Wind-in-Wood

Interspecific diversity of wind resistance strategies among temperate tree species: what is the role of radial variations of wood material properties in different tree organs?

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Context — Simulations of climatic changes at high spatial resolution predict intensification of autumnal storms in western Europe (Baatsen, Haarsma et al. 2014). In this context of presumed increased mechanical loading due to the wind, it is interesting to study the diversity of strategies elaborated by trees to tolerate/avoid wind loads and better understand security limits towards windbreak on a wide sample of species including also less studied species.

The sensibility of a tree to the risk of windbreak cannot be treated as a simple fracture problem in civil engineering because trees size them-selves in function of signals perceived from their environment (Fournier, Bonnesoeur et al. 2015). Without getting into the details of processes controlling the growth, relative sizing of different tree parts (height, diameter, volume of root system, surface of the crown exposed to the wind) as well as their properties (wood properties, crown aerodynamics, resistance of the root system) result in empirically observed and largely discussed rules (Fournier, Dlouhá et al. 2013). Similarly to what has been done by some authors on the security margin for hydraulics (Choat, Jansen et al. 2012; Delzon and Cochard 2014), we know need to gather and synthetize the information about the margins of mechanically security of species for the moment very scarce in the literature and nearly exclusively focused on tropical species (Read and Stokes 2006; van Gelder, Poorter et al. 2006; Butler, Gleason et al. 2012).

Objectives — As de la Fontaine reminds in his fable « The oak and the reed » (de La Fontaine 1888), the strategy to tolerate/avoid wind load is a function of tree size. Resistance of a tree submitted to longitudinal bending is largely determined by its diameter excepting for small diameters for which the role material properties may be essential. The hypothesis we want to test here is that radial variation of wood mechanical properties, often considered by wood technologists as a defect for final user, is an integral part of the tree strategy to resist windbreaks and to insure the transition from tree the size suitable for wind avoiding strategy to the size able to rely on the wind tolerating strategy; allowing in particular the large axis deformability of tiny seedlings. As the wind load is proportional to surface of the crown exposed to the wind, the need to have an aerodynamic crown increases with tree height and crown size. It is therefore interesting to study the coordination between the patterns of variation of radial properties at the stem level and at the branch level to understand how these variations contributes or not to wind resistance of a tree as a whole.

Approach — Ten species including seven hardwoods and tree softwoods were selected in function of wood properties, empirical estimations of a drag coefficient and results of a survey of arborists that allowed in particular for identification of species suffering frequently by branch rupture due to the wind as *Salix alba* or *Acer platanoides* L. The choice was limited by availability of young but architecturally fully developed trees suitable for the study near Nancy as branches need to be collected and prepared progressively and in function of meteorological condition to measure drag coefficient at Chambley aerodrome, which limited the zone of sampling. Each species was represented by five trees, fifty trees were sampled in total. All trees were scanned by T-lidar to obtain information about the crown and tree stem was cored to measure the radial variation of wood properties (density and microfibril angle). Experimental platform designed in the laboratory and allowing for measurements of wind force and moment applied by the wind on the branch as well as an anemometer measuring the wind speed was fixed on a roof of a car. The car was also equipped by tubular system allowing for flexible positioning of cameras in function of the branch tilt angle. Cameras followed the surface of leaves exposed to the wind as well as the branch deformation under the wind load. 2-3m long branches were cut in the upper third of the tree crown and its tilt angle was measured in order to place the branch on a car in the same position as it was on the tree. Car speed was increased at 5m/s steps from 0 to 25m/s and drag measurement was made during periods of steady speed. Design of this platform was greatly delayed by health problems of the project leader and is in the stage of final tests. Aerodynamic behavior of branches as well as mechanical properties of green branch wood will be performed in summer 2018.

Key results —

- Home-made design of a platform measuring the drag coefficient.
- Patterns of radial variations of wood properties in tree stems are under analysis.
- T-lidar data about the crown morphology are also under analysis.

Main conclusions including key points of discussion — First tests of drag coefficient are very promising, the force, moment and wind speed signals as well as camera outpus are well synchronized and quality of the landing strip coating is sufficient to obtain data of good quality.

Future perspectives —

Finalize calibration tests of the platform for drag measurements and develop the method of image analysis allowing to follow the shape change of the branch. Publish obtained results. Develop an analytic model to estimate the importance of radial variation of wood properties in the branch reconfiguration under the wind. Build a numerical model of the branch submitted to the wind load in collaboration with colleagues specialized in numerical modeling and see how we can extend the data measured on branch on the behavior of the whole tree.

Valorisation —

Organisation d’une rencontre internationale de l’association internationale des arboristes SAG « Baumstatik » le 4 octobre 2016 à l’INRA de Champenoux, en collaboration avec Bruno Moulia et Eric Badel de l’INRA de Clermont-Ferrand