ALLOCATION AND MANAGEMENT OF GENETICALLY IMPROVED STOCK: A "MISSING LINK"

C. B. Talbert[1]

Abstract.--Tree Improvement programs worldwide have devoted significant time and resources, quite successfully, to the development of varieties of commercial trees with substantially improved value potential. However, guidelines and procedures to assure maximum realization of the value of such varieties in operational forestry are seldom discussed, despite the significant opportunity costs and risks which can be incurred when such guidelines and procedures are lacking. Weyerhaeuser Company plants over 20,000 ha. annually to genetically improved seedlings of coastal Douglas-fir, Ponderosa and lodgepole pines, western hemlock and Noble fir on its western timberlands, and during the past two years, detailed standard guidelines and procedures have been developed and implemented to guide the characterization of families, the allocation of families to planting sites, and the tracking and monitoring of improved stands through time. From this experience was gained an understanding of the critical factors leading to successful implementation of genetic improvement in field forestry. These factors will be articulated, and supported by specific examples taken from Weyerhaeuser's Douglas-fir program. The benefits, expected and unexpected, from a well-planned and successful allocation system have been great, in consistent effective use of stock, in control of risk, in defensibility of genetic improvement practices outside the Company, and in improved communication and coordination between Tree Improvement and operational foresters.

Keywords: *Pseudotsuga menziesii,* realized gain, allocation, regeneration, seed source movement, genetic diversity, inventory, family blocks.

INTRODUCTION

The success of most genetic improvement programs is reflected in the changes which are realized in the attributes of the target species or in the products derived from those species within an operational production system. In the case of commercial forest trees, that operational production system is typically some type of planted and managed forest stand, from which a stream of products is harvested. Genetic improvement programs for commercial trees have focused the greatest time and energy to date on the development of varieties with improved productivity, stem form, wood quality, disease resistance,

---

1. Program Leader, Western Tree Improvement/Genetics Reserch, Weyerhaeuser Cornpany, Federal Way, Washington.

and/or hardiness to cold or drought; on propagation systems for 'packaging' of the improved genetic potential; and (particularly in recent years) on gene conservation activities supporting the long-term breeding program (Figure 1). This focus on varietal development has been very successful in terms of the potential it has created for improved value on the ground. However, with few exceptions two critical steps have seldom been discussed, steps involving effective allocation of genetically improved stock to operational planting sites, and effective utilization through optimal silviculture and processing. Lack of attention to these steps can mean loss of much or all of the value potential created in the selection, breeding and testing process. On the 'up-side', there is an enormous potential for additional value to be created in allocation and utilization. This added value can come from proper matching of genetic material to site and market requirements; from nursery management and silviculture which enhances positive attributes of the genetic materials or corrects negative attributes of those materials relative to site and market requirements; or from coordination in planting of specific varieties with design and location of processing facilities to ensure a consistent supply of a desired type of raw materials for target products, to name just a few. Experience and observations of a large number of programs indicates that the value impact of tree improvement is more limited by the ability to *deliver that value on the ground* (through allocation and utilization) than it is by the ability to improve *genetic potential* in selection, breeding and testing.

Allocation of Genetically Improved Stock - Definition

In the context of this discussion, the term *allocation* is employed to mean *the process of choosing planting stock for a site and deploying it on that site.*

Common Reasons for Loss of Gain Potential in Allocation

The effectiveness with which gain is realized through allocation is sometimes limited by organizational factors, sometimes by inefficient methods, and very often by conservative assumptions or risk-avoidance mechanisms which are applied more broadly than may be required. Some of the most common features of allocation processes or approaches that limit the realization of gain are:

1. Vaguely defined improvement goals or trait requirements.

It is very difficult to achieve an objective which has not been clearly articulated. However, it is an endemic problem in tree improvement that its goals apply to a timeframe which is decades out in the future, market and product definition in that timeframe is uncertain, and therefore trait requirements are uncertain. This problem is often confounded by the common situation that mill trial data or simulation models relating tree characteristics to product recovery and value are often limited in scope or lacking entirely, and geneticists often feel poorly qualified to expand these data and models (not to mention lacking the resources to do it). Despite these challenges, truly effective breeding programs and allocation systems must be based on clearly defined trait-improvement goals. Without such clear goals, it is difficult to obtain sufficient resources to get the job done well, resources are wasted in activities which do not further the goals, and decisionmaking often becomes highly conservative - no future scenario is pursued intensively for fear that the (unknown) right option will be lost in the process.

2. 'Generic' varieties, 'generic' allocation

When trait requirements are not clearly articulated (for the reasons described above), it is most common for tree improvement programs to be designed to produce a single 'generic' variety which provides at least some economic benefit for any probable end-use and site type (within geographic constraints) but optimizes benefit for no site or end-use. This approach, while conceptually and logistically simple, has a large opportunity cost associated with it, and in fact may never produce a sufficiently dramatic result to maintain long-term support for the tree improvement enterprise.

3. 'Zone' based management of the risk of maladaptation

Most tree improvement programs were initiated based on the appropriately conservative premise that the risk of maladaptation is best controlled by selecting, testing and allocating genetic material within a delineated geographic area - a 'breeding zone' or 'seed zone'. As more programs complete one or more generations of testing, it is becoming apparent that, in many regions of fairly mild climate, family and site variation within these zones is as large or larger than zone-to-zone variation, both for value traits and for adaptive traits. When this is the case, the 'zone' approach to allocation not only does not provide good control of adaptive risk, but also unnecessarily limits the selection intensity and gain available from broader allocation of tested, proven genetic material from a similar environment but a differentzone.

4. Genetic value predictions which are not comparable across all available materials

Most tree improvement programs have conducted their genetic testing in stages where different parents are tested in different series over a number of years. Often within a year there are different 'sets' of parents, only intercrossed within a set (disconnected diallels are an example of this). Second and third generation testing is now underway. Methods must be put in place (preferably at the mating and test design stage) so that comparable genetic values can be calculated across sets, years and generations, and so that genetic values can be compared for all family types which could be produced and allocated (wind-pollinated vs. SMP vs. control-pollinated). In addition, these genetic values must be well-understood by, and in the hands of, the people responsible for ordering and allocating planting stock for operational regeneration. Without such a system, the selection intensity available in selection and allocation can be considerably limited.

5. 'Stand-level' vs. 'landscape-level' requirements for genetic diversity

It is most often assumed that the risk of loss due to unforeseen genetic responses is best controlled through allocation of many families to any one planting site. On highly stressful sites or on sites where some type of highly heritable, density-dependent pest response is involved, this strategy is quite sound. Likewise, sites which are to be naturally regenerated in the next cycle should be planted with many families to minimize future inbreeding. However, this strategy passes over the very powerful knowledge base which can be gained through single-family block planting and monitoring through time - knowledge which can be applied directly to control of future risk, through elimination of certain families or adjustment of allocation rules. Single-family block planting and monitoring can also enable greatly improved targeting of certain families for particular site types, silvicultural regimes or product directions as operational experience is gained over a period of years. As long as many families are planted across a geography and the proportion of planting to any one family is controlled (i.e. 'landscape-level' diversity), the risk of significant loss to some future genetic response under many situations may actually be decreased via operational monitoring of single-family plantings.

Key Elements of an Effective Allocation System for Improved Stock

First, what are the criteria for an 'effective' allocation system? In general, an allocation system should provide a logic and a process for effective decision making about what genetic material should be used in what situation; it should provide for management of risk - both the risk of maladaptation under the current range of conditions and the risk of loss due to unforeseen, future genetic responses; it should provide mechanisms for tracking success and improving the allocation rules/procedures; and it should facilitate sharing of information and building of synergy among the groups responsible for developing, propagating and using the genetic material. Based on these criteria, certain elements can be listed as critical components of an effective allocation system:

** A process for describing trait requirements:* *Preferably one which is tied to specific tree-growing strategies, end use requirements and site features.*

** A means to describe genetic material in terms of those requirements:* *In a manner which enables comparison of genetic values across years, sets, generations and available family types (wind-pollinated, SMP, control-pollinated).*

** Unambiguous, documented rules for choosing genetic material for sites:* *These must be well-understood and accepted by foresters, with a mechanism* ***in*** *place for the foresters to feed back and improve the rules. The more specific the matching can be of families with sites or end-use requirements, the more effective will be the utilization of the full range of families and sites planted.*

Key Elements of an Effective Allocation System for Improved Stock (continued)

* *Specific prescriptions for management of risk: These should encompass all aspects of risk, including the risks of loss due to maladaptation or unforeseen future genetic responses, market risk or political risk*

* *Quantifiable goals, and processes in place to track success: These goals might be expressed in terms of the actual performance and losses realized in operational stands as compared to some specific baseline (such as stands of 'local' unimproved stock).*

* *Mechanisms for feeding back and responding to operational-stand performance data: This requires that the genetic identity of stands be recorded, that some kind of systematic monitoring of survival, adaptive performance and value characteristics be carried out, and that someone has the accountability to summarize that information and report it back to the people responsible for propagation and allocation.*

* *A strong formal and informal structure for information flow: The more people in the process who are sharing information about the genetic material, the greater will be the enthusiasm and synergy among those groups and the steeper will be the increase in efficiency and effectiveness of the production and allocation systems through time.*

In the next section, an example of an operational allocation system for improved Douglas-fir will be described, and some of the key learnings from the development and implementation of that system will be reviewed.

A CASE STUDY

Background

Since the mid 1980s Weyerhaeuser Company has been meeting its 20,000 ha/year annual low-elevation[2] Douglas-fir planting requirement in western Oregon and Washington with seedlings from first-generation, tested seed orchards. Company lands in this region are generally mild and highly productive, but are associated with a high degree of local variation in temperature, soil moisture, soil productivity, animal damage, vegetation competition and other factors. Sites also vary in operability, ease of management, and distance from particular market centers. Certain sites have been found to be poorer than others in expression of stem defects and other quality characteristics.

Douglas-fir is a species which is grown primarily for processing into solid wood products (i.e. lumber, beams, etc.), and is used most often in applications where product strength and stiffness and dimensional stability are required. Different geographies em-

2. Below 2000 feet.

phasize different products and markets, and a growing information base is becoming available on the relationship between site characteristics, raw material characteristics, and value for these products and markets. Weyerhaeuser is moving toward a more 'prescriptive' approach to forest management in each geography so that limited resources (forest management dollars, people time, genetic materials) can be put to their highest use.

Historically, Weyerhaeuser's Douglas-fir genetic material was developed, propagated and allocated within 6 'low-elevation' and 6 'high-elevation' breeding zones. Wind-pollinated orchard family mixtures containing 15-30 parents were used for operational planting. In the early 1980s, a series of broad-based research trials were installed to evaluate the stability of first-generation family performance across a wide range of environments both within and across breeding zone boundaries. A variety of hardiness and growth rhythm traits have been assessed in these trials along with growth performance, survival and frost damage in the field. A comprehensive review of the results of these trials was completed by Stonecypher in 1990. In summary, these trials show stable superiority of most families across a very diverse range of environments, including sites in 'non-local' breeding zones, and variation associated with sites and families within zones was considerably larger than zonal variation, for growth performance, growth rhythm and frost hardiness traits. These results likely reflect the mild selective environments and the 'fine-grained' pattern of site variation within Company ownership in low-elevations on the west side of the Cascade range.

In 1991, an effort was initiated to review, update and document operational allocation rules and procedures dealing with genetically improved Douglas-fir. A team was assembled representing the forestry operations, the nursery and orchard groups, tree improvement and forestry research, and the result of this team's work was a system for allocation which meets the criteria for effectiveness described above, and which is now implemented across the Company's low-elevation landbase.

Weyerhaeuser's Allocation Process for Improved Low-Elevation Douglas-fir

The allocation process consists of 5 principal steps, and these will be reviewed below.

1. First, planting units to be regenerated are classified in terms of their target market, their value potential, the operability and manageability, and their biological risk factors (cold, drought, defect potential, etc.). This is done by the foresters during the summer and fall, after site preparation, based on a standard worksheet and scoring system which uses the soil survey, physiographic characteristics, and local-stand characteristics. Planting units can then be ranked within and across geographies for value potential with key biological risk factors flagged out.

2. In parallel to the planting site classification process, genetic test data are summarized in the form of breeding values for growth potential, defect potential, wood specific

gravity and adaptive traits, and these breeding values are provided to foresters in the form of a catalog. Breeding values were standardized across years, sets and generations using a standard, unimproved check which was represented in all tests, and by scaling breeding values to an average variance derived as a pooled value from all tests. Defect potential, wood quality and adaptive traits are expressed as ' + '0' or '-' relative to the 'local' non-select.

3. A detailed 'rule-book' was written to guide the selection of families for planting sites based on the best possible match of growth quality and adaptive features:

* Combinations of 'stress-sensitive' families and high stress-risk sites are to be avoided.

* Combinations of defect-prone families and high defect-potential sites are to be avoided.

* Positive adaptive or value traits of certain families are matched to sites with a particular requirement for such traits, due to a biological risk factor or a target market.

* Otherwise, the fastest-growing families (highest volume breeding value) are allocated to the most productive sites.

However, extra safeguards are applied in the rules:

* Limits are placed on the maximum 'environmental distance' from parental origin to planting site. 'Environmental distance' is expressed in terms of elevation, latitude, soil moisture availability and distance from the coast.

* Limits are placed on the maximum proportion of planting to any one family, in a single year and over a 5-year period.

* The contiguous area which can be planted to any one family or relative is restricted.

4. Families are allocated to planting sites as single-family lots, except on very stressful or extreme sites where balanced multi-family mixtures are prescribed.

5. The genetic identity of all units is tracked through the Company inventory system, a subset of units of each family is monitored annually, and the monitoring results are summarized and fed back to the foresters via the family catalog (described in #2, above).

The cross-disciplinary team which assembled to design the allocation process now has assumed a long-term review and improvement role, makes decisions involving use of genetic material for the highest overall benefit to the Company, and provides an important communication and approval mechanism relating to genetic improvement initiatives.

Key Learnings from the Allocation Process to Date

* Clear specification of planting stock requirements and family attributes has proven to be extremely powerful. Not only is the most effective use being made of the wide variety of available genetic material, but no one has to trade off volume improvement for quality or adaptive trait improvement unless their sites or markets require it. The interchange of information which occurs during the specification process feeds information back into the breeding program about new trait priorities, and the process has generated a high degree of enthusiasm and involvement in tree improvement among foresters.

* Management of families in single family lots in the orchard, nursery and field creates a very rapid learning curve, and much more knowledge than mixed-family management allows. Nursery cultural regimes and family-site allocation rules are already being revised based on operational experience with particular families. It is critical, however, to have a database structure ready ahead of time to accept and process this information and get it into the right hands for process improvement.

* It has been extremely valuable to get the maximum amount of family information out into the hands of the orchard managers, nurserymen and foresters. Each of these people has become a more effective decision maker in management of their improved stock through the availability of this information, and they also become sources of important observational data.

* Focused attention is required on the implementation of an allocation system so that the new rules and procedures become an integral part of the way people do business does *what* and *when.* Implementation requires clearly defined assignments, written into performance criteria, and training up and down the organization to ensure consistent understanding and support. This has proven to require enormous time, energy and persistence, even in the presence of a generally supportive atmosphere.

LITERATURE CITED

Stonecypher, R.W. 1990. Assessing effects of seed transfer for selected parents of Douglas-fir: Experimental methods and early results. In: Proceedings of the Joint Meeting of the Western Forest Genetics Association and IUFRO Working Parties S2.02-05, 06, 12 and 14, Olympia, Washington.