

A. Project Title

Silviculture of the American Chestnut in the Cumberland Uplands of Tennessee

B. Summary

We request funds to continue and expand our study of American chestnut (*Castanea dentata* (Marshall) Borkhausen) seedlings in different sized canopy gaps at three sites in the Cumberland Uplands of Tennessee. Canopy gaps are breaks in the forest canopy that increase light availability; they might be used for seedling establishment in restoration efforts. Over the 2019 and 2020 growing seasons, we will compare the growth of saplings, including newly established trees, in 35 canopy gaps of various sizes. In April 2019, we measured the preseason height and crown diameter of the seedlings and will measure again in fall 2019 and spring 2020. A fall 2019 planting is planned for one of the sites that will expand the number of replications from three to six. Hemispherical photography will characterize the canopy gaps by percent canopy openness.

C. Principal Investigators and Institutional Affiliations

Dr. J. Hill Craddock

Hannah Crawford

University of Tennessee at Chattanooga

Department of Biology, Geology, and Environmental Science

D. Duration of Project

October 2019 – October 2020

E. Total Amount Requested

\$4112.53

F. Short- and Long-Term Goals of the Project

The short-term goal is to evaluate the effects of canopy gap size on the growth rate of *Castanea dentata* hybrid seedlings on three sites in the Cumberland Uplands of Tennessee. The long-term goal is to determine the silvicultural requirements for *C. dentata* hybrids for reintroduction to canopy gaps in forest environments. We hope, through this project, to forge a lasting partnership

between UTC, TACF and the Cumberland Trail State Park, a major stakeholder in the region that controls much habitat suited for American chestnut reintroductions.

G. Narrative

Introduction. American chestnut (*Castanea dentata* (Marshall) Borkhausen) populations in North America have been reduced to non-flowering shrubs in response to the introduced ascomycete fungus *Cryphonectria parasitica* Barr; they may be functionally extinct (Anagnostakis 1987, Roan et al. 1986). Light availability is probably the most limiting factor to growth and reproductive success of *C. dentata* in a forest ecosystem (Paillet 2002). Chestnut trees will only bloom in full sunlight, so they need to reach the forest canopy to reproduce. Light gaps are breaks in the forest canopy. They increase light availability for seedling establishment and growth and allow young trees to reach the forest canopy. Before the blight, *C. dentata* could take advantage of natural disturbances in the canopy such as those caused by windthrows or fire (Ashe 1911). Artificial and existing canopy gaps can be used for *C. dentata* seedling establishment and may encourage flowering in existing trees for restoration efforts. The lack of blight resistant planting material has limited what is known about the silvicultural requirements of *C. dentata*, including establishment in light gaps. The American Chestnut Foundation (TACF) has developed chestnut blight resistant hybrids, primarily through a program of backcross breeding begun in the 1980s (Hebard 2012). Large scale progeny tests of advanced TACF hybrids under forest conditions were begun only relatively recently (Clark et al. 2011).

Gaps. The size and structure of a canopy gap influence the seedlings beneath by affecting the wind, radiation, air temperature, atmospheric moisture, intercepted precipitation, soil temperature, and soil moisture. Canopy structure is the composition of above ground plant material. The radiation, or light, allowed through the canopy gap and surrounding canopy can be used for photosynthesis by seedlings as well as provide an indirect measurement of canopy cover within a gap (Percy 1991, Norman and Campbell 1991). Literature is not conclusive on the light requirements of *C. dentata* (Ashe 1911, Joesting et al. 2009, Wang et al. 2006). Seedlings and sprouts can grow slowly in the deep shade of the canopy and then assume rapid growth in light. However, seedling growth might be stunted in prolonged low light levels. Having characteristics of a shade tolerant and intolerant species, American chestnut can be classified to have intermediate shade tolerance (Ashe 1911, Joesting et al. 2009). However, Wang and his

colleagues (2006) found that they have a relatively low light saturation and compensation point compared to other eastern trees, which suggests they are shade tolerant.

The Plateau and Highland Rim Ecoregions. The Cumberland Highlands in Tennessee are tablelands of Pennsylvanian sandstone at about 1800 feet elevation and are one of the historical habitats of *C. dentata* (Schibig et al. 2006). Before the blight, *C. dentata* composed 15% of forest trees on the Cumberland Plateau and 20% of the forest in the Highland Rim. The tree clung to coves and north facing hills with deep and sandy soils (Ashe 1911). Even though the Cumberlands did not host the most abundant stands of chestnut, chestnut survival is higher in coves and northward slopes making the Cumberland Highlands an ideal location for reintroductions (Griffin 1991). The Justin P. Wilson Cumberland Trail State Park is a state scenic trail that runs from the Cumberland Gap to Prentice Cooper State Forest. The Park is currently being built and will have over 300 miles of trail upon completion. This park follows the eastern escarpment of the Cumberland Plateau in Tennessee, an important restoration area. The park's scenic trail crosses numerous state-designated natural areas and land owned by Tennessee Wildlife Resources Agency and the National Park Service. This study creates a lasting partnership between UTC, TACF, and Cumberland Trail State Park with the establishment of a chestnut seed orchard at Barker Pounds trailhead. The park staff are enthusiastic about *C. dentata* introduction on the State Park property for the current project and for future projects as well.

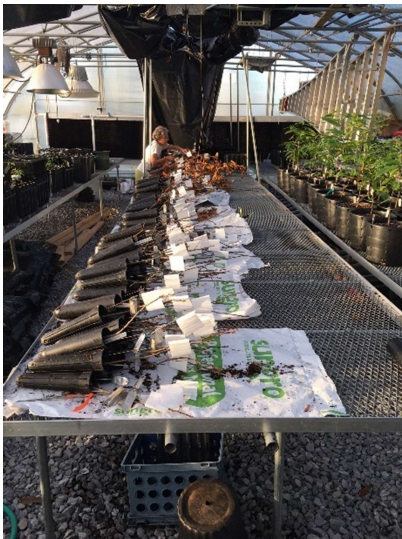
Work already accomplished. Gap studies were begun within the past few years by volunteers of the Tennessee Chapter of the TACF at two locations: the private conservation easement at Eagle Point Railroad near Dunlap (Sequatchie County, Cumberland Plateau); and on the private property of Rogers Starr near Manchester (Coffee County; Eastern Highland Rim). We have created a new site for a gap study near Barker Pounds trailhead at North Chickamauga Creek Gorge State Natural Area, which is managed by Justin P. Wilson Cumberland Trail State Park (Sequatchie County; Cumberland Plateau).

We studied the survival and growth of TACF seedlings in 35 various sized light gaps in the Cumberland Uplands during the 2019 season. We have and will continue to measure height and root collar diameter of the saplings (Rhodes et al. 2009). We measured pre-season height and diameter at each site in April/May 2019. The seedlings will be measured again in fall 2019 to capture a season of growth, and again in early April 2020 to observe survivorship. Qualities such as presence of blight have been and will be noted (Rhodes et al. 2009).

Eagle Point Railroad. At Eagle Point Railroad, we are studying 352 Chinese, American (transplants and native sprouts), F1, B3F2, and B3F3 trees in 18 light gaps. Trees were planted between 2013 and 2018 in gaps that were created for the purpose of a genotype x environment experiment (Tom Saielli, personal communication). Trees in the smaller plots were planted in a haphazard fashion, the trees in the one largest plot were planted in a randomized complete block design.

Rogers Starr's property. At our Highland Rim site, we are studying 62 American, B3F2, and B3F3 trees in 8 light gaps created and planted by Rogers Starr 2014 to 2019.

Barker Pounds. At our new Plateau site, we planted the seedlings in May 2019. We are studying 225 B3F2 trees in 9 light gaps: 3 each of small, medium, and large (open field) gaps. The seedlings are open pollinated third-backcross hybrids (B3 x opB3). The seedlings were dormant, in D40 containers, overwintered at 2-3 C in the cooler at the UTC Chestnut Research Greenhouse. We used a randomized complete block experimental design. In each plot, we planted the seedlings 1.2 m apart in 4.9 m x 4.9 m plots of 25 trees each, oriented north to south. Each tree's position within the plot was determined by a random number generator in Exel. These plots were plowed with a fireline dozer and fertilized with a tablespoon of Osmocote.



Left: The seedlings were given a metal tag stating the position of the tree and organized into plots the day before planting at Barker Pounds. Right: This seedling was growing in a small light gap at Barker Pounds, July 5th, 2019.

Work Proposed. Canopy gaps can be difficult to characterize because of the various structure and composition of the trees surrounding a light gap. Slope limits light availability as

well. Canopy gaps even of the same size will not allow the same amount of light to penetrate the canopy. We will measure canopy openness, which is the measure of diffuse light. Hemispherical photography has become a commonly accepted method to determine canopy openness (Norman and Campbell 1989, Saielli et al. 2014). Multiple photos will be taken of each light gap using a Nikon D750 SLR camera and a Sigma 4.5 f/2.8 EX DC HSM Circular Fisheye lens. Photos will be taken on overcast days in late August and September 2019. The camera will be leveled one meter above the ground. North will be oriented to the top of the photo. Gap Light Analyzer 2.0 will gage canopy openness by converting the photo to black and white pixels. Black pixels represent the canopy and white pixels represent the sky (Saielli et al. 2014). Canopy openness will be used in this study to characterize the light gaps and be use study seedling growth rate. We will return to each site in August/September 2019 to take hemispherical photos.

In October/November 2019, we will visit each site to measure height and root crown diameter to capture the end-of-season growth for 2019. This will likely require 2 trips each to Barker Pounds and the private property of Rogers Starr and 8 trips to Barker Pounds trailhead.

In November 2019, we will return to Barker Pounds trailhead for a fall planting to increase the number of replications from three to six.

In March/April 2019, we will return to all sites to make observations on survival. At Barker Pounds, we will make preseason measurements on the newly established seedlings.

Tree measurements will be analyzed using ANOVA, comparing the effects of canopy openness and genetic family on the measured variables; height and crown diameter. Canopy openness will be analyzed using Dunnet's test for significant differences compared to a closed canopy (Gendreau-Berthiaume and Kneeshaw 2009). We hypothesize that a medium gap size will encourage the greatest survival and growth among seedlings.

The present study is part of Hannah Crawford's undergraduate departmental honors thesis; it will characterize light gaps and their effect on *C. dentata* seedlings at different life stages in forest habitats at sites in the Cumberland Plateau and Eastern Highland Rim. The results will help define the silvicultural requirements for *C. dentata* in the forests of the Cumberland Highlands. The results may also be applied to American chestnut restoration programs in the unique soils, climate, and flora of these Tennessee biogeographic regions.

References:

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Shibig J, Vance M, Cumming S, Fly L, Neel C, Torkelson J. (2006) Ecology of the American chestnut and Allegheny chinquapin on the Cumberland Plateau of Kentucky and Tennessee. *Journal of the American Chestnut Foundation* 20(2): 44-50.

Wang GG, Bauerle WL, Mudder BT. (2006) Effects of light acclimation on the photosynthesis, growth, and biomass allocation in American chestnut (*Castanea dentata*) seedlings. *Forest Ecology and Management* 226: 173-180.

H. Timeline

April – May 2019

Establish 9 plots at Barker Pounds. Measure preseason height and diameter at Barker Pounds, Rogers Starr's property, and Eagle Point Railroad. – COMPLETED

August - September 2019

Take hemispherical photos for each plot at Barker Pounds, Rogers Starr's property, and Eagle Point Railroad. Note soil characteristics.

October – November 2019

Measure end-of-season diameter and height at Barker Pounds, Rogers Starr's property, and Eagle Point Railroad.

November 2019

Planting trip to Barker Pounds trailhead. Measure height and diameter of saplings at Barker Pounds trailhead.

December 2019 – March 2020

Use Gap Light Analyzer 2.0 to calculate canopy openness for each plot. Analyze growth rate and canopy openness using ANOVA.

April 2020

Check for survivorship at the Barker Pounds, Rogers Starr's property, and Eagle Point Railroad.

March – October 2020

Prepare manuscript. Analyze survivorship using ANOVA.

I. How results will be measured and reported

Results will be submitted to TACF at the end of the study. We hope to present the results at the UTC Research Dialogs and a regional or national-level science meeting (such as the Annual Meeting of The American Chestnut Foundation or another forestry journal).

J. Breakdown of how and when funds will be spent

We request \$4112.53 for the current study. The mileage in the budget considers the cost of travel to the sites in October/ November for end-of-season measurements and early April for survivorship. Based on Spring 2019’s data collection trips, Barker Pounds and Rogers Starr’s property will likely require 2 trips each. Eagle Point Railroad will require about 8 trips. Additionally, we will travel to Barker Pounds trailhead to plant in November. The distance is calculated starting at University of Tennessee Chattanooga and the reimbursement is based on the university mileage rate. The mileage is calculated in the chart below.

Mileage for Current Proposal							
	miles/round trip from UTC	trips required to measure trees	Fall 2019 measuring trip	Spring 2019 measuring trip	Fall 2019 planting trip	trips required to plant trees	total mileage per site
Barker Pounds	62	2	yes	yes	yes	4	496
Eagle Point Railroad	103	8	yes	yes	no	NA	1648
Rogers Starr's Property	168	2	yes	yes	no	NA	672
						Total mileage	2816
						University Mileage Reimbursement Rate	47 c/mile
						Mileage Reimbursement Requested	\$1,323.52

The UTC Undergraduate Student salary is based on comparable UTC undergraduate research assistant salary of \$9.00 per hour at 10 hours a week for 30 weeks. The salary will support an undergraduate student, Hannah Crawford, on work including measuring the seedlings at the three sites, planting trees at Barker Pounds and the greenhouse prep required, processing the hemispherical photos, data analysis, and report preparation. The research poster will be used at the UTC Research Dialogs and other science meetings.

Dr. Craddock funded the purchase of the hemispherical camera and lens through his own research money. Mileage for spring 2019 measurements and fall 2019 hemispherical photos were paid for by the student.

Budget	
Mileage	\$1323.52
UTC Undergraduate Student Salary	\$2700
Research Poster	\$89
Total	\$4112.53

K. Brief Curriculum Vitae for each Principal Investigator

Hannah Crawford

Undergraduate Student

Education

University of Tennessee Chattanooga, 2015 – current, Major: B. S. Environmental Science: Biodiversity, Conservation, and Natural Resources, Minor: Biology and Spanish, GPA 3.9
 Cookeville High School, 2015, Honors High School Diploma, Cookeville, TN

Educational Experience

Individual study in UTC Chestnut Research Greenhouse, Plant Taxonomy, Plant Ecology, Dendrology, Mycology, Maps and Mapping, Quantitative Analysis, Evolution, Genetics, Ecology.

Awards and Distinctions

2019 The Tucker Foundation Endowed Honors College Scholarship in Biology and Environmental Science

2019 Accepted Departmental Honors Thesis Proposal – Silvicultural of the American Chestnut in the Cumberland Uplands of Tennessee

2015 - 2019 Dean's List

Experience

Seasonal Interpretive Ranger, Cumberland Trail State Park, Pikeville, TN (Summer 2019)

Undergraduate Research Assistant in Plant Specimen Mounting, UTC, Chattanooga, TN (December 2018 – current)

Middle School Intern, First Presbyterian Church, Chattanooga, TN (2017 - current)
Counselor-in-Training Director, Cedar Lake Camp, Livingston, TN (Summer 2018)
Lifeguard, Chattanooga Downtown YMCA, Chattanooga, TN (2016 - 2017)
Chemistry Laboratory Assistant, UTC, Chattanooga, TN (Spring 2016)

J. Hill Craddock

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Education

Università di Torino, 1992, Dott. Ric. Promology, Turin, Italy
Oregon State University, 1987, M.S. Horticulture, Corvallis, OR
Indiana University, 1983, B. A. Biology and Fine Arts, Bloomington, IN

Positions Held

2008 – present: Professor, University of Tennessee at Chattanooga
1999 – 2007: Associate Professor, University of Tennessee at Chattanooga
1996 – 1998: Assistant Professor, University of Tennessee at Chattanooga
1994 – 1996: Postdoctoral Research Associate, Tennessee State University
1993 – 1994: Postdoctoral Fellow, Università di Torino
1989 – 1992: Graduate Research Assistant, Università di Torino
1984 – 1987: Res. Assistant, USDA-ARS National Clonal Germplasm Repository

Publications

Sisco, P.H., Neel, T.C., Hebard, F.V., Craddock, J.H. and Shaw, J. (2014) Cytoplasmic male sterility in interspecific hybrids between American and Asian *Castanea* species is correlated with the American D chloroplast haplotype. *Acta Hort.* 1019:215-222.

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- Perkins, M.T. and Craddock, J.H. (2012) The Effect of Phosphite on Mycorrhiza Formation in Chinese-American Hybrid Chestnuts (abstract). Page 33 in: Proc. 2012 American Chestnut Summit, USDA Forest Service and The American Chestnut Foundation, Oct. 19-21, 2012, Asheville, NC.
- Harris, A., Shaw, J., and Craddock, J.H. (2012) A Floral Survey and Census of American Chestnut at Bendabout Farm, Bradley County, Tennessee (abstract). Page 21 in: Proc. 2012 American Chestnut Summit, USDA Forest Service and The American Chestnut Foundation, Oct. 19-21, 2012, Asheville, NC.

Grants Received:

2015. American Chestnut Foundation external grants program award to partially fund the Craddock lab's research on *Phytophthora* resistance in chestnut (with M. Taylor Perkins)

2017 and 2018. American Chestnut Foundation external grants program award to partially fund the Craddock lab's research on conservation and collection of *Castanea* germplasm in the Southeast (with Trent Deason).

L. Conflict of Interest

Craddock is on the Board of Directors of TACF and sits on the External Grants Review Committee. He will recuse himself from review of this proposal.