Bulletin No. 774

# Genetic Improvement

# of Private Woodland Ecosystems in the Pacific Northwest

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***Cover photo: This 4-year-old tree is a result of good genetics and site management.***

# Introduction

Whether you actively manage woodlands or leave them to nature, as a woodland owner you are making decisions about the genetic future of your forests. With a little know-how, we can manage future generations of trees to maintain or improve the benefits of woodland ownership for our own enrichment and profit and for future generations. This publication introduces woodland owners and managers to some of the basic concepts and general practices of genetic improvement. Professional assistance and additional learning can help them put this information into practice on the lands they own or manage.

# What does genetic improvement mean?

Genetics is the basic science that attempts to explain why and how related organisms resemble each other...and why they are different from each other. It takes into account the effects of genes and the environment. When the basic knowledge of genetics is applied to breeding trees, the effort is referred to as *forest tree breeding* or *forest tree improvement*. Applying knowledge of genetics to develop improved trees through breeding can be as simple as harvesting seed from only the best sources, or as complicated as sophisticated multiphase, multigenerational programs of controlled pollination. *Genetic improvement* on private woodlands is the application of genetic principles in combination with cultural practices such as thinning, planting, or natural regeneration to improve the genetic composition of the residual trees or new seedlings.

***Early genetic considerations lead to healthy forests.***

***Picking cones from western white pine trees that have been bred for resistance to blister rust.***

## *Importance to private woodlands*

Most woodlands in the inland Pacific Northwest resulted from natural regeneration (were not planted) whereas many coastal woodlands were artificially regenerated (planted). Either type of woodland may be highly variable in species composition and genetic traits. At the opposite extreme, they may be pure stands of genetically similar trees from only a few parents. Any removals, by timber harvest or natural processes, will change the number of possible mating combinations and seed sources for future generations of trees. These changes can cause improvement or degradation, or may be neutral in their effects.

Cattle breeders have long understood this process and have selected and retained their best stock to renew and improve their herd. In the beginning, they had only the outward appearance (the *phenotype*) by which they made their selections, but the procedures have advanced over the years to where the true genetic composition of an individual (the *genotype*) is known after many generations of controlled breeding. In formal forest tree improvement programs, tree breeders are in the process of developing the same type of information and improved breeding stock for forest trees. But genetic improvement of forest trees can also be accomplished through everyday woodland management practices.

Through a process called *natural selection*, the rigors of nature often eliminate genetic combinations that have poor survival or reproductive characteristics. Those that remain have the inherent ability to survive current environmental conditions. However, natural selection is regressive in that it does not select genetic combinations in anticipation of future conditions. Genetic improvement through breeding can be used to artificially select genetic combinations for expected future environmental conditions. Breeding can also provide new genetic combinations to improve resistance to environmental stress including drought, insects, and disease. Woodland owners may also want to maintain traits that can enhance the economic or intrinsic value of their trees. They can accomplish this through methods that mimic natural selection - that is by favoring the individuals with desirable characteristics and eliminating trees with undesirable characteristics. Unfortunately, this process can also work in reverse. That is, with poor management practices, owners may retain parent trees that produce offspring (*progeny*) with weak survival ability and/or undesirable physical attributes. This happens when the best trees are removed and inferior trees are left to reproduce. The results can be a noticeable loss in tree quality and in productivity of the stand.

Woodland owners will learn much about the trees in their forests while making selections for elite (*plus*) trees. They may, for instance, detect previously unnoticed insect, disease, or animal damage problems. By leaving the best trees to reproduce, they will improve the next generation of trees, and benefit financially from the improved growth and health of the remaining trees (*leave trees*).

## *What is Plus Tree selection?*

Plus tree selection is a process that encourages or limits mating and reproduction to trees with desirable traits. The process is used when the desired characteristics are at least partly genetically controlled, and can result in improved average characteristics of the selected trees and desirable changes in their progeny. Plus tree selection can be used to change characteristics such as growth rate, disease resistance, crown form, cold hardiness, drought tolerance, straightness, or, as with Christmas trees, color, and branch density.

***This white pine test plantation is being assessed for blister rust resistance under field conditions.***

***The tree in the center of the photo has two highly heritable traits: fast height growth (a positive trait) and 14 multiple forks (a negative trait).***

# *Is Plus Tree selection complicated?*

Plus tree selection is *not* complicated to understand or apply. There are, however, some concepts and procedures that need to be understood for success. Many people had an introduction to genetics in biology classes, but for most of us, that was a long time ago. Your local school or public library should have non-technical books on genetics to aid your understanding of the genetic process. (We've listed a few selected references at the end of this bulletin.) Some of the important things to consider include:

(1) The *heritability* (the genetic part of the variation of a trait in a population) of a trait varies from one characteristic to the next. Each trait is also affected by the environment where the tree grows. For example, many of us have noticed that the diameters of trees in a forest vary with the amount of competition in the stand's environment. Diameter is under weak genetic control and varies considerably with the tree stand density and other environmental factors. Height growth, in contrast, is under stronger genetic control, and the genetic height potential of a tree can be expressed more readily even under a variety of environmental conditions. When we select for plus trees, the degree of genetic control, or heritability, of the traits we choose to improve is one factor in the amount of population change we can expect.

(2) The *selection intensity* we apply will also affect the amount of genetic improvement. When we select plus trees, we initially base our selections on the *phenotype* (outward appearance) of individual trees. By selecting the best appearing tree out of 100 trees versus the best out of ten, we increase the selection intensity and the probability of improved genetic quality, although not by a factor of ten. We are simply increasing the chances of getting better progeny in the next generation of trees.

(3) The *genetic gain* (amount of measurable improvement) we achieve is a result of many interacting factors, including heritability and selection intensity. It is important to recognize that individual traits may or may not be genetically related. For example, growth traits such as height and diameter may be related to each other in a positive sense, and may be negatively or not at all related to excessive branching or forking. There is

enough built-in diversity within a single tree to complicate selection for more than one or two traits at a time. However, when selecting many plus trees in natural populations, a list of selection criteria may be used that includes five or more traits listed in order of importance (Table 1). This procedure helps increase the probability that several desired attributes will be expressed in the progeny. However, there is some sacrifice in the amount of genetic gain for any single trait when selecting for an increasing number of dissimilar traits.

## *What traits should be selected?*

Many characteristics of trees affect their economic value, health, and beauty. Some examples of successful selection programs include blister-rust resistance in white pine, faster growth in Douglas-fir and greener needles in Scots pine Christmas trees. For most woodland owners, vigor, good form, and apparent good health will be the basis for selecting plus trees. Fast growth is often linked with resistance to insects and diseases, greener and denser foliage, improved seed production, and better ability to withstand storms and other damaging agents. Table 1 lists and ranks typical criteria for making selections based on desirable traits for stable, economically productive forest stands.

## *When and where should selections be made?*

On any woodland of a few acres or more, there are several opportunities for genetic improvement during the life of the stand. Because natural regeneration usually results in a clumpy distribution of trees, and sometimes several episodes of regeneration, there are opportunities for selection early in stand development. Trees can be thinned as saplings to leave the most vigorous and healthy ones to occupy the site. Species preference, height growth, and good form are usually the most important criteria in early stand selections.

In a stand where the trees are clumped and crowded, they cannot use the growing space efficiently. In such a situation, a woodland owner should *thin* the stand with a goal of redistributing the growing space to fewer trees that represent the best in the stand. For this reason, *it is more important to look for trees to leave*

***Selected for its resistance to blister rust this white pine tree also has many good form traits.***

***Thinning young stands will improve health and vigor and increase opportunities for future genetic selections.***

*than trees to cut.* The leave trees should be selected as much as possible on the same basis as the criteria listed in Figure 1 for more mature forest stands. Not all the trees left in the thinning will be eventual candidates for selection as parents for the next generation, but a careful selection at the time of thinning will increase opportunities for subsequent selection when it is time to replace the current stand through harvest/regeneration. Trees in competition with the selected plus trees should be removed during the thinning to allow full development of the residual trees' superior potential.

Undisturbed woodlands provide excellent opportunities for genetic selection of eventual parent trees for natural regeneration or seed collection for planting. Unfortunately, many private forests have been altered several times before the current owners had the opportunity for genetic improvement. Nonetheless, some improvement can almost always be made with the existing stand when relying on natural selection, and planting genetically improved trees can provide additional gains. While planting may require many years to realize an economic return, recent large increases in timber value make planting more profitable and common. The owner can also take satisfaction in the fact that the direction is toward improvement rather than toward degradation. Planted trees provide the greatest opportunity for genetic gain if they come from seed produced in a controlled breeding project. However, the seed source must be matched to the planting site or potential gain could be lost through mortality, poor growth rates, or deformed stems.

Whether seed for artificial regeneration (planting seedlings grown in a nursery) will be collected from a few selected trees or many trees selected over a large ownership, gains can be made by using specific criteria to identify the most rapidly growing, vigorous, healthy trees for seed collections. Greater reliability can be had if an inventory of the woodland can provide data about average tree characteristics such as age, diameter, height, crown length, and form quality. *(Plus trees are those whose characteristics are substantially better than average for a particular site.)*

A simpler process with greater probability of selecting phenotypes with improved genetic quality is called *comparison tree selection*. This method requires identification of a group of trees of the same species on a uniform site, similar in age and spacing. Given this similarity of conditions, the trees are compared to each other based on the selection criteria, and the best candidate is selected for plus-tree status. This method has the advantage that the selected tree has expressed better traits under an environment similar to that of its neighbors, increasing the likelihood that its desirable traits are genetically rather than environmentally controlled and will therefore be expressed in its progeny. Comparison tree selection is relatively simple because no inventory or mathematical analysis is required.

## *What do you do with selected Plus Trees?*

Many nurseries will grow seedlings for individual woodland owners from seed collected on the landowner's property, but only in large quantities. Most trees are also easily grown in a home garden, but time and method of transplanting are critical. Natural regeneration or direct seeding may be better options for small scale regeneration. By collecting seed from plus trees on their own land, private owners are assured of locally adapted seed. The use of seed from phenotypically superior trees increases the probability of genetic improvement. This approach can provide increased survival and more vigorous growth of newly planted areas compared to using nursery-grown seedlings of unknown origin. Controlled pollination can add an extra measure of genetic gain because both pollen (father tree) and seed (mother tree) are selected for good traits that can be transferred to the progeny.

***This forest stand is scheduled for harvest using a seed-tree method for natural regeneration.***

Many private woodlands, where appropriate seed sources exist, will not be planted. They will be regenerated by natural seeding. The selection and care of plus trees is adaptable to both even-aged and all-aged methods of harvest regeneration. For even-aged methods, a good distribution of genetically selected trees simplifies the application of the shelterwood or seed tree methods of harvest regeneration. The seed tree method (four to ten leave-trees per acre) has far greater potential to produce genetic gain than the shelterwood method (20-60 leave-trees per acre) because of the greater selection intensity in the seed tree and the likelihood of some inbreeding in the more closely spaced shelterwood. The all-aged selection method is best adapted to genetic improvement if groups rather than individual trees are

*The phenotypically best trees in this seed tree cut were left to provide seed for a new generation.*

harvested, and the trees around each opening are thinned to leave the superior trees for seed production. In using the all-aged selection method, it is important to track ages as well as sizes of the trees. In either situation, genetic improvement is gained by increasing the likelihood that newly regenerated trees are parented by the best available trees. Additional improvement can be gained by later thinning of newly regenerated saplings to leave phenotypically superior trees for further growth.

## *Where to get help*

A well-managed woodland requires a management plan that will not only guide the current owners but will leave a record for future owners and managers of an enduring, productive, and renewable resource. Genetic improvement must become a major component of management planning for woodland owners to maintain the ecological and economic viability of their forests. Existing plans should be reviewed and practices for genetic improvement should be incorporated. For new owners, or those that have never had a plan, help is available. Your local office of the Cooperative Extension System is a good place to begin. Literature is available on management planning ranging from the two-page leaflet "Management Planning for the Woodland Owner" (University of Idaho Extension CIS 675) to the more comprehensive and elaborate "Woodland Workbook" (Oregon State University Extension Service). On-the-ground assistance is available from state forestry agencies. For more comprehensive services including inventory, timber marking and harvest, and planting services, private forestry consultants can provide an excellent return for the cost of their services. Ask for local recommendations and make sure the consultant is a forestry graduate of an accredited university program.

### *Table 1—Plus Tree Selection Criteria*

**A. Forest Stand Characteristics**

Plus trees should be selected from stands (forest units with uniform topography and tree characteristics) that are:

1. Of natural origin
2. Even-aged
3. Fully stocked (most growing space occupied by trees)
4. Middle-aged (35-90 years old)
5. Vigorous and healthy
6. Enough trees of each species to permit phenotypic comparisons within species
7. On sites similar to planting sites in topography, aspect, soils, elevation, etc.

**B. Individual Tree Characteristics**

Within the selected stand, plus-trees selected should be:

1. In the dominant or co-dominant crown class (at or above the general tree canopy level)
2. Superior in height and diameter growth
3. Defect, insect, and disease free
4. Straight bole (trunk)
5. Producing cones (does not apply when thinning).

**C. *DO NOT* select trees with:**

1. Large branches
2. Major forks and/or repeated forking
3. Steep branch angles
4. Weakly developed, thin crowns
5. Boles with a crook, sweep, or twist.

*Adapted from guidelines developed by the Inland Empire Tree Improvement Cooperative. Listed in order of higher to lower priority.*

## *Selected References*

*Note: References developed for the general public on the subject of genetics and tree improvement are scarce. This is why we developed this publication. The references in Section A can provide some general background. Section B contains references developed for woodland owners that address subjects related to this publication.*

*Forest Service and other technical references are available from all state university libraries.*

**Section A: Tree Improvement and Plus Tree Selection**

Bassman, John H. and Fins, Lauren. *Genetic Considerations For Culture Of Immature Stands*. Proceedings - Future Forests of the Mountain West: A Stand Culture Symposium. USDA Forest Service, General Technical Report, INT 243. April 1988.

(continued on back)

Gonick, Larry, and Wheelis, Mark. *The Cartoon Guide to Genetics*. New York: Barnes and Noble Books, Harper and Row, 1983.

Zobel, B. and Talbert, J. *Applied Forest Tree Improvement*. New York: John Wiley & Sons, Inc., 1991.

**Section B: General Forest Stand Management**

*The UI and PNW Extension publications are available through local Cooperative Extension System offices. To order contact Connie King, Ag Publications Distribution, Moscow, ID 83843-2240. (208) 885-7982.*

**Pacific Northwest Extension Publications**

*Joint publications of the University of Idaho, Oregon State University, and Washington State University.*

Measuring trees (PNW 31)

Plant your trees right (PNW 33)

Raising forest tree seedlings at home (PNW 96)

Thinning: an introduction to an important timber management tool (PNW 184)

**University of Idaho**

Plant your container-grown seedlings right (CIS 528)

Diameter limit cutting: a questionable practice (CIS 630)

Basics of thinning for the woodland owner (CIS 654)

Management Planning for the woodland owner (CIS 675)

How to plan, plant and care for windbreak, reforestation and conservation plantings (MISC 13)

Stand and site evaluation for silvicultural prescriptions (SN 37)

**Washington State University**

Reforesting cutover woodland in the Pacific Northwest (FS 11)

Where to get trees to plant (EB 790)

Terminology for woodland owners (EB 1353)

**Oregon State University**

Regenerating Oregon's forests (MAN 7)

Seedling care and handling (EC 1095)

Certification of tree seed (EC 1101)

Management planning for woodland owners:why and how (EC 1125)

Management planning for woodland owners: an example (EC 1126)

Estimating site productivity on your woodland (EC 1128)

Tools for measuring your forest (EC 1129)

Glossary of woodland words (EC 1155)

Using pre-commercial thinning to enhance productivity (EC 1189)

Stand volume and growth: getting the numbers (EC 1190)

Selecting and buying quality seedlings (EC 1196)

Reforestation planning guide (EM 8241)

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