you can see that this organization hasn't been standing still the last 17 years. This is the 17th annual meeting. We owe Don a vote of thanks for the amount of work that he has put into this program. I am sure he has found the job of being Program Chairman to be a terrific amount of work.

REFORESTATION WITH VEGETATIVELY PROPAGATED TREES

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The traditional uses of forests have been as watershed protection, as habitat for game and other wildlife, for firewood, for lumber, and for that special spiritual renewal that many people find in the presence of trees. As the human population continues to require more resources, some of these traditional forest uses are being increased and we have returned to others, sometimes in non-traditional ways. For instance, wood alcohol may replace cordwood as transportable energy, and generators fueled by wood waste already feed electricity into our transmission lines. Plywood, laminated and end-glued products from tennis rackets to stadium beams, chipboards, particle boards, and fiberboards, have joined traditional sawn boards and timbers in many old and new uses. The demand for paper and paper products continues to increase and expand. And wood chemists can create plastics from dissolving pulps, food flavors from terpenes, and perhaps soon, food itself from enzymatically degraded cellulose. In short, our forests are taking on renewed importance. In the United States, the recent Humphrey-Rarick bill seeks to ensure that they receive appropriate attention. Foresters are attempting to find more effective techniques for managing the forest resource. The genetic leverage available with vegetative propagation makes reforestation using rooted cuttings one such attractive new management technique, and it appears that its time may now have come.

Some Problems and Features of Forest Regeneration — When one considers the likely costs of site preparation, of planting the trees, of release from competing vegetation, of protection from animal damage, of applying pesticides and fertilizers, of thinning, of pruning, of fire protection, of land-rent charges and taxes, and other costs which must be borne in order to establish a new forest (or even if establishment fails), then the costs of the planting stock are generally seen to be only a small fraction of the total investment necessary. In such a situation, a proportionally large increase in the costs of planting stock can be justified, even if it results in only a relatively small proportional increase in the value of the established forest.

For many of our forest species, seed crops in the wild do not occur every year, and many of the best-growing and best-formed trees have few seeds even in good seed years. Logging is responsive to market demand for wood, and it is difficult to forecast which year a particular stand will be cut and thus need seedlings for reforestation. Disasters such as windthrow and large fires are much more difficult to anticipate. The history of forest planting contains many examples of poor planting practices as a result of these uncertainties. For instance, seedlings from short heavy-limbed parent trees, or seedlings from trees which evolved under conditions significantly different from those of the planting site, have frequently been used because seedlings from good parents of appropriate origin were not available.

Classical tree improvement for forestry purposes has used selected trees gathered together in seed orchards to get the selected genes back into the forest in higher frequencies. The most common way to create a seed orchard is to graft scions from outstanding selected trees, replicating each clone many times to achieve a large production of seeds. In some of our species, graft incompatibilities have caused widespread mortality in the seed orchards. In some of our species, it appears that many of the very best-growing trees produce few seeds in the seed orchards. On the other hand, including genotypes in the seed orchards that are unusually prolific pollen and seed producers may reduce growth in the forest. The principle in both cases is that photosynthate devoted to sex is usually at the expense of wood production, and there is some evidence that sexiness is heritable in trees.

The question of maintaining diversity in our forests has been much discussed. The weight of current opinion is that monocultures, and particularly genetically-uniform monocultures, should be avoided. The main concern is that the majority of trees in a stand could thus be susceptible to a single biotic or physical event.

Most temperate-forest trees are outcrossing, which contributes to the maintenance of the internal diversity that typifies our native species in forest stands. With an outcrossing mating system, much of this genetic diversity occurs within families. The seed-orchard approach captures only the average performance of its families, but cannot take effective advantage of the outstanding individual genotypes that occur among the offspring within its families. Furthermore, most outcrossing species are sensitive to inbreeding, and thus mating between relatives should be avoided. This argues against the use of seedlings from selected families in seed orchards as a solution to the graft-incompatibility problem, because crosses between sibling seedlings can result in serious inbreeding. (Grafts are more acceptable with respect to inbreeding, because the inbreeding depression of selfs in most forest trees is so severe that few produce acceptable seedlings. Thus, the quality of orchard-origin seedlings after culling is little affected by crossing with clones.)

Seed orchards are expensive. This leads to a tendency to concentrate on only the most important species in each forest region. Thus, secondary species may be given little or no genetic attention, and may even not be included in forest plantings. There is also a tendency to make seed orchards large, for economic efficiency. The offspring of such large seed orchards will be used over extensive and perhaps ecologically diverse areas. Most seed orchards employ open-pollination. Therefore, they should be isolated from external sources of pollen, such as native and planted forests, and other seed orchards of the same species whose trees are selected from different regions or for different purposes.

Most of the problems outlined in this section are effectively solved by reforesting with selected vegetative propagules.

Arguments for Vegetative Propagation — A cutting orchard, made up of small trees kept trimmed as hedges, can supply propagating material on relatively short notice. New genotypes can be added in years when seed is produced on selected parent trees, and they will be available as cutting donors in years that seed is in short supply.

Large seed orchards can be replaced with small genetically diverse breeding orchards, whose primary function is the production of modest numbers of pedigreed seedlings for inclusion in the cutting orchard. Genotypes which devote little energy to sex can be encouraged to produce the necessary modest numbers of offspring.

Diversity in production forests can be maintained by mixing clones. Selected clones of secondary species can be included in the mix. As the performance of individual clones becomes known, these mixtures can be prescribed so that neighboring clones make complementary rather than competitive demands on the site.

As information on individual clonal performances accumulates, below-average members of families can be rogued out of the cutting orchard, and the very best can be expanded by adding additional hedges of those genotypes. If the families are open-pollinated and include a mixture of inbred and outcrossed seedlings, it will be mostly the outcrossed genotypes that are selected for extensive use in production forests. Such within-family selection is simply not available in the classical seed-orchard approach to forest management.

An entire region need not be served by exactly the same set of clones. Instead, the forester may order particular clones of some species for one site, and different combinations of species and clones for other sites . . . or even for differing subsites within a planting area. Thus, no two areas need be reforested with exactly the same combinations of genotypes.

Particular ecological conditions not extensive enough to warrant a separate seed orchard can contribute seedlings from their trees to the cutting orchard, and thus can be better served by it.

Disease considerations may still make it advisable to locate the cutting orchard away from forests. But cutting donors of the same species from very different ecological conditions may be maintained near each other, as they will not exchange genes.

Problems Remaining with Most Species — For many of our conifer species, we have not yet learned to root cuttings effectively or economically. In some, rooting percentages are still low. In others, most cuttings root, but they do so a few at a time, so that nursery management of the propagules is difficult. Ideally, we would like 90% or more of the cuttings to have rooted two or three months after being set, and to root within a period of two or three weeks. We need to find media that are appropriate for both rooting and subsequent growth of the cuttings, particularly if containers are used.

A major problem of both theoretical and practical importance is that of maturation. As maturation proceeds, not only does rooting become much more difficult, but the growth of those cuttings that do root generally differs significantly from the growth of the same clones which were rooted in a juvenile condition. The changes that occur with maturation of forest-tree clones are generally detrimental, particularly with respect to volume growth rate. Thus, it is futile to identify good clones if the clones have matured during the test period.

Our nursery people have learned to produce good seedlings of many of our important species. But rooted cuttings are not seedlings, and many of our nursery protocols may need modification or radical change to produce satisfactory rooted cuttings ready for outplanting. It seems likely that root systems will need particular attention.

It also seems likely that rooting percentages, the timing of the rooting event, and the quality of the plants produced, will be improved (perhaps slowly and erratically) as experience is gained with each species. The question of juvenility, however, needs less-conventional approaches. Two general strategies are available: arresting of maturation at appropriate stages; and rejuvenation of mature clones. Interestingly, the repeated hedging used to keep plants small in a cutting orchard seems to accomplish an arresting of maturation. Furthermore, it may be possible to fix different maturation stages of donor plants by the size at which they are hedged. It also seems that serial propagation (in which cuttings are taken from recently rooted cuttings rather than from long-maintained donor plants) may arrest maturation. It may be possible to grow cells from mature trees in culture, change their maturation state, and then recover juvenile plantlets from the cultures. This technique might be helped if we better understood the physical and chemical events associated with meiosis and fertilization, for that is how and when mature plants normally produce juvenile offspring.

The Current Reforestation Situation — The use of grafts or rooted cuttings for large-scale forest planting has been proposed at intervals in the past, and indeed has been accomplished for centuries with such non-coniferous species as cottonwood and willow. Only Japan has extensively used this technique with conifers, most notably with *Cryptomeria*, their national tree.

Within the past few years, Finland, and Lower Saxony in West Germany, have moved out of the pilot-plant stage, producing hundreds of thousands to slightly over a million cuttings of Norway spruce (*Picea abies*) per year for reforestation. New Zealand is in the pilot-plant stage, rooting tens of thousands of radiata pine (*Pinus radiata*) per year. In western United States and Canada, we are entering the pilot-plant stage with western hemlock (*Tsuga heterophylla*), coast redwood (*Sequoia sempervirens*), giant sequoia (*Sequoiadendron giganteum*) and douglas-fir (*Pseudotsuga menziesii*), with other species not far behind.

Two recent symposia have been published and are now available. They are:

1974 Special Issue on Vegetative Propagation. *New Zealand Jour. of Forestry Science* 4(2):119-458.

1976 Symposium on Juvenility in Woody Perennials. *Acta Horticulturae* 56(May):1-317.