Evaluating the strength and stretch of Orange Honeysuckle (*Lonicera ciliosa*)

Tegan Schellenberg and Keely Hammond

Science One Program

University of British Columbia

Vancouver, Canada

April 2011

Abstract:

Orange Honeysuckle (*Lonicera ciliosa*) vines were supposedly used to build suspension bridges by indigenous groups in British Columbia (Turner, 1990; Moerman, 1998). To verify the possibility of this claim, we measured the strength and stretch of Orange Honeysuckle vines. The strength was measured until breaking point for various vine diameters, and the stretch was measured at known intervals of mass addition up to 6.2 kg. From the stretch measurements, the Young's modulus was determined and found to be smaller than that of conventional building materials. Overall, the strength and stretch found would be sufficient for the construction of suspension bridges based on the well-documented bridge-building method of the Incas of South America.

Introduction:

Lonicera ciliosa, commonly known as Orange Honeysuckle, is a vine native to the southern parts of British Columbia (Turner, 1998). It climbs on trees or other materials, growing to heights of six metres (Turner, 1997). The vine itself is generally quite slender and malleable although woody in appearance (Turner, 1997; Turner, 1998). The flowers are easily recognisable with a trumpet shape and orange colour (Turner, 1997). As the plants are native to British Columbia, they were incorporated into the lives of BC First Nations in various ways.

The recorded uses for honeysuckle by these groups range from medicine to basket weaving, however, one of its most interesting uses is in the construction of suspension bridges by the Thompson people of BC's southern interior (Turner, 1990; Moerman, 1998). Little is known about the precise bridge design used by the Thompson, so we examine instead the bridge-building of other indigenous cultures to compare with our results. The Incas of South America built similar vine bridges that supported the weight of a horse (approximately 5880 N) and were safe enough so that the horse could fall on all fours and not stumble from the bridge (Wilford, 1999). The Inca suspension bridges were built out of many vines that were braided, woven, then braided again to provide a strong structure (Wilford, 1999).

The bridge design used by the Incas would maximize the strength of the honeysuckle vines, just as it maximized the strength of the vines that the Incas themselves used. First, three major longitudinal supports were made out of the braiding, weaving and braiding again method utilizing a total of 27 vines per major support (Wilford, 1999). These supports provided the base of the bridge, while two smaller vine systems provided the rails (Wilford, 1999). Planks of wood were then lain across the bottom, and vines were attached from the rails to the base to create the walls that would ensure no human or animal could fall from the bridge (Wilford, 1999). As weight was added to the bridge, it would take on a triangular shape, which is the strongest geometric configuration for bridge design (Skipor, [ ]). To test the likelihood that honeysuckle could be used to build a similar structure, we decided to test the strength and the stretch of individual *Lonicera ciliosa* vines of varying diameters.

To determine vine strength, we applied an increasing force to the centre of vine segments until they broke. This measurement was performed on twenty vines of varying diameters, collected from the same type of ecosystem to reduce environmental variation. In general, we found that the vines were able to support an unexpectedly large amount of weight. The apparatus used even had to be adjusted as the vines were stronger than some supporting materials, such as duct tape.

To determine stretch, an increasing force was applied to the end of twenty-one vine segments and the change in length was recorded. In this way, we were able to determine how the addition of weight would affect the vines acting as vertical supports in a suspension bridge. With the data, we were able to calculate Young's modulus for the vines of varying diameter and compare it to conventional building materials.

Methods and Materials:

Lonicera ciliosa vines were collected from two locations and were collected on three days, January 16, 2011, February 6, 2011 and February 25, 2011. The first and third collections were taken from Gonzales Hill, Victoria, BC, in a shaded and moist environment where the vines were growing on *Holodiscus discolor* (Ocean Spray) bushes. The second collection was taken from private property on Bazan Bay Rd. in North Saanich, BC, where the vines grew on *Rubus discolor* (Himalayan Blackberry) and various ornamental shrubs in a shaded, swampy environment. We referenced Pojar and Mackinnon, 1994, and Brayshaw, 1996, to verify the identity of the plants collected.

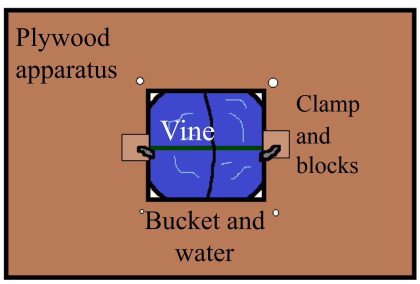

Figure 1. Top view of apparatus configuration for strength measurements.

For the strength measurements, a plywood and clamp apparatus (Figure 1) was used to attach a 30 cm ± 5 cm vine securely across an opening. A gradually increasing downward gravitational force was applied to the centre of the vine. Water was added to a bucket suspended from the centre of the vine, poured from containers holding a known mass of water (770 g ± 20 g per container), to provide downward force. The mass of water per container was determined using a Home Hardware kitchen scale, while a Con Air Consumer Products (Woodbridge, ON) bathroom scale was used to determine the mass of the bucket (450 g ± 20 g). When the vine broke, the total mass of the water and bucket was recorded. Vines of diameters ranging from 2 mm ± 0.2 mm to 5 mm ± 0.2 mm, as measured by Vector (Saint-Laurent, QC) Vernier calipers, were tested for strength.

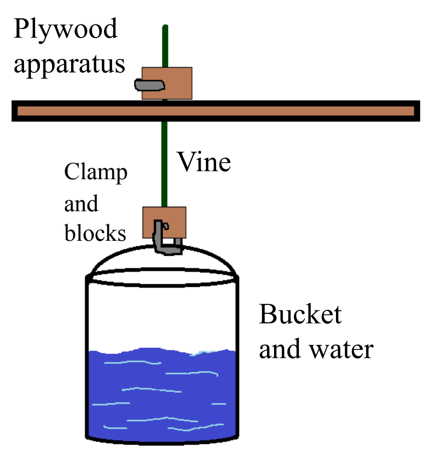

Figure 2. Apparatus configuration for stretch testing.

Following a similar procedure, we determined the Young's modulus (stretch) of vines of varying diameters. For the first eleven measurements, a modified procedure excluding the apparatus shown in Figure 2 was followed, involving one experimenter holding the vine, clamp and bucket system while the other added water and recorded length. This procedure was not feasible over many replicates, as it was too physically demanding for the experimenters. For the remaining measurements, vines of diameters 3 mm ± 0.2 mm to 8 mm ± 0.2 mm were hung from the apparatus of Figure 2, with a metal clamp attaching the bottom portion of the vine to the bucket. A top-loading balance was used to find the mass of the clamp, 318.84 g ± 0.01 g. Using a string, we followed the length of the vine from top clamp to bottom clamp and measured the string using a metre-stick, obtaining the length of the vine. By adding water in seven successive known amounts (770 g ± 20 g per addition) and measuring the length of the vine after each addition, the stretch of each vine was found.

Results:

For strength measurements, twenty vines were tested. Four of these measurements involved desiccated or dead vines and are not included in data analysis. A semi-log plot of breaking force versus diameter linearizes the data, graphed in Figure 3; using least-squares fitting, we determined a model for the strength of the vines,

$$\ln F = 440\,x + 3,$$
$$F(x) = 20\,e^{440\,x},$$

where force F is measured in newtons and diameter x in meters. The slope, 440 1/m ± 120 1/m, describes how quickly the breaking force increases with increasing diameter, and the intercept, 20 N ± 5 N, is the threshold force required to break a vine of a very small diameter.

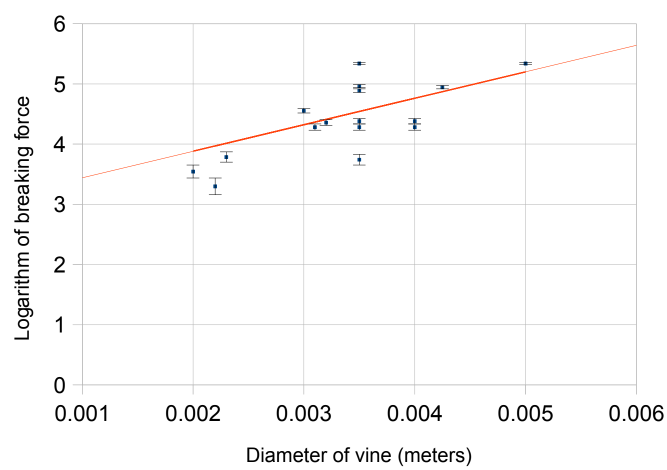

Figure 3. A semi-log plot of horizontal breaking force versus diameter for *Lonicera ciliosa* vines of diameters 2 ± 0.2 mm to 5 mm ± 0.2 mm, n = 16.

The Young's modulus of each vine is calculated based on the stretch of the vine after the application of 59 N, the measured diameter of the vine, and the original, unstretched length of the vine. The Young's modulus describes the fractional increase in length, or strain, of a specific material due to an applied force, indicating how easily the material can be stretched when forces are applied within its elastic limit, meaning the applied force must not be too close to its breaking point (Knight, 2008). Our choice of applied force is appropriate for all vines tested, as it is far from the vertical breaking point. Young's modulus Y is calculated from the relationship

$$Y = \left(\frac{Force}{\text{Area}}\right)\left(\frac{length}{\Delta\, length}\right),$$

where force F is measured in newtons, unstretched length L and change in length ΔL in meters, and cross-sectional area A in square meters. Despite the fact that Young's modulus is corrected for diameter by dividing the force by the cross-sectional area, the modulus values of the vines range from $4.8 \pm 1.1 \times 10^8$ N/m² to $1.8 \pm 2.4 \times 10^8$ N/m², with a trend of increasing Young's modulus with decreasing vine diameter, (correlation coefficient -0.43), as shown in Figure 4. The mean Young's modulus of all replicates is $2.8 \pm 1.9 \times 10^8$ N/m².

Figure 4. Table showing Young's modulus for varying diameters of *Lonicera ciliosa* vines, n = 21.

Vine diameter, millimeters	**Young's modulus, 10^8 N/m²** **(uncertainties are standard deviation)**
3.0 ± 0.2 - 3.4 ± 0.2, n = 7	3.8 ± 1.5
3.5 ± 0.2 - 3.9 ± 0.2, n = 2	4.8 ± 1.1
4.0 ± 0.2 - 4.9 ± 0.2, n = 4	2.0 ± 1.0
5.0 ± 0.2 - 5.9 ± 0.2, n = 3	2.0 ± 1.6
6.0 ± 0.2 - 8.0 ± 0.2, n = 5	1.8 ± 2.4
Mean Young's modulus, n = 21	**2.8 ± 1.9**

Discussion:

The results that we obtained have a large variation; for example, two vines of the same diameter broke under different amounts of force. This variation could arise from the "aliveness" of the vines. The first vines harvested had very little time to come out of their winter dormancy, and as such were presumably more brittle. The vines most recently harvested were more alive and likely more malleable. Other factors could include the general shape of the vine, how twisted it was, and whether or not a joint was present, where thinner branches of the vines split off from a main vine. Often, breaks would occur just to one side of a joint. Other times, the break would occur at one location but the bark would slide off from another. Also, the location of the break for the inner portion of the vine broke was not necessarily the same as where the bark broke.

We found similar variation in the stretch measurements. Again, this would presumably be due to the varying degrees of "aliveness." The bark also had an effect on how accurately the stretch could be measured. The wooden blocks gripped the woody bark more securely than they did for the smooth bark; the wooden block and clamp system was not always able to prevent the bark from separating from the inner portion of the vines. This allowed the vines to slide within the wooden holds and could account for some of the variation.

The vines themselves have a ringed structure, as is characteristic of dicotyledons, plants with a ringed stem arrangement and branching veins (Freeman *et al.* 2011). The centre of the vine is filled with pith, mostly air filled molecules with thin cell walls, which is surrounded by vascular bundles (Texas State, 1999). The vascular bundles themselves are composed of xylem and phloem, which are responsible for the distribution of nutrients throughout the plant (Texas State, 1999). The stretch that we were able to measure would have to be the stretch occurring in the cell walls of these various cell types. Each vine consists of an outer layer called the epidermis, or the woody bark, and the cortex, which is the layer separating the inner vascular bundles from the epidermis (Texas State, 1999). The overall strength of the vines would have to have contributions from both the inner and outer structures. The changing ratio of tissue types may explain the trend of increasing Young's modulus with decreasing vine diameter that we observed, with more bark making the vines less stretchy and increasing their Young's modulus. There is also considerable overlap within the uncertainty ranges of the means for each diameter, meaning the differences between means of each diameter are not very significant. We did notice, however, that it appeared to be the inside of the stems that broke before the outside, suggesting that the epidermis or cortex is the stronger material.

The vine strength for even the thinnest vines was far greater than our expectations. As such, it seems plausible that the vines could be used as a building material for suspension bridges. Considering that there would be a minimum of twenty-seven vines used in each main latitudinal support (Wilford, 1999) multiplying even the smallest force supported by a vine (27 N) by twenty-seven vines is larger than the force of gravity on a human (27 N × 27 vines = 729 N). To support a horse, as the Incas needed, a bridge would have to consist of vines with larger diameters. Even so, it would be easy to obtain the larger vine diameters required for a safe and strong suspension bridge.

In terms of stretch, the calculated mean Young's Modulus, $2.8 \pm 1.9 \times 10^8$ N/m², is smaller than the Young's Modulus of other common building materials such as steel, 2×10^{11} N/m², and wood from a Douglas Fir (*Pseudotsuga menziesii*), 1×10^8 N/m² (Knight, 2008). Having a lower value for Young's Modulus means that honeysuckle has more stretch than typical materials. This could be considered a problem, in that a suspension bridge would stretch under added weight. We did, however, remove water one container at a time from one of the stretch replicates as a "reverse" stretch experiment and found that the vine returned to its original length when the force was removed. However, this was only a single replicate, and from it we can draw no serious conclusions, but we note that the vines must return to their original length after weight is removed in order for vine bridges to be functional. To determine conclusively the effects of stretch, further experimentation would be required.

In order to better understand the behaviour of honeysuckle vines in suspension bridges, it would be necessary to determine the relationship between the addition of another vine and the increase in the amount of force that can be withstood. In this discussion, we assume that relationship to be linear, although that may not be the case. Understanding the stretch as weight is added and as weight is removed would also be beneficial. This would require further replicates of the reverse stretch experiment. To make an even more comprehensive analysis, the relative strengths of a vine braid and a vine weave, or twist, should also be compared. All of these experiments could be done using the same apparatus and equipment as previously described.

Acknowledgements:

We would like to thank Joe Hammond for the construction of our apparatus and the use of building materials, Dianne Pendray for assistance in honeysuckle collection, and Celeste Leander for her mentorship throughout our project. We would also like to thank Dr. Nancy Turner for information on the Thompson First Nation, as well as Shannon LaBelle at the Museum of Anthropology for her assistance, along with other staff members. Finally, a thank-you to Science One for lending us materials and for providing peer review and instruction.

Literature Cited:

Brayshaw, T. C. (1996). Trees and Shrubs of British Columbia. UBC Press, University of British Columbia, Vancouver BC.

Dept. of Energy, USA []. What is the strongest geometrical figure? Retrieved from http://www.newton.dep.anl.gov/newton/askasci/1993/eng/ENG1.HTM on 9 March 2011.

Freeman, S., M. Harrington, and J. Sharp (2011). Biological Science. Pearson Canada, Toronto ON.

Knight, R. D. (2008). Physics for Scientists and Engineers, second edition. Pearson Education, Glenview IL, USA.

Moerman, D. E. (1998). Native American Ethnobotany. Timber Press, Portland OR, USA.

Pojar, J. and A. Mackinnon (1994). Plants of Coastal British Columbia. Lone Pine Publishing, Vancouver BC.

Texas State University (1999). Herbaceous dicot stems. Retrieved from http://www.bio.txstate.edu/~dlemke/botany/1410lab/lab_exercises/lab4/stems/dicotstem.html on 9 March 2011.

Turner, N. J., L. C. Thompson, M. T. Thompson (1990). Thompson Ethnobotany. Royal British Columbia Museum, Victoria BC.

Turner, N. J. (1997). Food Plants of Coastal First Peoples. UBC Press, University of British Columbia, Vancouver BC.

Turner, N. J. (1998). Plant Technology of First Peoples in British Columbia. UBC Press, University of British Columbia, Vancouver BC.

Wilford, J. (1999). The Inca built first suspension bridges. Retrieved from http://www.aaanativearts.com/article1455.html on 9 March 2011.