Evaluating the Use of Plastic Shelters and Steel Cages to Improve Coast Live Oak Growth and Survival in Topanga Canyon and White Oak Farm of Malibu Creek

Part 2 – Long Term Experiment Design

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1 EXECUTIVE SUMMARY

TreePeople would like to determine whether their current practice of installing wire cages and plastic tree shields to protect oak saplings from animal browsing pressures and freezing temperatures is necessary for the successful restoration of coast live oak (*Quercus agrifolia*) and valley oak (*Q. lobata*) in the Santa Monica Mountains. While shelters are often recommended to moderate growing temperatures for tree saplings and reduce above-ground browsing, they can also reduce survival rates by altering the biomass distribution and contributing to heat stress. The long-term effects on the growth rates and morphology of mature native oaks that were planted using tree shelters for the first one to three years are not known. Chen *et al*. (2012) conducted an observational study of temperature effects on native oak restoration plantings at two locations with different temperature regimes in the winter and spring of 2012 that identified a significant greenhouse effect. Mid-day temperatures within tree shelters at Topanga Canyon increased an average of 7.8±0.5°C, at an average ambient temperature of 19.5°C, and at White Oak Farm of Malibu Creek, temperature increased an average of 6.6±0.3°C, at an average ambient temperature of 30.4°C. These temperature increases can create extended periods of high evapotranspirative demand, both daily and annually, which the oaks do not normally experience. Significantly increasing evapotranspirative demand can increase water stress and cause reduced growth rates and greater susceptibility to infection. The same study also observed temperatures within the tree shelters that fell as much as 1.4°C below the ambient temperature at morning ambient low temperatures of 13-14°C, which conflicts with the purpose of preventing freezing low temperatures. All of the trees sampled had survived the installation technique of tree shelter and cage, but while the observational study documented the potential for negative growth conditions created by the tree shelters at both morning low and mid-day high temperatures, the long term impacts on the survival, morphology and resulting reproductive fitness of these planting techniques cannot be predicted. Browsing plays a major role in the survival of planted oak saplings in the Santa Monica Mountains. Above- and below-ground browsing causes root, stem, and leaf damage, which can lead to death; however, there may be a longer-term fitness benefit to exposure to browsing as a sapling. Exposure to browsing from a young age may encourage root growth and establishment over height growth. Because all treatments in the observational study were protected from browsing, browsing effects were not observed (Chen *et al.* 2012).

The experimental study can be monitored every 1-5 years, or as resources allow, for 25-years or more to determine the long-term effects of increased temperature from the tree shelter and browsing exclusion by wire cage or tree shelter. A separate treatment with no cage or shelter will determine if no intervention will result in similar survival rates and more natural growth morphology. The observational study substantiates that tree shelters are likely detrimental to oak trees in the Santa Monica Mountains and that installing wire cages above and below ground to exclude browsing may increase the growth and establishment rates of oak saplings, but all three treatment combinations are of broader significance to oak restoration in southern California.

2 INTRODUCTION

The Forestry Program at TreePeople restores oak woodlands and oak savannas through tree plantings and removal of invasive species. The current management practice for oak plantings utilizes hexagonal wire cages and corrugated plastic tree shelters. The hexagonal wire cages are shaped into a basket and buried in the soil with the closed end facing downwards to protect the seedlings from burrowing fauna. The acorns are planted in the soil within the basket and are surrounded by a 3-foot tall, 4-inch wide cylindrical plastic shelter intended to protect against browsing and freezing temperatures. Currently, nearly all of TreePeople's oak plantings utilize this method, but the effects and pertinence of their use is not known.

In order to address this question, Chen *et al*. (2012) conducted an observational study on existing seedlings planted by TreePeople. Temperature measurements were taken inside and outside the tree shelters and various morphological measurements were taken to determine tree health and growth. Temperature measurements conducted by Chen *et al.* (2012) indicated that tree shelters create a more extreme environment for the trees they enclose. Warm, midday temperatures contributed to mean internal temperature changes of 7.8±0.5°C in Topanga Canyon and 6.6±0.3°C in Malibu Creek, which are consistent with the values found by Costello *et al*. (1991). It can be concluded that with warm ambient temperatures tree shelters contribute to significant internal temperature increases (Costello *et al*. 1991, Devine and Harrington 2008, Jacobs and Steinbeck 2001, Latagne 1995, Oliet and Jacobs 2007). These temperature increases can contribute to longer periods of water stress. Because water availability is a greater concern for plants in semi-arid environments than warm enough growing temperatures, shelters can contribute to decreased growth rates. Chen *et al.* (2012) found that cold, morning ambient temperatures contributed to internal temperatures that wavered slightly above and below the mean ambient temperature, indicating that shelters are unlikely to provide protection from freezing temperatures. The temperature changes created by tree shelters contribute to added stress from hot and cold temperatures and may decrease health and survival rates.

A comparison of the ratio of height to stem diameter in trees at TreePeople's Topanga Canyon site indicated that trees grown in shelters were taller and had narrower stems than trees grown without shelters (Chen *et al*. 2012). Because of the young age of the trees measured, it is difficult to determine whether the biomass distribution will remain the same as the trees grow and age. Because the study only measured preexisting trees, there were often too many variables to account for in the analysis. Consistent with the Chen et al. (2012) study, Tuley (1985), Jacobs and Steinbeck (2001) and Ponder (2003) found that in the first few years, sheltered trees grow more quickly than unsheltered trees. Once tree height reaches that of the shelter, growth rates are comparable to unsheltered trees (Lantagne 1995). Because most studies are conducted over short periods of time, it is unknown whether the short growth spurts experienced in the early stages of sheltered tree growth will have an effect on the trees' morphologies once mature. The long-term experimental study will attempt to bridge the gaps in the existing literature and inform decisions about the use of tree shelters and wire cages.

3 HYPOTHESES

1. During the first three years, trees grown in plastic shelters will have a higher height to stem diameter ratio than trees grown without plastic shelters.
2. After the shelter is removed, the height to stem diameter ratios between different treatments will become more similar, thus demonstrating no long-term effect on height to stem diameter ratio.
3. During the first three years, trees grown in plastic shelters will have a smaller crown area to height ratio than trees grown without plastic shelters.
4. Trees grown only in cages will have higher survival rates than trees grown in plastic shelters or with no browsing protection.

4 METHODS

4.1 STUDY AREA

Because of the significant differences in height to stem diameter ratios observed between sites in the observational study (Chen *et al.* 2012), the experimental study will be limited to one site location to reduce site-specific effects. The experimental study will take place in Malibu Creek State Park. Malibu Creek experiences summer average highs of 36°C (97°F) and lows of 14° C (57° F), and winter average highs of 20° C (68 °F) and lows of 3° C (37 °F) (TWC 2012). The site should consist of well-drained Botella loam soils with 2-9% slope. All areas with Botella loam soils within the vicinity of Malibu Creek State Park are indicated in blue in Figure 4-1. A well-drained soil type was selected based on its selection in previous studies by Chen *et al.* (2012) and Devine, Harrington, and Leonard (2007). Additionally, because these soils have minimal sloping, the site is more homogeneous and there will likely be less environmental variation. Because the determination of soil type in Figure 4-1 is based on the presence of 85% Botella loam, it is advised that TreePeople survey the site to confirm a homogeneous soil type. The site should also be surveyed for similar existing vegetative ground cover throughout so that existing vegetation does not become another variable. The site selected should be at least 6,000-m^2 (approximately 1.48 acres), with a buffer of 15-m between the experimental plantings and the existing tree canopy. These dimensions will allow for enough space to avoid shading and canopy interactions both between existing trees and plantings as well as amongst plantings.

Figure 4-1 Map of sites in Malibu Creek with well-drained Botella loam soils

4.2 Study Design

There will be 60 individuals distributed amongst three treatments, with 20 replicates per treatment group. All trees will be planted from acorns. The following three treatment groups will be used:

- Wire cages
- Wire cages and shelters
- No wire cages and no shelters

4.2.1 Treatment Installation and Distribution

The site should be measured and divided into a regular grid with boxes at least 10-m by 10-m. Groups of three acorns should be planted at the corner of each box and each group should be assigned a number 1-60. Treatment groups have been randomly assigned to a number, 1-60, on the grid in order to randomly distribute them throughout the site (Table 4-1). Samples should be planted as follows:

1. Clear the area of weeds and brush around each planting location.
2. Dig a hole 12-in in diameter and 15-in in depth so it is large enough to contain the wire cage.
3. Insert the cage in the hole for treatments one and two only.
4. Fill and pack down the soil in the hole until the soil is 1-in above the ground.

5. Plant three acorns in each hole. The pointed ends should be facing outwards and the acorns should be covered with enough soil so the hole is 1-in higher than ground level.
6. Install protection from browsing and grazing.
    a. For treatment one, attach a wire cage 3-ft tall with a closed top and open bottom to the lower cage by twisting the wires together.
    b. For treatment two, center a 3-ft plastic tree shelter over the acorns and press it less than ¼-in into the soil. Stabilize the shelter by sticking rebar into the ground and attaching it with zip-ties. A stick or zip-ties should be placed through the top of the shelter to prevent birds from flying in.
7. Create a berm around the tree to create a basin for watering the tree.
8. Add a handful of mulch around the planted acorns.
    a. For treatment two, place the mulch between the shelter and the cage.
9. Fill the basin with 15-gallons of water.
10. Number each tree using an aluminum tag and trees in treatment three should be flagged to ensure they receive the same attention as the other treatments.

Plastic shelters are recommended for removal after three years. TreePeople is entitled to remove the shelters prior to this amount of time as they see fit, as long as all shelters are removed after the same amount of time. Wire cages placed over the seedlings should be removed once tree height reaches the top of the cage.

Table 4-1 Table of the individuals assigned to each treatment type

Treatment 1	Treatment 2	Treatment 3
1	3	5
2	6	9
4	7	12
10	8	15
11	13	19
18	14	24
20	16	25
21	17	29
23	22	30
26	28	35
27	31	36
33	32	38
34	40	41
37	42	44
39	46	45
43	48	47

50	52	49
51	57	53
56	58	54
60	59	55

HOBO Datalogger Installation:

Four data loggers should be randomly distributed amongst the individuals with plastic tree shelters and installed to take continuous temperature measurements both within and immediately outside of the shelters. Running a small wooden stick through the tree shelter and wire cage will provide a way to zip tie the sensors--one on the outside and one inside the tree shelter. The sensors should hang from the wooden stick without touching anything. The outside sensor should be partially shaded to avoid the effects of direct solar radiation. In addition, it is important that the data loggers be installed away from the ground with the rubber bottom facing upwards to protect moisture from seeping into the logger. Refer to Appendix A for a diagram on how to properly position the HOBO data logger. The use of wire cages is recommended to protect both the temperature probes and the HOBO data loggers from animal and other disturbances (Figure 4-2). The HOBO devices can be mounted onto the wire cage using zip ties and should be located on the side closest to the tree shelter to prevent damage from browsing. The data loggers should be set to collect data every minute and deployed according to manufacturer instructions.

Note: HOBO data logger batteries are intended to last for three years of continuous use, but after the first year of use data loggers should be checked monthly to ensure proper battery functioning.

HOBO Installation: Redesign

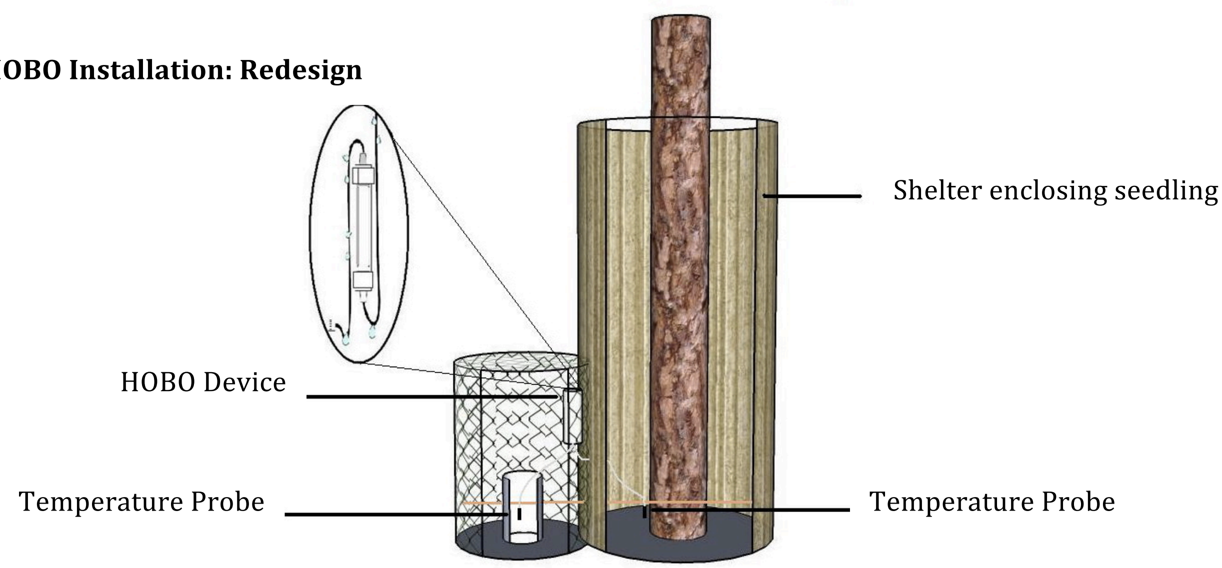

Figure 4-2 **Cutaway view of tree shelter with installed HOBO device**

4.3 DATA COLLECTION

Because trees can be observed throughout all stages of development in the experimental study, survival rates can be monitored and long-term differences in growth indicators between different treatment groups can be determined. This study will use the same metrics to measure tree growth as the study conducted by Chen *et al.* (2012), but some methods have been altered based on shortcomings. Unique to this study is the additional analysis of growth over time; since the experiment will begin when the seedling begins to grow, growth can be continuously monitored over time. It is recommended that the measurements indicated in Table 4-1 be taken at the same time of year at 1, 2, 3, 5, 15, 25, and 50 years of tree age. Temperatures should be measured continuously for four of the sheltered trees until the shelters are removed. Additionally, trees should be checked for survival at least two times a year, in the spring and the fall. See Appendix B for a sample datasheet.

Table 4-2 Table of growth indicators that will be measured and tools needed for each measurement

Measurement	Method	Tool Used for Measurement
Stem Diameter	Use of a digital caliper to measure diameter 5-cm from the ground in small trees and DBH tape to measure diameter at breast height in taller trees	Neiko Stainless Steel 12" Digital Caliper with Digital Screen
Tree Height	Measure the distance between the soil to the highest wooden point of the tree.	Meter stick, PVC pipe, or tape measurement
Crown Width	Measure the width of the crown at the widest point	Meter stick, PVC pipe, or tape measurement
Crown Height	Measure the height of the crown from the base of the bottom branches to the stem apex	Meter stick, PVC pipe, or tape measurement
Branch Measurements	Use of a digital caliper to measure the diameter and length of the 3 longest branches	Neiko Stainless Steel 12" Digital Caliper with Digital Screen, meter stick
Branching Characteristics	The following observations will be recorded: • Direction of branching • The concentration of branching in upper portion of tree • Any signs of constriction of lateral branching based on tree morphology	Not applicable
Dead or Loose Branches	Counting the number of dead or loose branches	Not applicable

Signs of Browsing	Observing if leaves have been noticeably chewed away or are visibly absent	Not applicable
Root Health	The following observations will be recorded: • Oozing from the lower trunk • Dead bark on the trunks or roots • Cracks in the soil near the roots	Not applicable
Temperature	Use of a digital thermometer to take internal and ambient temperatures. Temperatures will be collected in the early morning and midday.	Hanna Instrument HI 98509 Checktemp 1C Thermistor Thermometer with Stainless Steel Probe

4.4 Analysis

Analysis will include the use of statistical methods and comparisons of the relationship between different indicators of tree growth. ANOVA can be used to help determine if there are significant differences between treatments. The study has been designed to meet the four requirements of ANOVA: random sampling, independent measurements/observations, normal distributions, and equal variances. There will also be additional analyses of the relationship between trunk diameter and crown size from collected data using linear regression. Trees that have thin trunks, which are unable to support larger crown sizes, might not be able to support themselves once the tree shelter is removed; this possible linked consequence indicates that the analysis of growth indicators independently is not enough to provide a comprehensive understanding of growth. This relationship can then be compared to survival rates of trees from different treatment groups; this will determine which treatment produces a certain trunk to crown development ratio, and which is the most beneficial for tree survival.

5 Expected Results

The results of this experiment will help guide management decisions about the use of wire cages and plastic shelters. The three treatment groups are sufficient for comparing the current management practice to different cases. Treatment one, with only wire cages, will show how the trees react without the influence of browsing or of being confined in a plastic shelter. Treatment two, with a wire cage and a shelter, will represent the effects of the current management practice. Treatment three serves as the control and allows the trees to grow without the influence of protective devices. A treatment with a plastic shelter, but no cage will not be used because the requirement for additional samples and planting area is being weighed against the loss of power in interpreting the results. While this treatment type would add the dimension of being able to compare the relative benefit of using a cage versus using a tree shelter, the use of tree shelters with no cages is probably not a viable management option and thus is of less concern. By comparing the data obtained from treatment two to treatment one, we can confirm that the effects observed in treatment two are due to the effects of the plastic shelter.

Trees grown in tree shelters tend to grow taller then those grown without, due to the tree's propensity for sunlight (Jacobs and Steinbeck 2001, Ponder 2003, Tuley 1985). Because all of the energy is expended toward upward growth, stem diameter is typically smaller in sheltered trees and trees may be weaker and more susceptible to falling over. As a result, sheltered trees have a higher height to stem diameter ratio compared to trees grown without tree shelters. We expect the height to diameter ratio between samples with a difference in this variable to diverge from the time of planting until the time the shelters are removed. When the shelters are taken off, the restriction that encourages the tree to put all of its energy into upward growth and creates the difference in height to diameter ratios will no longer be in effect. The ratio will begin to converge and there will be no significant difference amongst mature trees of different treatments. We also expect trees grown in tree shelters to have a smaller crown area to height ratio. Space restriction within the tree shelters will result in upward branching. Combined with a tendency to grow larger, this will result in a small crown area to height ratio.

We expect that trees grown only in cages will have higher survival rates than trees grown in plastic shelters or with no browsing protection. Trees in the control group will not be exposed to the detrimental effects of the tree shelters – heat stress and tall, narrow stems – but they are exposed to the effects of above and below ground browsing. In contrast, the treatment group with shelters and cages eliminates browsing in the early stages. Trees may be lost from the water loss caused by heat stress or the vulnerability of the weak stem when the shelter is removed. The treatment with wire cages eliminates the effects of browsing when the trees are young without creating heat stress, while allowing the trees to develop a lower height to stem diameter ratio. Additionally, because the trees will be exposed to wind, the stems will develop stronger stems.

The results of the proposed experiment will advise TreePeople's decisions regarding the use of wire cages and plastic shelters. If the final results are as predicted, we can advise that TreePeople consider switching to the use of wire cages above and below the soil instead of using plastic shelters.

6 REFERENCES

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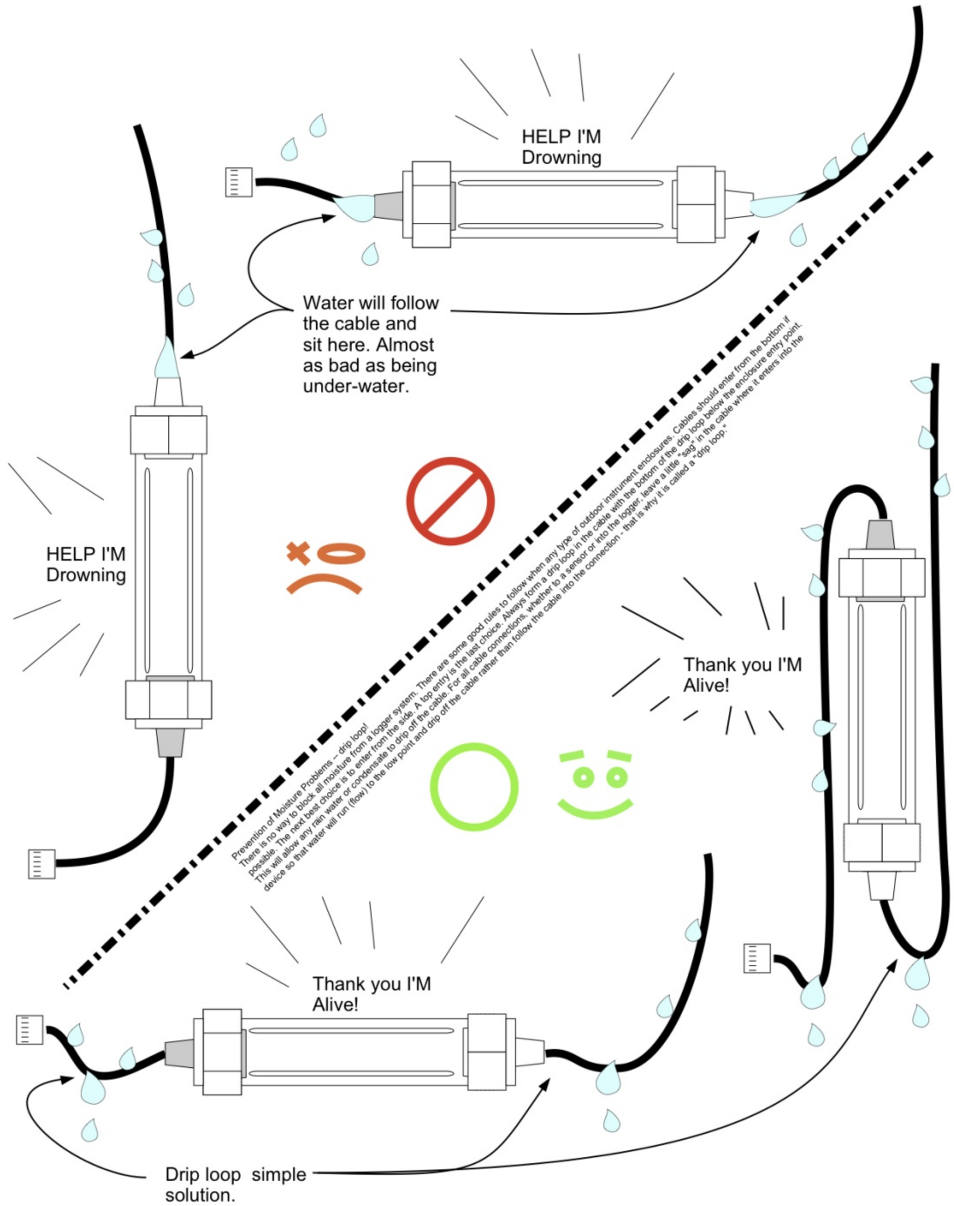
PREVENTING MOISTURE PROBLEMS IN HOBO DEVICES



Prevention of Moisture Problems – Drip Loop. Cartoon. Data Loggers: HOBO® Data Logger Products by Onset. 20 May 2012. http://www.onsetcomp.com/

APPENDIX B

DATA COLLECTION SHEET

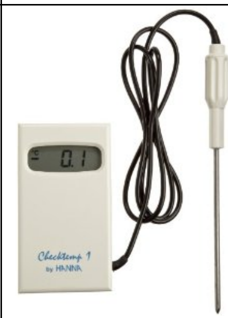
Date and Time:______________________
Tree ID:____________________________
Coordinates:________________________
Treatment Type (circle one):
(1)Cage, (2)Shelter + cage, (3)control
Temperature, trees with plastic shelters only
Inside:________ Ambient:________
Stem Diameter (mm):_________________
Tree Height (cm):____________________
Crown Width (cm):___________________
Crown Height (cm):__________________
Branch Diameter, 3 longest branches (mm)
1._________ 2._________ 3._________
Branch Length, 3 longest branches (mm)
1._________ 2._________ 3._________
Branching Characteristics, i.e. vertical, horizontal, etc. ____________________
Dead or Loose Branches: **Y / N**
Oozing Roots: **Y / N**
Cracked Soil: **Y / N**
Signs of Browsing: **Y / N**
Additional comments or observations:
____
____

Collector's Initials: ___________

Date and Time: _____________________
Tree ID:___________________________
Coordinates:________________________
Treatment Type (circle one):
(1)Cage, (2)Shelter + cage, (3)control
Temperature, trees with plastic shelters only
Inside:________ Ambient:________
Stem Diameter (mm):_________________
Tree Height (cm):____________________
Crown Width (cm):___________________
Crown Height (cm):__________________
Branch Diameter, 3 longest branches (mm)
1._________ 2._________ 3._________
Branch Length, 3 longest branches (mm)
1._________ 2._________ 3._________
Branching Characteristics, i.e. vertical, horizontal, etc. ____________________
Dead or Loose Branches: **Y / N**
Oozing Roots: **Y / N**
Cracked Soil: **Y / N**
Signs of Browsing: **Y / N**
Additional comments or observations:
____
____

Collector's Initials: ___________

BUDGET

Item	Cost	Website or Location	Image
Checktemp Thermistor Thermometer	$33.30 + $0 SH	http://www.amazon.com/Hanna-Instruments-Checktemp-Thermistor-Thermometer/dp/B002NX0VS8/ref=sr_	
12" Caliper	35.39 + $0 SH	http://www.amazon.com/Neiko-Stainless-Steel-Digital-Caliper/dp/B000EJUBBU/ref=tag_dpp_lp_edpp_ttl_in	
Meter stick (w/mm)	$6.95 + $0 SH	http://www.amazon.com/Westcott-Wooden-Meter-Stick-Brass/dp/B001BQZ2VY/ref=sr_1_1?ie=UTF8&qid=1330253336&sr=8-1	
100 Aluminum Tags w/ Numbers	$11.50 + $11.72 SH	http://www.cspforestry.com/Racetrack_Shaped_Aluminum_Tags_p/racetracktag.htm	
2-feet PVC Pipe (3/4inc)	$2.17	Home Depot	
HOBO Pro v2 2x External Temperature Data Loggers	$163 + $14 SH	http://www.onsetcomp.com/products/data-loggers/u23-003