FOREST GENETICS IN A CHANGING WORLD
A GENETICIST'S VISION OF THE FUTURE'

L. Fins[2]

Abstract - The beginning of this decade has been marked by major shifts in public attitudes toward forestry and whole new belief systems about forests. Ecosystem management and biodiversity have become the new buzzwords. Multi-storied management with a reliance on natural regeneration is hailed as "kinder and gentler" forestry, while "clearcut and plant" is seen as environmentally destructive and technologically primitive. Diversity is touted as necessary for ecosystem stability, while the planting of genetically improved trees is assumed to result in impoverished monocultures on the brink of disaster. In response, many public agencies and some privately held corporations have begun to move away from the forest practices that traditionally utilize genetically improved trees and some tree improvement programs are currently in a precarious position. These decisions appear to be based on a set of beliefs and assumptions that are unsupported by the evidence. Nonetheless, there is some hope. There are tremendous opportunities for forest geneticists in the future. Our expertise will continue to be important to descriptive and restoration ecologists, physiologists, pathologists, and ecosystem managers, as well as to those who are still in the business of growing wood and wood fiber as a crop.

Keywords: Forest genetics, genetic diversity, ecosystem management, tree improvement, forest health.

INTRODUCTION

As the direction of forestry has changed over the last few years, and more and more public land is withdrawn from production forestry, many forest geneticists and tree breeders have become concerned that the decisions are short-sighted with limited attention to the long-range genetic implications of the new policies. Nonetheless, I believe there are tremendous opportunities for geneticists to make a significant contribution to the future of forestry, if we are willing to see and understand the realities of peoples' perceptions, work to change some of those

---

[1] Paper presented at the Twenty-second Southern Forest Tree Improvement Conference, June 14-17, 1993. Atlanta, GA

[2] Professor of Forest Genetics, Department of Forest Resources, College of Forestry, Wildlife and Range Sciences, University of Idaho, Moscow, Idaho 83843

perceptions and accept others, and perhaps most importantly, to commit our expertise to re-vitalize the profession in this country and around the world.

Clearly, there have been major shifts in public attitudes toward forests and forestry over the last decade. Ecosystem management, forest health and biodiversity have become the new buzzwords. Natural regeneration is hailed as "kinder and gentler" forestry, while "clearcut and plant" is seen as environmentally destructive and technologically primitive. Ecosystem diversity is touted as necessary for ecosystem stability, and planting genetically improved trees is assumed to result in genetically impoverished monocultures on the brink of disaster. In response, many public agencies and some private corporations have begun to shun the forest practices that have traditionally relied on genetically improved planting stock. They now emphasize functional diversity with little attention to forest productivity.

PERCEPTIONS AND MISPERCEPTIONS

These shifts in attitudes appear to be based on beliefs and assumptions (I have identified five of them) that are unsupported by the evidence and which have no basis in reality. The first belief is that ecosystems are inherently stable if people would simply leave them alone. The second belief is that diversity and stability are closely linked. Third is the belief that evolution has finely tuned ecosystems, with genotypes perfectly matched to their sites of origin and therefore all genetic diversity is important and should be preserved. Fourth is the belief that any manipulation of the forest results in a severe loss of diversity, and that tree breeding programs produce genetically depauperate monocultures that are somehow unattractive and at high risk. And finally, linked with these ideas, is the belief that "natural" is inherently "best".

First of all, there is a broadening body of information from fossil, pollen and midden records that indicates that ecosystems are not stable. These findings have been reviewed by Brubaker (1988, 1991) and by Betancourt et al. (1990) and it appears that even some of the important plant associations that we observe today did not exist on the landscape as short as 3,000 years ago. The conclusion one must come to is that ecosystems are indeed dynamic; and therefore stability is not an inherent characteristic of ecosystems.

To the second point, the stability/diversity hypothesis was shown to be false almost 20 years ago. Stability is not linked to diversity. This notion is unsupported by any evidence and is no longer accepted by the community of ecologists. Goodman (1975) reviewed the theory, the models and the evidence for this hypothesis in a thorough work and concluded that

> *"The expectations of the diversity-stability hypothesis are borne out neither by experiment, by observation, nor by models... Clearly the belief that more diverse communities are more stable is without support."*

On the third point, while many studies have shown that forest trees are highly variable, few people understand that only a small fraction of that variation is distributed between populations (Hamrick et al. 1992) and local diversity may be as much a function of "evolutionary footprints" as adaptation to the local environment (Strauss et al. 1992). Furthermore, we find that similar adaptive responses are repeated across landscapes, even landscapes as highly variable as the northern Rocky Mountains (Rehfeldt 1991). The deployment strategies used with loblolly pine show that relatively restricted seed sources can be well-adapted to the climatic and soil conditions across a much broader geographic area (van Buijtenen 1992). To sum up, it is quite clear that evolution has not at all finely tuned the ecosystem. Genotypes are not uniquely matched and nor are they necessarily even closely matched to the environments in which we find them. Rather, many genotypes appear to be physiologically buffered so that they can thrive over a broad geographic area.

To the fourth point, there still seem to be many questions as to whether or not variation is being maintained when harvest regeneration methods, thinning treatments or selective breeding are used. Several studies have been conducted to address this issue. As just one example, in 1982 we sampled phenotypically superior, sub-dominant and randomly selected Douglas-fir trees in each of two even-aged naturally regenerated stands in northern Idaho (Fins, unpublished). The stands were approximately 50 and 56 years old at the time of sampling. The samples were compared for levels of genetic diversity using isozymes. Our hypothesis was that there would be differences in allele frequencies among the groups and we suspected that the select trees would have slightly higher levels of genetic diversity than the randomly chosen trees, and that the subdominants would have generally lower levels of diversity than the first two groups. Interestingly, differences in diversity among the three groups were generally small and not consistent between stands. The phenotypically superior trees had the highest level of genetic diversity in one stand, the sub-dominant trees had the highest level in the second stand and the randomly chosen trees had the lowest diversity in both stands. While this was an admittedly small study, it does suggest that **among the leave-trees,** overall genetic diversity for non-selected traits is not necessarily reduced nor enhanced by selection on phenotypic characteristics.

Nearly all of the studies conducted thus far indicate that silvicultural treatments do not decrease genetic diversity in the next generation (Neale 1985; Shimizu and Adams 1993; Yazdani et al. 1985). One study showed that diversity was re-distributed somewhat with overstory removal in a multi-aged stand (Millar et al. 1991); another showed that genetic diversity increased in seed-tree stands compared to the controls (Woods and Blake 1981).

The question of diversity has also been addressed for genetically improved populations. On the phenotypic level, a study by James (1979) showed that radiata pine, even from a seed orchard, is still highly variable phenotypically. As a consequence, James ultimately recommended planting 4 times the final stocking rate in order increase the frequency of the phenotypically better trees in the final harvest stand.

Several studies have also investigated the levels of genetic diversity in biochemical traits in seed orchard stock as compared to natural stands. While one study of **loblolly pine seed** orchards (Hamrick 1991) showed a decrease in genetic diversity of seed orchards compared to natural stands, several other studies with Douglas-fir (reviewed by Carlson and Yanchuk 1990), and Sitka spruce and redcedar (El-Kassaby 1992) showed nearly identical diversity or increased diversity of the seed orchards over the natural stands.

Overall, the studies to date indicate that harvest regeneration does not decrease diversity; thinning does not decrease diversity, and current breeding programs do not necessarily decrease diversity and may even increase it relative to natural stands.

As to the fifth point, whether natural is "best" is primarily a value-judgment. However, we must remember that "natural" does not necessarily mean most productive, best adapted or most diverse. But, knowledge of the current "natural" condition is probably a useful landmark to monitor the direction of change, whether it be the inevitable change through natural selection or the deliberate change through selective breeding programs.

THE FUTURE

As for the future, ultimately, geneticists must be a part of the planning process, working with managers to **develop long-range strategies** for public lands. Such strategies must satisfy the public's desire for "natural" forests while maintaining high productivity. I favor a national policy that institutes forest zoning on public lands such that highly productive lands would designated for production of wood and wood products (while maintaining good stewardship of the soil and water); other areas would be designated primarily for alternative uses including archive (conservation) populations as reservoirs for genetic diversity. We must understand and embrace the idea of a separation of the archive populations from the production and breeding populations (Savolainen and Kärkkäinen 1992). We must recognize that each type of population has a different function and likely different locations.

Furthermore, we should consider a division of labor, whereby a primary mission of the public agencies is to protect the archive populations on public lands while the private sector focuses on production of wood and wood products. Within the production populations, the focus must be directed to achieving gains. We must be willing to manage genetic diversity wisely, which may involve decreasing genetic diversity on a local level while maintaining it on a landscape level. This type of change would include some risk, as does any crop breeding program, diversity would be maintained and available as needed from the archive populations and additional (and perhaps new) diversity would be available from the breeding populations.

If we accept this division of populations, lands and labor, we must also help to allay the public's (and profession's) concerns that we are somehow destroying gene pools. We must publicize our efforts to preserve and utilize diversity in our natural populations, while emphasizing the need and demand for wood and wood products. We must help people see the parallel between raising trees and raising food and fiber crops.

We must help to **educate** the public, including children, public school teachers, the media, and members of our own profession about the ecological trade-offs of using metal and other non-renewable resources in place of the renewable resource of wood. We must all begin to give talks at local clubs, schools, talk to the press and so on. We must carry the message and help people make the intellectual connections. Forest ecosystems are dynamic and ever-changing. No amount of set-asides will keep them as they are today or get them back to how they were yesterday. Diversity is not linked to stability. Genotypes are not necessarily tightly adapted to environments. New mutations come and go in the natural world; it is futile to try to preserve all variants. Breeding can increase overall levels of genetic variation. We must help people get past the idea that "natural" is permanent, is "best" and is somehow "sacred".

We must align ourselves with ecologists, physiologists, silviculturists, and growth and yield scientists. We can also work with the restoration biologists to ensure that they use appropriate seed sources in their work. We have much to contribute to research on the effects of global climate change and we should work to accurately characterize populations based on their ranges of adaptive behavior. Studies of forest health must include investigations of physiological genetics of adaptive and growth traits. An understanding of genetic variation in traits such as nutrient efficiency, drought resistance, length of the growth period, and cold hardiness will be particularly important. We must continue to research and monitor changes in genetic diversity in our forest tree populations. We must help evaluate the changes in productivity as alternative management strategies affect genetic structures and diversity. If inherent productivity is lost or gained as a result of genetic changes in populations, we must carry that message to the public and the profession.

So, ultimately, my message is that with the current losses of forest lands to other uses, it is time for us to redouble our efforts to make people aware of our ability to contribute to all sectors of forestry from basic research in forest health to ecosystem management to timber production. We must do everything we can to achieve maximum timber production on our best sites to produce the wood and wood products that the public demands. This approach could include selecting only the very best genotypes for production, even at the risk of narrowing the genetic base in the production populations compared to natural stands. A carefully crafted breeding program that rapidly generates new and varied genotypes to replace old ones will be critical to the success of this approach.

As I see it, tree breeding can and should follow directly in the footsteps of American agriculture. Rather than lament the current state of our profession, we geneticists should embrace this time as an opportunity to utilize our talents and knowledge more fully and to contribute to all aspects of the profession. We can become the most efficient producers of timber in the world and still be a model of responsible stewardship.

LITERATURE CITED

Adams, W.T. 1981. Population genetics and gene conservation in Pacific Northwest conifers. P. 401-415 in Evolution Today. Proc. 2nd International Congress of Systematic and Evolutionary Ecology, G.G.E. Scudder and J.L. Reveal (eds.). Hunt Institute for Botanical Documentation. Pittsburgh, PA.

Betancourt, J.L., T.R. Van Devender and P.S. Martin. 1990. Synthesis and prospectus. P. 435-447 in Betancourt, J.L., T.R. Van Devender and P.S. Martin (eds.) Packrat Middens. The last 40,000 years of biotic change. University of Arizona Press, Tucson, AZ.

Brubaker, L. 1988. Vegetation history and anticipating future vegetation change. P. 41-61 in J.K. Agee and D.R. Johnson (eds.). Ecosystem Management for Parks and Wilderness. University of Washington Press, Seattle, WA.

Brubaker, L. 1991. Climatic change and origin of old-growth. P. 17-24 in Wildlife and Vegetation of Unmanaged Douglas-fir Forests. USDA Forest Service. Pacific Northwest Research Station General Technical Report PNW - GTR - 285. May 1991.

Carlson, M. and A. Yanchuk 1990. Maintaining genetic diversity in future man-made forests - What are we doing today? In Forests - Wild and Managed: Differences and Consequences. January 19-20, 1990. University of British Columbia, Vancouver, B.C.

El-Kassaby, Y.A. 1992. Domestication and genetic diversity - should we be concerned? Forestry Chronicle 68(6):687-700,

Goodman, D. 1975. The theory of diversity-stability relationships in ecology. The Quarterly Review of Biology 50(3):237-266.

Hamrick, J.L. 1991. Allozyme Diversity of Natural Stands versus Seed Orchards of Loblolly Pine. P. 21 in Proc. 23rd Meeting of the Canadian Tree Improvement Association, S. Magnusen, J. Lavereau, and T.J. Boyle (eds). Ottawa, Ontario.

Hamrick, J.L., M.J.W. Godt and S.L. Sherman-Broyles. 1992. Factors influencing levels of genetic diversity in woody plant species. New Forests 6:95-124.

James, R.N. 1979. Influence of tree breeding and stocking rate on tree crop quality. N.Z.J. For. 24(2):230-240.

Millar, C., R. Westfall and D. Delaney 1991. Effects of forest management on genetic diversity in Jeffrey pine. US Department of Agriculture, Forest Service Research News, Pacific Southwest Forest and Range Experiment Station, August 1, 1991, 3pp.

Neale, D.B. 1985. Genetic implications of shelterwood regeneration of Douglas-fir in southwest Oregon. Forest Sci. 31(4):995-1005.

Rehfeldt, G.R. 1991. Gene resource management: Using models of genetic variation in silviculture. In: Proc. Genetics/silviculture workshop. August 27031, 1990, Wenatchee, Washington. USDA Forest Service, pp 31-44.

Savolainen, 0. and K. Kärkkäinen 1992. Effect of forest management on gene pools. New Forests 6:329-345.

Shaw, D.V. and R.W. Allard 1982. Isozyme heterozygosity in adult and open-pollinated embryo samples of Douglas-fir. Silva Fennica 16:115-121.

Shimizu, J, Y. and W.T. Adams 1993. The effect of alternative silvicultural systems on genetic diversity in Douglas-fir. In Proc. 22nd Southern Forest Tree Improvement Conference. June 14-17, 1993. Atlanta, GA.

Strauss, S.H., J. Bousquet, V.D. Hipkins and Y.P. Hong 1992. Biochemical and molecular genetic markers in biosystematic studies of forest trees. New Forests 6:125-158.

van Buijtenen, H.P. 1992. Fundamental genetic principles. P. 46-49 in: Handbook of Quantitative Forest Genetics.

Woods, J. and G. Blake 1981. The effect of seed tree regeneration systems on the genetic diversity of ponderosa pine. pp. 9-10. In Progress Report of the Inland Empire Tree Improvement Cooperative. L.Fins, editor. August 1981. 36p.

Yazdani, R., 0. Muona, D. Rudin and A.E. Szmidt 1985. Genetic structure of a *Pinus sylvestris* seed-tree stand and naturally regenerated understory. Forest Sci. 31:430-436.