Genetic Gain and the Economic Benefits of Tree Improvement

BY SARA LIPOW

A vital component of forestry today for most commercially important tree species is reforestation with genetically improved planting stock produced by tree improvement. Tree improvement is the process by which knowledge of tree genetics is coupled with knowledge of silviculture, economics, and wood science to select and reforest with trees that possess desirable traits. These desirable traits usually relate to increased wood yield or higher wood quality, which are the focus of this article. Other desirable traits such as disease resistance and forest health are discussed elsewhere in this issue.

Tree improvement is expensive and takes decades

Foresters are accustomed to long-term thinking. During reforestation, we make investments in site preparation and tree planting knowing that financial gain from these activities will not be realized until trees are harvested decades later. Tree improvement also takes decades, and its investment starts long before a tree is even planted.

Most tree improvement programs in western North America began in the 1950s to 1980s and followed a similar pattern. Trees growing in natural stands were identified and cones were collected from them. Sometimes these "parent trees" were selected after comparing them to other trees in a uniform stand, but sometimes they were simply good looking trees that were easy to collect cones from. Regardless, seeds from those parent tree cones (their progeny) were then grown in field trials, called progeny trials. These field trials were expensive: they were replicated across multiple sites with each tree individually tagged and measured several times. By measuring a large number of progeny from each parent tree, geneticists identified the parent trees that possessed desirable traits due to having desirable genes. Traits of interest, especially height and diameter, were typically measured at least until 15 years of age and sometimes longer.

This first-generation tree improvement testing allowed geneticists to identify families of trees that displayed desirable traits that were inherited and thus could be passed on. For most species, the best trees, either progeny or parent trees, were then grafted into a seed orchard and managed to produce seeds for reforestation. Seed orchards are managed more like fruit orchards than like forestry plantations; they are mowed, sometimes irrigated, and often treated with plant hormones or other methods to stimulate cone production. They are expensive to establish and maintain. The time it takes to produce seed from a seed orchard tree varies, but generally ranges from eight to 15 years for species such as Douglas-fir, ponderosa pine, and noble fir. Thus, production of genetically improved seed involves years of expenses for both tree improvement research and for seed orchard management. In addition, for some species, tree improvement has gone on to a second generation where the best trees from the first generation were crossed together, seeds from those crosses grown in another round of replicated progeny trials, and the best second-generation trees selected—again a decade's long process. For a few species, including coastal Douglas-fir and western hemlock, a third generation of tree improvement is in progress.

Genetic gain

Most genetically improved seedlings planted in western North America during 2017 will be from some type of first-generation seed orchard. Those seedlings were produced by trees or their progeny that were found growing naturally in the forest—but identified through tree improvement as having desirable traits—and then raised in a seed orchard where they were pollinated by other, similarly selected trees. Given how "natural" these seedlings are, how much better are they compared to seedlings produced by "woodsrun" seed collected from natural stands? In other words, how much genetic gain do they achieve? The answer depends on many factors, especially the number of parent trees tested and the quality of the progeny testing.

The company I work for, Roseburg Forest Products Company, participates in tree improvement cooperatives for Douglas-fir that give us access to thousands of first-generation parent trees appropriate to our Oregon land base, and we have placed the top ones in intensively managed seed orchards. As a result, the first-generation seedlings we plant are expected, on average, to produce plantations that at age-15 are 8-15% taller with 15-40% more volume than if we had used woodsrun seed. These values are expressed for plantations that are 15 years old, which was a common age for the final measurement of many of the first-generation tests. All this genetic gain will not be recovered at rotation. Based on predictions from growth models and comparisons from other species, I conservatively estimate that half of this genetic gain will persist to rotation. For some of our land base, we have begun planting second-generation seed, which will yield even higher genetic gains.

Roseburg is not alone in achieving these high genetic gains. Similar values are expected for most landowners in

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Realized genetic gain trials that compare plots established with woodsrun stock (right) to those established with genetically improved stock (left) help demonstrate to forest managers the economic benefits of tree improvement. The faster growth rate achieved by tree improvement is visually apparent and statistically significant in the Molalla realized genetic gain trial for Douglas-fir, established in 1997 by the Northwest Tree Improvement Cooperative.

western Oregon and Washington that have invested in cooperative tree improvement for Douglas-fir and western hemlock. Genetic gains are usually lower for minor species, such as noble fir, which have lower investments in tree improvement.

A high return on investment

When many plantations are established using genetically improved stock, the increased wood production can be substantial, and this provides a strong economic motivation for investment in tree improvement programs. The return on investment can be quantified using discounted cash flow analysis: Landowners input tree improvement and seed orchard costs, when the costs were incurred, acreage to be planted, and the genetic gains achieved. Then, using a forest growth model, the amount of wood products produced over time using genetically improved seed versus woodsrun seed can be estimated and a monetary value assigned to those wood products. A "discount rate" (sometimes called the compounding interest rate) is included in the analysis to account for the time value of money, since money tied up for decades in tree improvement is not available for other investments. With this approach, projections of the future value of wood products can be discounted to arrive at a present value estimate for investing in tree improvement and seed orchards. Such economic analyses done for many tree improvement and seed orchards programs in western North America demonstrate a high return on investment under reasonable genetic and economic assumptions.

The economic benefits from tree improvement are realized in several ways. Plantations established with genetically improved stock have higher yields. They often also produce higher value wood products. Additionally, since they grow substantially faster, the wood can be harvested sooner, reducing the rotation age, and allowing the forestland to be cycled more quickly; this is captured in economic terms as increased land expectation value. Genetically improved stock can also result in more uniform stands, leading to lower harvesting and transportation costs. Inflation is also a consideration: when wood products experience positive real rates of inflation compared to other goods in the economy, this magnifies the genetic gains in yield and quality, making investment in tree improvement even more favorable.

The return on investment from a tree improvement and seed orchard program is tied to the size of the land base it serves. Whereas the costs of most silvicultural treatments are incurred on a per acre basis, (e.g., vegetation control and fertilization), many costs associated with tree improvement including selection, breeding, and testing occur at the program level. Therefore, landowners receive higher returns as they reforest more acres with genetically improved stock. This economy of scale has resulted in the formation of tree improvement cooperatives and accounts for their remarkable persistence despite many changes in land ownership, and thus cooperative membership. Moreover, genetic gains are cumulative across generations of tree improvement and across rotations of a plantation. Thus, whereas other silvicultural treatment must be repeated with each rotation, it is not necessary to repeat the costs of an entire tree improvement cycle for each rotation. For these reasons, continued investment in tree improvement and seed orchards, and continued economic benefits to its participants and the regional economy, is anticipated for valuable plantation species in western North America. ◆

Sara Lipow is a Tree Improvement supervisor with Roseburg Forest Products Company in Lebanon, Ore. She can be reached at 541-259-2651 or saral@rfpco.com.