The study simulated wind-induced uprooting by pulling trees over with an electric truck winch. The maximum pulling force was measured using a digital force gauge.

Standing up against hurricanes

By Ute Albrecht, Bo Meyering, Carol Tardivo, Gabriel Pugina and Kim D. Bowman

The approaching hurricane season poses the question of why strong winds cause some citrus trees to topple over while others remain firm in the ground. Grove location, grove topography and soil type are factors that influence a tree's ability to withstand tropical-force winds. The tree's root structure is another factor.

As mentioned in a previous Citrus Industry magazine article (citrusindustry.net/2022/07/25/citrus-root-structures-lessons-from-below), the root structure is determined by several factors. This includes the genetic background of the rootstock, the local physical and chemical soil environment, handling in the nursery and handling during transplant to the field.

A frequent concern is whether there is a correlation between the uprooting resistance and how the rootstock was propagated. Rootstocks have been historically grown from seeds, but because of seed shortages for popular rootstocks, many newer plantings include trees with rootstocks propagated by tissue culture. The method of propagation does have some influence on the root structure. Seed propagation generates a taproot system with a main vertical (tap) root that gives rise to multiple lateral roots. Tissue culture propagation, like cuttings propagation, generates an adventitious root system. These root systems lack a single taproot and are instead comprised of numerous adventitious roots that arise directly from the root base.

UPROOTING STUDIES

Researchers initiated two field trials in different growing locations on Florida's east coast (Indian River and St. Lucie counties) to explore whether different root systems influence tree uprooting resistance. Each trial included trees with four different rootstocks that had been propagated by seed, tissue culture and stem cuttings. The rootstocks included in both trials were US-812, US-897, US-942 and US-1516. Among these four, US-897 is known to produce the smallest trees and US-1516 the largest.

The scion in both trials was standard Valencia (SPB-1-14-19), and the trees were grown in the field under professional management for two years. Standard procedures were used to measure tree growth traits. All the trees were healthy and not visibly affected by HLB when uprooted.

To measure resistance to uprooting, trees were pulled over with a motorized winch to simulate wind-induced forces. A winch strap was attached at the base of the rootstock trunk and connected to the hook of a truck winch that pulled at a constant speed. A digital force gauge was attached between the winch strap and the hook to collect force data in regular time intervals. Digital angle sensors were attached to a tree trunk to measure the angle of the trunk throughout the extraction process. Both forces and angles were measured until the trees were completely removed from the soil. The pulling direction was 20-25° relative to the row orientation (north-south) toward the bed middle. In total, 266 trees were excavated.

The propagation method had no significant influence on the force needed to uproot the trees.

Researchers measured and cataloged the maximum force required to uproot the trees. Root system traits measured included depth, symmetry, number of lateral roots, angles, thickness, and the proportion of straight, curved, knotted, broken or pot-bound roots.

RESEARCH RESULTS

Not surprisingly, the smallest trees in the trials were produced by US-897, while US-1516 and US-812 produced the tallest trees. US-897 also produced trees with the smallest scion and rootstock trunk diameters and canopy volume. Generally, the largest scion trunk and canopy volume were measured for US-1516 and US-812 grafted trees. The propagation method did not influence any of the measured tree growth traits.

When individual roots arising from the root stump with a thickness of

Excavated root systems were measured to assess various root traits, including depth, density and symmetry.

¼-inch or more were assessed for each tree, US-897 root systems had fewer roots emerging from the root stump compared to the other rootstocks. US-897 also had the highest proportion of roots growing vertically into the soil and the largest proportion of curved roots. There were no significant differences in these traits among the other three rootstocks.

When comparing rootstock propagation methods, the main difference was found for the proportion of roots growing vertically, which was lowest for tissue-culture-propagated rootstocks. The root systems of tissue-culture-generated rootstocks also had a considerably lower root-stump depth than the other propagation types, but this did not affect the overall rooting depth.

The proportion of roots broken from uprooting was influenced by the rootstock, with US-897 having the most frequent breakage. Rootstock propagation method did not affect root breakage. Analyses are still in progress regarding root system symmetry, but there is preliminary evidence that US-897 had more asymmetries than the other rootstocks. The rootstock propagation method did not appear to influence the symmetry of the root system.

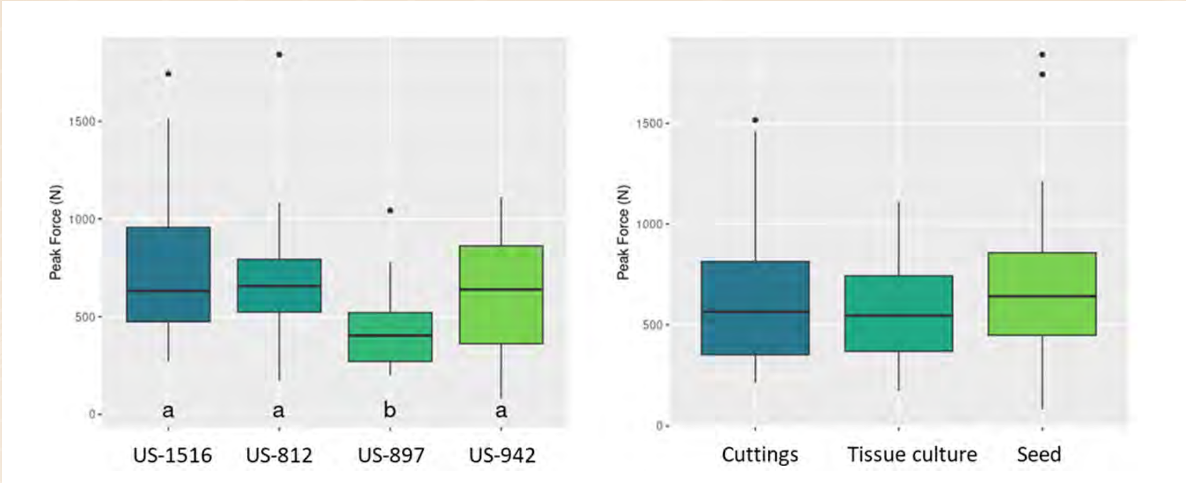
The maximum force needed to uproot the trees ranged from 250 to over 1,500 newtons. The peak force was strongly correlated to the size of the trees. Trees on US-812, US-942, and US-1516 required considerably more force to uproot than trees on US-897. In contrast, the propagation method had no significant influence on the force needed to uproot the trees. Researchers are still analyzing how other traits of the root systems affected uprooting resistance.

TAKE-HOME MESSAGES

Tree anchorage is directly associated with the size of a tree in most tree systems, and it increases with trunk diameter and stem weight. However, rooting depth and other root traits such as root thickness and root density in the leeward and windward direction of the wind force are also important factors determining whether a tree topples over or remains anchored in the ground.

Previous research shows today's commercially grown citrus trees lack a well-defined deep taproot, regardless of the rootstock propagation method. Anchorage is determined primarily by the strength and arrangement of the lateral, structural roots that are mostly concentrated in the upper 1 to 2 feet of the ground.

Anchorage strength or uprooting resistance was strongly correlated with the tree size but not with the rootstock propagation method. The simulations do not entirely reflect wind effects during a tropical storm or hurricane event. However, it is believed that they provide a good estimation of relative



Maximum pulling force was measured during tree uprooting with the winch. Different letters indicate significant differences among rootstocks.

tree anchorage provided by different rootstocks and propagation methods.

In addition, the scion variety and fruit load need to be considered. A tree with a vigorous scion (such as Sugar Belle) relative to the rootstock and a heavy fruit load is more likely to topple over during a strong wind event than a tree with fewer fruit and a less vigorous scion.

It should be noted that specific nursery and transplanting practices will vary. This will substantially affect root structure and anchorage strength and have a significant impact on the ability of a tree to withstand strong winds.

Acknowledgment: This project was supported with funds from the Citrus Research and Development Foundation.

Ute Albrecht (ualbrecht@ufl.edu) is an associate professor, Caroline Tardivo and Gabriel Pugina are PhD candidates, and Bo Meyering is a biological scientist at the UF/IFAS Southwest Florida Research and Education Center in Immokalee. Kim Bowman is a research geneticist at the U.S. Dept. of Agriculture-Agricultural Research Service U.S. Horticultural Research Laboratory in Fort Pierce.