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Project Protocol for Establishing American Chestnut Test Orchards on Two TNARNG Installations

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PROJECT PROTOCOL FOR #08-401

Establishing American Chestnut Test Orchards on Two TNARNG Installations: Contributing to Efforts to Restore an Ecological and Cultural Giant to the Forest Ecosystems of the Eastern United States

The Tennessee Army National Guard (TNARNG) American chestnut project all began with a lunchtime seminar hosted by the Tennessee Wildlife Resources Agency at which the president of the Tennessee chapter of the American Chestnut Foundation (TACF) gave a presentation on his organization's efforts to restore this species to the eastern landscape. It has been a complex process to get from that discussion to the several hundred chestnut seedlings growing in orchards on two TNARNG training sites. The goal of this paper is to document that process, highlighting problems, successes, and lessons learned, so that other installations/organizations may also find it possible to contribute to the rescue efforts for this species.

BACKGROUND

The American chestnut (*Castanea dentata*) was once one of the dominant trees in the eastern forests of the United States. It was a significant economic factor in the rural Appalachians due to high-quality timber and commercially valuable nuts, as well as providing an unparalleled food source for wildlife. In the early 20th century a disease called Asian chestnut blight (*Cryphonectria parasitica*) was accidentally imported into this country. By 1950, the American chestnut had all but vanished from its entire range. A few mature trees have survived scattered across the states that used to be dominated by chestnut, surviving through natural immunity to the blight or simple isolation. More common are clusters of young sprouts that grow from the root system of old trees: blight does not kill the underground portion of the tree, but as the sprouts mature it does invade their bark and kill them.

Several organizations are involved in different projects to re-establish the American chestnut. Central to these projects is the attempt to instill blight-resistance into American chestnut stock. The method chosen by TACF is backcross breeding. The native Chinese species of chestnut, *Castanea mollisima*, has a natural resistance and is minimally affected by blight. It does not, however, share the desirable physical characteristics of the American chestnut: tall, straight growth and straight-grained, highly decay resistant wood. By a specific method of hybridizing the two species, TACF hopes to produce a tree which is predominantly American chestnut, genetically and physically, but retains a high level of blight resistance.

The TACF backcross breeding program started in the 1980s by crossing American chestnuts to Chinese chestnuts. The offspring were selected for blight resistance and then crossed back to an American chestnut. That offspring was also tested for blight resistance and survivors were again crossed to a pure American chestnut. After three such backcross generations, the offspring will be crossed with other third backcross offspring, and the results again intercrossed. The progeny at this level will be approximately 94% American chestnut, but resistance testing at each generation should ensure blight resistance is also retained. The intercrossing should produce some individuals with high levels of blight resistance. At this stage TACF anticipates reintroducing the trees to the forests.

American chestnuts are fast-growing and early-maturing trees. Flowers may appear on seedlings and sprouts at just 2 or 3 years of age. Yet it does take multiple years to produce each of these generations. Blight resistance testing is generally conducted at about 6 years of age by inoculating the saplings with the blight fungus. Survivors are retained in the breeding program. In order to maintain the highest genetic diversity, as many native American chestnut trees as possible are incorporated into the breeding program and a wide variety of hybridizations are conducted. Tens of thousands of seeds are planted each year in this program. Because of the scale and timeframe of this program, land is one of the most important commodities involved. It takes many acres to grow all of these seedlings as well as manpower to maintain the orchards, and orchards are needed throughout the range of the American chestnut to ensure that when resistant seed is produced, there will be strains that are adapted to the different edaphic conditions across the eastern United States.

OBJECTIVES

The overall objective the TNARNG project is to provide locations where American chestnut backcross offspring can be grown, tested for blight resistance, and the survivors maintained to contribute to the breeding program, without interfering with the military mission. Eventually, the descendants of this breeding program will be returned to the eastern forests, improving wildlife habitat, increasing biodiversity, and enhancing overall ecosystem quality.

PROCESS

Approval

It almost goes without saying that the first step for such a project is to obtain permission. But the TNARNG project encountered many more levels of approval necessary than were expected. The plans were very small: only 1-2 acres at two training sites. Because of this small scale, the training site managers were consulted and were very supportive of the project, but the project was overlooked by much of the higher command staff. But the American chestnut has popular appeal; the project will get public notice and will get command attention eventually.

Involve the commander and public affairs from the start. If possible, present a Command Briefing at the proposal stage to make sure the facts being passed about are accurate. And still be prepared for staff turnover to cause shifts in attitudes toward the project.

Partnerships

The American Chestnut Foundation has 16 chapters in eastern states. See http://www.acf.org/ for contact information. The local chapter will be the best source of information on the significance of the American chestnut to a region and the need for test orchards. TACF is also the source of the backcross seed.

It is a requirement of TACF that partners sign a germplasm agreement prior to receiving any hybrid seeds or seedlings. This agreement states that all plants and plant parts remain the property of TACF and may not be sold, given, or otherwise transferred to any third party without the consent of TACF. TACF scientists have the right to access the site, with reasonable notice, to collect samples of the plant materials and test for blight resistance. If the partner chooses to terminate the agreement for any reason, including sale of the property, then TACF should be given 60 days' notice in which to transfer any materials desired, and all other plant materials must be destroyed. The agreement does not bind the partner to a period of time maintaining an orchard.

The local chapter of TACF should also be able to suggest other sources of support or information. In Tennessee, a professor at the University of Tennessee at Chattanooga who works extensively with the backcross hybridization program supplied the seed and seedlings planted on the TNARNG sites. He also provided knowledge and advice, as well as bringing several students to help with the planting at the Catoosa orchard site. A member of the TN TACF chapter provided guidance on establishing and securing an orchard and provided a tour of the chestnut orchard on his personal property to educate personnel from the TNARNG environmental office. Another member and experienced orchard operator assisted with the planting at the Milan site.

Site Selection

Once tentative approval is obtained and the local TACF chapter has been approached, it is necessary to select a site(s) for locating an orchard. The facility manager/commander must be involved in this. Many factors should be considered – current vegetation, soils, drainage, accessibility, availability of water (TACF state chapters can provide information on local site conditions appropriate for a chestnut orchard) -- but the deciding factor for the TNARNG was impact on the military mission.

The TNARNG maintains four large Volunteer Training Sites (VTS). Of these, two were quickly dismissed from consideration for chestnut orchard locations: the VTS-Smyrna is too small and lacks any appropriate unused acreage. The VTS-Tullahoma is a tenant operation located on another military facility, and it was determined that the complexities of the land management relationship would make establishment of an orchard difficult.

The VTS-Catoosa and VTS-Milan, however, were deemed suitable, though for different reasons. The VTS-Catoosa is located in northwest Georgia, about 20 miles south of Chattanooga. This is at the southern end of the American chestnut's original range, but the habitat is very typical for the species. The VTS-Milan is located in west Tennessee, just north of Jackson. This is the western edge of the chestnut's range (possibly beyond the original range, depending on the map consulted), and the specific locations available for use of the training site were less prime habitat, but the training site manager was very enthusiastic and supportive of the project. Conflict with training site command (see section on Approval above) led to the consideration of multiple armory facilities in the state, but none were as suitable as the two training sites.

Eventually, agreement was reached for the use of small areas on the training sites. At this stage it was necessary to work closely with the training site managers, considering training activities and site characteristics to find acceptable locations on the training sites. Of key importance was the requirement that the areas be currently unused for training and unlikely to be needed in the near future. Multiple locations were considered, and compromises were made. The final sites selected were not perfect, but they do meet the needs of the orchards with minimal impact on the military mission.

The VTS-Catoosa site was actually the second choice option presented by the training site, but their preferred location was untenable: it consisted of two small areas on either side of a road at the northern end of the training site. The areas were already mostly clear, but the cost of fencing two areas was beyond the budget allotted and small size would have made spacing and access an issue. The second option that the training site offered – the one ultimately chosen – involved substantially more site preparation as it was forested rather than open. But, located close to the facility boundary and on a relatively steep slope, the area had not been used for training in the past and was unlikely to be needed for maneuvers in the future. The Catoosa orchard (Figure 1) is about one acre in size. The mixed oak forest on the site was a good indicator that conditions would be suitable for American chestnut.

The VTS-Milan site chosen was the first option proposed by the training site manager. Other areas were considered at the recommendation of training site command, but everyone involved determined that the original option was preferred. The orchard (Figure 2) is approximately 2.7 acres, located on the training site boundary fence along a state highway. It is a triangular piece of ground between a tank trail and the fence line, and a power line right of way runs just inside the tank trail. The small size and presence of the power line make it virtually unusable for training. The site was an old field, making site preparation efforts minimal, and the ground is level though somewhat poorly drained for American chestnut. The southeastern corner of the area has not been planted with chestnuts because it tends to have standing water following rain events, but the majority of the area is acceptable, although not prime, habitat.

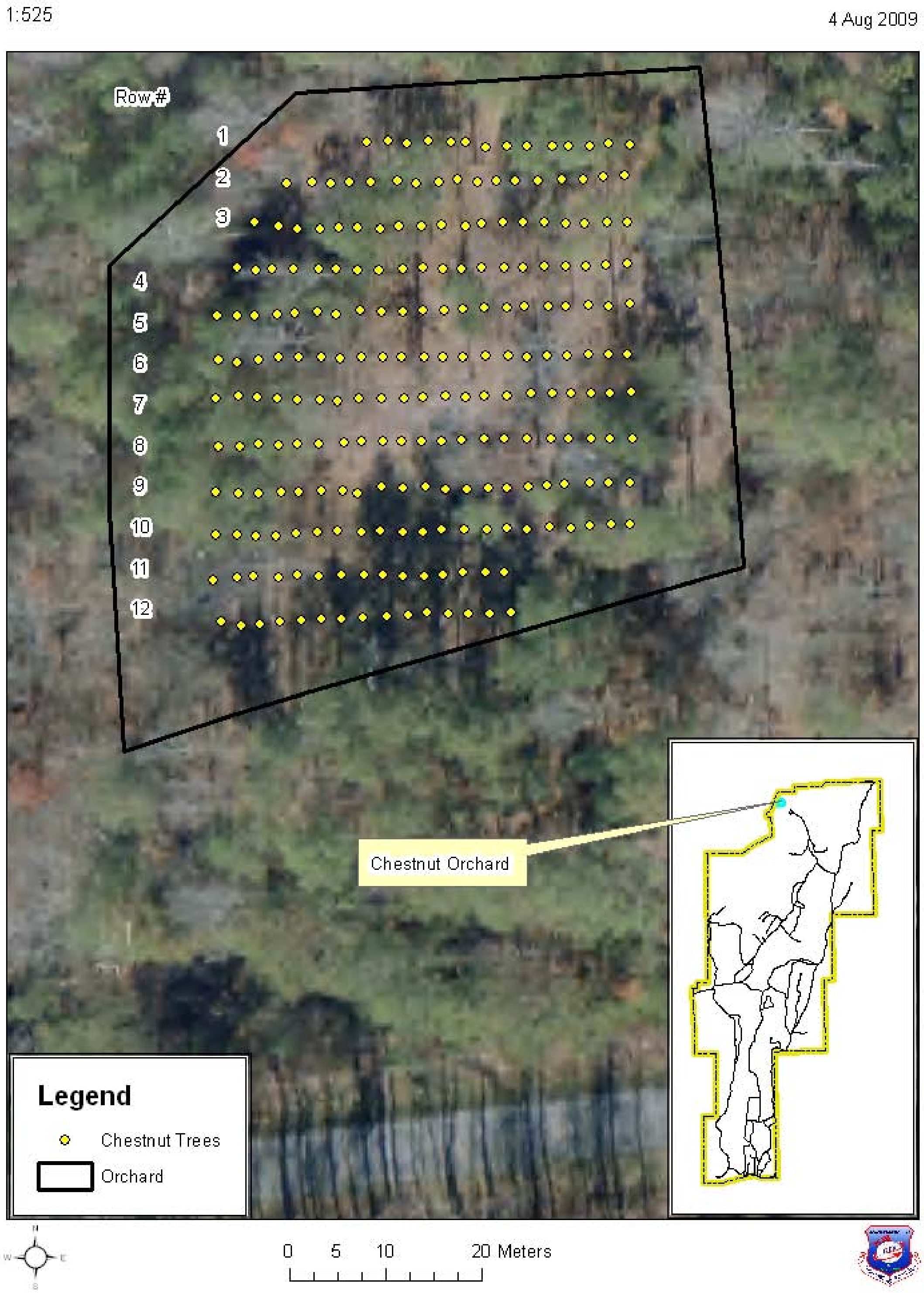

Figure 1: Location of the American chestnut orchard on the VTS-Catoosa.

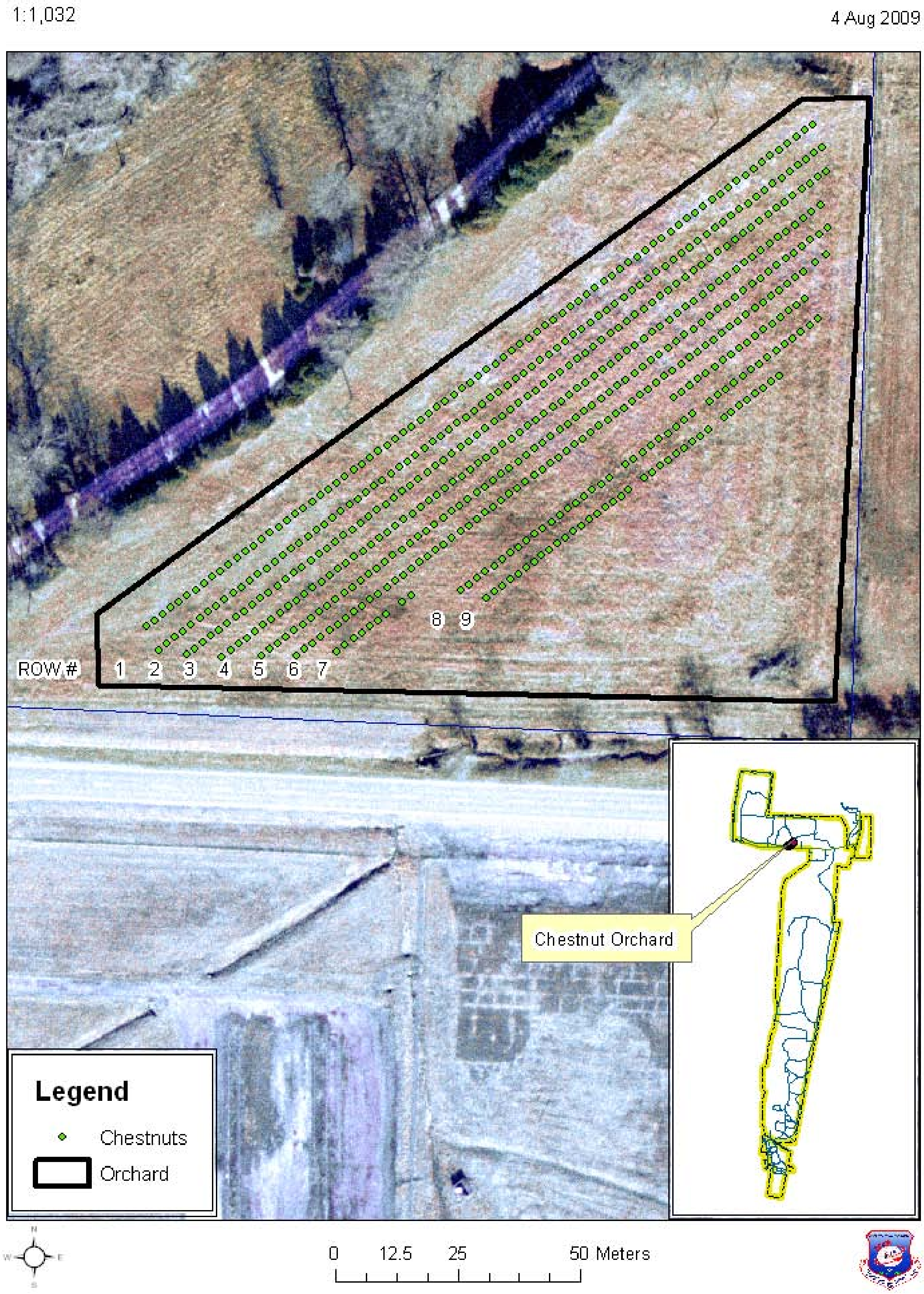

Figure 2: Location of the American chestnut orchard on the VTS-Milan.

Site Preparation
Once the site is selected, plans must be made and implemented to create suitable conditions for planting and maintaining an orchard. For TNARNG this included a combination of site clearing, fencing, and soil preparation.

<u>Catoosa</u>
The Catoosa orchard required much more intensive site preparation. There were approximately 80 trees with a DBH of 16 cm or greater on the site; 18 of those trees had a DBH of more than 30 cm. Large trees were felled and delimbed, with hardwood logs either being cut into firewood to be used on the training site or cut into 8-10 feet sections for use in future stream stabilization projects on Tiger Creek. Stumps were cut or ground down flush with the soil surface to make future mowing easier. Stumps were also treated with herbicide to minimize resprouting. Saplings and slash were either burned on site or mulched using the training site's forestry mower.

Including travel time, the clearing effort took 14 work days, using a combination of state active duty soldiers, state employees, and federal contractors, with an average of 5.4 persons on site per day. Hiring of a professional tree clearing service was considered. Barring inclement weather, a local business could have completed the work in approximately one week, but at substantially higher cost. Additional costs for the project as conducted included gas and oil for the saws and rental of the stump grinder (see budget in Appendix 1). It was also necessary to obtain burn permits daily from the state forestry office for disposing of the slash.

Once the orchard site was cleared of trees, construction of the 8-foot tall perimeter fence began. Treated pine 4x4 inch, 10 foot long posts were used for line posts and corner posts, while 6x6 inch, 12 foot long posts were employed as hinge posts for the orchard's two gates. Postholes were dug using a 12-inch hydraulic auger. All wooden posts were set with concrete. After attaching tensioning wire to brace posts and corner posts, it was determined that it would have been advisable to use larger and longer posts in the corners, as the stress of the wire (and later, the woven wire fence) was enough to bow the posts and, in some cases, risk breakage. The southwest corner of the orchard is near a natural drainage and often has saturated soils which allowed the corner post to shift and lean, which would have been less significant if the post could have been set deeper. To alleviate this problem, poles from the cut trees were used to prop up corner posts from the inside of corners, or, in the case of the wet, southwest corner, a larger pole (~10 inches DBH) was installed directly behind the corner post and used to anchor the unstable corner post using bracing wire.

An eight-foot tall fence was achieved by using two rows of 47-inch tall woven wire. Ten-foot galvanized steel t-posts were placed every 10-12 feet between brace posts and driven 2 feet into the ground. The fence was stretched using a combination of ratchet straps anchored to large, nearby trees and/or to the bucket of a front-end loader. Fence construction took approximately three and a half days using three TNARNG soldiers and two ENV personnel. The use of woven wire made erecting the fence much more complex than the installation of woven polypropylene deer-fence. The woven wire is sturdier and cheaper than the commercially available deer fences, but serious consideration should be given to the choice when planning an orchard.

Once the fence was established, the orchard rows were marked and tree spacing planned. The rows run roughly west to east, perpendicular to the slope. A 30-foot buffer inside the fence was left unplanted to allow for maneuvering of equipment. Rows are 15 feet apart to allow room for a bush hog to pass between rows, and trees are spaced 7 feet from one another. This close spacing is acceptable as many of the backcross trees are expected to be culled through natural mortality and then testing for blight susceptibility.

In many orchard settings, soil along rows is loosened to a depth of approximately 4 feet in order to provide good drainage and to encourage deep root growth; this is typically done using a tractor with a subsoiler attachment. As the training site did not have a subsoiler available, the plan was to use a soil trencher for this purpose, cutting a trench approximately 6-8 inches wide and 3-4 feet deep for each row. After using the trencher for one row at the Catoosa orchard, it was determined that this would not be a time effective solution because of the prevalence of hardwood stumps and roots throughout the area (it took approximately 2 hours to trench a 115 foot row). Instead, an 18 inch auger was used to drill individual holes for each seedling location and the soil was allowed to fall back into the hole. This turned out to be a relatively quick operation and provided excellent soil texture in which to plant seeds by cutting through small roots and loosening the soil down 3-4 feet. Using the auger, one auger operator, and one spotter on the ground, all holes were prepared for the orchard in less than 1.5 days.

<u>Milan</u>

The Milan orchard site preparation required much less effort. The area was a regularly bush-hogged field; there were no trees to be removed and little site clean-up to perform. The area was burned in December prior to fencing and planting in order to remove thatch and suppress some of the non-grass species present (*Sericea lespedeza* and Japanese honeysuckle).

Holes for the wooden line and corner posts were drilled using a hydraulic auger. This was accomplished in approximately two hours using two people. Setting the posts took five days and used an average of 3 persons per day. One of the reasons setting the posts took such a long time is that the 18-inch auger used to drill the holes was vastly oversized for the task. For a 4-inch post, and even for the 8x6 gate posts used, it would have been much more efficient to use an 8-12 inch auger. Because the holes were so wide, the amount of concrete needed for each post was much more than that purchased and available onsite. It was originally estimated that it would take one bag of concrete to stabilize each post, roughly surrounding the post with concrete to the top of the hole. However, when placing a 4-inch post in an 18-inch hole, one bag of concrete puddles at the bottom of the hole and is only 2-3 inches thick, not substantial enough to hold the post in place. The lessons learned from this experience are: 1) make sure to add a substantial buffer onto one's concrete order, and 2) have excellent communications with all equipment operators, especially if a project manager is not onsite at the time the work is being performed.

Woven wire fencing was chosen for the orchard at VTS-Milan, as well. Erecting the fence began in mid-April, the week before the scheduled planting. Locating the orchard in a triangular field with one of the short sides already fenced with installation-standard chainlink helped to reduce the length of fence to be installed by 410 feet (820 feet of 47-inch woven wire in total savings). A front-end loader was used to stretch the fence at Milan. Again, it was discovered that 4x4 inch posts are not strong enough to hold up to the strain of fence stretching, but in this case, unlike at the Catoosa orchard, two of the corner posts actually broke under the strain. Replacing these posts in the midst of fencing added a considerable amount of extra time to the fence construction, but even using four persons over 5 days, the fence was still up by the day of planting.

Rows at the VTS-Milan backcross orchard were oriented so that they would run parallel to the hypotenuse of the triangularly-shaped field in order to maximize use of the well-drained portion of the site and to make mowing easier. The plan was to have the soil worked using a subsoiler attachment on the training site's tractor. This would have been especially valuable in this field setting since soils tend to get compacted over the years because of repeated bushhogging and other traffic; a subsoiler would have extended into the hard clay in the subsoil, allowing water to penetrate. However, that attachment could not be located, and so the field was plowed instead. An attempt was made to complete two passes with the plow, in order to break the clumps of sod that had peeled to the side during the first pass; however, this idea proved ineffective and the single furrow from the first pass was left without additional plowing.

This helped the planting process by providing a delineated furrow, but it did not do a thorough job of loosening the soil. When there are any additional plantings at this site, it would be preferable to use either a subsoiler on new rows or an 18" auger in order to create individual holes for trees.

Soil samples were taken at both orchard sites and analyzed through the University of Tennessee Extension Office. The results were used to determine fertilizer needed for post-planting application. There was no pre-planting soil amendment done.

Soil samples from the VTS-Milan were also tested for a fungal pathogen, *Phythopthora cinnamomi*, through the Soils and Plant Sciences Laboratory at Clemson University. *P. cinnamomi* is a soil-borne water mold that invades root tissues of many plants, absorbing the root's nutrients and carbohydrates, causing the root to rot and preventing water and nutrient uptake by the rest of the plant. It is a serious problem for chestnut growers, especially in the southeast. American chestnut breeders are starting to select for resistance to *P. cinnamomi* in addition to resistance to the chestnut blight. Two 100% American chestnut seedlings had been planted in early 2008 to test the site for the pathogen -- if present, the trees would likely die or show considerable signs of deterioration within the first growing season. As the seedlings appeared to remain healthy throughout their first year in the proposed orchard site, it was determined that the site was most likely free of *P. cinnamomi*. The laboratory test was a secondary precaution. *Phythopthora* was absent from all cultures.

Planting

There were several delays in procurement of fencing materials (see Issues section below) that caused the fence construction to run behind schedule. This forced the planting of the orchards to be postponed until late April, which is at least a month later than the preferred timing. Seed and some seedlings were obtained through Dr. Hill Craddock at the University of Tennessee – Chattanooga (UTC) and volunteers were recruited from TNARNG soldiers, state, and federal personnel, federal contractors, friends and family members of personnel, UTC students, and people associated with the American Chestnut Foundation.

At each site, one day prior to planting, the positions of each tree were measured off and marked with wooden stakes that would later support and anchor the 24-inch protective tree tubes. The tops of the stakes were painted different colors in order to designate which seed type went into which position within the row. This helped to minimize confusion for volunteers and to insure that orchard records are accurate.

The planting at VTS-Catoosa occurred on April 25, 2009, with 18 participants. A mixture of seeds and one year-old seedlings were planted at the Catoosa orchard. Most of the rows followed a base-10 pattern: the 1st, 11th, 21st, etc. seedlings were controls (pure American, pure Chinese, or first generation cross); the intervening seedlings were various backcrosses. Four back cross families were planted in the orchard, along with American, Chinese, and F1 hybrid controls. Backcross families were generally grouped together, but the varieties that were most numerous were located on multiple rows to try account for some site variation. Of the seedlings planted in rows 1, 2, and 12, some are much more advanced backcrosses (B3F3 generation) and others are chinquapins, a species closely related to the American chestnut that are also affected by the chestnut blight. The entire planting event lasted about 3 hours and planted 225 seeds and seedlings.

The planting at the Milan orchard occurred on April 18, 2009, with twenty participants planting all seeds. The VTS-Milan backcross orchard was planted with 3 backcross families, along with American, Chinese, and F1 hybrid controls. Initially, each row was a single backcross family, other than the controls, but in latter rows, the unequal numbers of seeds for each family resulted in some mixing of backcross families on rows. In total, 554 seeds were planted at the Milan orchard, which took about six hours

Volunteers were divided into pairs or small groups to perform specific tasks:

- At each planting point, soil was loosened with a dibble bar or shovel;
- A weed-free, soilless amendment was added to the hole and mixed in;
- A polyacrylamide crystal (tradename TerraSorb) was added to each hole (at Catoosa only, for the purpose of holding water to be made available to roots slowly);
- Seeds (and seedling, at Catoosa) were planted;
- A 24-inch protective tube was placed around the seed or seedling and pushed down into the soil 2-3 inches to protect the plants from herbivory by voles and mice;
- The tree tubes were attached to the previously placed wooden stakes using cable ties;
- A piece of cylindrical plastic netting was placed over the top of the tube to discourage birds from flying into the tubes and becoming trapped;
- Aluminum tags were attached to the tree tubes identifying the species or cross; and,
- The plants were watered.

While this “assembly line” style of planting was efficient, it did introduce some possible confounding factors into the data. The seed was organized by backcross family, so one or two volunteers planted all of the seed from a given family. Planted this way, it is impossible to know whether germination success or failure is purely a result of the cross viability – it could be due to planting methods employed by that group of planters. The assembly line system also suffered from occasional communication breakdown where it was uncertain what had been completed for a given planting site. In future plantings, seed will be more equably distributed, and if possible the planters will conduct most of the tasks for each seed planted rather than a single task across the entire orchard.

Failure to germinate and mortality have resulted in far fewer American chestnut seedlings than the number of seeds originally planted in the orchards. This is expected in an orchard of this nature, and the original plan did include planting replacement stock in both orchards in 2010. At that time, 88 seeds and seedlings were planted at VTS-Catoosa, replacing the dead control varieties (11 individuals), supplementing two backcross families that had been in the original planting (8 and 13 seedlings), and introducing a new backcross family (56 seeds). The Milan orchard received 145 seeds and seedlings: replacements for controls (36 individuals), additions to two of the original backcross families (5 and 7 seedlings), and introduction of a new backcross family (97 seeds). Seeds and/or seedlings will be added to the orchards again in spring 2012.

Maintenance

The initial planting was conducted in spring 2009. Since that time the orchards have been maintained regularly. Undesirable vegetation is controlled as needed by herbicide, mowing, weeding, and bushhog. A glyphosate herbicide has been carefully applied to the rows of the orchards 2-3 times each year to limit vegetative competition for the seedlings. Glyphosate is also used along the fenceline to maintain a tidy appearance. The larger Milan orchard requires about 6 man-hours to fully treat the rows and fence using a backpack sprayer; Catoosa requires about 4 man-hours. As the seedlings grew taller than the tree tubes, spraying became more problematic. The wind has to be very still to minimize the risk of drift onto the chestnut leaves, and the spray nozzle has to be held just above the ground. The best results have usually been achieved by mowing the rows and then spraying one to two weeks later while the grass and weeds are growing actively but still short. Seedlings with low hanging branches or with the tree tube removed are not sprayed around – weeds around these are pulled or clipped by hand pruner.

Mowing or bushhogging is conducted more frequently than spraying – usually once a month during the growing season – both to control competition and to maintain a suitable appearance. The Catoosa orchard is generally bushhogged due to the prevalence of woody sprouts still arising from the root systems of the original overstory trees. A string trimmer is usually needed to cut vegetation close around the seedlings after bushhogging. This was a simple matter when all seedlings were still within tree tubes, but as they grow, the tubes are removed when they begin to impinge on the young tree. After this protection is removed, it is essential that the string trimmer not come into contact with the bark of the chestnut seedlings as it will cause serious damage and is likely to kill the seedlings. The orchard at VTS-Milan is typically mowed with a large riding mower. The mower can get very close to the trees with care and so string-trimming is less often necessary.

Small seedlings often appear to be choked out by weeds growing up inside the tree tube. These are pulled by hand as possible. When the soil is moist, the tube may be pulled up so that the weeds can be more thoroughly removed and the status of the seedling assessed. Care must be taken not to pull clumps of soil up off the seed/seedling when pulling grassy weeds, especially. In general, the seedlings are found healthy within a clump of weeds, but the competition is likely impacting the growth rate of such seedlings.

During the growing season, the seedlings are watered and fertilized twice a month at each orchard. A water-soluble 30-10-10 acid fertilizer is applied at a rate of about 4 teaspoons per gallon per tree. In very droughty periods, the fertilizer is not applied in order to avoid increasing water stress on the plants. This was not a concern during the relatively wet 2009 growing season, but in both 2010 and 2011 there were periods in late summer when the trees were watered but not fertilized. Seedlings will be watered and fertilized for at least three years following planting. As new seeds have been added in 2010 and are planned for 2012, this will continue to be a required maintenance for the orchards for several more years.

The VTS-Milan orchard was treated after the original planting with a mixture of water and spores from fungal species known to form ectomycorrhizal associations with hardwood deciduous trees, some specifically with American chestnuts. Ectomycorrhizae are structures formed by the symbiotic relationship between certain fungi and many plants. The fungus surrounds the tips of plant roots and receives photosynthetically-produced sugars, while, in turn, providing moisture and nutrients to the plant. As the orchard site at Milan has not been in a forested condition for a number of years, it was expected to have a very different mycorrhizal community than required for optimum chestnut growth. This mycorrhizal inoculant was not added to the soils at VTS-Catoosa as that site has very recently been covered in a forest that is expected to contain a healthy mixture of mycorrhizae compatible with American chestnut.

The area surrounding the VTS-Catoosa orchard is forested, and storms in 2010 damaged three trees which thereafter posed a threat to the fencing. These were taken down by a local tree service.

Monitoring

The seedlings are monitored at least once a year in the fall to measure growth and mortality. In practice, the seedlings were checked multiple times during their first growing season to determine when they germinated. They were not measured until the fall. At that time, the tree tubes had to be carefully removed so that height to the terminal bud and diameter at the base could be measured. Digital calipers and a tape measure were used; four people worked in two pairs to accomplish each orchard monitoring in a few hours. Removing and replacement of the tubes proved to be the most complicated task involved – if the soil is too moist, it tends to stick in the tube and may pull up over the seedling, exposing the top of its roots system. Very small seedlings may even be pulled up with the soil that sticks in the tube. If the soil is too dry, it is difficult to get the tube replaced in position and deep enough to provide protection. Later year monitoring becomes more difficult when the seedlings grow out of the tubes and begin to develop lateral branches. The tubes can no longer simply be slid up off the seedling, and it is often necessary to cut a notch in the top of the tube to allow it to slide up sufficiently to provide access to the base of the tree.

During the first year monitoring, seeds that had never germinated were dug up and examined to determine, if possible, the cause of the failure. In many cases, it was clear that the seed had been eaten, probably by a vole. Other seeds appeared to have rotted in the ground or were planted too deep. Some were not found.

Data files are shared with the president of the Tennessee chapter of TACF each year and with Dr. Craddock of the University of Tennessee at Chattanooga. At this point no statistical analyses of the data are being conducted; only general survival and growth rates are being calculated to describe the orchard success and apparent suitability of the backcross families. The data may be subjected to more complete analysis in the future or combined with other orchard data for analysis.

ISSUES

The establishment of American chestnut backcross orchards at VTS-Catoosa and VTS-Milan has been a successful project, though not without its complications and problems. Here are described the most significant issues encountered in the process:

- Command concerns and turnover – A series of changes in command at several levels in the TNARNG resulted in setbacks in the early stages as the project had to be presented anew and approval re-gained multiple times before work could begin. A general lack of understanding of the intent of Legacy-funded projects also contributed to resistance that was encountered at some levels. The Environmental Office has attempted to provide a clear explanation of the goals of Legacy and of this project, in particular, and also to communicate the simple fact that the project will not be allowed to restrict training. Overall, the project has been well-received. This is likely to be an on-going concern which will be addressed through education and clarification as the need arises.
    - Solution: Command staff briefing from the start and regularly throughout the project duration.

- Procurement of materials – Establishing an orchard involves a variety of materials that are not typical to government activities and thus are not readily obtained through standard state-approved vendors. From 10 foot t-posts to mycorrhizal inoculants, procurement activities for this project were complex. Some of the more esoteric (including the mycorrhiza) were supplied by TACF as an element of the partnership. Other items simply required perseverance in locating vendors, obtaining bids, and pushing the purchase orders through. The complications were particularly problematic in building the fence and resulted in a delay in completing that portion of the project, which then pushed the actual planting dates in the first year back farther than desired.
    - Solution: Begin procurement process as early as possible.

- Water availability – There is no piped water supply at either orchard site. Running water lines to the orchards was considered but determined to be too expensive and complicated for this project. At VTS-Milan, the water is hauled in by truck. In the first year, the training site's 250 gallon pressure sprayer was used to deliver water to the site from the cantonment area, about 5 miles away. In order to avoid contaminating the tank on that sprayer, the fertilizer was mixed in a separate container and applied with a bucket to each seedling. This was a very time-consuming and man-power-intensive job, and the tank was located on a large trailer that was difficult to maneuver through the orchard. Using FY10 Legacy funds, a tank sprayer and small trailer were purchased. As these are dedicated to the chestnut project, fertilizer is mixed directly in the tank, greatly simplifying and speeding up the watering and fertilizing process.

A rainwater collection system was built at the VTS-Catoosa orchard: rainwater that falls on a 20 foot storage connex is collected in two 300 gallon tanks. The tanks are located at the uphill end of the orchard, and water and fertilizer are gravity-fed through hoses to the rows of trees. The spray tank and trailer are available to be used at Catoosa in the event that rainfall is not sufficient to keep the collecting tanks full, but that has yet to be an issue.

  - Solution: Will vary from site to site.

- Difficulties building fence – The double rank of woven wire livestock fence was very difficult to put up. Without the availability of heavy equipment, it would have been impossible to effectively stretch the top layer. Larger posts should have been used to handle the pull and the weight from the fence. Other deer fencing materials and methods will be considered for any future requirements.
  - Solution: Ensure equipment and materials are suitable for fence building effort required. Investigate other methods of excluding deer from the orchard.

- Small diameter tree tubes – The Tubex tree tubes used to protect the seeds and young seedlings are generally very effective. Tubes are purchased in nested sets of five, with the largest diameter tube (105mm) on the outside and the smallest (73mm) in the center.   They prevent aboveground herbivory and help to minimize temperature extremes. However, there seemed to be a correlation between early seedling death and using the smallest diameter tubes. This observation was made while collecting tubes from trees or seeds known to be dead, when the number of small tubes removed for these reasons far outnumbered the larger tubes. Future plantings will utilize the larger sizes of tree tubes.
  - Solution: Use only the four larger sizes or investigate other tree tube sources.

- Milan drainage – West Tennessee has clay-rich soils that hold water and all sites at the facility available for the orchard were flat. This can be a problem when growing a species that prefers well-drained soils. To mitigate this, we planted on the highest portion of the field, avoided all low areas, and tested the soils for a fungal pathogen that is sometimes found in poorly-drained soils.
  - Solution: Dependent on site availability.

- Terrasorb – This polyacrylamide product was used at the VTS-Catoosa orchard to improve soil moisture availability, but may have created a barrier to seed germination and early growth. Using this material at a lower rate may eliminate this problem.
  - Solution: Use Terrasorb only where drought is considered a serious probability and use it in small quantities, well-mixed in the soil.

- Guidance for volunteers at planting – It was noted when digging up ungerminated seeds at the end of the first year that many appeared to have been planted much deeper than the one inch recommended. It is uncertain whether this is a primary cause of the low germination rates, especially as many of the successful seedlings arose from seeds that were planted deep. Future planting episodes will have a more thorough briefing which will stress issues encountered in the past. In addition, as noted above, the method of dividing the work of planting will be modified so that seed types are split across multiple planters to separate the effects of the two factors.
    - Solution: Develop a very clear pre-planting briefing and monitor efforts of all planters, especially with first dozen seeds.

- Voles – A lot of seeds were eaten, and holes and tunnels typical of voles were found in the field. Voles will also remove bark from seedlings and saplings, potentially girdling and killing the tree, and may have been the cause of some seedling mortality. There are two primary control methods for voles in orchards: cultural methods to make the habitat less desirable and poison administered through bait. The orchards are already mowed and maintained with low vegetation cover, but clearing of the ground further is not an option. Bait stations were constructed from pvc in 2011 and distributed around the orchards. A bait labeled for vole control was put out in early 2012 and will be repeated shortly before planting new seeds in spring 2012.
    - Solution: Keep vegetation throughout and surrounding orchard short. Utilize baits registered for vole control in orchards in accordance with the label.

- Germination and survival rates are disheartening – Many, many seeds (almost 50% at Milan and 30% at Catoosa) failed to germinate from the first year's planting. Rates were somewhat better in the second year (42% and 14% seed failure). And of those that germinate, a proportion dies. Overall survival rates for the two orchards are approximately 35% for the three years. The large gaps in the rows make mowing easier but are depressing after all the work put into the planting and care of the trees. But this is not unusual for American chestnut backcross orchards, and the average numbers do not tell the whole story. Two backcross families at Catoosa are doing substantially better than the others with survival rates of 63% and 54%, and Milan's best performing backcross has a survival rate of 66%.
    - Solution: Focus on the goal – finding backcross varieties that are blight resistant <u>and</u> well-suited to local environmental conditions – and the health and growth of the survivors.

SUCCESSES

As of fall 2011, 80 seedlings are alive at Catoosa and 160 at Milan. The initial natural thinning of the stock was significant, but the survivors are mostly fast-growing, healthy, and robust. Five seedlings have produced fruit in the past two years – at only 2 or 3 years old. Others are expected to follow suit in coming years. When the trees reach 6 or 7 years, TACF scientists will come in to test for blight resistance, and perhaps some of these survivors will be resistant and will be integrated back into the breeding program to contribute their genetic profile to the rebirth of the American chestnut.

FOR MORE INFORMATION

The American Chestnut Foundation. http://www.acf.org

Journal of the American Chestnut Foundation. http://www.acf.org/journal.php

Steiner, K.C., and Carlson, J.E., eds. 2006. Restoration of American Chestnut to Forest Lands – Proceedings of a Conference and Workshop. May 4-6, 2004, The North Carolina Arboretum. Natural Resources Report NPS/NCR/CUE/NRR – 2006/001, National Park Service. Washington, D.C. Available at http://sfr.psu.edu/public/chestnut/information/conference-2004/conference

Tubex Tree Shelters are available from http://treessentials.com/ or Forestry Suppliers http://www.forestry-suppliers.com/

Appendix 1: TNARNG American Chestnut Orchard Setup and Maintenance Purchases

VTS-Catoosa orchard: 1 ac, 800 ft fence, 2 gates, 225 planting points
VTS-Milan orchard: 2.7 ac, 1225 ft fence built, 2 gates, more than 550 planting points

Material	**Quantity**	**Price each**	**Total Cost**
Lumber (Milan)			
4x6x12 treated pine (gate posts)	4	16.50	66.00
4x4x10 treated pine (corner and line posts)	32	10.50	336.00
4x4x8 treated pine (H-brace sections)	11	8.00	88.00
➢ Delivery fee	1	15.00	15.00
Lumber (Catoosa)			
4x6x12 treated pine (gate posts)	4	22.99	91.96
4x4x10 treated pine (corner and line posts)	23	8.79	202.17
4x4x8 treated pine (H-brace sections)	12	6.49	77.88
➢ Delivery fee	1	15.00	15.00
Hand Tools			
Linesman pliers 7 ¼"	2	16.25	32.50
Linesman pliers 8"	2	12.57	25.14
Fencing pliers	2	25.07	50.14
Claw hammer	2	11.74	23.48
Tool box	1	14.18	14.18
Fencing Materials			
10' galvanized steel t-posts	140	18.52	2592.80
Extra t-post clips (bag of 25)	11	0.99	10.89
Field fence (47 in x 330 ft)	13	187.99	2443.87
1.5 in staples (50 lb)	50	1.79	89.50
Woven wire fence stretcher	1	38.99	38.99
High-carbon, galvanized pole barn nails, 16 ga. (10 lb)	10	2.60	26.00
9 ga. Bracing wire (170 ft)	3	14.99	44.97
In-line strainers	24	3.19	76.56
Fence bracket, c-shaped	48	0.80	38.40
Quik-crete, 60 lb	71	2.77	196.67
Gate Hardware			
Gate bolts, ¾"x10"	8	8.79	70.32
Equipment Rental			
Stump grinder	1	225.00	225.00
Gas fee	1	4.00	4.00
Herbicide			
Garlon 3A, 2 ½ gal (for site prep)	1	249.00	249.00
➢ Shipping	1	15.56	15.56
Razor Pro, 2.5 gal (for weed control)	2	66.45	132.90
Planting materials			
#4 Propagation Mix soil amendment (3 cu ft)	13	9.40	122.20
1"x1"x 36" pine stakes, bundle of 100	9	43.60	392.40
Tubex tree shelter 2', 5/pk	180	9.83	1769.40

Double-faced aluminum tags, 50/pk	20	3.38	67.60
21-7-7 Acid Special fertilizer, 25 lb bag	80	22.00	1760.00
➢ Shipping	1	145.00	145.00
Maintenance			
Tree removal (VTS-Catoosa)	1	750.00	750.00
Muck buckets for watering, 70 qt	4	23.99	95.96
Hose for watering (50 ft)	4	21.77	87.08
Hose cart	1	177.75	177.75
Hose adapters and bushing	Misc.		20.67
Double face sledge, 4 lb	1	22.64	22.64
Cable ties, 8" (100/pk)	2	24.93	49.86
Piston backpack sprayer, 4 gal	1	103.82	103.82
Bamboo stakes, ½" x 4', 250/pk	4	40.37	161.48
200 gal skid sprayer	1	1975.05	1975.05
Trailer for sprayer	1	1465.00	1465.00
PVC for vole bait stations	Misc.		492.18
Kaput Combo bait pellets, 2 oz pks, 100/box	4	60.25	241.00
➢ Shipping	1	20.00	20.00
Monitoring			
Solar powered digital calipers	2	187.65	375.30