# EFFECTS OF PRUNING ON WIND-LOADING OF TREES

A Research Report to the

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Abstract

Pruning is one of the most important cultural practices in the management of trees. One important reason for pruning is to reduce leaf area (crown thinning) in order to reduce aerodynamic drag, which may cause limb breakage and windthrow in storms. However, the decrease in aerodynamic drag through the reduction of the cross-sectional areas of leaves and branches is not well understood, and to our knowledge has not been quantitatively described. We used a modified orchard sprayer as a source of wind. We obtained five plant species with five uniform specimens for each species and measured drag force with precision scales as the amount of force needed to maintain a vertical orientation of the plant. We measured drag force when plant pots were secured and when plant pots were placed on a platform with an axle allowing the entire plant to tip in response to wind. We made measurements when plants had all their leaves, and at approximately 1/3 and 2/3 of leaf removal, and when all leaves were removed. We found that leaves, as compared to stems, exerted more resistance to wind movement than we had expected.

## Introduction and Background

Landscape trees are subject to a number of stresses caused by various factors. Although tree stress is generally related to such cultural practices as improper irrigation, adverse soil conditions and poor species adaptation, stress may also result from physical force. Perhaps the physical force most often applied to plants is moving air, or wind, which may cause limb breakage and tree failures. In earlier work, Leiser and co-workers showed that plant cultural practices were critical in affecting trunk taper and the distribution of stress along the trunk when young trees were subject to wind (Leiser and Kemper 1968, Leiser et al. 1972, Leiser and Kemper 1973). Those studies approached the question of stress distribution from a perspective of the physics involved, and both theoretical and empirical approaches were employed to understand the effects of trunk taper on stress distribution. Indeed, that work forms the basis of present day recommendations for tree staking practices. We think a similar approach will be effective for determining the effects of pruning on tree limb breakage and windthrow.

Wind carries kinetic energy, and results in an applied force to objects it encounters. Since kinetic energy (KE) is proportional to mass (m) and the velocity (v) squared

$$KE = (1/2)mv^2 \qquad \text{(Equation 1)}$$

the energy carried by wind will be affected by the mass of ambient air, which changes with temperature, pressure, and humidity; and KE increases rapidly as v increases. In the simplest case of a flat surface perpendicular to the wind direction, the applied force F is dependent upon wind velocity and the cross-sectional area of the surface. In considering the force on a flat surface further, we can surmise F will also depend on the orientation of the surface, and will be proportional to the sine of the angle of the surface relative to the wind direction. For very low wind speeds, the flow around objects may be laminar, but that situation is not of present interest. Rather, as wind speed increases, the irregular movements of leaves and branches indicate conditions become turbulent (high Reynolds number). Under turbulent conditions the flow of air is no longer smooth around objects, and eddies of air are formed which in effect increase aerodynamic drag. Under such conditions the force in Newtons applied to an object, such as a plant, may be expected to follow the general equation (Serway 1990):

$$F = (1/2)CA\rho v^2 \qquad \text{(Equation 2)}$$

where C is a dimensionless drag coefficient, A is cross-sectional area ($m^2$), ρ is the density of air (1.20 kg $m^{-3}$ for dry air at 1 atm and 20°C), and v is the wind velocity (m $s^{-1}$). As seen from Equation 2, the force applied is directly proportional both the cross-sectional area of the plant A and to the drag coefficient C. C varies between zero and one, includes both friction and pressure drag, and is dependent on the shape of the object. For plants, the determination of an overall drag coefficient analytically is a formidable problem due to the mathematically complex structure and surface roughness of plants. The drag coefficients for different plant parts have differing ranges, and C varies for an object such as a leaf, twig, or small branch as its alignment with wind direction changes. For flat leaves, the value of C is expected to be 0.02-0.2, while for more resistive structures such as branches and tree trunks the value may be 0.5-0.9 (Nobel 1999). If F becomes greater than the stress limit of wood, a branch or the trunk may fail. Alternatively, the plant may remain intact, but the torque exerted by wind may result in the plant being uprooted.

Cultural practices may favor the development of plant dimensions favoring survival of the plant during conditions of increased wind speeds. As noted above, Leiser, Kemper and co-workers showed that the stress distribution in sapling trees was dependent upon trunk taper, and in trees with adequate trunk taper the center of stress was found higher on the stem. In this upper region wood was newer and less lignified, and was able to bend more easily under wind-loading, and therefore the likelihood of stem failure was reduced. Trunk taper is affected by staking and also by pruning.

Pruning is one of the management practices most often applied to trees, and will affect trees because of both indirect effects on trunk taper and more directly by reducing area of leaves and branches. For shade trees, pruning may be undertaken specifically to reduce leaf area (crown thinning), a practice believed to reduce wind-loading and therefore to reduce limb breakage and windthrow, especially during storms. However, we are not aware of research supporting this pruning practice, especially with regard to the amount of foliage removed and the relative reduction in aerodynamic drag.

## Statement of the Problem

Although the removal of limbs, mostly through thinning cuts, is alleged to prevent windthrow of trees, the decrease in force from wind-loading by reducing leaf and branch areas has not been quantitatively described to our knowledge. Furthermore, because of the flexibility of leaves and small stems, the reduction of drag force by the wind may not be proportional to leaf removal. Rather, limbs and trunks may be much more susceptible to wind-loading, due to their non-streamlined shapes, rigidity, and corresponding high drag coefficients. While staking recommendations rest on firm empirical and theoretical foundations, recommendations for pruning amounts and locations within tree crowns to reduce the force exerted by wind have little research support.

## Experimental Methods

Trees used in the study included broadleaf deciduous, broadleaf evergreen, and needle evergreen species. We obtained five plant species with five uniform specimens for each species. Plants were pink trumpet tree (*Tabebuia impetiginosa*) 5 gal, Raywood ash *(Fraxinus oxycarpa* 'Raywood'*)* 5 gal, green columnar juniper (*Juniperus chinensis* 'Hetzii Columnaris') 5 gal, Wichita blue juniper (*Juniperus scopulorum* ‘Wichita Blue’) 7 gal, and D. D. Blanchard magnolia (*Magnolia grandiflora* 'D. D. Blanchard') 7 gal. Plant dimensions were measured including trunk taper, and number and diameters of major stems. Trees were exposed to three wind velocities generated with a modified orchard sprayer and speed was measured with an anemometer. The resulting force on plants was measured with precision spring scales attached to the trunk at 2/3 the total height, the same height that a stake would be tied. The torque exerted by wind on the whole plant was also measured by placing the plant on a hinged platform and exposing the crown to wind of measured velocity, measuring the torque as applied force.

After applying a wind load to the entire plant, leaves and branches were successively removed by pruning, and the force reduction noted. A leaf sample was measured for one-sided leaf area using a leaf area meter, and cross-sectional area of stems was also measured. Fresh weight and dry weight of leaves, stems and trunks was obtained for calculation of mass distribution and amount leaf area removed.

## Results

The data are still being analyzed and we cannot comment yet on species differences or potential difference between plant structural classes, e.g. deciduous vs. needle evergreen. As seen from the graphs attached, removal of foliage resulted in reduced drag force. However, the drag force was not zero even when all leaves were removed. We found that leaves provided more resistance to wind than we had expected.

Because of the principle of dynamic similarity widely used in wind-tunnel tests of air foils (small objects behave the same way as larger objects of the same shape), the proposed research is expected to have application for larger plant specimens. Results of the research will be used to understand the effects of tree pruning on wind-loading, and to develop pruning recommendations with regard to reduction of limb breakage and windthrow of trees.

## References


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