Plant Propagators to the Rescue!

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INTRODUCTION

Ladies and gentlemen, I am honored to have been asked to keynote this excellent I.P.P.S. meeting and extend my sincere gratitude to the meeting organizers for having invited me to come.

The organizing committee asked me to conclude this convention with an upbeat review of some of the many important contributions plant propagators make to the service of humankind. In response to this request, I have selected the title "Plant Propagators to the Rescue" and have chosen three case studies in which plant propagators have played a key role in solving a significant social problem. Two of these cases involve my own employer, Weyerhaeuser Company, while one involves the government of a communist country. Two are from here in the Pacific Northwest (PNW), one comes from the Peoples' Republic of China. Two involve forest trees, one involves medicinal plants. Two involve vegetative propagation systems, while one involves seed-based propagation. I was personally involved in two of these cases and completely uninvolved in the other. These choices are drawn directly from my own background in forestry in the PNW and all are subjects of my own personal interest.

CASE 1: TAXOL: RESCUING THE PACIFIC YEW

"I can think of no greater gift to mankind than the domestication of a wild plant" Thomas Jefferson.

Ovarian cancer is a particularly frightening disease. Because its symptoms often do not appear until it is too late for treatment, ovarian cancer kills about 12,000 American women every year. A ray of hope in the fight against ovarian cancer has arisen out of an extensive screening of natural plant products carried out by the National Cancer Institute (NCI) back in the 1960s. Of tens of thousands of natural products screened for activity against cancer, one called "taxol", a substance from the bark of the Pacific yew (*Taxus brevifolia*), showed considerable promise in tests against certain cancer types, especially those associated with ovarian cancer. The mode of action of taxol was found to be unique among cancer-fighting drugs and it promised to be a powerful new weapon.

Full-scale clinical testing of taxol began in 1981. These early trials showed great promise and more taxol was needed to continue further testing. Expensive and difficult to obtain, limited taxol supplies became a serious impediment to further evaluation of the drug. In addition, concern was mounting about the ability of the natural populations of Pacific yew trees to sustain this level of exploitation. Although the yew is neither threatened nor endangered, neither is it considered to be abundant. Furthermore, bark removal kills the tree and the trees are very slow growing.

In January, 1987, Dr. Nicholas Wheeler, a forest geneticist at Weyerhaeuser's Western Forestry Research Center, Centralia Washington, received a phone call from Dr. Gordon Cragg of the NCI. The NCI needed taxol to continue clinical testing and wondered if Weyerhaeuser could supply 27,000 kg of Pacific yew bark. Dr. Wheeler's response was that we had very little Pacific yew on our ownership and that there were serious concerns about extensive bark harvesting and its impact on populations of this native tree species. Why not instead, he suggested, grow the plant as a short rotation nursery crop strictly for taxol production? But no one had ever done this before.

Plant Propagators to the Rescue! A Weyerhaeuser taxol team was formed, agreements were entered into between Weyerhaeuser, the NCI, and Bristol-Myers Squibb (B-MS) a large pharmaceutical company which had earned the government right to market taxol. The agreement was for Weyerhaeuser to develop, within 3 years, a propagation and cultivation system aimed at producing taxol biomass on a short rotation in a nursery. B-MS would be the customer for the crop.

There were many unknowns:

1) Can slow-growing yew plants be intensively cultivated in a seedling conifer nursery and would these small plants produce taxol?

2) How would we propagate Pacific yew: from seeds? from cuttings? where would we get the cuttings?

3) Is the Pacific yew the only species containing taxol?

4) Is taxol present in other tissues besides bark? If not, how would we remove the bark from small seedlings?

5) How would taxol content in the biomass respond to seasonal cycles and cultural practices?

6) What opportunities might there be for genetic improvement, then cloning high-yielding strains?

To shorten a very long and exciting story: after 3 years of painstaking propagation and cultivation research and operational experience, answers are beginning to emerge. This is what we now know: Yews grow extremely well in some of our bareroot nurseries, but not so well in others. This seems to reflect the absence or presence of certain essential mycorrhizal species. Seed propagation is very difficult, but a container-based cutting propagation system has been developed and is very effective. Virtually all species of *Taxus* contain taxol, and it is present in virtually all tissues of the plant except the wood. Some species (or cultivars) contain more taxol than others, and it is distributed among tissues differently in different cultivars. Season and cultural regime significantly affect taxol content. Bareroot nursery rotations of from 3 to 4 years can result in economic yields of taxol-containing biomass. There is a great deal of natural variation in taxol content among species and strains, hence there is much opportunity for genetic improvement.

Our first full-scale commercial harvest of taxol-containing biomass was carried out throughout our nursery system during the summer of 1995 in which close to 11 million 3- to 4-year-old yew plants were harvested.

We believe that a nursery-based production system for taxol biomass has the potential for meeting present and future world demands for this drug, which is now being shown to be effective against other cancer types, such as breast, lung, and head and neck tumors. This can be done with no impact on native populations of Pacific yew.

CHINA: RESCUING THE ANCIENT CLONES

"Planting cuttings of the fir along the roads; enjoying the cool air in the moonlight of the future" Zhu Xi, Song Dynasty, China.

We modern propagators may believe that we are at the cutting edge with our rooting techniques, but at least 1000 years ago, in what today is the Peoples' Republic of China, people were apparently rooting cuttings by the millions. Someone, somewhere back in antiquity, had observed that when Chinese fir (*Cunninghamia lanceolata* [Lamb.] Hook.) trees are cut down and the site is burned, the tree produces "fire" sprouts from below the ground around the cut stump. If these are removed and stuck directly into the ground they will root and grow into a new tree a genetically perfect replica of the mother tree from which it came. They also learned that if suckers from only the largest and most vigorous trees were taken, they would tend to produce large and vigorous trees.

After a forest was harvested, people would seek out the largest stumps, collect cutting wood from them, and stick the best cuttings into the ground in groups around the original stumps. These groups were actually clones and a few of them were truly spectacular in their growth traits. Some of the exceptional clones were repropagated countless times over many centuries. Cloning became the backbone of Chinese forestry. It is reported that yield of some of the best clones was six times greater than that of wild forests (1170 m^3 ha^{-1} versus 193.5 m^3 ha^{-1} at 39 years) (Li, 1992).

Up until the 1950s this practice was carried out over hundreds of thousands of hectares across 14 provinces in southern China. Often the trees were interplanted with other crops in an early version of what we today call "agro-forestry". Sometimes they were planted in mixes with other species, but most often they were planted in mosaics of small mono-clonal blocks.

After 1950, however, China came under strong influence of the Soviet Union and unorthodox views of Soviet geneticists were forced upon Chinese agriculture and forestry. It was asserted, without basis in science, that vegetative propagation and cloning was eroding the genetic quality of the forests. Hence, the practice was discontinued. During the 1960s, 1970s, and 1980s nearly all reforestation in China was accomplished with seed and most of the priceless ancient clones were abandoned and lost forever.

Plant Propagators to the Rescue! Recently, Professor Minge Li, forest geneticist from the Central China Agricultural University, and his colleagues have recognized the folly, indeed tragedy, of this course of action. They have mounted an effort to return to the traditional methods of clonal propagation of Chinese fir throughout southern China. Through extraordinary efforts, they are recovering some of the priceless old clones and returning them to production. They are developing innovative methods of restoring juvenility to some of these trees that have matured over time. This technique involves burying twigs beneath the soil and harvesting the shoots that emerge. This practice apparently rejuvenates them and they can then be used to reestablish stock blocks of some of the valuable clones.

In 1991, over 60 million Chinese fir cuttings were rooted and planted throughout China (Ritchie, 1994).

MOUNT ST. HELENS; RESCUING THE TREE FARM

"I think it would be wonderfully exciting to witness the eruption of one of our Cascade volcanoes during our lifetime." Dr. Dixy Lee Ray, former Governor, State of Washington, 1980.

Exciting, indeed! When Mount St. Helens erupted on May 18, 1980, it not only blew away the top of the mountain itself, but along with it went 221 homes, 12 bridges, 27 km of railroad track, hundreds of kilometers of roads, about 5000 black-tailed deer, 1500 elk, millions of smaller animals and birds, and 56 human souls (Winjum, 1984). Losses to Weyerhaeuser Company, apart from forest trees, consisted of 12 logging sites and 10 rock pit operations; about 650 km of roads and bridges; and three non-resident logging camps containing maintenance shops, equipment, transfer stations, 39 rail cars, and 63,000 m^3 of decked logs (Winjum, 1984).

In all, approximately 61,000 ha of forest were destroyed, on both public and privately owned land. The greatest forest loss was that incurred by Weyerhaeuser Company—about 27,000 ha, or approximately 14% of the SW Washington Tree Farm. This included about 15,000 ha of highly valuable merchantable timber. In addition, about 10,000 ha of young plantations ranging from 1 to 35 years in age were completely destroyed (Winjum, 1984).

What to do? It was immediately apparent that Weyerhaeuser had sustained losses of monumental proportions and that management plans for the tree farm, indeed for the entire region, needed to be immediately and substantially changed. It was also clear that the recovery effort would require very close coordination and communication among corporate management, tree farm operations, seedling propagators, and various research groups within the company. Regenerating the area was in every way a new challenge. A review of the scientific literature revealed that such an operation had no precedent; hence, no one could be certain that successful reforestation was even possible.

The first small regeneration trial was conducted on 16 June using about 1000 each of bareroot Douglas-fir (*Pseudotsuga menziesii*) and container noble fir (*Abies procera*) seedlings. This early trial revealed several serious problems. In the first place, the St. Helens ash was completely devoid of plant nutrients; consequently, the ash had to be scalped before planting so that seedling roots were in contact with the mineral soil. Scalping, in turn, led to stem girdling by weevils (*Stremnius* spp.), that tended to concentrate in the scalping holes. This problem was subsequently solved by planting large diameter stock. In the second place, the ash cover provided an extremely harsh microclimate that resulted in severe seedling stress and loss of vigor. In the third place, the areas in which the ash was deepest were highly prone to surface erosion.

Plant Propagators to the Rescue! These early research trials generated sufficient information that operational plans could be made for subsequent large-scale reforestation activities. These plans called for reestablishment of plantations on about 18,000 ha between 1981 and 1985. The general strategy was to regenerate first the lands posing the least difficulty (those containing shallow ash, modest amounts of debris), while at the same time continuing research on regeneration of the deep-ash sites, site preparing the debris-laden areas and propagating the millions of required seedlings and transplants. There was a need as well to identify attributes of seedlings capable of surviving in this harsh moonscape.

Full-scale operational reforestation began in February 1981, with seedlings grown at Weyerhaeuser's Mima Forest Nursery near Olympia, Washington. This nursery, one of the largest on the west coast, has an annual production of about 23 million bareroot seedlings, mostly Douglas-fir. Lifting operations are conducted in December, January, and February; then stock is stored in freezers at -1C, where it remains in a dormant condition until it is field-planted.

The easiest sites to replant were plantations 1 to 10 years old that were relatively free of heavy ash and debris. These were hand-planted with shovels, the ash layer was scalped and small drainage channels were cut to enable water to drain out of (rather than into) the planting holes. During this first year, seedling supplies were low and stock from adjacent seed zones had to be used. About 2000 ha were regenerated in this manner.

Plantations between 10 and 20 years old were more difficult to work with because they were too dense to plant and were impossible to control burn since the ground was covered with ash and would not support fire. Hence, these young dead trees had to be felled first or crushed before burning. Some slash burns in these areas were larger than 600 ha.

Ash depths of more than 20 cm posed another serious problem. Hand scalping was not feasible in this material because of the ash's excessive weight and planter fatigue. The only method that proved successful was to prepare these sites with a tractor-mounted V-blade. About 1,000 ha were prepared and planted in this way. Unfortunately, scalping with a V-blade was feasible only on ground with less than a 30% slope. Power augers were tried on steeper slopes, but were only marginally successful.

Very deep ash (20 to 30 cm) posed serious problems. An initial approach employed direct planting in the ash, with subsequent addition of various fertilizer treatments. These trials were not successful.

Planting in 1982 focused on two types of ground: low-elevation, shallow ash sites (about 1500 ha) and middle- to high-elevation, deeper ash sites (about 2000 ha). The low-elevation sites were planted with Douglas-fir. Little or no site preparation was needed because there had already been extensive salvage logging on these areas. Seedling survival averaged 88%. Douglas-fir and noble fir stock was planted on mid- to high-elevation sites, respectively, with good success. Although this stock suffered winter desiccation aggravated by lack of vegetation on the barren, ash-covered landscapes, survival did approach 90%. A tribute to excellent stock production technology.

Subsequent activities reached a peak in 1983, when about 5000 ha were regenerated. By 1984, 2+1 Douglas-fir and noble fir transplants from the same seed zone (which had been ordered immediately after the eruption) became available. This stock was planted on some 3400 ha in 1984 and on an additional 1600 ha in 1985. Black cottonwood (*Populus balsamifera* ssp. *trichocarpa* syn. *P. trichocarpa*) was planted along riparian zones and mud flows and lodgepole pine (*Pinus contorta* [Dougl]) on exposed ridges.

By the end of 1985 the project was essentially completed. In all, about 18,000 ha of new plantations were established during this period. This required about 17 million bareroot Douglas-fir and noble fir seedlings. Seedling survival in most of these areas has been better than 85%. Of the remaining 9000 ha about 7000 ha were traded to the U.S. Government for inclusion in the Mount St. Helens National Monument. A satisfactory method of regenerating the remaining deep-ash and mud-flow areas has not yet been found and these areas, comprising about 2000 ha, will remain unplanted for the foreseeable future.

I invite, indeed encourage, each of you to make the easy drive up to the St. Helens National Monument while you are here in the Portland area. As you drive along this spectacular highway from Silver Lake, past the new C.W. Bingham Learning

Center, to the Visitors Center at the National Monument, virtually all of the young forests you will pass through along the way resulted from the propagation and planting effort I just described. These well-stocked forests, now 12 to 14 years old, contain trees approaching 10 m in height and will soon be in need of thinning. They teem with elk and other wildlife, the streams support healthy populations of Coho salmon and steelhead (Rochelle, et al., 1992). The rapid and successful establishment of these magnificent young forests is a tribute to the skill and efforts of many dedicated people especially plant propagators!

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POSTER SESSIONS

Controlled-Release Urea Fertilizers Affect the Growth and Quality of Selected Foliage Plants

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Three formulations of an encapsulated urea product and one sulfur-coated urea were evaluated at 0 to 4 times the recommended rate on *Chamaedorea elegans*, *C. seifrizii*, *Chrysalidocarpus lutescens*, *Spathiphyllum* 'Tasson', and *Rhapis excelsa* against a standard controlled-release fertilizer at equal N rates. Each plant species responded differently to the fertilizer sources. *Chamaedorea seifrizii* and *S.* 'Tasson' did not exhibit preferences for fertilizer sources from top-growth measurements. *Chamaedorea elegans*, *C. lutescens*, and *R. excelsa* growth measurements indicate that fertilizer source affected growth and quality of the plants. The general recommendation for foliage plant production is an equal ratio of ammoniacal to nitrate nitrogen sources. Economically, this ratio makes the fertilizer more expensive than other traditional fertilizers. The use of a controlled-release urea fertilizer has the benefit of being a cheaper source of N and would lower the cost of production, but results on the selected foliage plants indicate that the fertilizer composition is important in plant production.