Technical Resource Bulletin

September 2019 TRB-013

Factors that Influence Toppling of Longleaf Pine

Bill Pickens & Sarah Crate - NC Forest Service, Raleigh, NC

Tree toppling is a term used to define instability in young forest stands. Toppling includes trees that are completely blown over and those that are leaning and continue to grow. Toppling in pines has been reported in the Southeast since the 1980's for both loblolly and longleaf pine. Reports of toppling are usually correlated with passage of hurricanes or strong winds. Recent field observations indicate many of the trees blown over are longleaf pine, typically container longleaf seedlings planted in former agricultural fields. Close examination of the affected trees reveal a deformed root system, poor lateral distribution, and no tap or sinker roots. Soil features that restrict root growth such as soil texture, compaction, moisture, and the presence of a hardpan influence the likelihood of toppling. Foliage density, root growth in the container and after planting, and the duration, and intensity of a wind event are other factors that contribute to tree blow over. This paper provides a summary of the many factors that affect longleaf pine's ability to grow a healthy, extensive root system that provides a stable anchorage against toppling.

All trees develop root systems with taproots and well-distributed laterals to anchor and support them. **Longleaf pine is known to grow an extensive root system that provides a firm anchorage against windthrow.**

Naturally regenerated longleaf pines grow large straight taproots that extend deep into the soil and numerous far-reaching lateral roots. Secondary sinker roots formed off the primary laterals provide further stability. As a grass-stage seedling longleaf invests all its energy developing roots. Once the roots are big enough longleaf surges in height. The growth spurt, called the rocket stage, quickly positions the growing tip above typical flame lengths of most fires.

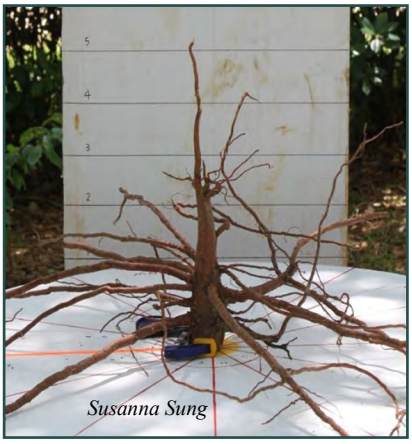

Figure 1. This six-year-old naturally regenerated longleaf pine has numerous straight and well-distributed lateral roots and a deep, large diameter taproot.

The root development of container longleaf seedlings differs as the taproot is air-pruned at the container's drainage hole and forms a callus. Once outplanted, one or more adventitious roots grow downward as a sinker root.

"A container-grown seedling may have a truncated taproot at the bottom of the root plug where it would have been air-pruned. New roots develop from the end of the truncated taproot after planting and normally they grow downward as would a taproot. The new vertical roots originating from the end of the truncated taproot are called sinker roots. Some seedlings still produce new roots from truncated taproot but these roots are either horizontal or oblique in orientation."
Susanna Sung - unpublished

Figure 2. Windthrow of longleaf saplings from Hurricane Irene. Arrows indicate the direction of toppling. Note the dense foliage and different directions of the longleaf toppled from this slow moving storm.

In some outplanted seedlings no sinker roots develop or they grow horizontally. In addition, lateral roots grown in containers may deflect off the side wall and grow in different directions resulting in crisscross, spiraling, or skewed growth after outplanting.

Figure 3. Multiple taproots or sinker roots developed at the callus due to air-pruning in container seedlings.

Despite these drawbacks **container longleaf seedlings are likely to remain the preferred seedling choice due to greater survival, quicker height growth initiation, and extended planting window.**

Once out-planted, many factors influence longleaf pine's ability to protect against toppling.

Tree morphology such as crown density, taproot growth, and lateral root distribution are important factors that directly affect the tree's ability to resist windthrow by increasing or decreasing stability.

Longleaf trees with longer needles, more limbs, and fuller crowns catch the wind better. Usually observed on fertile sites, the longer needles may catch the wind with enough force to push over sapling and small pole-size trees especially if their root system is poorly developed.

Figure 4. Long needles of young longleaf trees may act like a sail, catching the wind, and increasing the risk of windthrow.

Trees with healthy, deep root systems are less likely to topple than trees with deformed or poorly formed lateral roots and those lacking a stout taproot.

- Research shows about 4-17% of container longleaf seedlings do not produce a "taproot" after outplanting. The true taproot is air-pruned at the containers drain hole and forms a callus. After outplanting, the new sinker root grows from adventitious buds, but does not always grow downward.
- Lateral roots in container longleaf seedlings are not always well-distributed around the taproot and may form on only one side of the taproot. Asymmetrical lateral root distribution compromises tree stability, even if it has a deep taproot, since the tree lacks support on one side.
- After out-planting container grown longleaf may develop deformed roots in which the lateral roots are spiraled or crisscross. The wrapping of the laterals around the taproot constrict the development of both the taproot and lateral roots. The crossed laterals may fuse together, restrict growth, and encourage root decay.

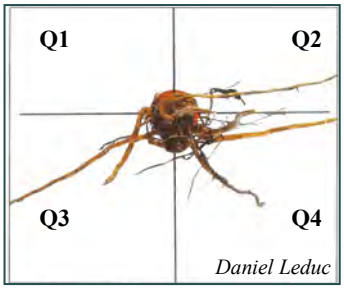

Figure 5. Poor lateral root distribution around the taproot reduces stem stability. Laterals sometimes emerge in only two of the four quadrants, as shown in this image looking directly down on the roots.

Figure 6. Asymmetrical growth patterns of lateral roots after outplanting. Note the lack of a downward growth by the sinker roots, spiraling tendency, crisscross potential, and one-sided growth of the lateral roots

Figure 7. The lateral roots on this seedling grew on one side of the taproot after the seed germinated next to the container side wall.

Containers designed to air prune laterals (like copper-coated containers) reduce spiraling and improve lateral root development, thereby increasing resistance to windthrow. They also reduce the number of roots growing down the plug wall, resulting in uniformly distributed laterals from top to bottom. In other types of containers, the roots tend to accumulate in the bottom of the container increasing the likelihood of malformed laterals after outplanting.

Soil texture and soil compaction impact tree stability by impeding root growth and thereby reducing the depth of the taproot or the extent of the lateral roots. Soil texture is determined by the relative proportion of sand, silt, or clay found. Soil texture factors that impact root growth include soil structure, porosity, permeability, and water holding capacity.

- Root growth is less constrained in **sandy soils or friable (crumbly) soils** that have better structure, high porosity, and rapid permeability.
- Soils with poor structure, low porosity, and slow permeability, such as **clay soils** or **compacted soils,** restrict root growth.
- **Wet soils** and soils with high water holding capacity have lower soil strength allowing for better root penetration and subsequent growth.

High site fertility, good soil moisture, previous land-use, and presence of a hardpan may also restrict or impede root growth. Reports of toppling occur more frequently in former agricultural fields than in former cutover stands.

- Tree roots grow in decayed root channels from previous tree stands, following a path of easy root penetration and least growth resistance that is also rich in nutrients. These are not present in agricultural sites.
- High water tables, fragipans or plow pans weaken, stop, or redirect taproot and secondary sinker root growth. Plow pans are common in agricultural fields. Cultivation of the A horizon allows easier path for root growth and encourages horizontal or oblique root growth.
- Longleaf trees grown on high quality soils like agricultural fields do not need extensive root systems to adequately supply water and nutrients needed by the above ground biomass. Trees growing on droughty, infertile sites must produce deeper taproots and far-reaching lateral roots to meet its resource needs.
- Toppling may be higher in agricultural fields because there are no adjacent woods to buffer winds.

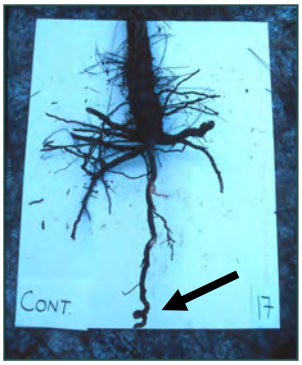

Figure 8. The taproot of this four-year-old sapling spiraled as it tried to grow through a fragipan layer in a spodosol soil type.

Wind and Rain—intensity, duration and amount matter. Strong winds have the potential to topple trees so it is no surprise that reports of toppling are correlated with severe winds. Since it also takes less wind to blow over trees when the soil is saturated, toppling is more likely when heavy rains precede the high winds. damage.

- Intense hurricanes winds are sustained for a long period of time, blow in different directions, and are accompanied by heavy rains, creating ideal conditions for toppling and potentially cause the most widespread damage.
- Less wind is needed to blow over trees with poor vertical and horizontal root development compared to a healthy root system. This is true regardless of the cause.

Summary

- The majority of toppled trees fail due to no or poorly developed tap or sinker roots and asymmetric laterals.
- Studies show that about 4-17% of container seedlings do not develop a tap or sinker root after out-planting.
- Lateral root symmetry (distribution around the taproot) is as important as the presence of a tap or sinker root.
- Toppling is more likely to occur in agricultural fields.
- Young trees in sapling or pole stage seem the most susceptible to windthrow.
- Saturated soils increase the likelihood of toppling.
- Soils with hardpans and heavier textured soils are more prone to windthrow.

What Can We Do to Mitigate ?

- **Plant high quality seedlings (**less than one-year-old) grown in containers with vertical ribs in the wall that prevent laterals from spiraling. The plug should have a volume of at least 6 cubic inches and be at least 5 inches in length.
- **Plant healthy seedlings** with firm potting soil that does not fall off after extraction. A healthy root system has light brown roots with white tips. Black colored roots are likely dead or diseased.
- **Follow proper planting techniques for longleaf**. Plant longleaf seedlings with the terminal bud at or just above the soil surface. Do not jam the plug into the planting slit to avoid forming a j-rooted taproot.
- **Sub-soil** heavy textured and compacted soils to loosen compaction and fracture hard pans for better root growth. Sub-soiling is most effective when applied to dry soils.
- **Prop up small trees to a vertical position**. Whether the trees will recover from the damage toppling caused to the root system is unknown, but recovery is more likely for saplings than larger trees.

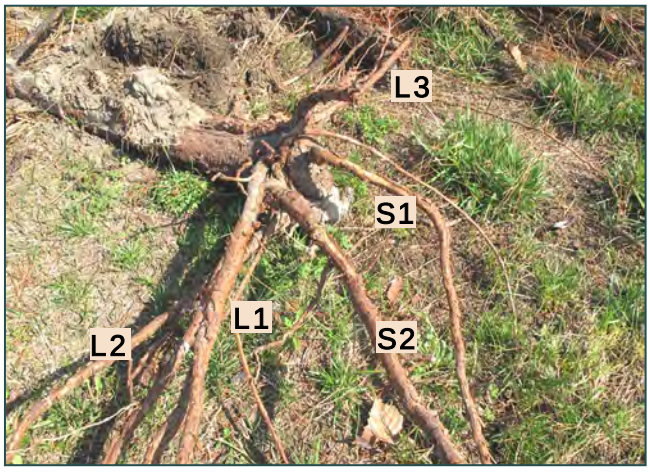

Figure 9. This longleaf sapling developed two sinker roots (S1-S2), one small and the other not centered. There was some wood decay in the callus area of the original taproot. The laterals (L1 - L3) grew in parallel planes providing support on only two sides.

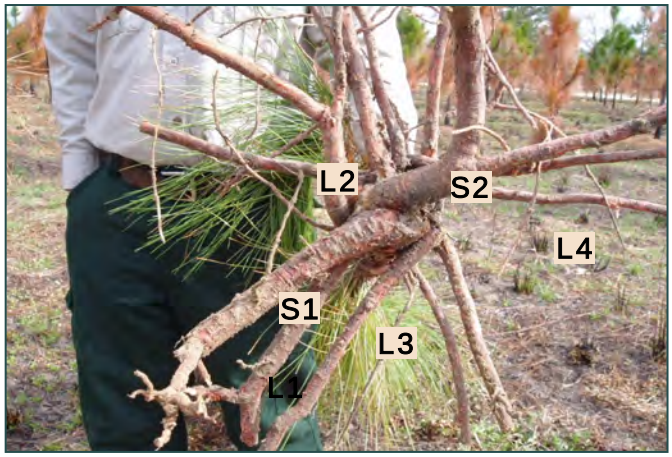

Figure 10. The sinker roots (S1,S2) in this longleaf sapling grew horizontal, perhaps after hitting a plow hard pan,. The laterals (L1 - L4) radiate from the stem from three sides and show some spiraling.

References

Dumroese, K.R., et.al. 2009. 2008 Interim guidelines for growing longleaf seedlings in container nurseries. .In: National Proceedings: Forest and Conservation Nursery Associations—2008. Proc. RMRS-P-58. USDA Forest Service, Rocky Mountain Research Station. Pp101-107

Mergen, F. 1954. Mechanical aspects of wind-breakage and wind firmness. Journal of Forestry. 1954. 52:2. pp. 119-125

Sword-Sayer, M.A., J. D. Haywood, and S. Sung. 2009. Cavity size and copper root pruning affect production and establishment of container grown longleaf pine seedlings. Forest Science. 55 (5): 377- 390

Leduc, D.J., J.D. Haywood, and S. Sung. 2011. Comparing planting tools for container longleaf pine. Tree Planter Notes. 54(1):24-27

Pickens, B. and T. Howell. 2002. Morphological differences of the root system of bareroot and container-grown longleaf pine after outplanting. In: proceedings; Southern Forest Nursery Association and the Northeastern Forest and Conservation Nursery Association Meeting. Pp. 17-20.

Sung, Susana. 2009. Personal communication.

Sung, S.S., Haywood, J. D.; Zarnoch, S., Sword Sayer, M. 2009. Long-Term Container Effects on Root System Architecture of Longleaf Pine. In: Proc. of the 2009 Society of American Foresters National Convention, 2009 September 30-October 4, Orlando, FL. Washington DC: SAF. 9 pp.