

Genetic Variation and Early Performance of Giant Sequoia in Plantations¹

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Abstract: Giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz) is genetically less variable than expected; furthermore, it is less variable and its populations are less structured than are several associated or related conifers. Giant sequoia seedlings from open-pollinated seeds of isolated trees or from small outlier groves do not survive and grow as well as those from large groves, and cold susceptibility is related to elevation of origin. On the basis of these observations and other considerations, planting strategies for within and outside the native range are recommended. More information is needed to develop guidelines for nursery and planting practices and for identifying appropriate sites for giant sequoia.

GENETIC VARIATION

Many species of animals such as fruit flies, mice, and humans maintain a great deal of genetic variation within their populations. Unlike most animals, most annual plants cannot escape or modify unfavorable elements of their environments, and perhaps that is why such plants maintain even more genetic variation than do animals. Trees, which must endure all of the physical and biotic variations of their environments for decades and even centuries, on average maintain even more genetic variation than do annual plants (Hamrick and others 1979). One might thus expect that giant sequoia (*Sequoiadendron giganteum* [Lindl.] Buchholz), which often endures for millennia, would be among the most genetically variable species.

My graduate students and I first studied the genetic variability of giant sequoia using enzyme variation as a measure of variation in the genes that code for those enzymes (Fins and Libby 1982). To our surprise, giant sequoia's genetic variation as measured at this enzyme level is distinctly subdued, compared with that of other Sierra Nevada conifers and of other trees in general. This result is supported by a recent study of giant sequoia's early survival, growth, and form (Mahalovich 1985). Trees from 21 of the 23 sampled groves on average survived and grew similarly. The relationship of elevation, latitude, and longitude of the sampled groves to performance

of their offspring in the experiment was slight, if present at all. Although giant sequoias differ in such characteristics as foliage color, crown shape, and stem taper, and occasional trees have such deviations as variegated foliage or drooping branches, giant sequoia generally has a more predictable form than is typical of most other conifers.

Cloned giant sequoias were included in our recent study (Mahalovich 1985), and thus we were able to investigate whether genetic differences in growth and form exist between individual trees. Such tree-to-tree differences do exist, and they are biologically, statistically, and (perhaps) economically significant. But, consistent with earlier observations on form and enzymes, they are of much smaller magnitudes than have been found in associated and related conifers, for example, ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), white fir (*Abies concolor* var. *lowiana* [Gord.] Lemm.), sugar pine (*Pinus lambertiana* Dougl.), or coast redwood (*Sequoia sempervirens* [D. Don] Endl.).

At the population (grove) level, there are two exceptions to the above generalization that are worth special note. First, trees from the northernmost (Placer) and southernmost (Deer Creek) groves grew substantially and significantly slower than, and differed in other respects from, trees of the other 21 sampled groves (Fins and Libby 1982, Mahalovich 1985). The Placer Grove has only 6 trees, and the Deer Creek Grove has about 30. Seedlings from isolated trees have also done poorly (Guinon and others 1982). Small population sizes probably result in inbreeding, which typically results in poor offspring performance.

Second, in tests on some European and New Zealand sites, particularly where many giant sequoias were injured by cold, trees from the Atwell Mill Grove (the southern grove in Sequoia-Kings Canyon National Park and one of the highest of the native groves) usually survived and grew relatively well (Kleinschmit 1982, Thulin 1982). In experiments where such cold damage occurred, it was significantly related to the elevation of the origin groves (Guinon and others 1982).

The above observations lead to a few recommendations for planting giant sequoia:

For planting outside native groves---Plants from isolated parents or of Placer Grove or Deer Creek Grove origins will probably not do as well as other giant sequoias. On a potentially good site for giant sequoia, plants from any of the other groves are, to the best of our current knowledge, equally likely to do well. On sites where cold damage may occur, plants from the Atwell Mill Grove or from other high-elevation populations may be more successful than those from lower elevations.

For planting in or near native groves---Just as designated "specimen" trees in native groves should be protected from human-caused destruction, so should the genetic integrity of these native groves be protected. While subdued, there is

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genetic variation within the giant sequoia species. Groves other than Placer, Deer Creek, and Atwell Mill may contain genetic variation that is interesting or valuable or both, and that is also unusual or even unique. Natural regeneration (probably following fire) is thus preferable to planting. If planting is done in or near native groves, it should be done with seeds or seedlings from that grove. The seeds should be collected from 20 or more representative trees in the grove to ensure an adequate sample of the grove's genetic variation.³

ARTIFICIAL REGENERATION

Planted giant sequoias may be placed in four performance classes: (1) they soon die; (2) they grow slowly and never grow well; (3) they grow slowly for about a decade, and then grow rapidly and well for a very long time; (4) they grow rapidly and well, commencing within 2 years of planting. Analyses of these four classes suggest the following:

For class 1, most likely something was wrong with nursery or planting practice, although in some cases the site or weather may have caused the mortality.

For class 2, the site is probably inappropriate for good growth of giant sequoia. Such planting experiences will accumulate, be increasingly understood, and provide guidelines for appropriate sites and conditions for giant sequoia.

For class 3, nursery practice or planting practice or elements of both were likely the problem. This pattern of growth has been commonly observed. It might be considered normal for sites appropriate for giant sequoia, were it not for occasional class 4 performance.

For class 4, nursery, planting and post-planting practices, and site apparently were all correct. As we learn more about these essential components of good plantation performance in reference to giant sequoia, this class will increasingly become the norm for giant sequoia plantations.

³If inadequate numbers of seeds are available, cloned material may be available from source-identified clone donors maintained at the Forest Service's Tree-Improvement Center at Chico, phone (916) 895-1176.

MIXED SPECIES PLANTINGS

Given good nursery stock and good planting technique on a site where giant sequoia grows well, giant sequoia will outgrow conifers native to Europe or to the Sierra Nevada-Cascade Mountains of western North America. The differences in growth are frequently large. The only exception frequently observed is European larch (*Larix decidua* Mill.), which may grow faster than giant sequoia during the first decade or so. Observations in Europe (Libby 1981) and in California (Fins 1979, Mahalovich 1985) are consistent with this generalization.

A common practice is planting about 15 percent giant sequoia mixed with one or more other conifer species on about 3-meter (10-ft) centers. One usually has confidence that the other species will successfully grow on the site. If giant sequoia fails, it usually fails early, and an early loss on the order of 15 percent can usually be accepted. If giant sequoia grows well, subsequent silviculture can adjust the developing stand to any percentage of giant sequoia desired.

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