Institute of Forest Tree Breeding: Improvement and Gene Conservation of Iconic Tree Species in the 21st Century[1]

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Background

Our nation's forests and forest trees are undergoing unprecedented stress from invasive pathogens and pests, climate change, land fragmentation, and urbanization. Some of these stresses are acute, either regionally or locally, and are having significant negative impacts on regional and local economies and ecosystems. Managing and improving the genetic resources of impacted iconic[4] forest tree species is key to ensuring their existence into the future. However, our national capacity in forest genetics and tree improvement has been declining for decades (Wheeler et al. 2015). Many of the current programs addressing genetic improvement of our hardwood and non-commercial softwood species are isolated, under-staffed and under-funded, resulting in limited success in achieving and deploying improved trees. In addition, they lack a committed source of long-term funding to make them sustainable across the time periods that are needed for genetic improvement in long-lived organisms such as forest trees. Experience has shown that most hardwood tree improvement programs have failed to outlive their initial phase and usually are suspended indefinitely or terminated upon retirement of the founding forest geneticist/tree breeder.

Despite these obstacles, there are exceptions; programs that have had success including some that have achieved success in relatively short periods. The American Chestnut Foundation (TACF) has been breeding hybrid chestnuts (*Castanea* spp.) to develop improved resistance to chestnut blight (caused by the fungus *Cryphonectria parasitica*) for over 25 years (spanning nearly the complete career of the lead tree breeder). This program has achieved longevity through concerted efforts that included following a well-reviewed breeding plan, engaging in a participatory breeding model, and maintaining stable funding (through an active membership program). In addition, TACF has hired a new breeder to continue to work toward the production of ample resistant planting stock with r regional adaptation for use in species restoration efforts. Other notable longer-term programs include the University of Tennessee Tree Improvement Program and a program run by the University of Missouri. These later programs rely on state-funding to distribute work on a number of important species.

Within the U.S. Department of Agriculture Forest Service (USDA FS), the Dorena Genetic Resource Center (DGRC) in Oregon, celebrating their 50 year anniversary this year, is a successful long-term program that began in response to white pine blister rust (*Cronartium ribicola*). Originally focused on western white (*Pinus monticola*) and sugar (*P. lambertiana*) pines, it now has blister rust resistance programs in all impacted western five-needle pine species, including the threatened whitebark pine (*P. albicaulis*). The DGRC has also expanded to include resistance programs to newer invasive pathogens including *Phytophthora lateralis*, threatening Port-Orford-cedar (*Chamaecyparis lawsoniana*). In the case of Port-Orford-cedar and whitebark pine, sufficient resistance was developed to begin restoration within a relatively short period of time (~10 years). Such rapid success is due to several factors, including the availability and types of resistance, having a tree improvement program in place that included stable

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[4] We define iconic species as foundational or keystone species in the ecological sense indicating that they disproportionately affect the forest's flora and fauna and the succession of the forest itself.

funding, experienced staff—including breeders and geneticists— and physical infrastructure (e.g., nursery, screening facilities, land for research plantings). The USDA FS resistance breeding programs in the West include not only those at DGRC, but also the Institute of Forest Genetics (Pacific Southwest Research Center and Pacific Southwestern Region) and the Coer d'Alene nursery (Intermountain Region). The value of putting tree breeding principles to practice to save tree species from potential extirpation is illustrated by the western United States resistance programs in Port-Orford-cedar and whitebark pine (Sniezko and Koch[5]).

Although the eastern United States lacks the longevity and infrastructure of programs in the West, there are USDA FS programs that have been established more recently including the Hardwood Tree Improvement and Regeneration Center at Purdue University, a collaborative effort between the university and the USDA FS's Northern Research Station (NRS), that is focusing on a few high-value hardwood species largely within the state of Indiana but also species threatened by invasive diseases including butternut and black walnut. Other programs in the NRS include, for example, a beech bark disease (caused by an interaction between the beech scale insect, *Cryptococcus fagisuga* and the fungal pathogen *Nectria coccinea* var. *faginata*) resistance program and a research-oriented program that is developing materials in ash (*Fraxinus*) species to study the genetics of resistance to the emerald ash borer (*Agrilus planipennis*) and provide resistant materials for further breeding work. These eastern USDA FS programs, like many modern tree improvement efforts, rely in part on piecing together funding in the 1- to 3-year cycles dictated by the few granting programs that will fund this type of applied research, putting them and the species they aim to save, at high risk for failure over the long-term.

A potential approach to solving this problem, in general, is the formation of an institute of tree breeding that provides an avenue for stable, long-term funding to support the breeding work that is critically important to saving iconic forest tree species in the eastern United States. Such an institute would support development and retention of necessary infrastructure and provide the continuity, skill and longevity needed for success by employing a tree breeder and an assistant (apprentice) for each high priority major tree species or group of related species (species/group). The institute's breeders would work in conjunction with experienced USDA FS and university geneticists to develop peer-reviewed, range-wide breeding plans. Programs that are part of the institute will collaborate with each other and other partners to develop region-wide testing programs for each species, web- and mobile-enabled data management software, curriculum for training new tree breeders and their assistants, and production and distribution systems for the improved materials. We propose to form the Institute of Forest Tree Breeding (IFTB) with funding from the USDA FS and matching funds from associated universities, state forestry agencies, non-government organizations, non-profit foundations and private individuals. Some USDA FS funding is already committed to tree breeding efforts with various levels of matching assets and we suggest that these efforts be consolidated within the IFTB. Merging these efforts into the IFTB would provide for an initial critical mass for the institute and a solid base to build and grow the institute to meet current critical needs and to be positioned to address future needs as they arise (e.g., new invasive insects and pathogens, climate change) in a timely, efficient and cost-effective manner.

Mission and Goal of the IFTB

To cost effectively provide for long-term, region-wide breeding programs for iconic forest tree species that are critically important to national forests, state agencies and private landowners in the eastern and southern regions.

[5] **Sniezko, R.A.; Koch, J.L.** Breeding trees resistant to insects and diseases-putting theory into application. Manuscript submitted to Journal.

General features of the IFTB

- Networked consortium of tree breeders and their breeding programs or components of their programs.
- A lead tree breeder and an assistant (apprentice) for each species/group, with an operating budget and in kind institutional support.
- A set of quality assurance standards for entering a species/group into the IFTB, including economic and ecologic justification, a well-documented user's group, and a sustainable funding plan.
- Peer reviewed regional breeding plans that cover appropriate portions of the species' native ranges and annual progress reports for each species.
- Breeders collaborate with each other to facilitate progress and success in all programs while being responsible for their own program. Collaboration among IFTB breeders will include sharing test sites, facilitating test establishment and germplasm collections, developing and sharing data management and analysis software, sharing best practices for recruiting and utilizing volunteers, developing curriculum for training new tree breeders and volunteers.
- Breeders individually and as an institute report to a board of directors, where the board consists of representatives (one person each) of the following: USDA FS Southern Research Station and NRS Station Directors or Assistant Directors, USDA FS Region 8 (Southern) and Region 9 (Eastern) Regional Foresters or Deputy Regional Foresters, and a northern and southern representative state forester, as well as representative as appropriate from associated universities and other nongovernmental organizations.
- USDA FS funding committed in 5 year intervals, not to exceed four renewals or 25 years total. Programs must stay on track in order to be renewed for subsequent 5 year periods, with the goal of developing a path to full funding. A sliding scale of matching requirements will be developed, for example, with USDA FS funding covering 50 percent in first two periods (years 1 to10), 25 percent in the next two periods (years 11 to 20) and 10 percent in final period (years 21 to 25).
- USDA FS funding permitting, new species/groups may apply for funding and entry into the IFTB. Applications will be reviewed by expert panel with recommendations made to IFTB's board of directors.
- Appropriate genetic materials produced by the IFTB will be publicly available through material transfer agreements (MTAs) for research purposes, seed orchard establishment for forest management and restoration activities and continued breeding (i.e., cultivar development). Cultivars developed through such MTAs will be jointly owned by IFTB and the collaborator developing the cultivar.
- Affiliated breeders would agree to provide certain materials or services to IFTB in exchange for funding or other services or materials. All expectations for both parties will be formally documented in a MTA. Materials provided by affiliated breeders would be part of IFTB with respect to being subject to peer-review and being available through MTAs.

Specific Objectives of the IFTB

1. Provide sustainable (including funding plan), long-term, region-wide breeding programs for iconic forest tree species with critical ecologic or economic need. Initially we propose these to be:
    a. Black walnut (*Juglans nigra*) and butternut (*J. cinerea*) (walnut group)—black walnut is the most economically valued hardwood species and butternut is a highly endangered (from butternut canker, caused by *Sirococcus clavigignenti-juglandacearum*) and valued hardwood species.

   b. Green ash (*F. pennsylvanica*) and white ash (*F. americana*) (ash group)—two of the most important forest and urban landscape trees and economically valued hardwoods; both under extirpation pressure from emerald ash borer.
   c. Redbay (*Persea borbonia*), sweet bay (*Magnolia virginiana*), sassafras (*Sassafras albidum*) (laurel group)—three important coastal and inland forest trees with very high ecological value; all three under intense extirpation pressure from laurel wilt (caused by *Raffaelea lauricola*).
   d. White oak (*Quercus alba*), northern red oak (*Q. rubra*) and American beech (*Fagus grandifolia*) (oak group)—the oak species are among the most economically and ecologically important hardwood species across the eastern United States, and the closely related American beech is an important wildlife species.
2. Work with university partners to develop and deliver curriculum for a Master Tree Breeder certificate to train professionals, landowners and others in forest tree breeding.
3. Develop participatory tree breeding methods and implement these methods in each species' program and new programs as they enter the institute.

Path Forward

We suggest the following steps to move this proposal abstract to a full proposal and ultimately a functional institute:

1. Convene a writing team to complete the proposal/business plan.
2. Enlist letters of interest from potential participants and funding sponsors.
3. Submit the proposal to peer review by forest geneticists.
4. Present revised proposal to the USDA FS and others for consideration of funding.

Literature Cited

Wheeler, N.C; Steiner, K.C.; Schlarbaum, S.E.; Neale, D.B. 2015. The evolution of forest genetics and tree improvement research in the United States. Journal of Forestry. 113(5): 500–510. doi: http://dx.doi.org/10.5849/jof.14-120.