

# APICAL BUD TOUGHNESS TESTS AND TREE SWAY MOVEMENTS TO EXAMINE CROWN ABRASION: PRELIMINARY RESULTS

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## ABSTRACT

Apical bud toughness differences were examined for several species to determine if crown abrasion affects shoot growth of determinate and indeterminate species during stand development. Determinate buds will set and harden after initial shoot elongation in the spring, while the indeterminate shoots form leaves from the apical meristem continuously based on the resources that are available at the time of growth. These growth differences can influence which species' buds are abraded or broken upon impact with adjoining crowns affecting crown growth. Shoot and bud toughness by species and shoot growth form were evaluated using a pendulum impact tester. Crown movement was assessed by using 3-axial accelerometers in outer most extreme points of crowns. Accelerometers automatically logged the movement of branches in the tree crown over a period of time and are evaluated with local wind data. By using both the crown sway information and associated bud and branch toughness models, evidence is provided to suggest that crown friction and abrasion are contributors to crown and stand development patterns in mixed species stands, often allowing species with determinate shoot growth to stratify above trees with indeterminate growth.

## INTRODUCTION

Crown abrasion is the physical loss of terminal buds and branches when tree crowns overlap during wind sway (Rudnicki and others 2001). Crown abrasion could be affecting stand development, crown differentiation, and crown dynamics. Clatterbuck and Hodges (1988) observed an even-age stand of sweetgum (*Liquidambar styraciflua*) and oak (*Quercus* spp.) where sweetgum quickly captured the site, but around age 20 to 25 the oaks were able to stratify above the sweetgum. Crowns of surrounding sweetgums recede from the crown of the oak, possibly caused by abrasion. Crown abrasion has been studied in coniferous forests (Meng and others 2006, Rudnicki and others 2003). In Costa Rica, abrasion has also been observed in black mangrove (*Avicennia germinans*) forests (Putz and others 1984). Tarbox and Reed (1924) found crown abrasion led to reduced yields in overstocked pine plantations. Mechanical abrasion by neighboring trees is hypothesized as a factor influencing suppression of shoot extensions (Oliver

and Larson 1996). Quantitative data of this phenomenon is limited to pine (*Pinus* spp.).

Tree throw, stem break and root break are well known disturbances that can occur from wind events (Mayer 1987). Mechanical abrasion may be a more persistent and subtle form of disturbance from wind events. Mechanical abrasion is the physical shearing of crowns during wind sway. As trees grow in height, their limbs grow longer and sway farther (Oliver and Larson 1996). No tree can survive a powerful wind event without some damage (Mayer 1987).

Tree crowns create carbohydrates from converting sunlight, CO<sub>2</sub> and H<sub>2</sub>O, which are used by all parts of the tree. The amount of crown is dynamically related to the growth of the tree because production of photosynthate dictates shape and size of all other parts of a tree (Holland and Rolfe 1997). Crowns are one of the most easily impacted components of a tree by environmental conditions. Crown expansion is limited when crown abrasion occurs, which can impact crown size and photosynthate production.

Oliver and Larson (1996) hypothesized that one species' terminal branches could be severed by tougher branches of another species. Terminal buds have different growth forms that could be influencing abrasion in mixed species stands. Preformed growth form (determinate) and the sustained growth form (indeterminate) are the two growth forms of interest. Preformed shoots contain all the leaf primordial and internodes that that will expand during the flush of the growing seasons. Sustained growth trees will form leaves from the apical meristem continuously depending on the resources that are available at the time of growth (Kozlowski and Pallardy 1997).

Lockhart and others (2006) found when cherrybark oak (*Quercus pagoda* Raf.) were at or above the height of neighboring sweetgums, the sweetgum branches were often damaged, especially terminal branches. The sweetgums

with damaged terminal branches grew more laterally. This resulted in sweetgum crowns receding from cherrybark oak crowns. Subsequently, most of the neighboring cherrybark oaks' growth was in height, allowing cherrybark oaks to stratify above sweetgum. Lockhart and others (2006) suggests that crown abrasion is the major component allowing this to occur.

The primary objective of this study was to evaluate different quantitative methods that might be used in assessing how crown abrasion occurs and how it impacts stand development. Two components of crown abrasion were assessed: (a) toughness of the bud and twig of various growth forms and (b) how the branches move in the wind. In order to evaluate these two components, the following were investigated:

- 1) Use a pendulum impact tester to determine bud toughness.
- 2) Measure and compare crown movement during the dormant season using accelerometers.

Standard methodologies for studying crown abrasion are not yet developed, therefore, new techniques were investigated to evaluate crown abrasion and their impacts on stand development. A pendulum impact tester was used to evaluate bud toughness, which is the amount of energy a material can absorb before fracture. A pendulum impact tester was selected over other testing methods due to its consistency in testing, and its similarities to colliding branches that are perpendicular. Rudicki and others (2001) used clinometers to measure bole displacement in lodgepole pine (*Pinus contorta*). This work inspired the use of accelerometers to measure gravitational force on crown edge and to 2-dimensionally map movement of a branch.

## MATERIALS AND METHODS

### APICAL BUD TOUGHNESS

Apical bud toughness was tested on several species on a Tinius Olsen Model 92T Impact Tester. The impact tester is a pendulum that swings through and strikes the sample. The amount of energy that is absorbed into the sample is given in Joules. Buds are braced with a block of wood to ensure the break occurs at the bud collar. If samples are not braced, the sample would not break anywhere because the vice holding the sample was too low.

Species with preformed bud growth and species with sustained bud growth were sampled in the dormant season. Samples were collected and broken within hours to ensure natural wood moisture content. Notes were made if samples had more than one terminal bud that was broken.

### TREE SWAY MOVEMENTS

The study area is located at the East Tennessee Nursery near Delano, Tennessee. Data were collected in 2011 in a Nuttall oak (*Quercus texana*) tree that was planted in the spring of 1993. The trees in the stand averaged 40 feet tall with live crown starting at 9 feet, and branches expanded 16 feet from the stem. One tree in the southwestern corner was selected to place tri-axis accelerometers because of its exposure to prevailing wind, crown symmetry, and accessibility.

The accelerometers were placed about 20 feet into the crown in each cardinal direction. The 4 accelerometers were placed about 2 feet from the end of the branches to ensure that movement was not influenced by the weight of the device. Accelerometers record gravitational force on each axis (X, Y and Z) and were set to record at +/- 4 g's. They also record at 10 hertz, resulting in data recording 10 times a second. Data were collected during various windstorm events during the dormant season.

An anemometer was used to record local wind data near the stand. The anemometer was placed 9 feet high and recorded average wind speed and top wind gust. The device was set to record once every minute while accelerometer data were being recorded. All wind speeds were recorded in miles per hour.

## RESULTS AND DISCUSSION

Preliminary data suggest differences in bud toughness between preformed and sustained bud growth forms. Mockernut hickory (*Carya tomentosa*) has a preformed bud growth form, while red maple (*Acer rubrum*) has a sustained bud growth form (Table 1). Tests show that mockernut hickory has an average bud collar diameter of 0.18 inches. Red maple has a bud collar diameter of 0.09 inches. Mockernut hickory required an average of 0.182 Joules to cause failure at the bud/stem matrix. Red maple buds fractured on average around 0.014 Joules. The energy required for mockernut hickory bud failure was about 1:1. This ratio for red maple was about 1:6.

If these two species were to collide during a wind event in a mixed species stand, the hickory would be able to withstand more energy than the red maple, resulting in the red maple being abraded. A smaller hickory growing alongside and below a red maple may be able to abrade the maple enough to increase growing space for itself. The increased growing space could result in more space and leaf area for the hickory, allowing growth to accelerate. The recession of the red maple crown is a continuous process as the mockernut hickory crown potentially stratifies above the red maple crown.

Structure of these species buds vary. Some species, such as hickory, will have a single terminal bud. Other species, such as oak, can have several terminal buds emanating from the same point. When buds were broken using the impact tester, we were careful to only break the largest terminal buds that were dominant on the terminal shoot. This could cause the species of oak to appear more fragile than they actually are. An advantage of several terminal buds would be the protection of inner buds that are surrounded by outer buds. The presence of several buds allows the tree to continue terminal growth even if one or more of the outer terminal buds are damaged. Species such as sweetgum would not have this ability.

Preliminary data suggest that preformed bud growth may be able to abrade sustained bud growth. Although Nuttall oak (*Quercus texana*), a preformed growth species, has a lower amount of energy required to cause bud fracture than many of the sustained growth species, Nuttall oak has more than one terminal bud on each branch tip. More terminal buds could increase the likelihood of that branch continuing terminal growth, even if one or more buds are damaged. A damaged bud of sustained growth would result in the apical dominance to be reverted back to a lower bud, causing growth to be hindered.

Preliminary crown movement indicates that the most acceleration occurs on the Z and X axis. The Y axis does not display much acceleration because accelerometers were not placed high enough to experience movement from the bole (Figure 1). As expected, acceleration increased as wind speed increased. Almost no acceleration was recorded up to a 15 mph (miles per hour) wind speed. Winds around 40 mph caused accelerations up to 2g's, twice as much gravitational force as one experiences from the earth. These recordings can be expected to be larger farther out on the tip of the branch, as the accelerometer had to be placed 2 feet from the tip to avoid influence from weight.

Even-aged monoculture hardwood stands generally do not stratify to the extent mixed species stands can. If crown abrasion is a factor that influences crown dynamics, then data suggest that monocultures of a single species would be evenly matched on terminal bud toughness. The intra-species competition would lead to no "winners," resulting in a lack of stratification and lateral damage that is equally distributed throughout the canopy.

## FUTURE CONSIDERATIONS

Mixed species stands could experience crown abrasion. Crown abrasion could be playing a critical role in stratification of slower, hardier species such as oaks into the upper canopy. Further investigation using these methods during the growing season will help us better understand species bud toughness and crown movement as branches become heavier with more leaf mass. Branch analysis will be conducted to study abrasion in pure and mixed, overstocked stands.

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**Table 1—Bud toughness test results by species using a pendulum impact test with average bud collar diameter (inches) and energy needed to fracture the bud as the variables. The ratio provided is the energy required for a break to bud collar diameter. Tests were conducted during the dormant season. Asterisk (\*) is considered preformed bud growth form**

Species	<i>n</i>	Bud Collar Diameter (inches)	Energy to Break (Joules)	Ratio Energy:Diameter
		Inches	Joules	%
<i>Carya tomentosa</i> *	177	0.183	0.184	101%
<i>Quercus alba</i> *	77	0.116	0.049	42%
<i>Quercus texana</i> *	75	0.091	0.017	19%
<i>Platanus occidentalis</i>	78	0.163	0.053	33%
<i>Liriodendron tulipifera</i>	180	0.115	0.045	40%
<i>Liquidambar styraciflua</i>	80	0.109	0.037	34%
<i>Acer rubrum</i>	77	0.090	0.014	15%

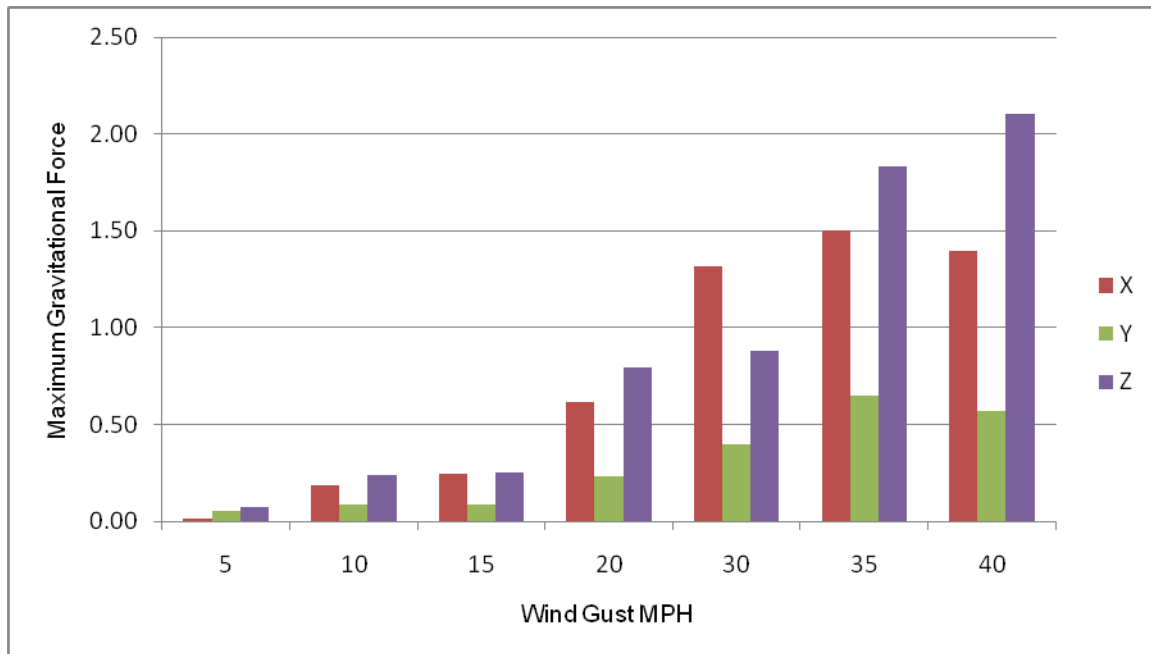


Figure 1—Gravitational force of branch movement as a function of wind speed. Maximum force was recorded from all accelerometers at the time of the wind events.