reduction cuts that expose less wood, we can reduce the likelihood of introducing decay into the main trunk (Eisner et al. 2002). When large cuts are made and internal wood is exposed in trees, the host responds by producing chemicals through oxidation reactions that help deter microorganisms (Shigo and Hillis 1973). However, these defenses can be short lived or overcome by many wood decay fungi (Shigo and Hillis 1973). Eisner et. al (2002) showed that the amount of discolored wood (i.e., precursor to decay sensu Alex Shigo) following branch removal cuts increased with stem diameter ratio.

While we speculated that sprout production and growth would correlate with wound closure, we saw no evidence to support this. However, like previous studies, we saw a higher frequency of sprout production associated with large pruning cut size (Desrochers et al. 2015; Zhang et al. 2022). In one study, authors found that pruning intensity increased the number and biomass of sprouts produced by hybrid poplars, and these sprouts had minimal contribution to stored carbohydrates when removed (Desrochers et al. 2015). Similarly, Zhang et al. (2022) showed that with increasing pruning severity a higher abundance of sprouts were formed within 20 cm of the pruning cuts in teak trees. Interestingly, in our study there was an increased frequency of sprout growth with reduction cuts, but the removal (100% treatment) had a lower number of sprouts than the 50% and 75% treatments (Figure S1). This may be due to exposure from weather or animals that damaged or broke sprouts. It is also possible that the axillary buds that formed the sprouts near the removal (100% pruning severity) cuts desiccated due to the large amount of exposed wood. On that note, we did find that as the pruning cut size increased there was a lower degree of wound closure and larger amount of internal wood exposure. As previously shown in red maples, discolored wood and decay can be significantly reduced by making pruning cuts on codominant stems with stem diameter ratio (Eisner et al. 2002; Gilman and Grabosky 2006). Further, the full removal of a stem in a pair of codominant stems should be avoided due to larger amounts of wood exposed and a higher likelihood of pith connection, which both can lead to more discoloration and decay (Eisner et al. 2002).

The recommendation for repruning or development of a pruning cycle can be based on objectives, pruning system, species, tree health, site, and growth rate (American National Standards Institute 2017). To continue the reduction in stem size ratios and to minimize sprout growth, trees in this study that received

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the 25% or 50% treatments may need to be pruned again after one or two years. Trees that received the 75% or 100% treatment may not need to be repruned for 2 to 3 years. We see no reason that a more frequent interval would cause additional harm to the tree.

## CONCLUSIONS

Overall, we found similar results to previous work that suggest that stem diameter ratio can be reduced on codominant stems by stem subordination. Pruning cuts that are equivalent to 50% and 75% of the stem basal diameter can reduce the stem diameter ratio for at least 2 years following pruning. Furthermore, only the 50% treatment fell into the acceptable category for aesthetics immediately following pruning and had significantly less exposed internal wood after 3 growing seasons following pruning. Pruning should be a balanced approach that takes into consideration structure, aesthetics, and vigor to determine appropriate specifications and pruning frequency. Finally, pruning specifications should remove the least amount of photosynthetic material and make the smallest wounds to achieve the pruning objective defined by the arborist and their client. Future work should determine the effects of subordinating all codominant stems within a canopy at 50% and 75% pruning severity cut treatments to determine a realistic frequency of pruning and if tree health effects are magnified by making more than one cut on a given *A. rubrum* 'October Glory.'

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The authors reported no conflicts of interest.

**Résumé.** Contexte: Les tiges codominantes sont une source de préoccupation courante chez les arbres d'ornement. Comprendre l'impact des différents degrés de raccourcissement des tiges peut aider les praticiens à prendre des décisions éclairées en matière d'élagage. Méthodes: À cette fin, une seule coupe de réduction ou de coupe complète a été effectuée sur chaque paire de tiges codominantes d'*Acer rubrum* 'October Glory', d'âge moyen, dans une proportion relative de 25 %, 50 %, 75 % et 100 % par rapport au niveau de l'embranchement commun ou a été conservée comme témoin non élagué. Les changements dans le rapport entre le diamètre des tiges, la croissance en diamètre de chaque tige, la production de gourmands, la fermeture des plaies et l'esthétique ont été documentés pendant 4 ans à partir de 2020. Résultats: Le rapport de diamètre des tiges a été significativement réduit dans les tiges codominantes élaguées dans une proportion relative de 50 % ou 75 % après une seule saison de croissance. La coupe effectuée à 75 % a réduit la croissance pendant deux saisons de croissance. Il n'y avait plus de différences significatives dans le changement du rapport de diamètre des tiges avec n'importe quel traitement après 3 saisons de croissance. Des coupes de dimensions plus importantes ont entraîné l'apparition d'un plus grand nombre de gourmands et d'une plus grande superficie de bois exposé après 3 ans. L'esthétique des arbres suite à l'élagage a été jugé acceptable pour les arbres témoins et ceux élagués à 25 % et à 50 % pour toutes les années, mais a été jugée modérément ou non acceptable pour les traitements à 75 % et à 100 % après deux saisons de croissance. Les arbres élagués à 75 % sont devenus esthétiquement acceptables après trois saisons de croissance. Conclusions: La taille des tiges codominantes d'*A. rubrum* 'October Glory' avec une coupe de raccourcissement des tiges de 50 % ou 75 % par rapport à l'embranchement commun est appropriée pour réduire le rapport de diamètre des tiges, minimiser la superficie de bois exposé et maintenir l'aspect esthétique général après 2 à 3 ans.

**Zusammenfassung.** Hintergrund: Kodominante Stämme sind ein häufiges Problem bei Landschaftsbäumen. Das Verständnis der Auswirkungen verschiedener Grade der Stammreduzierung kann Praktikern helfen, fundierte Schnittentscheidungen zu treffen. Methoden: Um dies festzustellen, wurde an jedem Paar kodominanter Stämme von *Acer rubrum* 'October Glory' mittleren Alters ein einziger Reduktions- oder Entfernungsschnitt bei etwa 25 %, 50 %, 75 % und 100 % des Durchmessers im Verhältnis zum Basaldurchmesser an der gemeinsamen Verbindung vorgenommen oder als ungeschnittene Kontrollen belassen. Die Veränderungen des Stammdurchmesserverhältnisses, des Stammdurchmesserwachstums, der Triebproduktion, des Wundverschlusses und der Ästhetik wurden ab 2020 über 4 Jahre hinweg dokumentiert. Ergebnisse: Das Verhältnis des Stammdurchmessers war bei kodominanten Stämmen, die nach einer einzigen Vegetationsperiode auf einen relativen Durchmesser von 50 % oder 75 % beschnitten wurden, deutlich reduziert. Die 75%-Behandlung reduzierte das Wachstum für 2 Wachstumsperioden. Nach 3 Vegetationsperioden gab es bei keiner Behandlung signifikante Unterschiede in der Veränderung des Stammdurchmesserverhältnisses. Größere Schnittflächen führten nach 3 Jahren zu mehr Trieben und mehr freiliegendem Holz. Die Ästhetik der Bäume nach dem Schnitt war in allen Jahren bei den nicht beschnittenen, 25-prozentigen und 50-prozentigen Behandlungen akzeptabel, wurde aber bei den 75-prozentigen und 100-prozentigen Behandlungen nach zwei Vegetationsperioden als nicht akzeptabel oder mäßig akzeptabel eingestuft. Bäume mit einer 75%igen Behandlung wurden nach 3 Wachstumsperioden ästhetisch akzeptabel. Schlussfolgerungen: Das Beschneiden der kodominanten Stämme von *A. rubrum* 'October Glory' mit einem Schnitt, der 50 % oder 75 % des Durchmessers des Basaldurchmessers an der gemeinsamen Verbindung beträgt, ist geeignet, das Verhältnis der Stammdurchmesser zu reduzieren, das freiliegende Holz zu minimieren und das ästhetische Gesamterscheinungsbild nach 2 bis 3 Jahren zu erhalten.

**Resumen.** Antecedentes: Los tallos codominantes son una condición común de preocupación en los árboles del paisaje. Comprender el impacto de los diversos grados de reducción del tallo puede ayudar a los profesionales a tomar decisiones informadas sobre la poda. Métodos: Para determinar esto, se realizó un solo corte de reducción o remoción en cada par de tallos codominantes en *Acer rubrum* 'October Glory' de mediana edad a aproximadamente 25%, 50%, 75% y 100% del diámetro en relación con el diámetro basal en la unión compartida o dejados como controles no podados. Los cambios en la relación del diámetro del tallo, el crecimiento del diámetro del tronco, la producción de brotes, el cierre de la herida y la estética se documentaron durante 4 años a partir de 2020. Resultados: La relación entre el diámetro del tallo se redujo significativamente en los tallos codominantes podados a un diámetro relativo de 50% o 75% después de una sola temporada de crecimiento. El tratamiento con un 75% redujo el crecimiento durante 2 temporadas de crecimiento. No hubo diferencias significativas en la relación de cambio de diámetro del tallo con ningún tratamiento después de 3 temporadas de crecimiento. Los cortes de poda más grandes dieron como resultado el crecimiento de más brotes y más madera expuesta después de 3 años. La estética de los árboles después de la poda fue aceptable para los tratamientos no podados, 25% y 50% en todos los años,

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pero se calificaron como no aceptable o moderadamente aceptable para los tratamientos 75% y 100% después de 2 temporadas de crecimiento. Los árboles con el tratamiento del 75% se volvieron estéticamente aceptables después de 3 temporadas de crecimiento. Conclusiones: La poda de tallos codominantes de *A. rubrum* 'October Glory' con un corte que sea del 50% o 75% del diámetro basal en la unión compartida es apropiada para reducir la relación de diámetro del tallo, minimizar la madera expuesta y mantener la apariencia estética general después de 2 a 3 años.

## *Arboriculture & Urban Forestry* Quiz Questions

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*Appendix on next page*

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**Appendix.**

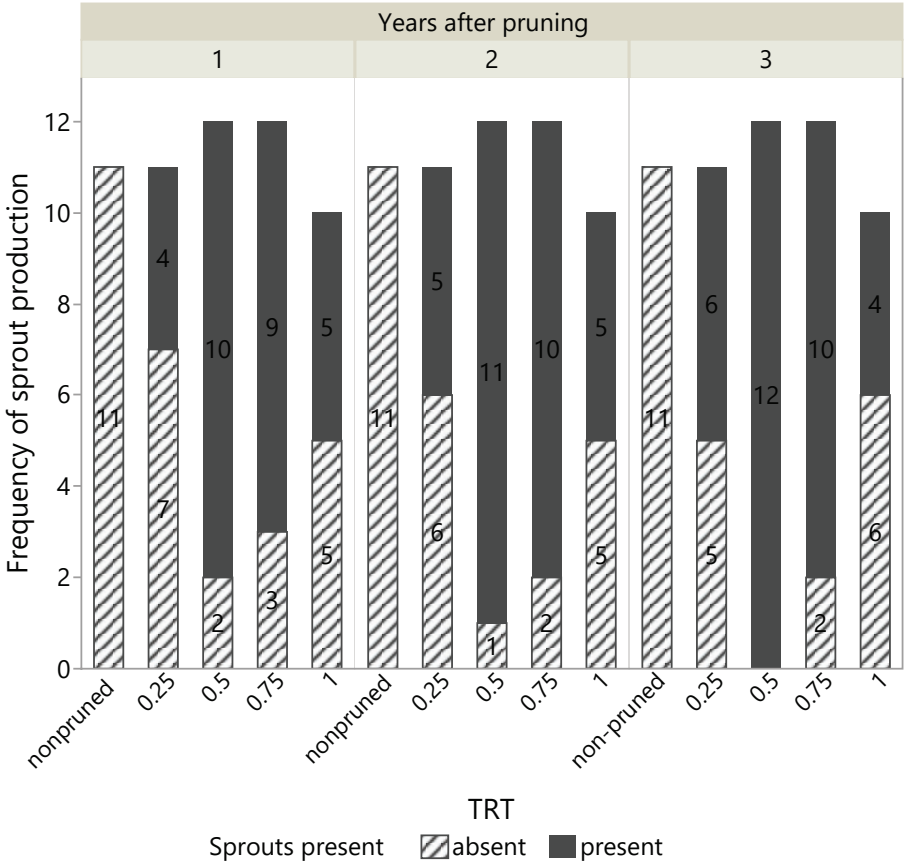


**Figure S1. Frequency of sprouts produced within 30 cm of the pruned stem over various time points postpruning (TRT).**

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