Predicting Branch Attachment Strength in Norway Maple (*Acer platanoides*)

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Introduction

Branch failure during storm events is a common problem experienced by urban trees, causing property damage, power outages, and human injury and fatality. Improving our knowledge of characteristics that affect branch attachment strength is crucial to help improve the resiliency of urban trees to storm damage. Previous research has shown that branch attachments with a low branch-trunk diameter ratio (aspect ratio) are stronger than attachments with a large aspect ratio (Fig. 1) (Gilman 2003, Kane et al. 2007). Included bark, which occurs when bark on the branch and trunk become embedded between them at the union, has also been shown to reduce the attachment strength of codominant stems (i.e. high aspect ratio) (Smiley 2003). However, there is a lack of research investigating relationships between traits such as aspect ratio, included bark, and branch union shape and their effect on branch attachment strength.

Objective: To determine if outwardly observable characteristics, such as aspect ratio, included bark, union shape (U or V), and their interactions effect branch attachment strength in Norway Maple (*Acer platanoides)*.

Methods

- Ninety trunk sections with branches were harvested from a twenty year old stand of Norway maple (*Acer platanoides*).
- Aspect ratio ranged from 0.3 to 1.0 and branch diameter ranged from 40mm to 80mm.
- Morphological characteristics recorded previous to breakage included aspect ratio (Fig. 1), union shape (Fig. 2), and included bark (Fig. 3).
- Trunk sections with attached branches were secured to a custom made branch breaking apparatus using high strength ratchet straps. (Fig .4a)
- A 2,273 kg capacity load cell was attached to the branch at the pull point, and to a manual winch cable.
- As the winch was operated the load cell measured applied force at a rate of 20 Hz and data was recorded to a laptop computer until failure occurred.
- Post-failure visual inspection confirmed the presence or absence of included bark.
- Breaking stress (σ) was calculated for each branch attachment using the equation: $\sigma=(32PL\sin\Theta/(\pi x^2 y)$ (Fig. 4b).

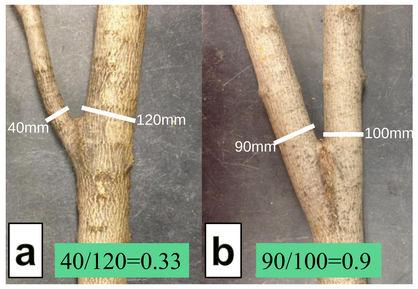

Figure 1. Aspect ratio is determined by dividing branch diameter by trunk diameter. (left) A branch with a small aspect ratio. (right) A branch with a large aspect ratio.

Figure 2. a) A branch with a clear "U" shaped union. b) A branch with a clear "V" shaped union.

Figure 3. a) A bulging ridge typically found on branch unions with included bark. b)The same union split apart to expose the included bark.

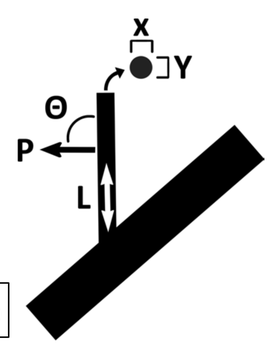

Figure 4. a) The branch breaking apparatus set up with a branch union. b) A free body diagram illustrating the variables represented in the stress equation: P is the maximum load (kN), L is the distance from branch attachment to pull point(m), Θ is the angle between the branch and cable, and x and y are in-line and perpendicular diameters (m) respectively.

Results and Discussion

- Branch attachment strength decreased as aspect ratio increased for branches with and without included bark ($R^2 = 0.60$ and 0.53 respectively). The effect of this relationship was greater when included bark was present ($P<0.01$) (Fig. 5).
- The presence of included bark occurred much more frequently on V-shaped unions than U-shaped unions (Fig. 6).
- Breaking stress was greater for U-shaped unions than for V-shaped unions ($P<0.05$) (Fig .7).
- These findings suggest that trees with high aspect ratio will be more likely to fail during storms, and the presence of included bark and V-shaped unions may increase this likelihood.

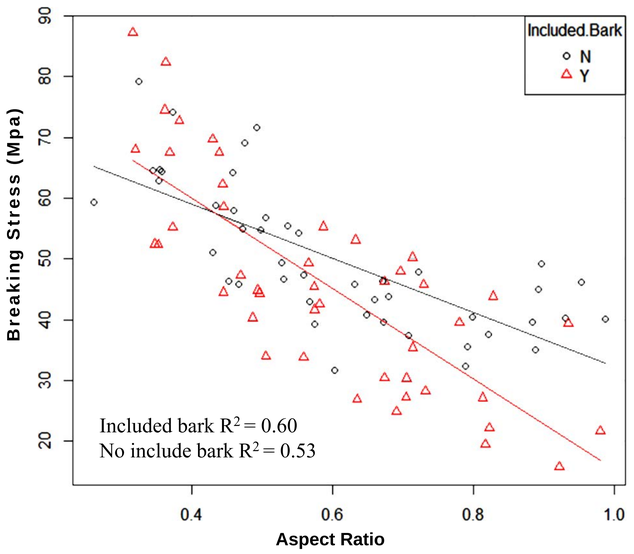

Figure 5. Breaking stress plotted against aspect ratio
Line of best fit equations:
Included Bark: Stress= -74.52(aspect ratio) + 89.84
No included Bark: Stress= -44.517 (aspect ratio) + 76.79
The difference in slope between the two trend lines indicate the relationship between breaking stress and aspect ratio is affected by the presence of included bark *(P*<0.01).

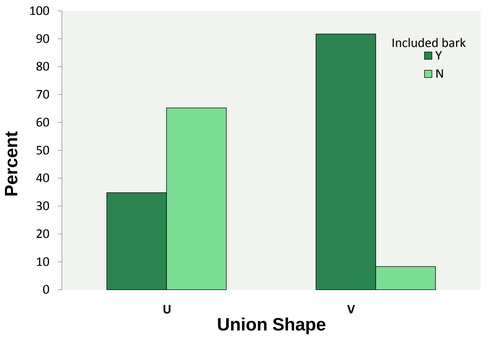

Figure 6. Bark inclusion between union shapes
Results were gathered using a Chi-Squared test (*P*<.0005)

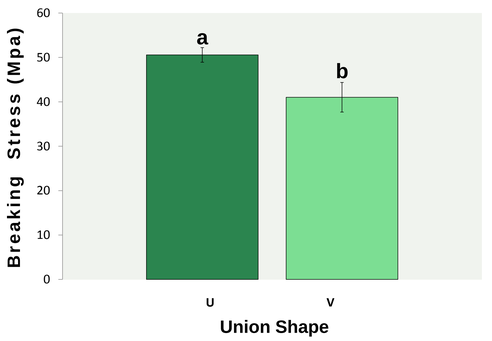

Figure 7. Average breaking stress between union shapes
Breaking stress was found to be significantly higher for U shaped unions than V shaped unions.

Conclusion

The findings from this study could help arborists improve pruning techniques used on urban trees. While aspect ratio has been shown to be correlated with attachment strength, the influence of included bark on this relationship has not previously been shown. Further research on different tree species would help to further validate these results and help tree care professionals improve the resiliency of urban trees to storm damage.

Literature Cited

1. Gilman, E.F. 2003. Branch-to-stem diameter ratio affects strength of attachment. Journal of Arboriculture 29:291–294.
2. Kane, B., Farrell, R., Zedaker, S., Loferski, J.R. and Smith, D.W. 2008. Failure mode and prediction of the strength of branch attachments. Journal of Arboriculture and Urban Forestry 34:308-316.
3. Smiley, E.T. 2003. Does included bark reduce the strength of codominant stems? Journal of Arboriculture 29:104.

Acknowledgments

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