New Applications in Clonal Forestry

W. J. Libby
Forestry Consultant, 28 Valencia Rd, Orinda, California 94563

DEFINITION

For many folks, clonal forestry simply means planting cloned trees in forests. However, it is increasingly coming to imply much more than that (Libby and Ahuja, 1993a). In brief, full clonal forestry means that a relatively few, tested, well-understood clones are deployed to the forest. Furthermore, it means that not only is the value of the forest increased because the clones have outstanding value, but also that the efficiency of management is increased because management can adapt to the strengths and requirements of each well-known clone.

HISTORY

The history of clonal forestry extends back at least 1000 years and that of cloning trees even longer (Libby and Ahuja, 1993b). Yet it is a recent development in main-stream forestry, and most of the so-called new applications discussed below are pretty early in this developing field.

The oldest continuous program of clonal forestry is from south-central China, with Chinese-fir (*Cunninghamia lanceolata*), a near relative of our coast redwood. That story is being developed for publication by Professor Minghe Li, of Huazhong (Central China) Agricultural University in Wuhan, Hubei Province, collaborating with Weyerhaeuser's Gary Ritchie. For 10 centuries, Chinese farmers and foresters have rooted shoots of good Chinese-firs, and thus developed locally adapted clones with excellent properties.

A better-known program of clonal forestry, also with one of redwood's relatives, has long been operational in Japan with sugi (*Cryptomeria japonica*). Increasingly well-known cultivars, often a mixture of several similar clones, have been grown in Japanese forests for over 500 years. Recent production of sugi cloned as rooted cuttings has varied between about 20 million and 50 million plants per year (Ohba, 1993).

Poplars and willows have also been clonally produced for millenia (Zsuffa et al., 1993), and the well-known Lombardy poplar and weeping willow clones both originated and became widespread over 300 years ago (Kleinschmit et al., 1993). During the past century, some of the most advanced strategies for using clones in forestry have been developed with clones of these two genera, and particularly with hybrids between the American *Populus deltoides* and the European *Populus nigra* (Zsuffa et al., 1993).

Some of the greatest excitement lately has been generated by recent successes of clonal forestry with eucalypts. In the Aracruz Florestal program in Brazil, for example, average productivity was quickly jumped from 33 m^3 ha^{-1} of wood per year in seedling plantations to 70, by selecting healthy well-formed clones from those seedling plantations. This increase in wood-volume growth was accompanied by an increase in the average basic density of the harvested wood, and thus a decrease of 19% in the cubic meters of wood consumed per ton of pulp produced (Zobel, 1993). Some clones now in test grow over 100 m^3 ha^{-1} of wood per year (average wood productivity of commercial American forests is about 4 m^3 ha^{-1} per year).

Finally, and perhaps why I'm here, the company I work with in New Zealand produces about 8 million Monterey pine stecklings and plantlings (the rooted-cutting and tissue-culture stocktypes) per year, at our nursery at Te Teko. It has been over 4 years since we've planted a Monterey pine seedling on our North Island forests, except a few for research purposes.

RATIONALE

There are at least three reasons to be involved in clonal forestry: (1) We will need more wood from less land. (2) Raising wood clonally is more profitable. (3) Clonal forestry is, in several ways, a better way to professionally grow new forests.

Will We Really Need More Wood from Less Land? We've heard cries of timber famine before, and yet, timber gluts have been more common than timber famines during the recent century. However, in his presentation to the Portland Oregon Meeting on planted forests last year, Dr. Wink Sutton reviewed not only the upward trend in human population worldwide, he also reviewed the continuing rise in per-capita use of wood and wood products in both developed and undeveloped economies. He calculated that the combination of these two trends will, in the near future, require an increase in world wood supplies about every 6 months that is equivalent to all the wood produced annually by New Zealand plantations. Or, closer to home, about every 6 years Earth's forests will need to add an increment to annual forest harvest that is equal to the recent annual wood harvest in British Columbia.

In most countries today, forest land is being converted to agricultural and urban purposes, and/or forest land is being withdrawn from timber production for watershed, wildlife, recreation and aesthetic purposes. With few exceptions, these withdrawals are larger than the new forests that are being created on unforested lands. Growing wood more effectively in timber-producing forests is at least a good way to delay a possible timber famine. Perhaps that timber famine can thus continue to be avoided until we achieve a sustainable human population in tune with sustainable forest harvests.

Is Raising Wood Clonally More Profitable? This is not a guarantee that it always is. I'll give you two case examples drawn from New Zealand experience. Both will be given in New Zealand dollars (currently about 70% of the U.S. dollar), but I think the principles will be clear.

The first is how, in the mid 1980s, John Gleed (1993) convinced corporate management to raise and plant expensive cloned propagules rather than much cheaper seedlings. A series of arguments is given in his cited paper, but two of them carried the day. They are both focused on reducing early costs, rather than the more traditional argument that good clones increase later returns.

When New Zealand foresters planted unselected Monterey pine seedlings, they were planted at a density of about 2500 stems per ha, and then thinned in several stages to a harvest density of about 250 trees. Large amounts of time and money were devoted to deciding which trees to prune, and to thinning out the 9 poorer trees in each 10-tree neighborhood. Using reliable clones, the initial planting density can be about 600 stems per ha, with lower per-hectare planting costs as well as much lower subsequent thinning costs to achieve the same 250 (probably higher quality) stems per ha to grow on to harvest.

Because the clones are at a somewhat greater maturation state than seedlings, their branch architecture allows more effective and cheaper pruning than does that of the typical seedling. That, plus the fact there are fewer trees per hectare that need be pruned, leads to additional pruning cost savings.

The combination of planting fewer trees, pruning fewer trees, thinning out fewer trees, and spending less time pruning each pruned tree, added up to substantial cost savings per hectare. These savings were recovered within the first decade after planting. Never mind that the trees will be worth more at harvest as well. The early net cost savings alone convinced management to accept the higher cost per planted propagule.

Our clonal program began in earnest in 1987. Managers of other organizations were still requiring that nursery-cost-per-propagule be equal to or less than nursery-cost-per-seedling in order to consider cloning. (This requirement, by the way, is generally satisfied for Chinese-fir, sugi, poplars, and willows.) Then, during the following 4 years, another financial element came into play.

In the late 1980s, Monterey-pine seeds cost less than $1000 per kg. It cost between $1300 and $1700 to raise rooted cuttings that would equal the number of seedlings that could be raised from a kilogram of seeds. But, because others were doing benefit/cost analyses similar to John Gleed's, managers were increasingly willing to pay more for seeds from proven families. The demand for seeds of the better proven families drove their price over $2000 per kilo, and it has recently been between $6000 and $10,000 per kilo for seeds from the very best families. This sharp upward shift in price for genetically reliable planting stock of many tree species became clear during a 1992 symposium (Bey et al., 1992). It doesn't take a very sophisticated analysis to figure out that buying relatively few seeds at $8000 per kilo, and then vegetatively propagating them at $1500 per-kilo-equivalent, is a sensible thing to do. Several other organizations in New Zealand and Australia have joined the one I work for, which by the way is now called Fletcher Challenge Forestry, in planting 100% vegetative propagules in their wood-production forests.

It is well established with fruit-tree species that reliable clones produce a more profitable harvest than genetically variable seedlings. The same principle should hold for forest trees, although we don't yet have much harvest data to back up that principle.

Finally, many smaller forest owners don't have, and probably can't afford to have, their own clonal propagating nurseries. So, for some of you who DO have the capability to clonally propagate trees, there may be a fine opportunity to make your own profits in that niche.

How is Clonal Forestry Better Professionally? Before answering this question, it is perhaps useful to indicate that wood is an important and environmentally sound natural resource. This has been well done in two recent articles (Koch, 1992; Postel and Heise, 1988). Postel and Heise reviewed the needs of many of Earth's peoples, and the availability of wood to satisfy those needs. Koch calculated the costs of wood and of various substitutes such as plastic, steel, aluminum, and cement. Rather than monetary costs, he calculated the energy costs of production, manufacture and delivery, the fossil carbon dioxide thereby released, and the toxic pollutants released incidental to that production and manufacture. With very few exceptions, wood has much lower environmental costs than do these and other substitutes considered.

In brief, clonal forestry allows the forester much greater control. Knowing the requirements and performance of the deployed clones allows management activities such as pesticide application, fertilization, thinning, and pruning to be scheduled and executed more efficiently. It probably means less pesticide and fertilizer over-applied, or inappropriately applied. It also allows more precise control of deployed diversity and, perhaps surprisingly, more effective deployment of genetic diversity than does the planting of sexually-recombined and thus individually-unknown seedlings. In short, it allows us to grow forests that are less at risk of environmental damage, and are less at risk of disease or insect epidemics, than were previous plantations of seedlings, or even naturally-regenerated forests. That sounds pretty egotistical. We think we can do it (Libby, 1982).

NEW APPLICATIONS

Well, finally to the topic requested. I can be brief, partly because you already know about most of these approaches to cloning.

We are developing better ways to root cuttings, both to lower costs and to produce propagules that, upon outplanting, grow better than seedlings (Bey et al., 1992).

Tissue culture and somatic embryogenesis are both moving from research projects to operational forestry much faster than many of us had anticipated (Talbert et al., 1993). Some of you may have noticed the 8000 acres of eucalypts west of I-5 near Corning. In recent years, new plantings in that Simpson Timber Company plantation are almost exclusively of tissue-culture origin. In New Zealand, Fletcher Challenge Forestry is now operationally putting about 2,000,000 tissue-cultured Monterey pines out the nursery gate annually at Te Teko. Emblings (plants of somatic-embryo origin) of yellow-poplar (*Liriodendron tulipifera*) and of several pine and spruce species are now growing by the thousands in early tests of this stocktype. (As yet, no somatic embryos of forest-tree species have been operationally encapsulated in artificial seeds.)

Although grafting was tried and rejected for production plantations in the first half of this century (Larsen, 1956), values of individual trees are now becoming high enough so that this is again being considered.

Maturation of a clone is a problem for both propagation and subsequent growth (Frampton and Foster, 1993; Greenwood and Hutchison, 1993). It is also an opportunity. For example, compared to juvenile clones or seedlings of Monterey pine, mid-adolescent clones grow straighter, have fewer and smaller branches, and are more resistant to juvenile diseases such as western gall rust.

Finally, ecosystem restoration is an increasingly important activity, and it is often done counterproductively (Millar and Libby, 1989). One problem is that nonlocal plants of native species are often planted into the ecosystem being restored. They can then cross pollinate with the remaining local plants of that species, thus probably reducing the adaptedness of the offspring to the site. One solution is to clonally propagate some of the remaining local plants, thus increasing numbers and keeping the gene pool truly local.

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