Is That Tree Big Enough?

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Abstract

Those in the practice of technical rescue do not know the true strength of the materials they rely on. Limited research has been done to reliably secure a rescue load using a tree as a trustworthy anchor. This study was conducted in order to define a correlation between the base diameter of the one-seed juniper and its ability to stay completely rooted when rescue load forces are applied. The trees were pull tested using a hydraulic ram that was anchored to a Ford F-150 with ten feet of steel chains. The generated peak forces of these tests were captured and recorded using a load cell device. The trees were pulled at an angle that was parallel to the ground and perpendicular to the tree's trunk, where it enters the ground. The trees were pulled to a point of failure. A failure was defined as the uprooting of a tree or the tree was pulled to an angel so sharp that the anchor material slipped over the top of the tree. A linear equation relating the base diameter of juniper trees to its correlating failure strength was

created. Using this linear equation we are able to make recommendations for safe anchor building when using a One-Seed Juniper for rescue loads. Recommendations are made while maintaining a 10:1 safety factor which is considered a standard in the rescue world. This study gives real data of how much force can be applied to a Juniper tree, without the usual doubt and speculations we often rely on when in rescues and trainings. Estimating anchor strengths is dangerous and could lead to death or main-line and/or belay-line failure. The research was constructed to further understand and mitigate the risks of anchor failure.

Background

Many rescues that are performed in mountain environments involve high-angle and low-angle rope rescue systems. The most crucial element of rope rescue is to have solid and trust worthy anchors to build raising and lowering systems. An anchor is defined as a fixed object to which a rescuer's rope is secured. In a rescue situation, an anchor that can withstand 20kN of force is highly desirable in order to safely hold a patient and a rescuer with a 10:1 safety factor. Any time that a system is built, rescuer's and patient's lives are at risk and completely dependent on the integrity of the system that is constructed. Rock climbing anchors such as anchors, bolts, cams, and pitons all offer different strengths when used as anchors ranging from 7-10kN. When incorporated into a multi-point pre-equalized anchor, these anchors collectively have shown to withstand 20kN of force only 50% of the time (Beverly, 2005). Large boulders and trees are often utilized as anchors because of their immense strength and ease to construct.

Purpose

There is little research on using trees as anchors and none to the best of our knowledge specifically regarding juniper trees. Rope access guidelines published by the Department of the Interior, state the minimum diameter of 8 inches should be used in order to determine if a tree will be able to hold forces above 22.2kN, dependent on its root system and lack of rot (Holan, 2004). A tree climbing guide published by the United States Forest Service states that a minimum of a 12 inch diameter should be used when judging if a tree will act as a safe and reliable anchor (Davis, 2005). These are very vague guidelines and are not specific to any one type of tree. In addition, trees with a diameter of greater than 12 inches may be hard to find or too far from the rescue location to utilize as an anchor. Juniper trees are one of the most abundant types of trees found in the Sandia Mountain range in New Mexico. The purpose of our research is to find a reliable and measurable means for choosing a juniper tree that can withstand a rescue load, if it were to be utilized as an anchor. Our goal is to find a correlation between tree diameter and the ability for a tree to hold steadily, without uprooting or failing under compression, while supporting a load of 2kN with a safety factor of 10:1.

One-Seed Juniper

The one-seed juniper is found in Arizona, New Mexico, Texas, and Colorado and is the most widespread tree in the Sandia foothills near Albuquerque, NM (Julyan, 2005). The one-seed juniper (*Juniperus monosperma*) is found in the foothill scrub community and the piñon-juniper woodland community in the Sandia/Manzano Mountains (Sivinski, 2007). It is also common in the desert grassland across New Mexico and Arizona. These trees are often shrubby in form and can be identified by their berry-like cone, generally only containing one seed. The height of a one-seed juniper can reach 35 feet and can have a diameter of up to 20 inches. These trees are very slow growing with an average growth of 6.3 inches in height and a stem diameter of 0.5

inches per decade. The adaptive ability to stunt growth during times of drought coupled with their slow growing characteristics make the one-seed juniper appear deceptively young. In reality, many of these mature trees have well developed tap root systems up to twelve feet deep. They also have many lateral roots close to the surface sometimes with lengths 2-3 times the height of the tree (Johnson, 2002). These characteristics along with their abundance are the reasons we chose the one-seed juniper for our research.

Methods

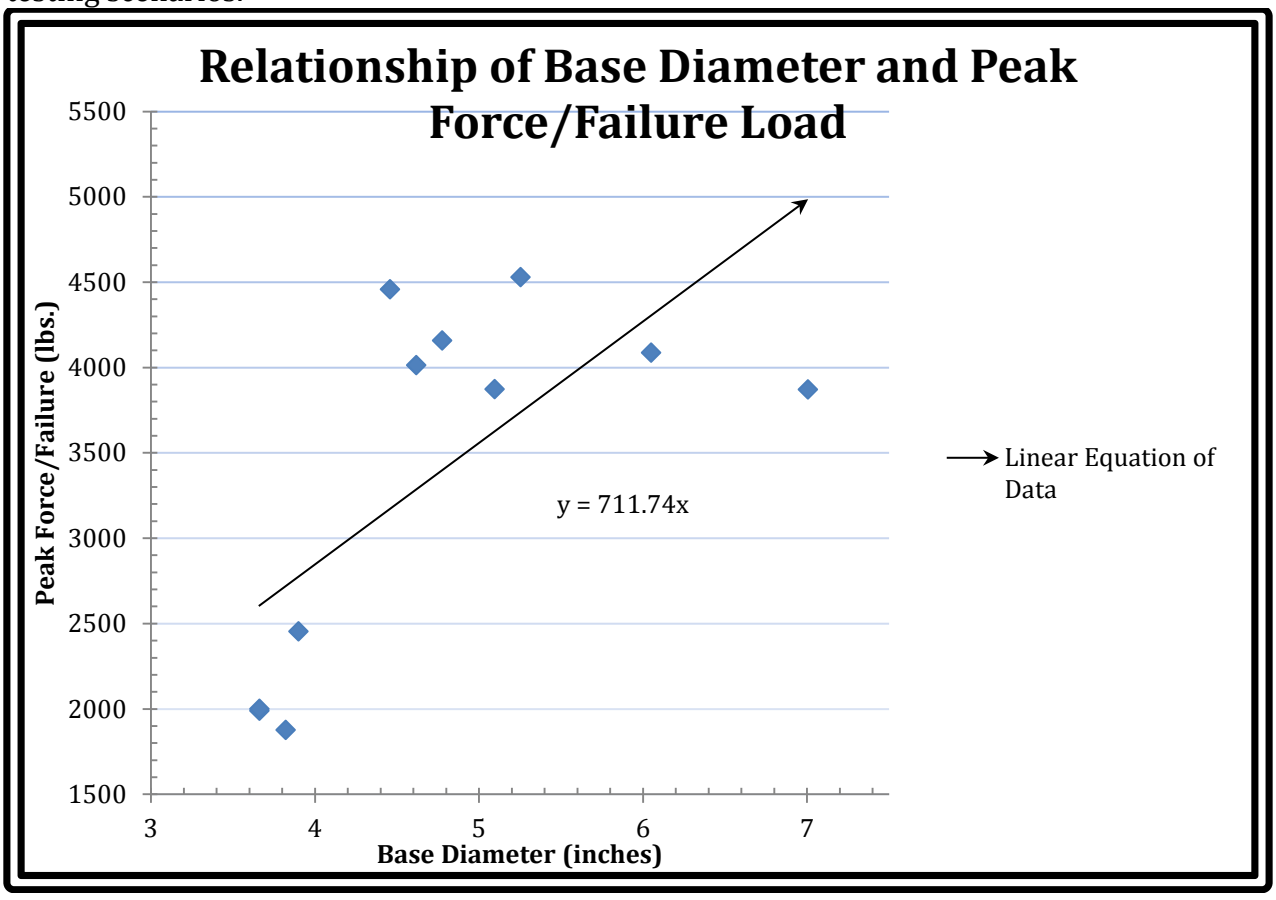
In order to conduct this study, we used various One-seed juniper trees as our test subjects. The trees were on private land in Tijeras, NM near the Sandia Mountains and were pull-tested while the environment was dry. This helped to simulate typical New Mexico terrain. The trees were pull tested using a hydraulic ram that was anchored to a Ford F-150 with ten feet of steel chains. The truck was stabilized with wood logs under the tires with the emergency brake engaged in order to prevent movement. The hydraulic ram was connected directly to the load cell with a steel carabineer. On the other side of the load cell there was a second steel carabineer that was attached to 30 feet of 8mm rope that was tied with a double fisherman's knot to make a complete circle and then basketed around the base of the juniper tree. The load cell was zeroed and then set to record the peak forces that the ram was pulling on the juniper tree. Blankets were placed over chains and rope in case of failure. The pull testing was conducted as a slow pull test and was terminated under two conditions. First, if the tree was uprooted by the forced and second, if the load cell was pulled to a max of 20kN or 4500lbs. Once the pull testing for each subject had been completed, peak forces were documented. In similar research performed by Weber (2010), he states that, "If an anchor can be affixed to a tree at a point on the trunk no higher off the ground than a distance equal to the tree's diameter, then the trunk diameter at that point should be no less than 6.5 inches (16.5 centimeters)". In our research we attempted to keep the anchor system as close to the base of the tree as possible in order to prevent torque (1-2 inches). Based on Weber's observations and recommendations we began our pull testing on trees with approximately 6-inch base diameters.

Results

A positive relationship between the base diameters of one seed junipers and their points of failure when loaded parallel to the ground, nearest to the base of the tree, are displayed in the graph below. The linear equation of this graph shows a positive relationship between these two factors (y=711.74x). As depicted by the results of this research, a rescuer, climber, or anyone attempting to use a one-seed juniper as a reliable anchor can use this research. Our results were generated in a dry desert environment. Those who would like to use these results for personal and reliable use should be cognizant that environments and soil conditions can cause major differences in the strength and reliability of one-seed juniper trees. It should also be noted that these results were generated using slow pull testing. The physics of a dynamic event can generate very high forces in a very short amount of time. This graph should not be used to calculate the strength of a one seed juniper in a dynamic event.

Conclusion

Based on our results, the following recommendations can be made: 1.) The one-seed juniper tree being used as an anchor should be at least 6.5 inches in base diameter in order to withstand a 20kN load. 2.) The anchor cords/webbing should be attached as close to the ground as possible but no higher than 6 inches from the base of the tree to prevent leveraging. 3.) The equation 700x, where x is the base diameter (in.) of the tree, can be used to estimate the peak load bearing strength in lbs. of the one seed juniper in slow pull testing scenarios.



26-Apr-14: Tijeras, NM, Weather: 66F Light Wind, Overcast, Soil: Dry, Loose, Fine Dirt, Anchor Type: Basket 30ft 8mm

Test #	*Base Diameter (in.)*	*Base Circumference (in.)*	*Height of Anchor from base (in.)*	*lbs. at Failure*	*Comments*
1	7.006369427	22	1 in.	3606	Hydraulic Fluid Reservoir Failure at 3606 lbs.

9-May-14: Tijeras, NM, Weather: 70F, No Wind, Sunny, Soil: Dry, Loose, Fine Dirt, Anchor Type: Basket 30ft 8mm

Test #	*Base Diameter (in.)*	*Base Circumference (in.)*	*Height of Anchor from base (in.)*	*lbs. at Failure*	*Comments*
2	4.617834395	14.5	1	4014	no movement
3	3.662420382	11.5	1	About 2000	Peak Force not set on Load Cell DON'T USE. Pulled over
4	3.901273885	12.25	1	2453	Pulled tree over with leverage. Sheered bark. Did not uproot.
5	3.662420382	11.5	1	1989	Pulled tree over with leverage. Sheered bark. Did not uproot.
6	4.777070064	15	1	4158	Ram did not have any throw left. Tree bent ~10 degrees. Did not uproot/sheer
7	5.25477707	16.5	1	4529	Tree bent slightly but no sign of failure, bark sheering or uprooting.
8	4.458598726	14	1	4458	tree uprooting after bending and bark sheered
9	5.095541401	16	1	3873	Tree up rooted. Mild bark sheer.
10	3.821656051	12	1	1877	tree bent, then uprooted, bark sheer
11	7.006369427	22	2	3872	No movement from tree. Soil around base began to crack. Truck Anchor began sliding in dirt towards tree.
12	5.732484076	18	1	1718	Carabiner from chain to hydraulic ram broke. **Excluded*
13	6.050955414	19	1	4087	No movement from tree. Truck began sliding in dirt. No failure.

Future Research

Upon completion of this research we would like to encourage and promote further pull testing of commonly used trees as reliable anchors. We would also like to continue this research by testing dynamic loads and a more specifically a one meter fall on three meters of rope to test the BCCTR standard. Because these tests were done in a controlled setting and there were no dynamic forces exerted, we cannot fully legitimize how the integrity of the one-seed juniper would hold in real world scenarios. Please use these results as a guideline and not as a standard. When in doubt it would be wise to use a back-tie to reinforce the strength of your anchors.

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