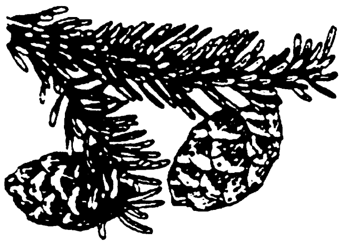
CANADIAN TREE IMPROVEMENT ASSOCIATION/
ASSOCIATION CANADIENNE POUR L'AMÉLIORATION DES ARBRES



Tree Seed Working Group

NEWS BULLETIN

No. 47 August 2008

SEED USE EFFICIENCY

THIS ISSUE AT A GLANCE

CHAIR'S 'ARMCHAIR' REPORT

Hello and welcome to News Bulletin Number 47. The intent was for the News Bulletin to be an open forum for seed topics and when June rolled around Dale and I received no contributions outside of our immediate circles. That was disappointing as we start flirting with the 25th anniversary of the News Bulletin and our group. This edition will primarily be focused on summaries of presentations that occurred at a Seed Use Efficiency meeting held in Langley, BC on July 30 and 31. I'll elaborate more on the workshop in the News Bulletin itself, but I consider it a success with about 95 people attending to learn more about different perspectives on and activities to increase seed use efficiency from cone collection to sowing [the seed handling system]. Thank you to all of our speakers, participants, and those who helped with all of the preparations.

Hopefully the News Bulletin arrives to you before the CTIA meeting with our Tree Seed Working Group tour (August 24th) and workshop (August 25th). The link to the conference, including papers to be presented, can be found at this address: http://www.iufro-ctia2008.ca. Thank you in advance to Fabienne and others who helped organize these events.

As indicated, our December News Bulletin will mark the 25th anniversary of the Tree Seed Working Group. The Group formed from successful seed workshops at both the 1981 and 1983 CTIA meetings. Ben Wang served as the first interim chair with Bob Farmer, Fred Haavisto, Yves Lamontagne and Doug Skeates as executive members and George Edwards taking on the editorial duties of the newly minted News Bulletin. For those interested in a trip down memory lane, all past editions of the News Bulletin are available at: http://www.for.gov.bc.ca/hti/treeseedcentre/tsc/t swg.htm.

For our December (25th anniversary) edition, I'm again asking for contributions. These can be articles related to seed science & technology, changes in seed policy or legislation, meeting summaries, or personal opinions. I'm also keen on any contributions regarding those no longer with us, but who made significant contributions to our field. All articles are welcome and I'll ask that people send their contributions to Dale Simpson before December 10th to enable him to edit and assemble them before the holidays.

In British Columbia we have just been through a little navel-gazing with a challenge dialogue process (not as scary as it sounds) to address Forest Tree Genetic Resource Management and Conservation (GRM). Background information and our final report can be found at the following link: http://www.for.gov.bc.ca/hti/grm/grm_dialogue.htm. One aspect that I have been directly involved with is trying to advance our "cataloguing methods" with regards to our seed bank samples solely dedicated to genetic conservation. I'll be speaking about this at the TSWG workshop. The information will help us manage our seed bank and also flow into the national CAFGRIS initiative aimed at providing a national perspective on genetic conservation by tree species.

I look forward to seeing many of you at CTIA and finally meeting many international e-mail colleagues at the IUFRO Tree Seed meeting at Royal Botanic Gardens, Kew, England.

Dave Kolotelo
TSWG Chair

EDITOR'S NOTES

The efficient use of seed was not an issue until seed orchard seed started to become available. As orchards began to produce their first seed crops everybody was excited to finally see the "fruit" of their labour. At the same time this seed was in short supply and reforestation programs had large demands. Adjusting seedling lines to sow as few seed as possible per cavity was one way of helping this seed go farther.

Genetically improved seed is expensive to produce but the cost is still a minor component of the overall reforestation costs. By efficiently using seed, less seed orchard area needs to be planted and managed thereby saving the orchard manager money. Efficient seed use impacts the financial operating line of nurseries. With costs continuing to rise and revenue from seedling sales remaining constant or slightly increasing nursery managers must be continuously innovative in developing ways and means of controlling their costs.

Dave put together an excellent program for a two day Seed Use Efficiency meeting held just a few weeks ago. I appreciate the response from so many speakers in being able to provide abstracts/summaries of their presentations to share their knowledge and ideas with a larger audience. Unfortunately not all speakers were able to submit an article. If you are interested in a particular topic that is not presented in this News Bulletin I am sure that Dave can put you in contact with that speaker.

Another reason for organizing the meeting was to celebrate the 50th anniversary of the BC Tree Seed Centre. This is an impressive facility that is vitally important for the management of BC's forests. Congratulations!

Also, as Dave pointed out, this is the 25th anniversary of the Tree Seed Working Group. Wow! I hope that many of you will consider submitting an article for the December issue of the News Bulletin when given a 'gentle' nudge.

Dale Simpson
Editor

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Comments, suggestions, and contributions for the News Bulletin are welcomed by the Chairperson and Editor.

SEED USE EFFICIENCY MEETING

In conjunction with our 50th Anniversary as part of the BC Forest Service, the Tree Seed Centre hosted a Seed Use Efficiency meeting in Langley, BC (July 30 and 31). The meeting included 1.5 days of presentations followed by a tour of the Tree Seed Centre and a BBQ at our facility. An outline of the program is included below. The intent was to start with a big picture "spaceship" view and zoom in on the activities, challenges, opportunities and costs throughout the seed handling system. All of the speakers did a great job – thank you.

The event attracted about 95 people from breeding and seed orchard programs, cone collectors and processors, nursery personnel and a host of forestry professionals looking for ways to increase seed use efficiency. Many more individuals expressed an interest, but due to our difficult economic times were unable to attend. The plan is to present summaries of most talks in the News Bulletin and also prepare a dedicated website where the presentations could reside. Not all speakers are able to provide summaries.

There were many good discussions and I think a far better understanding of the various businesses involved in the Seed Handling System after the meeting. We will keep on examining opportunities for increased seed use efficiencies and welcome comments on the subject from attendees and others who have ideas, practices, or results to increase seed use efficiency.

Day 1

Introduction		Dave Kolotelo
Seed Use Efficiency at Weyerhaeuser, USA		Dave Hodgin
Policy and Genetic Resource Management Directions		Brian Barber
Forest Genetics Council Seed Planning Structure		Jack Woods
Potential Efficiency Gains in the Seed Handling System		Dr. Yousry El-Kassaby
Climate-based Seed Transfer		Dr. Greg O'Neill
Natural Stand Seed Production		Emile Begin
Seed Orchard Seed Production	Coast :	Annette van Niejenhuis
	Interior:	Chris Walsh
Seedlot Production		Dave Kolotelo
Seedling Production		John Kitchen
Sowing Guidelines and SPAR[1] Aids to Efficiency		Susan Zedel

Day 2

Costs: Seed and Seedling Costs Over time		Al McDonald
Seedling Specification Perspectives	Producer:	Norm Livingstone
	Purchaser:	Stephen Joyce
Cone Collection Technologies (also equipment exhibits @ TSC BBQ)		
Fandrich Cone Harvesters		Helmut Fandrich
SilvaTech Developments		Erik Bergvinson / Fred Prufer
Operational Seed Efficiency Gains With Coastal Douglas-fir		Bevin Wigmore
Upgrading of *Abies* Seedlots		Jamie Farrer
Benefits of Thermal Priming and Other Seed Handling Practices		Robin Dawes
Mini-plug Transplants		Fernando Rey

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[1] SPAR is the Seed Planning and Registration web based tool that has the following main functions: tree seed and vegetative lot registry, service requests, and reporting. See http://www.for.gov.bc.ca/hti/spar/index.htm for more information.

INTRODUCTION

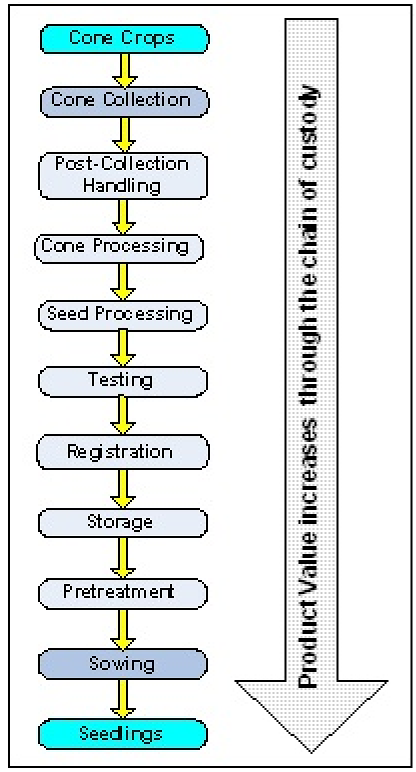
The objectives of the Seed Use Efficiency meeting were:

- To promote activities to increase seed use efficiency.
- To provide a dedicated forum for the exchange of information spanning the entire Seed Handling System.
- To better understand each other's business, the drivers, and bottlenecks (both financial and biological.
- To celebrate the Tree Seed Centre's 50th anniversary

The scope of the meeting was the Seed Handling System spanning all activities from cone collection (or cone induction for seed orchard operations) to the sowing of seed in the nursery. This chain of custody involves a variety of businesses with different drivers and bottlenecks. An appreciation of the entire system is important as any previous link can impact the quality of the product produced. It is also important to appreciate that product value increases through the system as 'investments' are made to go from reproductive buds to the seedlings we desire for reforestation.

Conifers are extremely variable organisms and this diversity is a very good thing for these long-lived species. It is also this variability that complicates direct adoption of seed treatments designed for low variability agricultural crops. One of the fundamental tenants of quality assurance is to reduce variability and to some extent seed is part of a sophisticated material handling system. The trick is to not remove any genetic variability as we try to make the system more efficient.

I'll initially provide some broad context to seed use in BC and then briefly present seed characteristics of our major reforestation species. In 2008, provincial sowing aimed to produce 214 million seedlings - down substantially from 265 million in 2007, but approximately equal to our 15-year average. Seed orchard seed accounted for 46% of sowing in 2008 and is expected to continue to rise to approximately 70% by 2013. In BC, there are approximately twenty one tree species used in commercial forestry, but lodgepole pine (*Pinus contorta*) and interior spruce (*Picea glauca* x *engelmannii*) together account for 78% of the sowing. Adding Douglas-fir (*Pseudotsuga menziesii*) and western red-cedar (*Thuja plicata*) to the mix we have the "Big Four" accounting for 93% of provincial sowing.



The germination patterns of these four species illustrate the extremely rapid germination of lodgepole pine and the delayed germination of western redcedar (Fig. 1).

Seeds per gram SPG), used to describe seed 'size', is the other seedlot input, in addition to germination capacity, that translates orders for trees into grams of seed to withdraw, possibly treat, and ship to nurseries. Seeds per gram averages are shown in Table 1 for the Big 4 species by genetic class (orchard or wild stand) and a ratio indicating relative difference. The largest difference in seed size between orchard and wild seed is found with lodgepole pine.

As we move through the seed handling system it is important to address what the largest sources of variability or bottlenecks are. Path analysis is suggested as a good means to address this quantification. A system that is complicated with different business drivers also will include some unforeseen feedback loops. If anyone has seen the 'gorilla' video you will understand "you can miss some really big things if you are focussed too much in one area" and I think that is worth considering. I'll also offer the following favourite quote "Most mistakes in thinking are inadequacies of perception rather than mistakes of logic". Enjoy the meeting!

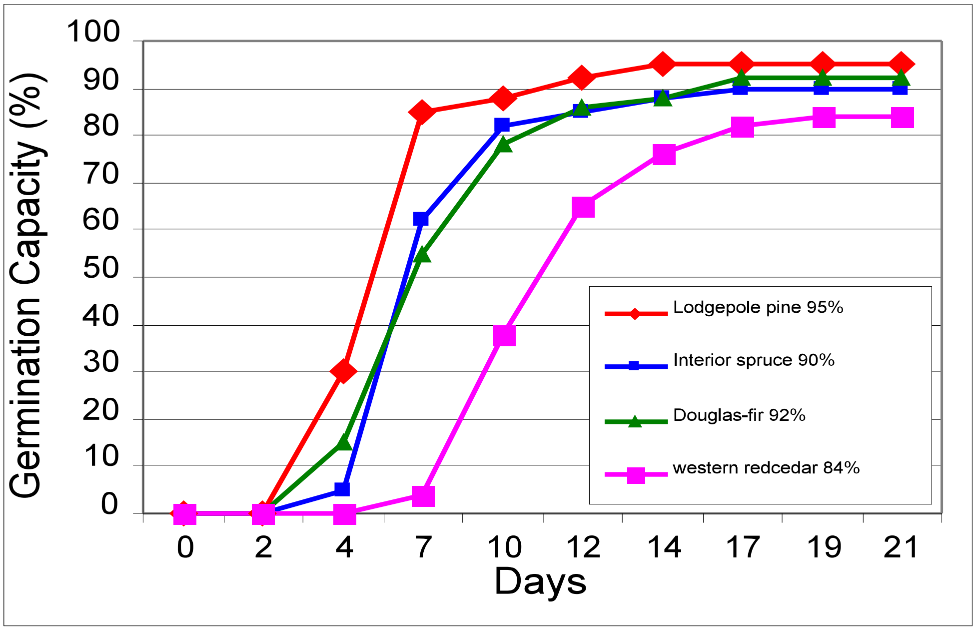


Figure 1. Comparison of germination capacity among the four principal tree species planted in British Columbia.

Table 1. Average seeds per gram (SPG) for four tree species for seed from seed orchards and wild stands and their ratio.

Species	Orchard SPG	Wild SPG	Orchard/Wild
Lodgepole pine	253	338	0.75
Interior spruce	390	459	0.85
Douglas-fir	87	96	0.91
Western redcedar	751	805	0.93

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WEYERHAEUSER – AN INTEGRATED SEED-SEEDLING SUPPLY SYSTEM

The subject of efficient use of seed, in particular A class seed, has arisen twice at Weyerhaeuser. The first time was in the early 1980's, with the initial production phase of our seed orchards, when supply was limited and the goal was to maximize the breadth of acreage that we were able to impact with genetically improved stock. When our seed supply capacity exceeded our requirements, the emphasis refocused on seedling quality and order volume, frequently at the expense of efficient use of seed. This was particularly true as we initiated development of new stock types, where the growing processes were as yet poorly defined.

The increasing use of A class seed and its increased cost structure, necessitates that growing facilities review their growing processes for improvements which will lead to more efficient use of seed. Seed cost, as a component of total seedling cost, is a significant proportion even in an internal supply system and in particular when an end-user is purchasing A class seed. This component of total seedling cost is often overlooked when the seed is supplied to a contract growing facility by the end-user.

All seed producers, growers, and foresters strive to do the very best job possible. Each have their own metrics of success, but sometimes they do not include the success of the next in line customer. For the seed producer it is volume of cones harvested and seed yielded, the grower achieving order and seedling specification targets, and the forester achieving a target number of trees /land unit and planting cost. These are all good metrics, but are intermediate or component metrics. The absolute measurement of success is the right genetics delivered to a specific unit and survival of the seedlings to free to grow, at the least possible cost. Only then will forestry operations achieve a return on investment that warrants continued investment, particularly in the private sector

At Weyerhaeuser each component of the supply system has its intermediate metrics, but we are collectively held accountable to each other to achieve successful plantation establishment. Each year seed producers and seedling growers visit each internal customer to review the successes and failures of the last and previous planting seasons. In cooperation with each other, and including the nursery and silvicultural scientists, courses of corrective actions are developed to address weak performance. We communicate across the spectrum of the delivery system.

Corrective actions can and do span across each discipline and frequently are articulated from outside the discipline. We have control over our seed, both supply dependability and genetics. We know more about the seedlot attributes than germination, but also its growth habits and frost susceptibility. Growth curves and yields are tracked by seed type and growing prescriptions and growing locations are modified to compensate. We have developed focused physiological requirements for stock types and planting environments. We have achieved and been able to achieve this because we operate as a system, each held accountable to the other. We have achieved this through good communication.

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POLICY AND GENETIC RESOURCE MANAGEMENT DIRECTIONS or *Who moved my seed*?

There are a number of provincial issues and policies influencing, or will influence, seed use in BC. These include state of the BC forest sector, the mountain pine beetle (MPB) epidemic, climate change, and policy responses to them.

A weak US housing market, strong Canadian $, and increased energy costs have reduced softwood lumber sales in 2007 (-24% compared to 2006 and -36% compared to 2003). As a result, only 80% of the provincial annual allowable cut (AAC) of 80 million m^3 is being harvested. Reduced harvest levels equate to fewer areas being reforested. Seedlings requested for planting in 2007 were 270 million. However, requests for sowing in 2008 were only 214 million seedlings. Reforestation of areas denuded by the MPB and planting for increased fibre production through government funded programs such as Forests for Tomorrow are, however, expected to increase planting and seed use over the next five years. Issuance of new tenures, to communities and First Nations, are also increasing the number and diversity of seed uses. As a result, there will be continued demand for high quality seed, but with increased pressure to reduce costs and optimize seed use efficiency.

The BC Government has introduced aggressive greenhouse gas (GHG) emission reduction targets. They have also committed to achieve *net zero deforestation* (conversion of forestland to other uses, e.g., housing) in BC by 2012. The role of forests in offsetting GHG emissions under a regional cap and trade system has yet to be determined. Managing forests for carbon storage and biofuels is being considered and these will likely become new forest values.

Managing forests in response to climate change (adaptation) is also a focus of the Ministry of Forests and Range (MFR) under the Future Forest Ecosystem Initiative (FFEI) http://www.for.gov.bc.ca/hts/Future_Forests/ .

Changes to species selection guidelines and seed transfer standards are being examined so planted forests may be better adapted to future climates. Research in assisted migration is underway with the intent of introducing a new climate-based seed transfer system within 3–5 years (see O'Neill's summary). In the interim, minor changes to the elevational transfer limits for several species are being considered for the fall of 2008. Information and updates regarding changes to seed transfer will be posted at: http://www.for.gov.bc.ca/hti/climate_change/index.htm.

Changes to species selection and seed transfer will have significant impacts on seed supply and use over the coming years. Increasing species diversity in plantations may increase seed demand for broadleaf species. Tree breeding programs and seed orchards may need to shift focus and locations as the climate warms. Seed crops in orchards and wild stands may also face increased incidence of insect and disease damage. Seed ownership and inventories will also need to move as the seed suitable for one operating area shifts over time. The utility of some seed sources will increase and the utility of others will diminish.

In response to the state of the forest industry, MPB, climate change, and other drivers, the Forest Genetics Council of BC (FGC), Tree Improvement Branch, and Research Branch undertook *Challenge Dialogue*^{TM} with members of the genetic resource management (GRM) community of practice and stakeholders in 2006–08. The purpose of this dialogue was to create a collective vision and strategy for managing and conserving BC's forest tree genetic resources. This goal was accomplished and objectives for the 3 main components of GRM (Conservation, Resilience, and Value) were identified. The final GRM report can be downloaded at: http://www.for.gov.bc.ca/hti/grm/grm_dialogue.htm . This report will guide the establishment of the FGC's next 5-year strategic plan, which will include performance measures for the identified objectives.

In changing times and climes, seed demand and use will continue to change. To avoid surprises, take note of the sage advice offered by Stephen Johnson in his parable *Who moved my cheese?*

Change happens - *they keep moving the seed.* **Anticipate change** - *get ready for the seed to move.* **Monitor change** – *check the seed often so you know when it is getting old.* **Adapt to change quickly** - *the quicker you let go of old seed, the sooner you can enjoy new seed.* **Change** - *move with the seed.* **Enjoy change!** - *savor the adventure and enjoy the new seed!* **Be ready to change quickly and enjoy it again & again** - *keep moving the seed.*

Congratulations to the Tree Seed Centre in celebrating 50 years of excellence in cone and seed services.

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FOREST GENETICS COUNCIL OF BC: SEED PLANNING STRUCTURE

Provincial objectives set by the multi-stakeholder Forest Genetics Council of British Columbia (FGC) call for 75% select[1] seed use by 2013 and for an average genetic worth for growth of 20% by 2020. With annual provincial planting averaging about 225 million seedlings per year across over 14 species, priority setting and seed planning are significant tasks.

The planning process involves a series of steps. Initially, there is a process for setting priorities amoung various seed planning units[2] (SPU). For SPUs that meet criteria for breeding and seed orchard investments, seed needs within each zone are forecast. Historic orchard production curves are developed, and based on these, total orchard size needs are predicted. Seed use and orchard production figures are tracked and presented

[1] Select seed is seed from trees that have been genetically selected from natural populations, including orchard seed from parents with known and positive breeding values and seed from provenances with known superior traits. No seed used in BC is genetically modified.

[2] A seed planning unit is a unique combination of species, seed zone, and elevation band which is used for seed planning and which have specific breeding and seed orchard populations. An example would be Douglas-fir in the maritime seed zone under 700 m elevation.

annually to aid orchard managers in the development of specific orchards and to help broader planning to ensure provincial objectives are met. Breeding investments are guided by SPU priorities and by orchard development timing. Orchard roguing decisions are made by individual owners, but cooperative planning and discussions provide them with the information they need to make informed decisions. Provincial financial support for boosting seed orchard quality (seedlot genetic worth) and for adjustments to meet FGC objectives provide added incentive for orchard operators to undertake management that will ultimately support FGC objectives.

In the multi-stakeholder system in BC, orchards are owned and operated by both the public and private sectors. Providing good information on seed needs, on annual production and on forecast production, is a key element to ensuring open discussion and cooperation among participants and to the development of a comprehensive seed production system that meets broader stakeholder objectives.

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SEED USE EFFICIENCY: FROM THE FOREST TO THE FOREST

Seed utilization is viewed as an integral component of an inter-connected tree improvement delivery system. Investigating any component of the system, such as seed utilization, must be viewed holistically (i.e., it cannot be determined or explained by its component parts alone; instead, the system as a whole determines, in an important way, how the parts behave). Thus, efficient seed utilization is affected by the phenotypic selection of superior individuals forming the breeding population; the intricacies of breeding → testing → genotypic selection of production populations' (seed orchards) parents; seed crop management practices (cone harvesting, processing, seed handling, storage, and pre-treatments; and ends with the production of seedlings for reforestation). Changes in genetic gain and diversity were monitored throughout the system, indicating that the interaction between genetics (the magnitude of genetic control over reproductive phenology and output, germination speed, dormancy and aging) and management practices (e.g., individual vs. bulk seed harvesting, single vs. multiple sowing) could impart significant unintentional directional selection where genetic gain and diversity could be drastically affected.

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CLIMATE-BASED SEED TRANSFER

Background

A well designed seed transfer system maximizes plantation productivity and wood quality, ensures the capture of genetic gains, and minimizes the risk of maladaptation due to pests, disease and climate change by ensuring that trees are well adapted to their planting location.

A revolution in the field of genecology relating to the development of new climate models, geographic information systems (GIS), the availability of mature provenance data, and new statistical techniques make it possible to develop an improved seed transfer system. A new climate-based seed transfer (CBST) system will greatly enable effective implementation of assisting migration of seed (i.e., planting seed adapted to future climates), which has been widely regarded as a key climate change adaptation strategy in forestry.[1]

Research Branch has initiated a project to develop a CBST system that will identify seedlots that are best suited climatically to each plantation over the course of the rotation. The system will be operationally simple, will apply to both selected (class A) and wildstand (class B) seed, and will be well suited for implementing measures to mitigate the impacts of climate change.

[1] A small degree of assisted migration can be accommodated within the current seed transfer system. In September 2008 Research Branch will recommend minor changes to the current system to encourage assisted migration.

Methods

Five fixed-zone seed transfer systems were developed and compared with BC's current B class seed transfer system to assess the degree of adaptation and deployability that each system would provide. Five zonation systems were created, each dividing British Columbia into 12 climate zones. The zonation systems were based on: mean annual temperature (MAT), MAT and mean annual precipitation (MAT x MAP), two principal components (PC) which consolidated eight climate variables, two principal components which were clustered (PC cluster) using a hierarchical clustering procedure to minimize climatic variation among clusters, and BC's forested biogeoclimatic zones. The MAT x MAP zonation system is illustrated in Fig. 1.

The level of maladaptation (and associated disease, pest, stem deformation, and growth losses) associated with seed transfer increases with climatic transfer distance. Therefore, to evaluate the level of adaptation that would be inherent in each zonation system, a large number of hypothetical seed transfers was created within each zone of each system and the climatic transfer distance determined for each transfer. Climatic transfer distance was then averaged over each zone and zonation system. To assess deployability, the areal extent of each zone of each system was determined using a geographical information system.

Results and Discussion

Climate transfer distance of seed transfers was substantially shorter in the zonation systems that were based on MAT x MAP, PC, and PC cluster than the systems based on MAT, biogeoclimatic zones, or the current class B zonation system (Fig. 2).

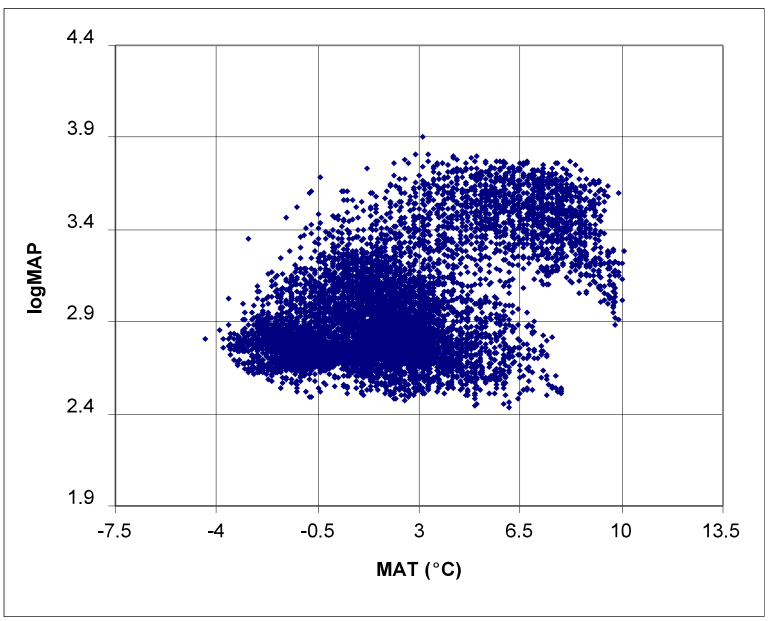

Figure. 1. An example of one of the five climate-based seed transfer systems examined. Twelve fixed-zone climate zones were created for British Columbia on the basis of mean annual temperature (MAT) and log of mean annual precipitation (logMAP).

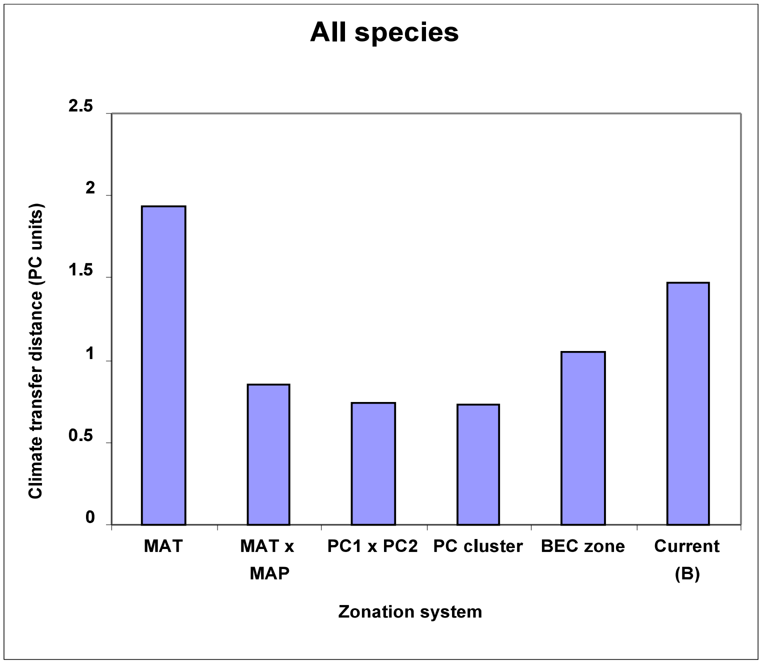

Figure. 2. Results of analysis to estimate the level of adaptation expected to be associated with seed transfers from five climate-based seed transfer systems and the current class B seed transfer system in British Columbia. Climate transfer distance is used as a surrogate measure of maladaptation.

Deployability was considerably greater for all five zonation systems compared with the current class B zonation system (Fig. 3). These results suggest that a new seed transfer system based on fixed zones developed from MAT x MAP, PC, or PC clusters would provide substantial improvements in adaptation and seed deployability. In addition, these systems would facilitate the implementation of a system of assisted migration that could be incorporated incrementally and without the need to revise zone boundaries.

Research Branch staff of the Ministry of Forests and Range intend to complete analyses required to propose a new climate-based seed transfer system by mid 2009. Tree Improvement Branch will then review and implement the recommended system. To minimize disruption in seed planning for licensees, a "roll-out" period (3–5 years) is being considered to provide time for stakeholders to adjust seed inventories.

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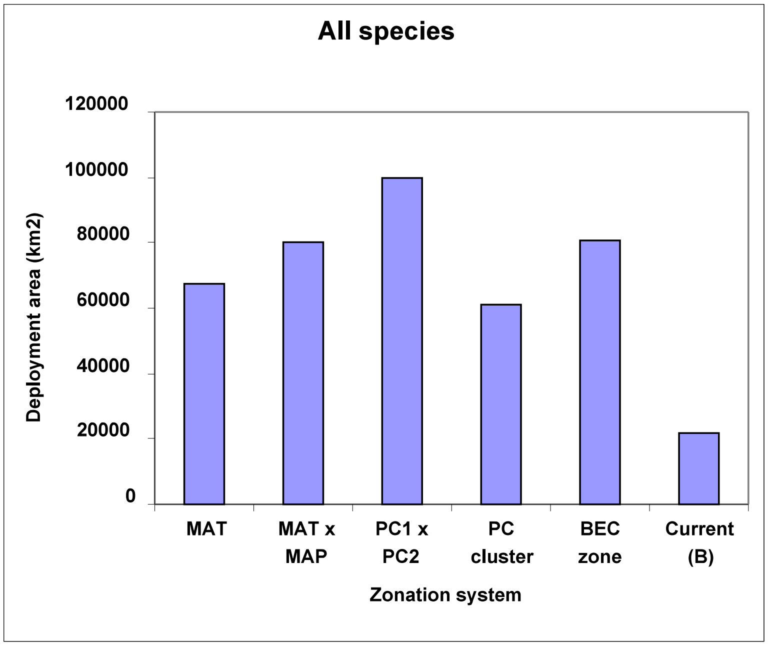

Figure. 3. Results of an analysis to estimate the level of deployability expected to be associated with seed transfers from five climate-based seed transfer systems and the current class B seed transfer system in British Columbia. Deployability is the spatial extent (km^2) to which each seedlot can be transferred.

NATURAL STAND SEED PRODUCTION

The presentation reviews most aspects of Class "B" cone collection including: legislation, natural seed planning zones, lodgepole pine (*Pinus contorta*) biology, mountain pine beetle considerations, and operational activities with costs leading to SPAR registration. The focus is on lodgepole pine collections within the Prince George Business Area including defining many challenges and solutions for consideration in preparing and undertaking a cone collection program. A draft process, currently in use with BCTS Prince George, is provided and can be used to develop a cone collection program from harvesting to collections. BCTS Prince George is currently collecting over 20 years of lodgepole pine seed in each seed planning zone, including seed from other species supporting BC Timber Sales meeting legal reforestation obligations.

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COASTAL SEED ORCHARD PRODUCTION

The expert staff at the coastal seed orchard production facilities deliver orchard seed of high genetic quality and good viability. Production reflects the status of breeding programs and meets most coastal needs. Long-term plan implementation will address current shortfalls. Costs of orchard seed are significantly greater than those of wild seed collections because of crop management inputs and cost-averaging that includes good and poor crops.

Orchard sites are selected for spring drought and low background pollen levels. Grafting selected parents, planting the orchard, and tending the trees to cone-bearing size requires irrigation, fertilization, and pest and competition control. Cone crops are induced by water stress, girdling, pruning, and hormone treatments. Seed set is improved with supplemental mass pollination. Timely cone harvest and curing, followed by seed extraction and seedlot registration results in seed for regeneration programs.

To meet the Chief Forester's Standards for Seed Use, effective population size and weighted average genetic worth of the parents contributing to the lot are calculated. Male contribution estimates employ pollen data, and female contribution calculations use harvest measures.

Pesticides, including hormones, are infrequently labelled for use in conifer seed orchards. Pest control and induction options are therefore limited. Drainage is a challenge at some orchard sites, affecting orchard tree survival.

Advanced generation orchard seed is listed surplus in SPAR for low elevation western redcedar (*Thuja plicata*), low elevation Douglas-fir (*Pseudotsuga menziesii*), low and high elevation western hemlock (*Tsuga heterophylla*), and blister-rust tolerant western white pine (*Pinus monticola*). High elevation Douglas-fir and weevil-resistant Sitka spruce (*Picea sitchensis*) will come on stream as orchard production increases. United States orchards supply seed for low elevation Douglas-fir needs.

Can high-value seed in short supply at present deliver more seedlings? Can client cost be unaffected, but the nursery price increase and the seed price decrease with the provision of less seed for seedling orders? High-value seed with high germination rates provides opportunity for negotiations among nursery service providers and clients.

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INTERIOR SEED ORCHARD PRODUCTION

Seed orchards deliver improved seed for reforestation. Seed orchard efficiency in its simplest terms is concerned with how we can produce seed as economically as possible. Five facets are discussed regarding how seed orchards can affect the efficiency of the entire seed handling system. They are: orchard planning and design, maximizing cones produced per orchard tree, maximizing seeds per cone, optimizing cone condition to maximize seed recovery at extraction, and maximizing germination capacity of seed produced. Orchard planning attempts to match orchard production to seedling needs. Cones per tree, seeds per cone, and seed recovery are affected by orchard management practices including cone induction, pest control, cultural treatments, and cone handling. Germination capacity significantly determines seed use efficiency in nurseries. Some observations are presented on how timing of collection relates to germination capacity.

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SEEDLOT PRODUCTION

Seedlot production involves the steps of cone and seed processing, seed testing, registration, storage, pre-treatment, and distribution for seedling production. In British Columbia the previously mentioned underlined items are considered stewardship responsibilities and costs not forwarded to clients. Cone and seed processing and seed pre-treatment are offered on a cost recovery basis. Quality Assurance (QA) will be emphasized and is defined as "the evaluation, monitoring, and management of information and practices related to activities in the Seed Handling System". Our QA foundations are:

1. Avoid physical contamination (debris).
2. Avoid genetic contamination (between seedlots).
3. Information management (organization).
4. Handling a perishable product (care).

Considerations regarding quality begin at the stage of pre-collection evaluation when crop size is estimated to plan for required resources, the presence of pest problems is determined, and the maturity level assessed to ensure cones are collected at the optimum time. Interim field storage is important to reduce cone moisture slowly in most crops, but serotinous lodgepole pine (*Pinus contorta*) cones can be shipped immediately. Cutting tests or seed anatomy tests are important tools for assessing maturity, quality, and determining if pests are an issue.

Cone processing consists of: 1) removal of seed already released from cones, 2) kilning, for most species, and 3) separation of seed from cones through tumbling. Species containing resin vesicles (*Abies* spp., western redcedar (*Thuja plicata*), and hemlock (*Tsuga heterophylla*)) are currently not kilned, but allowed to dry under cool conditioning so that the cone scales will flex. Lodgepole pine is kilned at a peak temperature of 60ºC while all other species are kilned at a peak temperature of 40ºC. The stage of tumbling is critical as it is the separation of seeds from cones, so monitoring is important to ensure all viable seeds are removed.

Seed processing starts with scalping to remove debris that can be abrasive, add moisture, or contain pathogens. This stage also greatly reduces the volume of material subsequently handled. Dewinging is performed on all species except western redcedar and yellow-cedar (*Chamaecyparis nootkatensis*). For pine and spruce species, wet dewinging is employed as the wing connection is quite weak and wetting allows for efficient release of the wings from the seed. The remaining species have a stronger wing-seed connection and wings are removed solely through mechanical forces, although small wing fragments may be retained compared to wet dewinged species. Wings are removed by vacuum during the process and the process shifts from removing debris to removing non-viable seed during final cleaning. This can occur via pneumatic separators or the gravity table, but both separate seed into three fractions based on specific gravity. Equipment calibration and decisions regarding seed to include/exclude in seedlots is supported by cutting tests and seed evaluations. In contrast to other seed processes, some seed may require final cleaning multiple times to ensure that viable and non-viable seeds are separated. Once final cleaning is completed the seedlot can be blended and then sampled for testing.

Seedlot sampling is conducted in accordance with ISTA sampling guidelines. Moisture content is first tested and if between 4.0 and 9.9% the seedlot can then be placed into long-term storage at -18 C. Seedlot purity is then determined and must be above 97% for registration. Moisture content and purity are legislated requirements under the Chief Forester's Standards for Seed Use in BC. The seed weight test is performed and in combination with seedlot purity the variable seeds per gram is calculated [seeds per gram = purity% / weight of 100 seeds]. Germination tests are also performed and the germination capacity and seeds per gram are the variables used to translate between seed and seedlings. Germination is retested at intervals in relation to the species deterioration rate, so a rapidly declining species like western redcedar is tested every 18 months, but a species with good storage longevity like Sitka spruce (*Picea sitchensis*) is retested every 48 months.

In addition to the standard tests described above for seedlots, there are a variety of QA tests performed on a subset of a seedlot. These include moisture content of unkilned seed, pellet assessments, germination testing of sowing requests, and returned seed.

Seedlot registration occurs following testing, confirmation of seedlot weight, and for seed orchard crops, calculation of the Genetic Worth (GW) and effective population size (Ne). For seedling production, seed pretreatments are equivalent to those used in testing. Activities involved in seed preparation are: 1) scheduling (nursery sow date is what we work back from), 2) manage changes, 3) withdraw seed, 4) prepare seed in one of the following ways – soak and stratify, pellet, or send dry to nursery, 5) monitor during stratification, especially with species requiring long stratification periods, and 6) ship seed to the nursery.

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SOWING GUIDELINES, SPAR AND SEED USE EFFICIENCIES

The Seed Planning and Registry web application (SPAR) contains the registry of all seedlots from commercial forest species that are collected in British Columbia. Seedlots are registered following current BC Ministry of Forests and Range legislation and policy (*Chief Forester's Standards for Seed Use*). Seedlots are then used to produce seedlings for reforestation of Crown land.

For each seedling request entered in SPAR, a seedlot is selected for the request using default sowing guideline calculations. Sowing guidelines are a set of calculations that convert the number of seedlings requested by forest professionals to the quantity of seed that needs to be removed from long-term freezer storage.

Sowing guidelines have evolved since the 1980's when very basic sowing rules existed (2, 3 or 4 seeds per cavity, and 1 seed/cavity for Class A lots) with > 90% germination, along with oversow factors. In 1996 a "Sowing Guideline Task group" was formed and recommended that the difference between Class A and B rules be removed and that seeds per cavity and sowing correction factors be adjusted.

Sowing guideline changes in 1999 streamlined the allocation of seeds to correspond closely to germination capacity changes and fractional sowing was introduced (see Extension Note Vol 3 No 4). In 2001 the sowing guidelines refined the calculations of "seeds per seedling". Extension Note Vol 5 No 2 describes sowing guidelines and the calculation method. In 2007, reductions in seeds per seedling were made for interior lodgepole pine (*Pinus contorta* var. *latifolia*) only (see SPAR website).

The general business and information flow for seed and seedlings in SPAR is:

1. Seedlots are registered on SPAR and stored at the Tree Seed Centre.
2. Seedling Requests are entered by agencies (e.g., licensees, BC Timber Sales, FFT, woodlots) for species, seedlot, quantity, stock type, planting year/season. Grams of seed required for each request are calculated using default sowing guidelines, based on seedlot germination capacity, seeds per gram, and amount of seedlings requested. The SPAR calculations are used by many forest companies and nurseries, however, some adjust the grams of seed required (usually downwards) based on past experience or limitations placed on high-value seed by the owner.
3. A nursery can also change sowing dates for requests assigned to them to stagger the time that seed will arrive at the nursery for sowing.
4. Information flows between SPAR and CONSEP (local Tree Seed Centre system).
5. Tree Seed Centre does seed withdrawal, preparation (some nurseries do stratification) and ships seed to nurseries based on sowing dates.
6. Nurseries receive seed and sow in specified container type on appropriate sowing dates.

In terms of seed use efficiency, the quantity of seed saved by reducing grams for seedling requests is measured by the difference between seedlings requested and seedlings calculated.

For the 2008 sowing year, for all species, 214.4 million seedlings were requested. The gram amount calculates to 188 million seedlings, so seed for the potential of 26.4 million seedlings were saved.

For lodgepole pine only, in 2008, 99.1 million seedlings were requested and 81.5 million calculated. Therefore, 17.6 million potential seedlings were saved.

Economic incentives to reduce seed quantities for request agencies are obvious as it reduces their seed costs, but economic incentives for reducing grams at the nursery are not as straight-forward. Discussions (negotiations) between the customer and nursery are encouraged and will result in greater seed-use efficiencies. Nurseries are encouraged to calculate the actual grams of seed required for their seedling requests based on their own practices and experience.

Thank you to those nurseries and seed owners who reduced grams of seed for seedling requests and saved valuable seed, which also reduced the amount of seed returned to the Tree Seed Centre, saving resources.

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UPGRADING *Abies* SEEDLOTS

Overview

This topic is directly tied to the discussions we have been having on the need to better utilize our seed resources. Whereas the overall reduction of certain types of seed is required to guarantee the long term sustainability of our industry, the upgrading of *Abies* seedlots is a good example of how nurseries have been trying to make the best use of the seed they get for upwards of 15 years (the length of time we have been upgrading). Nurseries are currently expending a large amount of time and money working on better utilizing their seed resources, even on minor crops, such as *Abies*.

Abies Production in BC

Total production of forest seedlings in BC for 2008 was 214 million. Total production of *Abies* seedlings was 2.2 million (approximately 1% of total grown).

Reasons for Upgrading

The average germination capacity of amabilis fir (*Abies amabilis*) and subalpine fir (*Abies lasiocarpa*) is 60%. With the Ministry sowing rules that gives us 4.3 seeds per cavity. This is operationally very difficult to accurately sow. The process of upgrading was developed to remove as much of the unproductive seed as possible to better facilitate the sowing and growing of the crop (4.3 seeds per cavity can often be reduced to 3.5 seeds per cavity by upgrading). Upgrading removes empty seeds and leaves less, but more productive seed that can be better distributed in the blocks during sowing. Better distributed seed leads to more uniform germination, less transplanting, and a more consistent crop.

Limitations to the Upgrading Process

Upgrading cannot remove all seed issues. Empty seeds are easily removed in the process, but the following can still be present after the upgrading is complete: insect damage, immature seed, mechanical damage, and disease.

Upgrading Process

Planning is critical to the success of the operation. PRT is producing just over 950 000 *Abies* seedlings in 2008 (half of the total *Abies* production in the province). There were roughly 123 kg of *Abies* seed that needed to be upgraded. All of this to produce trees for less than half of 1% of the total trees grown in 2008.

Upgrading must be planned so that the process is complete and seed is at the desired nursery in time for it to be sown. Equipment needs are minimal. Seed is soaked for 1–8 hrs in clear Rubbermaid bins. As seed sinks, the percentage of filled seeds is checked to determine if the process is complete. Once the percentage of filled seed remaining floating is less than 10%, it is skimmed and discarded. The total seeds available is recalculated and a new seeds per cavity number is generated for sowing.

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MINI-PLUG TRANSPLANTS

Mini-plug transplants are recognized to be one of the best production systems for optimizing seed use efficiency. In container conifer seedling production, this system allows nurserymen to maximize seed usage by single-sowing any seedlot, regardless of its germination capacity, into mini trays and by transplanting them into bigger containers to produce the requested stocktypes. Other benefits this system offers include reduction of heating costs by increasing greenhouse space efficiency, and by reducing thinning and manual transplanting operations.

The implementation of the mini-plug technology into conifer seedling production at PRT-Pelton (formerly Pelton Reforestation) however, has taken several years to develop. Adaptation of existing technology used in the horticulture sector had to overcome limitations such as compatibility with the Styroblock container system and the lack of cohesiveness of mini-plug conifer seedlings to withstand handling through the different phases of production. At PRT-Pelton we use a heat sensitive fibre (Fibreneth®) blended with Coir medium to fill the trays and pre-form the mini plugs before seeding.

A successful mini-plug transplant program starts with accurate single-sow seeding of mini trays to optimize use seed efficiency. For optimal germination and early growth of mini-plug seedlings, we have set up a "growth chamber" with insulated walls and supplementary lighting at photosynthetic levels of intensity. These environmental conditions promote the production of compact seedlings to facilitate the subsequent phases of mini-transplants. Depending on the germination capacity of the seedlot, the mini-trays can have a number of blank cells. As the machines transplant every cell from the mini-tray to the destination Styroblock, the blank cells are removed and replaced (gapped-up) by other mini-seedlings. This operation is accomplished by running the mini-trays through scanning equipment to blowout the empties and through another scanner that directs the robotic arm to gap the blank cells with seedlings from another mini-tray to produce a 100% filled tray. Gapping the mini-trays makes the transplanting operation more efficient. Mini-plug trays can also be used to manually backfill empty cavities in conventional single-sown Styroblocks, reducing transplanting shock and producing a more uniform crop.

Early results and experiences of implementing this technology into seedling production presented different challenges. Optimal conditions of medium density in the mini-plug trays for germinant radicle penetration, optimal growing conditions to promote compact-seedling growth in high density trays, algae, and liverwort control to eliminate scanning interference for gapping up, and customer's acceptance of transplanted stock were some of the difficulties to overcome. Successful results of mini-plug transplants include species like spruces, Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). Using mini-plug transplants in 2008 has allowed us to produce 80 000 to 300 000 extra seedlings of spruces, western larch, and Douglas-fir over the conventional direct-seeded production system.

There are great advantages of using mini-plug transplants in the production of conifers such as: efficient use of seed, 100% cavity fills on styroblock containers, lower thinning costs, reduction/elimination of manual transplanting, and reduction of heating costs. However, there are some limitations of the system that can discourage its implementation such as: high capital cost, limited production capacity (slow process), higher production risks from its high seedling density in a small growing area, precise scheduling requirements of the different stages of production, and limited stocktype availability. Moreover, the increasing trend for the demand of smaller stocktype seedlings makes the mini-plug transplant system less effective as a powerful tool to increase seed use efficiency.

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REPORT ON *Juniperus* BIBLIOGRAPHY FOR ISTA TREE AND SHRUB SEED COMMITTEE

The purpose of the project for the International Seed Testing Association was to provide an up-to-date bibliography of all *Juniperus* seed research for people in underdeveloped and developed nations to access easily on the internet or through word processing software. Mostly articles relating to seeds are included in the bibliography. Other citations on fire and management may be included for some species.

Beti Piotto was the leader of the project. USDA Forest Service National Seed Laboratory purchased Procite software and Jill Barbour typed or copied the abstracts into Procite Software. Beti received assistance from colleagues within Italy to search several databases for journal articles on *Juniperus* propagation.

Juniperus is an extremely ecologically important genus in many parts of the world. Seed propagation is quite difficult for many *Juniperus* species because the seed can have different kinds of dormancy. To propagate the species successfully it is important that people have information to aid them in germinating the seeds.

All *Juniperus* species are included. Each bibliography contains 1,010 citations organized by year in descending order from 2006 to 1893. Abstracts are in English even though the article may be in a different language.

Several bibliography formats were created from Procite. Each format is saved as .rtf (rich text format) files and then converted to .pdf (portable document format) files for the internet. The bibliographies can be searched through .pdf software or word processing software. Three formats are available: Subject by date.rft; By workform.rtf; Subject by keywords.rft. The workform format is the only bibliography that lists the author's location at the time the article was written.

Subject by Keywords.rft

Keywords are organized by species' scientific name. Next to the name in parentheses are the number of articles listed. Under each species articles are sorted in alphabetical order by the authors' last name. If the author has more than one citation, the citations are organized by the oldest date to the most recent date. Scientific names are in italics. The species' scientific name is always the first word under the keywords section. Each citation is arranged by author, article title, journal title, date, volume, issue, page number, ISSN number (if available), keywords, and abstract.

By Workform.rtf

This bibliography is alphabetically arranged by author's last name with a record number. Each citation is arranged in outline form with record number, author name, article title, journal title, date, volume, issue, pages, address, ISSN, Notes, abstract, call number, keywords.

Subject by Date.rft

This bibliography organizes the articles by year in descending order. The number of articles are included in parentheses next to each date. The authors are alphabetized by last name within each year. The citations are organized by author name, article title, journal title, date, volume, issue, pages, ISSN, keywords, and abstract.

Conclusion

Now that the bibliographies are complete and have been edited one time they need to be placed on as many websites as possible so that as many people as possible can use them. The most recent articles from 2006 and 2007 will be added to the bibliography as an update in the near future.

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EDITOR'S NOTE: You may access this bibliography by going to the following web site: http://www.nsl.fs.fed.us/nsl_fsstc.html

UPCOMING MEETINGS

CTIA Tree Seed Working Group Tour and Workshop
August 24/25, 2008 Berthier and Quebec City
Contact: Fabienne Colas
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Canadian Tree Improvement Association
joint with IUFRO Work. Grps. 2.04.01 & 2.04.10
"Adaptation, Breeding and Conservation in the Era of Forest Tree Genomics and Environmental Change"
Aug 25–28, 2008 Quebec City, QC
Contact: Jean Beaulieu
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IUFRO Tree Seed Symposium
"Tree Seeds 2008 – Trees, Seeds and a Changing Climate"
Sep 22–25, 2008 Wakehurst Place, UK
Contact: Matt Daws m.daws@kew.org

ISTA Tropical Tree and Shrub Seed Workshop
Purity, Moisture Content, Germination, Storage, Tetrazolium
April 7–10, 2009 Curitiba, Brazil
Contact: Antonio Medeiros
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