a. Project title

Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau

b. Summary (100 word cap)

This study is following the establishment success of BC_3F_3 hybrid American chestnut seed and seedlings planted following each of the three cuts of the three-stage shelterwood sequence commonly used to regenerate oak on the Allegheny plateau of western Pennsylvania. The results of this study will help refine our understanding of the growth, survival, and competitive ability of chestnut planted across a gradient of light and competition intensities. This information will help managers incorporate chestnut reintroduction into oak regeneration management activities.

c. Principal Investigators and Institutional Affiliations

Cornelia (Leila) Pinchot
Research Ecologist
Northern Research Station
USDA Forest Service

Scott Tepke
Forester – Certified Silviculturist
Allegheny National Forest
USDA Forest Service

Scott E. Schlarbaum
Professor and Director
Department of Forestry, Wildlife & Fisheries
The University of Tennessee, Knoxville

d. Duration of project

Early results from this study will be produced by year three, however we plan to follow the study for 10+ years.

e. Total amount requested

We requested and received a total of $1,650 for year one and $5,200 for year two. In this proposal, we request $3,055 for year three.

f. Short and long-term goals:

- **Short term (3 years):** compare the early survival and growth of BC_3F_3 chestnuts planted as seeds and seedlings across three silvicultural treatments.

- **Long-term (10 years):** evaluate the effects of biotic (competing vegetation, seedling quality) and abiotic (available light) factors on long-term chestnut survival, growth, and competitive ability. Evaluate success of chestnuts planted as seeds vs. seedlings. Develop practical guidelines for reintroducing American chestnut to oak-hickory stands in the Allegheny Plateau.

g. Narrative:

Managers on the Allegheny National Forest are eagerly anticipating the availability of blight-resistant chestnut seedlings for reintroduction onto the Forest. Incorporating American chestnut restoration into management strategies for more expansive management goals such as oak regeneration will give foresters more flexibility in planning chestnut reintroduction. This spring we established a study to evaluate the long-term growth and survival of hybrid American chestnut seed and seedlings planted in each stage of the three-stage shelterwood system used to regenerate oak.

While much of the Allegheny National Forest (ANF) is comprised of northern hardwood forest stands, oak-hickory forest communities are found on dry slopes and ridges in the southern parts of the forest (Braun 1950). American chestnut historically was found in these forests; Braun (1950) notes that chestnut comprised between 4.4 and 11.2 percent of canopy trees located on study sites in Clarion and Forest counties, PA. Merging chestnut reintroduction with other forest management goals will help National Forests make the most use of their limited resources, which will ultimately lead to increased efforts for chestnut restoration. Regenerating oak in oak-hickory forests throughout much of Pennsylvania has become increasingly challenging due to various factors including increased deer populations and associated browsing of seedlings. With the goal of increasing oak regeneration, a three-stage shelterwood system has become the predominant silvicultural tool in oak-hickory forests on the ANF. The shelterwood system involves a preparatory cut (prep-cut) from below in a fully-stocked stand with intact canopy in order to reduce the stand to approximately 70 percent relative density. The purpose of this cut is to increase light availability for acorns to germinate and become established, while discouraging fast-growing shade-intolerant species. Once the oak regeneration on site has developed a root collar of one-quarter inch in diameter, on average, the site is ready for the shelterwood seed cut, which will leave about 50 percent relative density. This cut serves to increase the light available to developing oak seedlings, now large enough to compete with shade intolerant regeneration that became established in response to the prep-cut. Finally, once oak-seedlings are three feet in height on average, the removal cut will occur, removing most of the residual trees and releasing the developed regeneration to full sunlight. At this point the established oak seedlings have a very good chance of growing into dominant canopy positions. The entire three-stage sequence takes approximately fifteen to twenty years to complete.

This three-stage shelterwood system was developed for oak seedlings which, in general, are intermediate in their tolerance of shade (Burns and Honkala 1990). American chestnut is

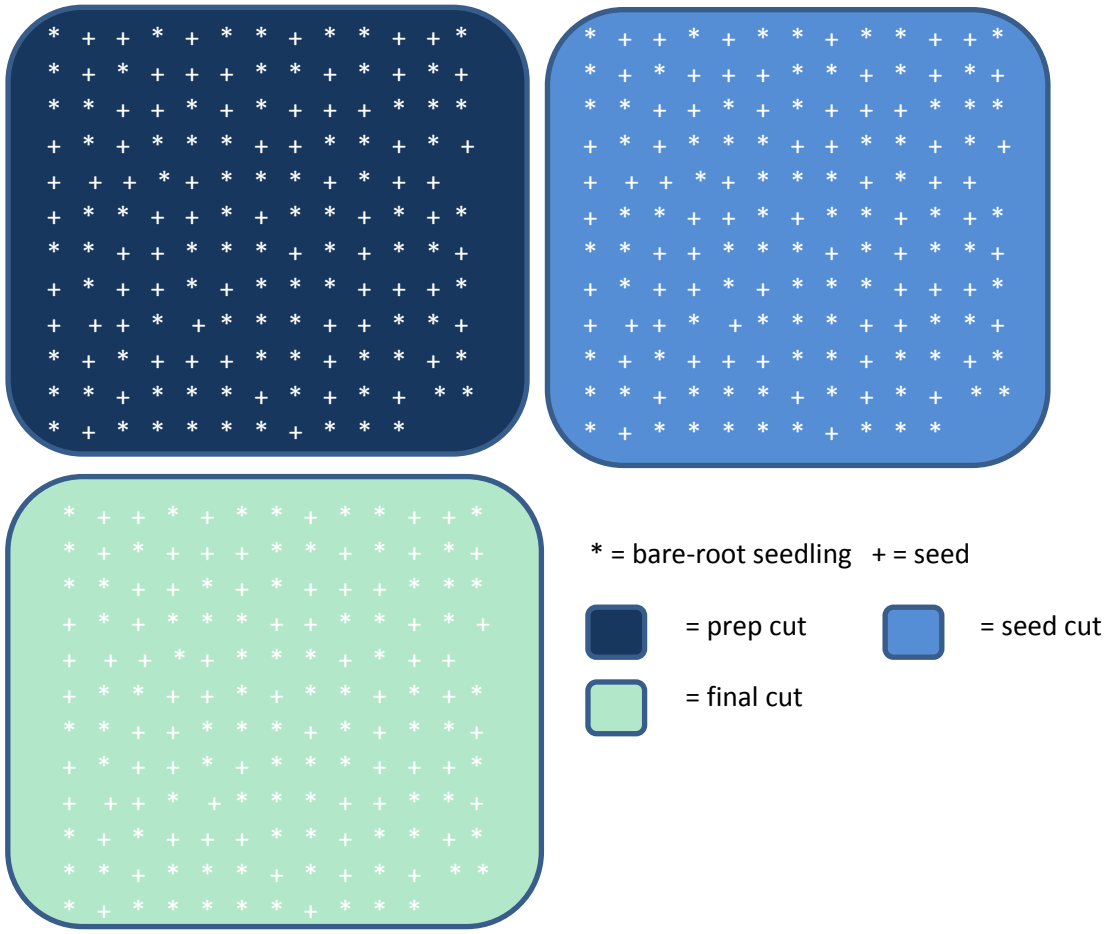
categorized as shade tolerant (*c.f.* Wang et al. 2013), and can survive for long periods of time in shade (Ashe 1911, Paillet, 1984). Several recent studies have evaluated the establishment success of American and hybrid chestnut seedlings planted under various silvicultural treatments. Three studies compare chestnut establishment in midstory removal treatments to various shelterwood systems leaving residual relative density of between 23 and 35 percent (Rhoades et al. 2009; Clark et al. 2012; Pinchot et al. 2017). These studies found that chestnut seedlings growing in shelterwood harvests added substantially more height and diameter growth than those in harvests with less light, while early survival (two to five years after planting) was not affected by light level. No studies that we are aware of have evaluated the ability of bare-root seedling or direct-seeded chestnuts to survive for long periods of time under low light conditions. Research shows chestnut stump sprouts can survive for decades under low light, and respond quickly to a gap in the canopy by growing from adventitious buds (Paillet 1984). Planted seedlings may differ in their ability to survive under shade, as they do not have the large carbohydrate-rich root systems that chestnut sprouts do. No studies have evaluated how planted chestnut seedlings respond to a release after becoming established in low-light conditions. Our study evaluates long-term (10+ year) survival and growth of chestnut seed and seedlings planted in each of the three stages of the three-stage shelterwood harvest system commonly used to regenerate oak in the Allegheny plateau region. These treatments will create a gradient of light availability and competition from sprouts and seedlings of other hardwood species. Results will help determine how long planted chestnut seedlings can survive in low light conditions while still retaining the ability to respond quickly to increased light due to harvest, how well chestnuts compete with other vegetation in varying light levels, and will help managers decide at what point in the 20-year shelterwood system sequence to plant chestnut seedlings.

Methods:

This study is located on the Allegheny National Forest in northwestern Pennsylvania. In the fall of 2016, 2500 hybrid American chestnut seeds from seven families were hand planted in the Vallonia nursery in Vallonia, Indiana. Five of the chestnut families planted are BC_3F_3 hybrids from The American Chestnut Foundation (TACF) and two are BC_2F_3 hybrids from the Connecticut Agricultural Experiment Station. The seedlings were lifted in March, 2017. In April, 2017, 756 of the largest chestnut seedlings and 612 chestnut seeds (from five TACF BC_3F_3 families, two in common with the seedling families) were planted in a 10’ x 10’ grid, with 84 seedlings and 68 seeds planted in each of three replicates of the three silvicultural treatments for a total of 1,368 chestnuts (Figure 1). All chestnuts are protected from browsing using five foot-tall tree shelters. In five to seven years, depending on density of competing stems, chestnuts planted in the final removal cut sites will be manually released using cutting and/or herbicide treatments. During the first and fifth growing seasons, hemispherical photos will be taken adjacent to a randomly selected subset of the chestnut seedlings at each site to evaluate light availability. At the end of the first five growing seasons, height and diameter of each seedling will be recorded, as well as height and species of the tallest competing seedling. At the end of the

second growing season, 12 direct-seed seedlings from each of the three shelterwood harvest treatments will be carefully harvested to evaluate root development. Taproot length and stem and root dry mass will be measured to evaluate the effect of silvicultural treatment on chestnut root development.

Figure 1. One replicate of each of the silvicultural treatments. Each replicate of the three silvicultural treatments: prep-cut, shelterwood, and overstory removal, was planted with 84 seedlings and 68 seeds for a total of 152 chestnuts. The entire study consists of 3 replicates of each of the treatments = 1,368 chestnuts.



h. Timeline

Timeline	Activity
Completed November, 2015	Hand plant seeds at Vallonia Nursery
Completed summer- fall, 2016	Identify planting sites
Completed March, 2017	Lift seedlings at Vallonia Nursery
Completed April, 2017	Plant seeds and seedlings
Summer 2017 and 2021	Take hemispherical photos by a sub-sample of seedlings
Summers 2017-2021	Collect data on competing vegetation
Late summer 2017 -2021	Collect end of season growth and survival measurements
Late summer 2018	Harvest seedlings for root development evaluation

i. How results will be measured and reported

Our goal is to report results in at least one peer-reviewed publication. Results will also be disseminated to the public and TACF through presentations and written reports. A report of progress to date can be found on pages 12-13.

j. Breakdown of how and when funds will be spent

We received $1,650 for year one from TACF's external grants program for technician salary for assistance with study site selection. For year two we received $5,200 to cover the cost of two technicians to collect first year data and hemispherical photos. In year three we request $3,055 to cover part of the cost of two technicians to collect second year data and hemispherical photos. Matching funds from USFS Northern Research Station, the Allegheny National Forest, and the National Forest Foundation in the form of scientist, technician and forester salary and travel (seedling lifting, planting, monitoring), equipment and supplies (tree shelters, pin flags, tree tags, etc.) total $32,840 for years 1-3.

Year	Expense	Requested funding	Contributed funding
One	Salary	$1,650	$3,600
	Travel costs		$780
Two	Salary	$5,200	$12,400
	Travel costs		$2,773
	Supplies		$8,007
Three	Salary	$3,055	$4,800
	Travel		$480

k. CVs

Curriculum Vitae: **Cornelia (Leila) Pinchot**

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Education:
University of Tennessee, Knoxville, TN, Natural resources Ph.D., 2011
Yale School of Forestry and Environmental Studies, New Haven, CT, Master of Forestry, 2008
Oberlin College, Oberlin, OH, Biology, B.A., 2003

Professional Experience:
2014 to present: Research Ecologist, USDA Forest Service, Northern Research Station, Delaware, OH
2012-2014: Research Fellow, The Pinchot Institute for Conservation, Milford, PA
2011-2012: Postdoctoral Fellow, The University of Tennessee, Knoxville, TN
2008-2011: Graduate Teaching Assistant, The University of Tennessee, Knoxville, TN
2006-2008: New England Regional Science Coordinator, The American Chestnut Foundation, New Haven, CT
2004-2005: Research Technician, University of Tennessee Tree Improvement Program, Grand Junction, TN

Grants Received:
2017: Forest Service State and Private Forestry funding opportunity, 2017. Developing a framework for restoring American elm along the urban-rural gradient in the United States. $190,000. Co-investigator.
2017: Region 9/Northeastern Area/Northern Research Station Youth Engagement Funding Request, 2017. Invasive shrub removal and restoration of degraded urban riparian forests. $4,633. Co-investigator.
2016: Planting American Chestnut Trees in National Forests. Submitted by The American Chestnut Foundation. Funded by the National Forest Foundation in the amount of $4,807. Collaborator.
2015: Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau. Funded by The American Chestnut Foundation in the amount of $1,650 in 2015 and $5,200 in 2016. Co-investigator.
2015: Restoring Dutch elm-disease tolerant American elm in the Eastern United States. Funded by the Manton Foundation in the amount of $1,432,609. Co-investigator.

Selected Publications:
Pinchot C.C., Schlarbaum S.E., Clark S.L., Saxton A.M., Sharp A.M., Schweitzer C.J., Hebard FV. 2017. Growth, survival, and competitive ability of chestnut (Castanea Mill.) seedlings planted across a gradient of light levels. New Forests *in press*.
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Pinchot, C.C., Schlarbaum, S.C., Saxton, A.M., Clark, S.L., Schweitzer, C.L., Smith, D.R., Mangini, A.M. and Hebard, F.V. 2011. Incidence of *Craesus Castanea* Rohwer (Insecta: Hymenoptera: Tenthredinidae) on chestnut seedlings planted in the Daniel Boone National Forest, Kentucky. J. Entomological Sci. 46(3): 265-268.

Popular Press Articles

Pinchot, Leila. 2014. American chestnut: A test case for genetic engineering? Forest Wisdom: 2014(3)
Pinchot, Leila. 2012. Reproduction in the American chestnut – an overview, Journal of the American Chestnut Foundation, Issue. 2, volume 27, July – August, 2012.
Pinchot, Leila. 2008. American chestnut – the return of an American legacy, Forest Wisdom: 2008(3).

Curriculum Vitae: **Scott H. Tepke**

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Education:

Southern Illinois University at Carbondale, Carbondale, IL, Forestry, BS, Forest Resource Management, Specialization, 1984

Professional Experience:

2002 to present: Forester – Silviculture, USDA FS, Allegheny NF, Marienville, PA
1998 to 2002: Forester – Inventory, USDA FS, Allegheny NF, Marienville, PA
1988 to 1998: Forester, USDA FS, Northeastern Forest Experiment Station, Newtown Square, PA
1985 to 1988: Forest Technician, USDA FS, Northeastern Forest Experiment Station, Broomall, PA

Certifications:

Certified Forest Service Silviculturist, January 2014 to December 2017
Certified Public Pesticide Applicator, Pennsylvania, October 2013 to September 2016

Curriculum Vitae: **Scott E. Schlarbaum**

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Education:

Colorado State University, College of Forestry, Department of Forest Science. B.S. Forest Biology (1974).

University of Nebraska, Institute of Agriculture, Department of Horticulture, M.S. Horticulture (1977).

Colorado State University, College of Agriculture, Department of Agronomy, Ph.D. Plant Genetics (1980)

Experience:

Professor of Forest Genetics, Department of Forestry, Wildlife and Fisheries, The University of Tennessee and Director of the University of Tennessee's Tree Improvement Program. Current position.

Postdoctoral Research Associate, Department of Plant Pathology, Kansas State University, Manhattan, 1981-1983.

Selected Publications:

Pinchot C.C., **Scott E. Schlarbaum**., Stacy L.Clark, Arnold M. Saxton, Ami M. Sharp, Callie J. Schweitzer Frederick V. Heberd. 2017. Growth, survival, and competitive ability of chestnut (Castanea Mill.) seedlings planted across a gradient of light levels. New Forests *in press*.

Case, Ashley E., Albert E. Mayfield III, Stacy L. Clark, **Scott E. Schlarbaum**, and Barbara C. Reynolds. 2016. Frequency and Abundance of Asiatic Oak Weevil (*Cyrtepistomus castaneus)* on American, Chinese, and Hybrid Chestnut (*Castanea*) Seedlings. J. Entomol. Sci. 00:00-00. (In press).

Clark, Stacy L., **Scott E. Schlarbaum**, and Callie J. Schweitzer. 2015. Effects of visual grading on northern red oak (*Quercus rubra* L.) seedlings planted in two shelterwood stands on the Cumberland Plateau of Tennessee, USA. Forests 6: 3779-3798; DOI:10.3390/f6103779.

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Pinchot, Cornelia C., Stacy L. Clark, **Scott E. Schlarbaum**, Arnold M. Saxton, Shi-Jean S. Sung, and Frederick V. Hebard. 2015. Effects of temporal dynamics and nut weight and size effects on growth of American chestnut, Chinese chestnut, and backcross generations in a commercial nursery. Forests 6: 1537-1556; doi:10.3390/f6051537

Clark, S. L., **Scott E. Schlarbaum**, Cornelia C. Pinchot, Sandra L. Anagnostakis, Michael R. Saunders, Melissa Thomas-Van Gundy, Paul G. Schaberg, Jim McKenna, Jane Bard, Paul Berrang, David M. Casey, Chris E. Casey, Barbara Crane, Brian Jackson, Jeff Kochenderfer, Robert Lewis, Russ MacFarlane, Robert Makowski, Mark Miller, Jason Rodrigue, Jim Stelick, Chris Thornton, and Tyler Williamson. 2014. American Chestnut

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l. The Co-PIs declare there are no known conflicts of interest or commitment.

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Progress report
July, 2017

Title: Defining methods for reintroducing American chestnut to oak-hickory forests of the Allegheny Plateau study

Progress, year 1

- Seeds from five TACF BC_3F_3 and two BC_2F_3 families from The Connecticut Agricultural Experiment Station were hand planted at the Vallonia Nursery in Vallonia, Indiana on November 13, 2015.

- Between June and November, 2016, three shelterwood, three prep-cut, and three overstory removal sites on the Allegheny National Forest were selected for this study. These sites, selected from a larger pool of sites, were chosen based on year of treatment (between 2015 and 2016), similarity of density and height of competing vegetation, and ease of access. While four sites per treatment was the original goal, availability of suitable sites was limited.

Progress, year 2

- In March, 2017, the chestnut seedlings were lifted at Vallonia nursery and transported to The Tennessee Tree Improvement Program's facility in Knoxville, TN, where they were prepared for planting. The largest seedlings from each family (mean height of selected seedlings was 81±1 cm and mean root collar diameter was 7.8±0.1 mm) were selected for use in the study and their roots trimmed to 20 cm. Seedlings were individually tagged to maintain pedigree and associated seedling size data. Seedlings were kept in cold storage until planting.

- Between April 18th and 26th, 2017, 756 1-0 chestnut seedlings and 612 chestnut seeds were planted across the 9 sites on the Allegheny National Forest (Figure 2). Following planting, seedling height and ground-level diameter was recorded and then a 1.5 m tall Plantra tree shelter was placed over each seed and seedling to prevent browsing by deer. 15 students from the Tidioute Charter School helped plant additional chestnut seedlings at two sites (Figure 2)

- In June and July, 2017, competition surrounding each chestnut seedling was characterized. Height and species of the tallest woody stem, and the total number of woody stems within a 1.3 meter radius circle around each seedling was recorded. Additionally, diameter of mid-story and over-story trees, as well as percent herbaceous cover in the competition plot were recorded.

Figure 2. A) Tidioute Charter School students planting chestnuts in a Shelterwood site, B) Chestnuts in shelters in shelterwood site, April, C) Chestnuts in removal site, May, D) Seedling-planted chestnut, July, and E) seed-planted chestnut, July. Shelter was temporarily removed to take the photo.