Southeastern Tree Improvement Tour

Trip Report

November 6 – 12, 2000

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Forest Genetics Council
of British Columbia

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Southeastern Tree Improvement Tour

Edited by Jack Woods

Introduction

From November 6th to 12th, 2000, ten people affiliated with the Forest Genetics Council of BC joined with members of the North West Tree Improvement Co-op (NWTIC) from Washington and Oregon, and the Director of the Inland Empire Tree Improvement Co-op (IETIC), on a tour of industrial forest land and tree improvement facilities in Georgia. The tour was ably organized and led by David Todd (formerly with International Paper in Florida). Sites visited included seed orchards, operational plantations, progeny tests, nurseries and various research trials. In addition, participants attended an annual meeting of the Cooperative Forest Genetic Research Program (CFGRP – University of Florida based tree improvement co-op), where six North American tree improvement "Co-ops" were represented.

This tour provided a first-class overview of industrial forestry and tree improvement in the southeastern United States. In addition, it allowed the opportunity for extended discussion and interaction among participants.

Brithsh Columbia participation was organized through the Forest Genetics Council of BC. We are grateful to Forest Renewal BC for partially funding this tour on behalf of BC participants.

BC Tour Participants:

Tim Crowder, TimberWest	Dr. John Barker, University of BC
Patti Brown, Canadian Forest Products	Jim Loftus, Weyerhaeuser Canada
Tim Lee, Vernon Seed Orchard Company	George Nicholson, Riverside Forest Products
David Reid, Ministry of Forests	Chris Walsh, Ministry of Forests
Art Lacourciere, Weldwood of Canada	Jack Woods, Forest Genetics Council

Meeting of Co-ops – Dr. John Barker, UBC and Art Lacourciere, Weldwood of Canada

Florida, NC State, Western Gulf, Inland Empire, North West and British Columbia -- Thursday, November 9th

This was a significant meeting which brought together participants from 7 tree improvement cooperatives from across North America to share information. Although contact meetings between the south eastern members have been ongoing, this meeting was the first to include the Northwest Tree Improvement Cooperative (NWTIC), (which includes the Hemlock Tree Improvement Cooperative HEMTIC), the Inland Empire Tree Improvement Cooperative and the British Columbia program. The day was spent discussing the various coops, their structures and activities.

Cooperative Forest Genetics Research Program

Discussions were led off by Dr. Tim White from the University of Florida. He outlined the CFGRP tree improvement program structure and its plans. This co-op is focused on improvement of loblolly and slash pines for use on the lower coastal plain of Georgia, Alabama, Mississippi and northern Florida. The co-op is centered at the University of Florida and has 10 industrial members. Its funding is 40% state, 45% dues and 20% from external sources. Six faculty members are associated with the program. More detail can be found on the web at:

http://www.sfrc.ufl.edu/Faculty/Web_Pages/TWhite/research.html

Dues for members are US$8,800 per year plus an in-kind contribution through test establishment etc. The CFGRP has the following objectives:

- breeding program coordination
- database management and data analysis
- research
- technical assistance for cooperators
- teaching of graduate students

Two research projects were summarized in detail to illustrate the kinds of graduate student work that is ongoing. One involved a study on fusiform rust resistance and a second on wood properties in loblolly pine.

Dr. Dudley Huber, the quantitative geneticist for the CFGRP, provided a summary of breeding and testing progress in slash and loblolly pines. The program is returning to natural populations to further refine knowledge on geographic variation and enhance the genetic base of the program. One problem encountered was uncertainty regarding the true provenance of material throughout the region because of earlier seed transfers not being known.

A final presentation for the CFGRP was made by Greg Powell, the program manager who described new computing capability (SUN Workstation) and an in-detail description of expected activities for the year to come. His presentation also involved a canvassing of partners to undertake specific projects on the work plan. The meeting was thus a way of not only outlining future plans, but also obtaining the necessary in-kind support from the partners.

North West Tree Improvement Cooperative

A presentation was made on behalf of the NWTIC by Director, Keith Jayawickrama. This co-op began as a Douglas-fir co-op in 1966 and has evolved through the years to its present structure. Technical direction for the program has been provided through a contractual agreement with a genetics consultant. This

arrangement ended recently and the program is now housed at Oregon State University. This brings the structure in line with the southeastern co-ops which all have close University contact and support.

The current program involves 32 companies working on and western hemlock. The US Forest Service was a founding member but withdrew during the 1980's. There is some technical support still given but it is limited.

A number of "meta-coops" have arisen to further improve selections and testing within sub regional areas. The impact of Swiss needle cast disease in Douglas-fir has increased interest in hemlock tree improvement.

BC Forest Genetics Council

Jack Woods presented a general description of the BC program which has been in progress for essentially the same length of time as the others. The principal differences are a result of the tenure structure in BC being mainly governmental ownership and the need to breed for several species. The gene conservation activity in the BC program is unique. University involvement is somewhat different in B.C. with technical direction for programs coming principally from the breeders who are employees of the government.

Western Gulf Forest Tree Improvement Coop

This co-op is centered with the Texas Forest Service (TFS) and is located at Texas A&M University (TAMU). It was established in 1969 and has 20 members. It has a pine program and a hardwood program . Membership fees are US$11,400 per year for the pine program.

Detail on their programs can be found at:

http://txforestservice.tamu.edu/forest%5Fmanagement/western%5Fgulf%5Fforest%5Ftree.html

Current staffing stands at four. Dues cover most of operating costs and salaries. TAMU supplies office space and utilities while the TFS provides administrative support.

NC State University - Industry Cooperative Tree Improvement Program

This is the oldest program (established in 1956), and has been a model for other programs.

It currently has 20 partners and annual dues of US$18,945. The annual operating budget was $ 769,000 for 1999. Faculty and staffing stands at five. They have a new director, Dr. Tim Mullin.

The NC State co-op is focused principally on loblolly pine, and has moved through to a third generation of breeding. Total annual planting of member companies approaches one billion trees.

Their web site is at: http://www.cfr.ncsu.edu/for/research/tip/tip.html

General Comments

The meeting illustrated clearly the value of cooperation in tree improvement. The integration of the expertise residing in Universities, industry and government has led to large gains in productivity, value and health in over 1.5 billion trees planted annually in the region. Material is shared freely within the cooperatives as is test information. The presence of this financial incentive for the private landowners has maintained a high level of corporate interest and involvement.

Georgia Silviculture – Jim Loftus, Weyerhaeuser

International Paper - John Rose and Bill Garbett: November 9, 2000

- Site preparation - typical: the slash is piled and burned, and the sandy soil is strip mounded in rows oriented to facilitate drainage, with a D6 Cat and root raker.
- Mechanical planting – typical: 1+0 BR Loblolly Pine, normally from Nov. to end of March, but only after 1 to 1.5 months of rain to settle out air pockets from the fluffed up mounded soil. Typical density is 615 trees/ac @ 12'x6' spacing (range 500 – 700 spa). Trees are planted deep, 2" above the root collar. Plant 3,000 ac in 2 weeks with 12 machines each @ 10,000 tr/day.
- Family blocks: Families are matched to planting site. Family identity is maintained even when seedlings are sold to outside customers. Foresters are able to custom order nursery sowing density to achieve various height and diameter needs. Genetic diversity is maintained by limiting one family to 125 acres in one year over a few thousand-acre forest area. That family can be planted again in the general forest area after a few years.
- Tractor band spray herbicide 42 oz/ac Velpar first spring and a tractor broadcast spray herbicide 3 oz/acre Oust first summer. Another herbicide treatment can be planned second June. Garlon is also used.
- Fertilize first spring w 125 lbs / ac - DAP (18-46-0). Up to 3 other fertilizer treatments planned @ ages 3, 6 and 9 w 300 lbs / ac - Urea (46-0-0). Some sites get micronutrients. Micro nutrient deficiency may become a problem in the future. Ground fertilization is possible but production is too slow, thus aerial application.
- Spray for tip moths 2x in early years.
- No pruning.
- Fusiform rust is problematic but generally does not kill Loblolly.
- Tree length harvesting: 2" top to pulp mill and 4" top to chip and saw mill.
- Conventional rotation 25 years with 30% chip and saw and up to 60% cant sawn on best sites. Thinning @ age 12 and 17. IP's conventional program generally has 1 or 2 fertilizations and 1 herbicide treatment.
- Previous ownership, Union Camp had started an intensive culture (IC) program with a 12 – 15 year rotation and no thinning. Goal was max pulp fibre. IP has not decided whether to continue with the program; it wants saw timber. The IC program has 4 fertilizations and a weed free plantation for 2 years. IC gains 7 yr. on the conventional growth curves.
- Now growing 75' – 80' Loblolly in 16 yrs vs 33 yrs in older plantations.

Rayonier, Ben Cazell and Early McCall: November 7, 2000

- Focus is mostly Slash Pine on wetter coastal Georgia and Florida sites. Fusiform rust is a huge problem. Rust kills if not compartmentalized.
- Site prep is two pass strip mounding, with mechanical planting at a density of 750 +/- 50 spa @ 11'x5' spacing.
- Fertilize 200 lbs DAP @ age 3 and 300 lbs Urea @ age 8. Objective is to increase early leaf area. Soils are very fine sand.

Normal site preparation used for operational plantations and progeny test sites in the southern coastal plain of Georgia. Note the very sandy soil, lack of a organic horizon and long raised beds designed to improve drainage for planted trees. J. Woods photo.

Loblolly pine seedlings ready for lift at the 32 million seedling/year nursery owned by The Timber Company, near Jesup Georgia. Sowing is by open-pollinated family. J. Woods photo.

Jack Woods holds a smaller-than-average seedling from this loblolly pine plantation on International Paper land. Planted in the spring of 2000 (1 growing season). Trees are machine planted on raised beds to improve drainage. Two herbicide and one fertilization treatment have been applied since planting. D. Reid photo.

Seedling Production with Improved Seed in the State of Georgia, USA – George Nicholson, Riverside Forest Products

Seedling production in the state of Georgia consists of three main species, Loblolly Pine (*Pinus taeda*), Slash Pine (*Pinus elliotti*) and Longleaf Pine (*Pinus palustris*). Production for the whole south east region is about 1.5 billion trees annually and consists mostly of second generation half sib families grown as 1-year-old bareroot seedlings.

Nursery soils are very fine sand loam with less than two percent organic matter and low nutrient status. Nursery beds are shaped and sprayed with a soil stabilizer to maintain the raised bed structure in preparation for sowing. Without these stabilizers the beds would loose their shape with rainfall. Seed is sown with a tractor drawn precision vacuum drum seeder, but some nurseries are going back to a drill seeder to gain sowing speed. Their seed orchards are producing enough seed at an economical price that the extra seed usage is not an issue for them.

Seed is collected, extracted, stored and grown by family. The mixing of families is done on the landscape with the highest gain families being planted on the highest site indexes.

The seed is stratified for 30 days and sown in the first week of April. Germination averages 98% in the nursery beds. Sowing densities are 22 trees per square foot and 88 – 90 per lineal foot of bed.

Seedlings are top pruned twice during the growing season, June and July, root wrenched in August, and root pruned or undercut in October. These treatments ensure the seedling produces adequate roots while controlling top height growth.

Seedling harvest begins in early November and is completed by the end of February. The seedlings are mechanically harvested and delivered from the fields to the sorting sheds in large bins. Seedlings are manually sorted for height and caliper quality and packaged into shipping bags with an average of 800 trees per bag. Harvest production is 100 – 150 thousand seedlings daily. Once the bags are filled they are loaded into metal racks and placed in cold storage for 3 days to 3 weeks. No long term storage is used in the production cycle as the seedlings are planted within this time frame.

All bareroot seedlings are mechanically planted on a 5.5 x 11 or 6 x 12 foot spacing. Small amounts of slash and longleaf pine are grown in containers to be planted in areas where mechanical planting cannot be achieved.

Sites visited :

- The Timber Company : Jesup, Georgia – production of 32 million annually
- International Paper : Bellville Nursery, Bellville Georgia – Production of 60 – 70 million annually

Breeding and Progeny Testing – Jack Woods (Forest Genetics Council)

This report provides an overview of the breeding and progeny testing methods used in the south east US. As the main focus of the tour was orchards, nurseries and operations, the information presented here may contain bias towards the sites observed.

Who does the work?

In all south east US co-ops (NC State, Cooperative Forest Genetics Research Program (Florida), and Western Gulf Forestry Tree Improvement Program) , breeding and progeny test design is provided by co-op staff. Actual breeding and testing work is done by the cooperators.

Mating design and testing designs

North Carolina State Co-op

The NC State Co-op is focused on loblolly pine (*Pinus taeda*). They use small sublines of 4 or 5 parents, with matings done within sublines using a modified half-diallel structure. They are on a third generation for loblolly pine. The small sublines assist with organizing the breeding population and disbursing mating work to cooperators. They use a complimentary design, with polymix mating for general combining ability (GCA) tests, and full-sib crosses within sublines for selection of a new breeding population. Elite populations of 24 parents are drawn from the best materials across all sublines and mated to generate high-gain materials for seed orchards. Small sublines assist with co-ancestry (inbreeding) control, and provide options in future generations.

They maintain three populations; northern, Peidmont and Coastal. Breeding population census numbers range from 240 (northern) to 360 (coastal). Status numbers (considering co-ancestry among parents) are from 160 (northern) to 240 (coastal). Despite maintaining three breeding populations, there seems to be little concern with wide movement of material throughout the southeast. As southern coastal material is the fastest growing, those populations are generally chosen for seed orchards.

Cooperative Forest Genetics Research Program (Florida)

Most effort with this co-op is on loblolly and slash pine (*Pinus elliottii)*. Work with longleaf (*P. palustris*) and sand (*P. clausa*) pines proceeded through a first generation testing effort, but further work has been dropped due to lack of interest.

Loblolly and slash pine breeding programs are in advanced generations. As with most breeding programs, advanced generation breeding consolidates several previous test series and attempts to generate better information where gaps exist (i.e. poorly estimated GCA's for some test series). Breeding population sizes are 500 for loblolly and about 350 for slash pine (although due to some re-testing of first generation parents, the second generation test population is larger). Sublines or "breeding groups" of about 12 to 15 parents are used. Complimentary mating is used, with a polymix for GCA testing. Breeding groups are sorted into three tiers based on breeding value, and matings are made among parents within and between tiers in an assortative manner. These full-sib families will be used for forward selection.

Western Gulf Forestry Tree Improvement Progam

Cooperators work primarily with loblolly and slash pine. A first generation of testing is completed, and the programs are moving into a second round of testing using a complimentary mating design. The WGFTIP strategy is similar to other SE programs, with polymix families used for GCA testing, and full-sibs families within sublines for forward selections. Subline sizes are about 25 trees, and breeding populations are about 350 to 500 (no exact numbers provided).

Progeny testing

As with BC programs, the exact layout and technical protocols vary among programs. In addition, different land owners will choose to organize test establishment and maintenance to suit their operations.

All programs have moved from the use of row-plots to either single-tree or non-contiguous plots with about 30 to 40 trees per family per testsite. Single-tree plots are favoured due to some microsite variability on test plots. However, relative to the microsite variability normally experienced in BC (particularly the coast), their problems are virtually non-existent. As far as I could determine, none of the Co-ops are using incomplete-block designs, such as the Alpha design now being used for some BC programs. This is partly due to the ease of finding large testsites and the comparatively low cost of test establishment.

The site was visited on Rayonier land. They use a full pre-randomization in the nursery with test seedlings grown in Leech tubes. Trees are then planted in the field in pre-determined order. As their test areas have no non-plantable spots (no rocks, stumps, duff, debris, wet holes, etc.), this is feasible. However, I believe that the protocols used in BC, where planting locations are not pre-assigned and family identities are mapped after planting, is a more efficient and robust method when properly organized.

In all ways, their progeny test situations are simple relative to BC conditions. Operational silviculture normally prepares sites to what we would consider a farm-field condition. Several herbicide and fertilization treatments before age 4 or 5 keep trees free-growing, and are normal procedure on all operational plantations. Sites are fully occupied within about 3 to 4 years, and with a 20 to 25 year rotation, test measurements at full crown closure (about age 5) or by age 8 will provide a final assessment done at about 1/4 to 1/3 of rotation age. The only down sides are heat, fire ants, snakes and deep-fried food.

The Timber Company: Jesup Seed Orchard – David Reid (Ministry of Forests)

Information from Fact Sheet provided

Overview:

The Jesup Seed Orchard Complex was originally owned by Brunswick Pulp until it was acquired by Georgia-Pacific in 1989. The Jesup Seed Orchard Complex is comprised of several separate seed orchards located in Southeast Georgia. The complex currently has over 82 acres of slash pine orchards, 100 acres of loblolly pine orchards, and 11 acres of longleaf pine orchards, and 110 acres of longleaf seed production areas. With the exception of the longleaf SPA, all seed produced is genetically improved. The oldest orchard currently in production is a 38-year old loblolly pine orchard.

Cone Production:

The complex produces 6,000 - 8,000 bushels of loblolly, slash, and longleaf pine cones annually. These cones will yield enough seed to produce 70 - 95 million seedlings, which can regenerate 95,000 - 130,000 acres. Each year's cone harvest varies due to many factors, but the major two are yearly orchard flower production and seed demand.

Cone Harvest:

Slash and longleaf pine cones are harvested by using a tree shaker which vibrates the tree to dislodge the cones from the tree limbs. After falling from the tree, the cones are picked off of the ground by hand. Loblolly pine cones are picked by hand from ramet limbs by workers in bucket trucks. Once harvested, all cones are placed in 20-bushel crates and shipped to contract extraction plants for extraction and cleaning. All clean seed is stored in seed coolers until used by one of the three TTC Southern Nurseries.

Orchard Management:

The Timber Company is an active member of the NC State, Western Gulf, and Florida Tree Improvement Cooperatives. The Timber Company orchards are managed using the latest techniques. All orchards are fertilized twice per year and are sub-soiled regularly to increase flower production. Orchards are aerially sprayed with insecticides to reduce cone insect and flower damage. Integrated Pest Management (IPM) techniques are used to minimize insecticide usage-..

Employees:

The Jesup Seed Orchard Complex employs three full-time employees and 12 seasonal workers.

Additional Notes

- Orchards are grafted onto one-year-old field planted rootstock. This is to minimize transplant shock.
- Rootstocks are planted in clumps of three, with at least two of them grafted using "V" grafts. Each ramet has it's own irrigation emitter. Clumps are later thinned to the single best ramet.
- Orchards are established with about 20 to 25 clones to start.
- Orchard spacing is either 25' x 30' or 30' x 30'.
- Wind patterns are used to try and minimize contamination, but expect 25 - 30% contamination. Orchard blocks are separated by a 400 foot buffer but even with a one mile separation they would have contamination, as pollen can travel over 600 miles in the south.
- They may fertilize to get crown development.
- Orchards are aerially sprayed for pest management.
- Irrigation lines are buried to avoid rat damage. Emitters are one gallon per hour.

- Normally their orchard sites are spread out to minimize risk. The McKinnon site is approximately 200 acres in size and they are concerned with the risk of hurricane or tornado damage.
- Their oldest orchard is 38 years, and they use 100 foot lift trucks to undertake control mass pollination (CMP). This is a 1 $^{1/2}$ generation orchard.
- Loblolly orchards are not top pruned as this is detrimental to seed production, so they leave the leader alone.
- They do lots of CMP; some orchards are in clonal rows.
- Loblolly cones have to be hand snipped; slash and longleaf pine ramets are machine shaken and cones fall to the ground. They estimate they get 95% of all the cones this way. Shaking can cause some cambium and branch loss damage.
- Orchard lifespan is generally from 20 to 25 years.
- Orchard size is planned to be 10% over needs.
- They like to stockpile at least a four year seed supply.
- They will sell some seed: price will range from $50 to $200 per pound.
- Minimum wage is US$5.50 per hour.
- A ten year old loblolly tree will produce 2 to 3 bushels of cones. They get 100 to 150 seeds per cone, 1.5 pounds of seed per bushel, and 17,000 - 24,000 seed per pound.
- There are no buildings or infrastructure on site at the 200 acre McKinnon site other than a pumphouse and fence. There are also no signs. The orchards are located deep inside their private land holdings for security reasons. Maintenance crews bring all the equipment with them. They have over 600 acres of grass to mow on all of their orchard sites; this is a full time job.

Site prepared for a new advanced generation loblolly pine seed orchard owned by The Timber Company near McKinnon, Georgia. Note that the only infrastructure on this 200 acre site are a pump-house and fence. D. Reid photo.

The Timber Company seed orchard at McKinnon, Georgia. Chris Walsh examines 11.5 acres of Loblolly grafts and rootstock (grafting to be completed in 2001). Note that rootstock are established at 2 or 3 per planting spot, and grafting is done in the field. Surrounding stands are full of loblolly pine, contamination is high and unavoidable without controlled mating. D. Reid photo.

A 38-year-old loblolly pine seed orchard near Jesup, Georgia, owned by The Timber Company. 100 foot lift trucks are used to pick cones. All loblolly pine cones are clipped. Orchards owned by The Timber Company at this Georgia facility produce enough seed for 70 to 80 million seedlings per year. D. Reid photo.

Controlled Mass Pollination of Loblolly Pine – Tim Lee, Vernon Seed Orchard Company

Control mass pollination (CMP) is used to control which pollen is applied to the female cones of a selected parent, to ensure the identity of the breeding pair is known. Controlled pollinations are achieved by placing a bag over a branch with female flowers to isolate them from wind carried pollen. Pollen from another parent tree is then injected into the bag. The resulting seed is of higher gain if known good quality parents are used. The term controlled mass pollination is used when controlled pollinations are done on a large scale to produce high quality seed for planting.

When large amounts of wind-carried contaminant pollen cannot be controlled, CMP is one method of realizing the potential gains of orchard parents. In Georgia non-orchard pollen can cause anywhere from 30 to 80% contamination of orchard seed. Pollen levels can become so high during the spring, Georgains sometimes refer to it as the "yellow plague".

For large companies like International Paper or Weyerhaeuser, where their planting programs are over 100 million trees per year, it is not possible for CMP to meet the total seedling need. CMP seed is used as a means of deploying their best parents on their best sites. Amplification of this small quantity of seed has many companies looking to bulk the high-gain CMP seed by planting it as donor stock for rooted cuttings. At this point in time, companies are not able to meet more than 1 or 2 percent of their total planting needs with CMP seed; most planting still uses open-pollinated orchard seed

CMP procedures

Companies in the southeast use primarily stored pollen to simplify the logistics of organizing the CMP project. Methods of extraction and storage are similar to those used in BC. Bagging of females is usually done on large ramets using 100 foot lift trucks for access (see photo). Bags are commercially available brown paper pollen bags about 25 cm in diameter and 40 cm long, without windows. Male buds are removed prior to bagging. An attempt is made to bag all females on a ramet, as at the time of picking it is assumed all cones picked from a ramet are CMP treated. Phenology is checked on representative bags.

When females are receptive, pollination is carried out using an injector system driven by compressed air. The injector wands allocate a predetermined amount of pollen (1cc for loblolly) into each bag (one pull on the injector trigger puffs 1cc of pollen into a bag). Each bag is pollinated twice, about two days apart. Bags are marked with spray paint at each pollination. It is assumed that the force of injection with the compressed air adequately disburses the pollen within each bag.

All bagging and pollination work is carried out by contractors. Orchard staff monitor phenologies and direct contractors to specific trees. Bags are removed as quickly as possible once female cones are no longer receptive.

Costs for CMP are about 3 cents (Can.) per filled seed, but we were not told what site costs were loaded into this number so it is assumed this is the direct contract cost involved.

Large loblolly pine orchard ramets may have as many as 300 to 400 bags applied. Some orchards may place as many as 15,000 pollination bags on in one season.

In British Columbia a limited amount of CMP work has been carried out. It is effective with some species (spruces), but more difficult with other species (hemlock, Douglas-fir and lodgepole pine) due to the amount and distribution of male pollen buds that must be removed. CMP is a tool we must consider for the limited production of insect or disease resistant seed.

Controlled mass pollination of loblolly pine at the Weyerhaeuser seed orchard near Lyons, Beorgia. All cones on a tree are bagged, pollen is applied twice, and bags are removed following receptivity. Photo courtesy Weyerhaeuser.

Tim Lee and Chris Walsh examine crates of recently picked loblolly pine cones at the International Paper nursery and seed center near Belville, Georgia. D. Reid photo.

Seed cleaning equipment at the International Paper nursery and seed center near Belville, Georgia. J. Woods photo.

Top Grafting – Chris Walsh (Ministry of Forests)

For one and one-half days of our Georgia trip we joined the annual meeting of CFGRP (Cooperative Forest Genetics Research Program, out of Florida). The field portion of the meeting was held at Weyerhaeuser's Lyons Seed Orchard where one of the topics presented was "top grafting".

Top grafting, also known as top-working, refers to making grafts on large trees, rather than seedling rootstock. The grafts are made at heights of two to eight metres using bucket lifts to reach the crown of orchard trees. Since the orchard trees are grafts themselves, each tree becomes a composite of genotypes: the original rootstock, the "interstock" (the original orchard graft) and one or more top grafts. Grafting is done on branch tips in the same way they are made on the main stem of a seedling. The major use for top grafting has been to speed up breeding. Successes with this have led to its use on a pilot scale to upgrade existing orchards by replacing undesirable clones with better ones.

Top grafting shortens the breeding cycle by creating grafts that produce flowers earlier. We were told that top-grafts will flower on average two years earlier than seedling grafts and that females are often available for crossing in the same year as the graft was made. Pollen production usually takes another year. Grafts made lower in the crown, on shoots that would typically bear pollen, are more likely to produce pollen, while grafts made higher in the crown will produce cones. Often, several different parent clones are grafted onto a single tree. Graft survival is 50% - 75%, when using young material for scion. Top grafting has replaced the greenhouse and container work that had been used previously for breeding.

Top grafting for orchard upgrading is being tried in an older orchard (est.1986) that had been established with untested material. After progeny testing it was decided that only 20% of the clones were to be kept. Rather than cut down the large orchard trees they have been top grafting the desirable clones and getting flowers sooner then would be the case if they rouged and replanted with seedling rootstock.

The procedure is to cut the top off the tree to be top grafted and make the grafts on the remaining shoots in the following year. As the grafts grow, the old tree (the interstock) is gradually pruned away. No trees have died from this process.

References:

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Tim Lee inspects a loblolly pine top-graft at the Weyerhaeuser seed orchard facility near Lyons, Georgia. Unneeded orchard ramets may be used as rootstock for grafts of new selections. Top grafting high in the crown of an existing ramet facilitates breeding through earlier male and female cone production compared to grafting on small rootstock. Note that this procedure is only being tried at a pilot scale for orchard seed production, but it is being used routinely to speed up the process of breeding for testing purposes. C. Walsh photo.

A top graph of loblolly pine at the Weyerhaeuser seed orchard facility near Lyons, Georgia. All foliage on this ramet is above the graft. Rootstock branches have been recently pruned. Note that, to date, they have had no mortality of the large ramets used as rootstock. C. Walsh photo.

100 foot lifts at the Weyerhaeuser orchard site near Lyons, Georgia. This facility has five lifts of this size. More are brought in by contractors during pollination season for the controlled mass pollination work. J. Woods photo.

North Carolina State Research Co-operative Rooted Cutting Program – Patti Brown, Canadian Forest Products

A research co-operative was formed to investigate rooted cutting technologies for loblolly and slash pines through the NC State University in 1992. The initiative was a result of the southeastern United States' forest industry concerns surrounding the increased demand for wood combined with a decreasing land base. The goal of the rooted cutting research co-operative program is to provide it's ten member companies with the technology that allows them to bulk up large quantities of genetically improved pine for their own operations. The Co-op annual fee is US$14,000.

Currently, most of the 1.5 billion improved pine seedlings that are planted annually in the southern United States are from open pollinated families which offer volume gains in the 7 – 10% range. Rooted cuttings are an affordable option for increasing genetic gains to up to 40% for clonal propagation and deployment. Mass controlled pollination (CMP) is the competing technique that is being used to increase the genetic gains from the southeastern US pine orchards. Producing CMP seed is much cheaper than rooted cuttings, however the amount of high gain seed that would be available for operational usage is limited. The combination of both technologies (bulking up CMP seed through rooted cuttings) is ideal but did not appear to be a strategy used by any of the larger forest companies. Rayonier was the only company that was operationally using the technology (300,000 cuttings annually) and their strategy was to use it to bulk up fusiform rust resistant slash pine. Somatic embryogenesis is another competing technology that is being pursued by many of the larger forest companies but is as yet not economically feasible.

The research co-operative's four main areas of emphasis are:

- hedge management,
- rooting environment,
- propagule quality, and
- applications in clonal forestry.

Most of the work to date has been on developing techniques that produce vigorous, multi-branched hedges that yield consistent quality cuttings for use in reforestation. Seven year growth data shows no differences between cuttings and seedlings. The application of rooted cutting technologies to clonal forestry is only in the beginning stages as they are still deciding on the number of families and clones to put in test, the design of the tests, and the expected lift in genetic gains. Somatic embryogenesis would play a role in the cutting program's clonal forestry application by supplying the program with the juvenile replicates needed for replacing aging hedges.

Comparisons with B.C.'s Rooted Cutting Programs

Rooted cutting technologies have already been developed and are operational for many B.C. species (yellow cedar, western hemlock, red cedar, and the spruces) and could probably be developed for more if it becomes desirable. These programs were developed for the same basic reasons as the southeast US program, to produce large quantities of genetically superior reforestation material. The main difference is that we are using it as an interim measure until our new high gain or pest resistant orchards are producing enough seed, while in the US it is needed to realize the gains from their orchards due to the huge wild pollen contamination problem they have.

The actual technologies used for producing the rooted cuttings are very similar to ours with minor refinements for each species. We carry hedges for donors in yellow cedar, but use one year old potted stock as donors for all other species. This is more a result of the large number of yellow cedar cuttings needed annually rather than it not being applicable to the other species. Maintaining hedges in other species is an option that could be pursued in B.C. to increase the numbers of cuttings from each donor. B.C. may also be able to build on the southeast US's rooting techniques for pines. It would be very beneficial to be able to bulk up blister rust resistant white pine via rooted cuttings as little is still known about the inheritance patterns of resistance in this species.

Five-year-old loblolly pine stand density / cultural interaction trial on the International Paper research forest near Rincon, Georgia. D. Reid photo.

Tour host David Todd shows Mike Albrecht of the NWTIC loblolly pine field grafts established in a new Rayonier seed orchard near McKinnon, Georgia. The poorer ramet will be removed at about age 4. J. Woods photo.

David Reid reflects on history in a cotton plantation in central Georgia. Most pine plantations are on sites previously planted to cotton. Prior to harvest, the cotton plants are sprayed with herbicide to kill them. Harvest takes place when the leaves have dropped. This field is ready to be picked.

The Coastal Plain Stand Density / Cultural Interaction Study – Tim Crowder, TimberWest

The Pine Management Research Cooperative (PMRC) at the UNIVERSITY of FLORIDA initiated a study into the intensive levels of forest management carried out on Slash and Loblolly Pines in the SE US.

We visited a study site at Rincon GA., managed by International Paper (IP). The site is part of a 3000 acre research forest initially established by Union Camp which has recently merged with IP The objectives of the study are as follows:

- Determine if traditional growth and yield relationships hold for intensively cultured Loblolly and slash pine.
- Examine the effects of soil differences on these relationships.
- Develop a stand leaf area index (LAI) under various treatments.

This study site was one of 42 locations throughout the SE, 18 of which were located throughout the lower coastal plain on sand based soils with high water tables. The remaining 24 were located on the upper coastal plain or piedmont that has older more clay based soils. Plantations were established in the fall of 1995 with one full sib family grown at one nursery.

Planting densities per acre were: 1815 (6′x4′), 1512 (6′x4.8′), 1210 (6′x6′), 908 (8′x9′), 605 (12′x6′), 302 (12′x12′).

Basic culture consisted of creating a 3′ wide x 2′ high planting bed early in the summer, followed by a fall herbicide treatment and spring planting with aerial application of 500 lbs. per acre 10-10-10 + micro-nutrients (boron and selenium).

Intensive culture is the same as basic culture except that the plots are kept weed free until crown closure (3-5 years depending in plant density) and applications of 300lbs/acre urea every 3 years and insecticide treatment for pine tip moth in the first 2 years.

Results after 5 growing seasons showed:

- Intensive culture increased diameter and height growth, but also increased the percentage of forked trees.
- Intensive weed control increased the number and size of branches and reduced branch mortality.
- Intensive culture of loblolly pine produced the best response on all coastal plains sites.
- Loblolly pine under basic culture produced better height growth than slash pine under intensive culture.
- At 5 years it was too early to assess stocking density effects, however all densities had enough crown closure to eliminate weed competition and most densities had comparable height growth.

Take home message for the Pacific Northwest operators:

Range-wide inter-agency cooperative silviculture tests provide good scientific data on which individual operators can base some of their decisions.

Five year old loblolly demonstration planting on the Rayonier Research Forest near Rincon, Georgia. Select orchard open-pollinated family 7-56 on the left; a Georgia unimproved check lot on the right. A 1-year-old plantation is in the foreground. D. Reid photo.

Some North American tree improvement Co-op directors/managers: L to R, Keith Jayawickrama (NWTIC), Jack Woods (Forest Genetics Council of BC), Tim Mullin (North Carolina State Tree Improvement Coop), Marc Rust (Inland Empire Tree Improvement Coop), Tom Bryam (Western Gulf Forest Tree Improvement co-op – Texas), Tim White (Cooperative Forest Genetics Research Program – Florida). D. Reid photo.

Final day: BC and NWTIC group with hosts David Todd (front, 3rd from left), Greg Leech (International Paper – front 5th from left) and NC State Co-op Director, Dr. Tim Mullin (back row, 4th from right).