CANADIAN FOREST GENETICS ASSOCIATION
ASSOCIATION CANADIENNE DE GÉNÉTIQUE FORESTIÈRE

Tree Seed Working Group

NEWS BULLETIN

No. 53 June 2011

THIS ISSUE AT A GLANCE

CHAIR'S 'ARMCHAIR' REPORT

Hello, hopefully our summer is on its way. It seems we've only got it in 2–3 day segments thus far. In the last edition I spoke of the separation of our BC Forest Service into two ministries and since then we've had another restructuring and are back together just in time for our 100th anniversary next year. We are now officially the Ministry of Forests, Lands and Natural Resource Operations (FLNR). The forest geneticists and tree breeders remain as an integral part of Tree Improvement Branch: http://www.for.gov.bc.ca/hti/index.htm

The CFGA meeting will occur in Thunder Bay between August 16 and 18 with the Tree Seed Working Group Workshop and tour on August 15th and the CON**FOR**GEN Forum on August 19th. Please see http://fgo.ca/home.htm for additional details as they develop. We currently do not have an agenda for the TSWG Workshop primarily due to most agencies not yet receiving their budgets and travel approvals. We have several speakers lined up and will forward an agenda to the above website when travel approval is granted. If approved, I will discuss our experiences with the processing and testing of cones and seed from mountain pine beetle killed trees. It has been a wild ride, but we have made some adjustments for this material that we'd like to share – hopefully no one else will have a use for this information ☺, but better safe than sorry.

The TSWG tour will feature a visit to SeedTek which specializes in upgrading seed through IDS and pre-vac technologies. It's a great opportunity to learn more about these techniques and visit one of the few seed upgrading facilities in the country. We will also visit a bareroot nursery and a few tree improvement installations including a white pine blister rust resistance trial, second-generation progeny tests, and a black spruce clonal seed

orchard.

I'd also like to acknowledge several individuals involved in the BC Forest Service tree improvement/forest genetics program who have retired over the past year. I also invite all of you to use the Newsbulletin as a venue to help celebrate the retirements of those in your programs. At BCFS seed orchards, two managers, Carolyn Lohr and Keith Cox have retired as well as Ray Cardy, Phyllis Taylor, and Gladys Baird. From the forest genetics section some larger than life individuals have retired, Michael Carlson and John King, but they are continuing their contributions in an Emeritus status. Other changes have been the redeployment (hopefully temporarily) of Jodie Krakowski and the workforce adjustment that impacted Robb Bennett.

From BC, it has been quite a year with record cone crops and large increases in sowing requests. This past year seed was sown for 238 million seedlings which is about a 60 million or almost a 25% increase from last year. It certainly validates the need for a robust seed supply to deal with such profound year-to-year adjustments in seed demand. Hopefully many of you will be able to attend the CFGA meeting. For the summer of 2011, let the fires be few.

Dave Kolotelo
TSWG Chair

EDITOR'S NOTES

There is a nice mix of articles covering a range of topics. This is an open issue. We like to do these from time to time as it gets to be more of a challenge to come up with a new theme. Perhaps it is time to start recycling past themes.

It is great that there will be a seed workshop prior to the CFGA meeting. This is an opportunity for seed people to come together and talk about topics that are of interest and of a practical nature. The field tour has some interesting stops. I hope to see many of you there.

Dale Simpson
Editor

TREE SEED WORKING GROUP

Chairperson
Dave Kolotelo
Ministry of Forests, Lands and
Natural Resource Operations
Tree Seed Centre
18793 - 32nd Avenue
Surrey, BC V3S 0L5
Tel.: (604) 541-1683 x 2228
Fax.: (604) 541-1685
E-mail: Dave.Kolotelo@gov.bc.ca

Editor
Dale Simpson
Natural Resources Canada
Canadian Forest Service
Atlantic Forestry Centre
National Tree Seed Centre
P.O. Box 4000
Fredericton, NB E3B 5P7
Tel.: (506) 452-3530
Fax.: (506) 452-3525
E-mail: Dale.Simpson@nrcan.gc.ca

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

All issues of the News Bulletin are available at:
http://www.for.gov.bc.ca/hti/treeseedcentre/tsc/tswg.htm

Megastigmus AND CONIFERS: THE BIOLOGY OF INVASION

The "*Megastigmus* and Conifers: The Biology of Invasion" project is a collaboration of researchers in France and Canada funded by the Strategic Project Grants Program of NSERC and the Agence Nationale de Recherche – Programme Blanc International. The goal is to determine if *Megastigmus*, a genus of chalcid wasp of which some species parasitize the seeds of conifers, is actively parasitizing Cupressaceae species in North America, as it is in other parts of the world. In such areas, this invasive genus of wasp is detrimental to forest stand regeneration and seed orchard operation by drastically decreasing Cupressaceae fecundity. To date, there has only been one recorded incident of *Megastigmus* parasitizing North American Cupressaceae, *Chamaecyparis thyoides*, in North Carolina. The

insects isolated were named a new species, *Megastigmus thyoides*. Since there is currently no way of determining whether a seed or cone is infested with these larvae without X-raying the seeds or carefully dissecting them, it is highly possible that *Megastigmus* has invaded North America, but has remained unnoticed due to its cryptic life cycle. It is also possible that any *Megastigmus* introduced from imported seeds have not established here for lack of a suitable host. This project is designed to be one step ahead of the possible invasion of this insect into North America, to gather information at large on the phenology of Megastigmus parasitism, and to ultimately, prevent further worldwide distribution.

We are currently in the process of gathering cone samples from as many Cupressaceae species in North America as possible. If you have any pertinent information, can contribute seed or cone samples, or have contact information for North American arboretums, seed orchards, or researchers working with Cupressaceae, please contact me. More information can be found on the project blog at: http://ashleyclingen.wordpress.com/.

Ashley Clingen
Natural Resources Canada
Canadian Forest Service
1219 Queen St. East
Sault Ste. Marie, ON P6A 2E5
E-mail: aclingen@nrcan.gc.ca

NEW YELLOW CYPRESS STRATIFICATION TREATMENT

The BC Forest Service Tree Seed Centre is introducing a new stratification regime for yellow cypress (*Chamaecyparis nootkatensis*). It has long been recognized that the current test regime (48 hour running water soak – 28 day warm stratification at 20°C – 56 day cold stratification at 2–5°C) is not sufficient to break dormancy in all seeds. Past efforts at extending the cold stratification duration to 119 days resulted in a large amount (26%) of pregermination prior to the completion of stratification. This made the long cold stratification period impractical to implement.

The new standard pretreatment extends the duration of cold stratification by three weeks and also incorporates in the standard test the 72-hour soak that we have been using operationally for several years. The new germination test code is G57 with the following characteristics: 72-hour running water soak – 28 day warm stratification at 20°C – 77 day cold stratification at 2–5°C. We are currently testing all yellow cypress seedlots over 60 g (approximately 2000 potential trees) with the new treatment. Results will be available for the 41 seedlots in mid October.

David Kolotelo

COMPARISON OF BLACK ASH EXCISED EMBRYO TESTS vs. GERMINATION TESTS

Black ash (*Fraxinus nigra*) seed has been collected by the National Tree Seed Centre since 2004 to conserve germplasm due to the threat to the resource posed by emerald ash borer (*Agrilis planipennis*). Black ash seed pose a challenge to germination because, when shed in the autumn, they are immature and dormant. This necessitates treatments to mature the embryo and to alleviate dormancy. Several years ago, a lengthy trial was conducted to determine the duration of treatments to promote maximum germination (Daigle and Simpson 2007). Results demonstrated that seed need to be treated for up to 12 months in order to maximize germination. Due to this long time period, seed quality had been routinely evaluated by viability testing by excising the embryos and incubating them which provided results in 14 days. With the collection of 23 seedlots in 2009 it was decided to compare viability testing with germination testing. Fifteen older seedlots were also used.

Methods

To conduct viability tests the seed was removed from the pericarp and placed in water at 3 C for 120 hours. The purpose of this treatment is to soften the seed coat and allow the seed to imbibe moisture making it easier to process. After soaking, an incision was made along the longitudinal axis of the seed and the embryo was removed and placed on Versa-Pak in a Petawawa Germination Box. Three replications of up to 25 seed each were prepared. The germination boxes were placed in a Conviron G30 germination cabinet set at 25ºC with a daily light duration of 8 hours and a constant relative humidity of 85%. After 14 days the embryos were assessed. An embryo was viable if it remained at the same color (creamy-white) as it was when

excised or one or both cotyledons turned green, and/or the radicle started to develop. Embryos showing signs of decay were classified as non-viable.

At the time the viability tests were set up, samples of 100 black ash samaras were placed in plastic bags with about 100 ml of moist peat (moisture content ~ 75%) and subjected to the following treatment combination prior to germination testing: moist chilling for 60 days, warm treatment for 120 days, and moist chilling for 180 days. The cold treatments were carried out in a walk-in cooler (3ºC) and the warm treatment was at ambient laboratory temperature (22ºC) in a dark cabinet. Upon completion of the treatments, four replicates of 25 seed were placed on moistened Versa-Pak™ in Petawawa Germination Boxes and transferred to a Conviron G30 germination cabinet for 28 days using germination conditions of 8 h light at 30ºC followed by 16 h darkness at 20ºC with a constant relative humidity of 85%. Germination was assessed every 7 days and successful germination was achieved once radicle emergence had occurred. On day 28, seed that failed to germinate were cut and examined to determine if they were empty, dead, or fresh (filled seed which may be capable of germinating).

Results and Discussion

Overall, germination was substantially less than viability (38% vs. 58%). The cut test, following the completion of the germination test, revealed that, on average, 20% of the embryos were fresh as evidenced by being fully elongated, firm, and creamy-white in color and thus should have been capable of germinating. The most likely explanation for why these seed failed to germinate was they did not receive a sufficient second duration of moist chilling to alleviate dormancy even though 180 days of moist chilling was ample in the previously reported trial (Daigle and Simpson 2007). When average germination and fresh seed are added, the summed value was the same as mean viability (58%). There were five seedlots that exhibited germination close to their respective viability (mean germination = 50% vs. mean viability = 51%) which supports the hypothesis that viability is a good predictor of potential germination.

Literature Cited

Daigle, B.I.; Simpson, J.D. 2007. Black ash germination experiment. Pages 17–30. *In* National Tree Seed Centre Annual Report 2006. Nat. Res. Can., Can. For. Serv-Atlantic, 49 p.

Dale Simpson and Bernard Daigle
Natural Resources Canada
Canadian Forest Service
Atlantic Forestry Centre
National Tree Seed Centre
P.O. Box 4000
Fredericton, NB E3B 5P7
E-mail: Dale.Simpson@nrcan.gc.ca

BC FOREST SERVICE SEED ORCHARDS PRODUCE RECORD CROP IN 2010

The British Columbia Forest Service Tree Improvement Branch seed orchards produced a record seed orchard crop in 2010. The Branch operates 42 seed orchards at six different sites around the province. In 2010, 24 orchards produced a record 1,717 hl of cones (that required the hiring of 125 cone pickers – another record) which yielded 1,612 kg of seed from seven species: white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), western white pine (*Pinus monticola*), western hemlock (*Tsuga heterophylla*), and western red cedar (*Thuja plicata*). This crop is sufficient to produce over 233 million seedlings. The 2010 crop beat the previous largest crop by 349 kg. Previous large crops were collected in: 2007 - 1,120 kg, 2002 - 1,053 kg, and 1993 - 1,264 kg. When production from 29 private sector seed orchards is included, total provincial seed production for the year was 2,281 kg. Thus, Tree Improvement Branch produced 71% of the provincial total in 2010. For further information, please contact:

David Reid
Ministry of Forests, Lands and Natural Resource Operations
7380 Puckle Road
Saanichton, BC V8M 1W4
E-mail: David.Reid@gov.bc.ca

UNKILNED SEED MOISTURE CONTENT TESTING RESULTS

The BC Forest Service Tree Seed Centre (TSC) removes debris from seedlots and extracts the seed from the cones. Seed extraction from cones can take place prior to kilning (from already opened cones) and/or after kilning. The material that is removed from the seedlot prior to kilning is called the unkilned product. Unkilned seed (contained within the unkilned product) often has a higher percentage of filled seed than their kilned counterparts, in addition to a higher moisture content. In 1995, the need for an unkilned seed moisture content test result was recognized and the QAK moisture content test (**Q**uality **A**ssurance un**K**ilned) was created. The QAK moisture content test result assists staff in rectifying the moisture content of unkilned seed to 4.0% to 9.9% (for long-term freezer storage) and in equilibrating the moisture content of the unkilned seed with kilned seed to produce a seedlot with a uniform moisture content.

When processing unkilned seed portions, there are certain factors/complications that must be considered. The ratio of total seedlot volume to unkilned volume, size of the unkilned portion, species, and the volume and type of debris all play a role in how the unkilned portion of a seedlot is processed and at what stage in processing the unkilned seed is combined with the kilned seed.

The QAK moisture content test result is often used in combination with a cutting test on unkilned seed. The cutting test provides information regarding the relative usefulness of the QAK moisture content test as it quantifies the proportion of viable seeds in the QAK sample. However, the QAK test result cannot be used in isolation to determine the moisture content of the unkilned seed as volume and type of debris must also be considered. The QAK test result is used as one of a series of tools that cone and seed processing staff uses to process a seedlot's unkilned product to preserve the integrity and germination potential of the seedlot.

Materials and Methods

An initial cleaning is conducted by passing the unkilned portion of the seedlot over a gravity table to remove large debris (e.g., sticks, cone scales, large clumps of pitch). Small debris such as needles, twig pieces, chaff, wings, pitch, vegetative buds, and pollen cones remain within the unkilned product after initial cleaning. During the initial cleaning, a primary sample is extracted from every bag of the unkilned product in order to create a composite sample.

To perform a QAK test, 6 g of a seedlot's unkilned product is submitted to the lab where it is divided into two replicates of 3 g each. The fresh weights of the replicates are recorded, and then the replicates are placed into an oven and dried for 17 hours at 103°C. The oven dried weights of the replicates are recorded and a moisture content percentage for the submitted QAK sample is calculated based upon the following equation:

$$MC\% = \frac{[\text{Fresh Weight} - \text{Oven Dried Weight}]}{\text{Fresh Weight}} * 100$$

Results and Discussion

During production years 1995 – 2010, 1,229 QAK tests were performed on 17 species. Nine species, coastal Douglas-fir (Fdc), interior Douglas-fir (Fdi), western hemlock (Hw), western larch (Lw), interior lodgepole pine (Pli), white pine (Pw), yellow pine (Py), and interior spruce (Sx), had a combined total of 1,217 QAK tests as outlined in Table 1. Two thirds of all QAK testing performed during this time period (804 tests) were on orchard seedlots. The average number of QAK tests per production year was 76 tests.

Almost two thirds (62.7% - 763 tests) of all QAK tests performed over the past 16 years were dominated by Sx, Cw, and Fdi. Interior spruce made up almost one third (32.3%) of all QAK tests, with 92.6% of these tests coming from valuable orchard seedlots.

Interior lodgepole pine (Pli) had the highest percentage of orchard QAK tests. The heavy amount of QAK testing on lodgepole pine orchard seedlots reflects the efforts made to increase the inventory of lodgepole pine seed.

The QAK moisture content range within a species can be quite large as outlined in Table 2. For example, interior spruce (Sx) has a relatively large moisture content range of 15.5%. The large number of QAK tests (seedlot samples) to draw from could account for the greater range in the moisture content results observed for this species.

Table 1. Total number of QAK moisture content tests, percentage of QAK moisture content tests, and percentage of orchard QAK moisture content tests by species.

	Cw	Fdc	Fdi	Hw	Lw	Pli	Pw	Py	Sx
# of QAK tests/ species	196	62	174	48	103	107	42	92	393
% of QAK tests by species	16.1	5.1	14.3	3.9	8.5	8.8	3.5	7.6	32.3
% of orchard QAK tests according to species	74.5	96.8	17.2	70.8	38.8	97.2	61.9	0.0	92.6

Table 2. Total number of QAK tests performed per species as well as the lowest, average, highest and range of QAK moisture content (%) from production years 1995 to 2010.

Species	Cw	Fdc	Fdi	Hw	Lw	Pli	Pw	Py	Sx
# QAK tests performed	196	62	174	48	103	107	42	92	393
Lowest MC	5.7	6.7	6.5	5.2	6.7	5.0	7.4	6.5	5.2
Average MC	12.2	11.7	12.0	9.6	12.2	11.8	11.2	13.4	12.6
Highest MC	38.5	15.1	17.8	26.0	17.3	15.3	15.3	18.5	20.7
MC range	32.8	8.4	11.3	20.8	10.6	10.3	7.9	12.0	15.5

Low dormancy species, western red cedar (Cw) and western hemlock (Hw), have the highest QAK moisture content ranges of all nine species (32.8% and 20.8%, respectively). This is most likely related to the variability in moisture content of cones arriving on site. Unlike other species that arrive at the TSC preconditioned, low dormancy species are usually shipped to the TSC, or arrive with some limited degree of preconditioning. Consequently the seedlots of these two species have cones with a higher range of hydration levels.

A general decrease in average QAK moisture content per production year for the past 16 production years is noted for (Cw), interior Douglas-fir (Fdi), western hemlock (Hw), western larch (Lw), white pine (Pw), yellow pine (Py) and interior spruce (Sx). A greater amount of preconditioning for these species is most likely the cause of this trend. Moisture content averages for all species varied widely during the 1995 - 2003 production years. However, from 2004 onwards there was a notable decrease in the average moisture content variation per production year. The four species with the most notable average moisture content decrease during this time was Cw, Py, Lw and Hw respectively. This is probably a result of protocol changes to cone handling and storage. A decrease in the range of average QAK moisture content per production year is noted from 2004 onward. The range in moisture content five years before 2004 (1999 – 2003) 11.7% to 14.0% while for the five years after 2004 (2005 – 2009) the moisture content range was 10.4% to10.7%.

The species with the highest overall average QAK moisture content average over the past 16 years of testing was yellow pine (Py) at 13.4%. The species with the lowest average QAK moisture content test average was western hemlock (9.6%). A lower moisture content in western hemlock during stratification is characteristic of the species. In addition to having the lowest average QAK moisture content test, Hw also has the highest frequency (70%) of QAK moisture content tests results falling within the 4.0 to 9.9% range (Table 3). Of the 13 years that Hw has received QAK testing, the average QAK moisture content test result fell within this ideal range for nine years.

Table 3. Percentage of production years with yearly QAK MC test results averages above 9.9% and within 4.0% to 9.9% moisture content range limit by species.

	Cw	Fdc	Fdi	Hw	Lw	Pli	Pw	Py	Sx
Above 9.9%	66	92	100	30	80	100	78	92	100
Within 4.0% to 9.9%	34	8	0	70	20	0	22	8	0

Elevated seed moisture content reduces the longevity and viability of seed in long-term freezer storage. Thus, rectifying the unkilned seed fraction to a lower moisture content (4.0 – 9.9%) is key in ensuring the longevity and viability of the unkilned seed portion, and thus the seedlot as a whole. It is for this reason that the QAK moisture content test has become an essential tool in assisting the Tree Seed Centre in its mandate of excellence in cone and seed services.

Katherine Rapske
Ministry of Forests, Lands and Natural Resource Operations
Tree Seed Centre
18793 – 32nd Avenue
Surry, BC V3S 0L5
E-mail: Katherine.Rapske@gov.bc.ca

BOOK REVIEW: "LIVES OF CONIFERS"

Graham R. Powell, 2009. ISBN-13: 978-1-55041-869-9 Fitzhenry and Whiteside Limited, Markham, Ontario. Hardcover. 276 pages. $ 50.

This book chronicles the birth, life, and death of 12 coniferous tree species indigenous to northeastern North America. The author is Professor Emeritus in the Faculty of Forestry and Environmental Management at the University of New Brunswick where he taught courses in silviculture, dendrology, silvics, tree development, tree reproduction, and forest botany. The book consists of nine chapters as well as a glossary which is crucial due to the use of terminology throughout. There are hundreds of color photographs throughout providing vivid detail and examples of the many points that Dr. Powell makes plus there are many illustrations and diagrams that provide further information.

Chapter 2 is where is all begins, seeds, by describing the external characteristics of seed for each species followed by what is found inside and concludes with life histories. Seed germination followed by first- and second-season development is covered in Chapter 3. Chapter 4 discusses how the developing seedlings react to shade as they grow and develop in natural environments. Development of branches and differences in crown form are dealt with in Chapter 5 as trees grow in the sapling stage of their lives. Reproduction is dealt with in Chapter 6 which covers onset and buildup of cone production, positions of cones on shoots, frequency of cone production, numbers of cones produced and seed production as it relates to cone size or cone position on a shoot. Chapter 7 continues with reproduction but deals with the details of it such as the formation and development of reproductive buds; pollination, fertilization, embryo, and seed development; cone and seed maturation and seed release. As trees grow, develop, and age branch and crown development show unique characteristic among species. This is discussed in Chapter 8. In Chapter 9 trees continue to grow and develop until they reach the stage when they can no longer increase in size and they start to lose vigor and ultimately die.

This book is not for the casual reader but for those who have an interest in furthering their knowledge and understanding about how trees grow and develop. I see this book as a valuable textbook for university courses on tree development and reproduction. It is available in hardcover and the quality paper that is used is sure to withstand the test of time as scholars thumb through the pages gleaning the incredible quantity of information printed on their surfaces.

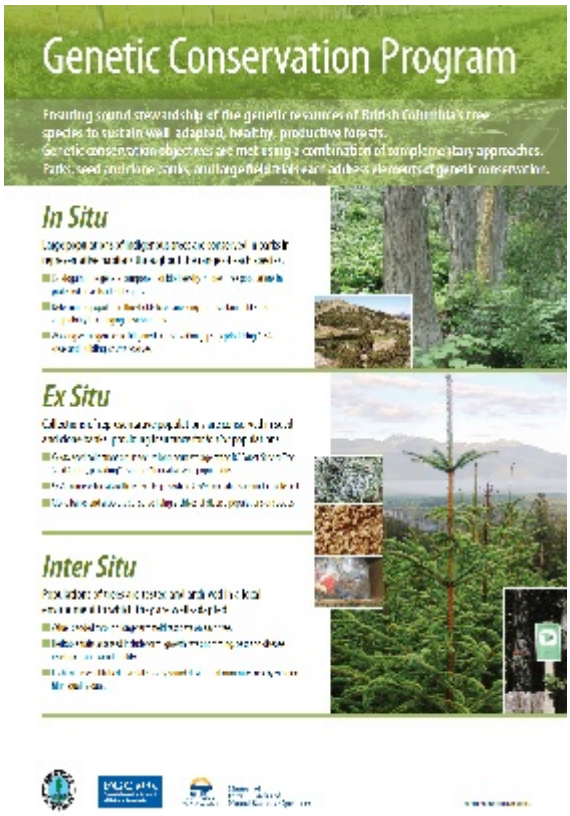
Dale Simpson

GENETIC RESOURCE MANAGEMENT AND CONSERVATION POSTER SERIES

The British Columbia Ministry of Forests, Lands, and Natural Resource Operations has developed a series of 61 cm wide x 91 cm tall posters that can be viewed or downloaded for free at the Production Resources website http://www.for.gov.bc.ca/hfd/pubs/Docs/P/P085.htm An example is provided below. Hard copies can be ordered at cost from Crown Publications – contact http://www.for.gov.bc.ca/hfd/pubs/orderinfo.htm for details.

The extension series is targeted towards an audience with an interest and general background in forestry and natural resources. There are five posters: two provide higher-level overviews and three illustrate examples for native tree species, with a summary of the genetic conservation status and genetic resource management issues for each. The posters illustrate issues and facts about: 1) the Ministry genetic conservation program, 2) genetic resource management in forestry, 3) genetic resource management of western redcedar, 4) genetic resource management of western larch, and 5) genetic resource management of western white pine.

Forest genetic resource management is incorporated in British Columbia forest conservation and operations. Knowledge of how each species is adapted to the environment helps ensure sound stewardship of the genetic resources of British Columbia's tree species to sustain well-adapted, healthy, productive forests.



Jodie Krakowski
Ministry of Forests, Lands, and Natural Resource Operations
Cowichan Lake Research Station
P.O. Box 335
Mesachie Lake, BC V0R 2N0
E-mail: Jodie.Krakowski@gov.bc.ca

UPCOMING MEETINGS

Whitebark Pine Science & Management Workshop
July 14–15, 2011 Lillooet, BC
Contact: Randy Moody
Randy@keeferco.com

Western Forest Genetics Association Meeting
July 25–28, 2011 Troutdale, OR
Contact: Richard Zabel
richard@westernforestry.org

32nd Canadian Forest Genetics Association Meeting
"Forest Genetics and Tree Improvement: New Knowledge, Challenges and Strategies"
Aug 16–18, 2011 Thunder Bay, Ontario
Contact: Paul Charrette
paul.charrette@lakeheadu.ca

Forest Nursery Association of British Columbia
Sep 12–14, 2011 Salmon Arm, BC

IUFRO Seed Orchards and Breeding Theory Working Groups
May 21–25, 2012 Egirdir, Isparta, Turkey
Contact: Nebi Bilir
nebibilir@orman.sdu.edu.tr
http://atabeymyo.sdu.edu.tr/seedconference

RECENT PUBLICATIONS

Aoki, C.F.; Romme, W.H.; Rocca, M.E. 2011. Lodgepole pine seed germination following tree death from mountain pine beetle attack in Colorado, USA. Amer. Midl. Nat. 165(2):446–451.

Avsar, M.D. 2010. Using flotation in ethanol to separate filled and empty seeds of *Pinus nigra* ssp. *pallasiana*. African. J. Biotechnol. 9(25):3822–3827.

Bochenek, G.M.; Eriksen, B. 2011. First come, first served: Delayed fertilization does not enhance pollen competition in a wind-pollinated tree, *Fraxinus excelsior* L. (Oleaceae). Int. J. Plant Sci. 172(1):60–69.

Bower, A.D.; Kolotelo, D.; Aitken, S.N. 2011. Effects of length of storage and stratification on germination of whitebark pine seeds. West. J. Appl. For. (26)1:24–29.

Crone, E.E.; McIntire, E.J.B.; Brodie, J. 2011. What defines mast seeding? Spatio-temporal patterns of cone production by whitebark pine. J. Ecol 99:438–444.

Devine, W.D.; Harrington, C.A.; Kraft, J.M. 2010. Acorn storage alternatives tested on Oregon white oak. Native Plants J. 11(1):65–76.

Funda, T.; Liewlaksaneeyanawin, C.; Fundova, I.; Lai, B.S.K.; Walsh, C.; van Niejenhuis, A.; Cook, C.; Graham, H.; Woods, J.; El-Kassaby, Y.A. 2011. Congruence between parental reproductive investment and success determined by DNA-based pedigree reconstruction in conifer seed orchards. Can. J. For. Res. 41(2):380–389.

Keane, R.E.; Tomback, D.F.; Murray, M.P.; Smith, C.M., eds. 2011. The future of high-elevation, five-needle white pines in Western North America: Proceedings of the High Five Symposium. 28–30 June 2010, Missoula, MT. USDA, For Serv., Rocky Mtn. Res. Sta., Fort Collins, CO. Proc. RMRS-P-63. 376 p. Online at http://www.fs.fed.us/rm/pubs/rmrs_p063.html

Koenig, W.D.; Knops, J.M.H.; Carmen, W.J. 2010. Testing the environmental prediction hypothesis for mast-seeding in California oaks. Can. J. For. Res. 40(11):2115–2122.

Lai, B.S.; Funda, T.; Liewlaksaneeyanawin, C.; Klapste, J.; van Niejenhuis, A.; Cook, C.; Stoehr, M.U.; Woods, J.; El-Kassaby, Y.A. 2010. Pollination dynamics in a Douglas-fir seed orchard as revealed by pedigree reconstruction. Ann. For. Sci. 67(8):808.

Liu, T-W.; Wu, F-H.; Wang, W-H.; Chen, J.; Li, Z-J.; Dong, X-J.; Patton, J.; Pei, Z-M.; Zheng, H-L. 2011. Effects of calcium on seed germination, seedling growth and photosynthesis of six forest tree species under simulated acid rain. Tree Phys. 31(4):402–413.

Lorenz, T.J.; Sullivan, K.A. 2010. Comparison of survey methods for monitoring Clark's Nutcrackers and predicting dispersal of whitebark pine seeds. J. Field Ornith. 81(4):430–441.

Lorenz, T.J.; Sullivan, K.A.; Bakian, A.V.; Aubry, C.A. 2011. Cache-site selection in Clark's Nutcracker (*Nucifraga columbiana*). Auk 128(2):237–247.

Lstiburek, M.; El-Kassaby, Y.A. 2010. Minimum-inbreeding seed orchard design. For. Sci. 56(6):603–608.

Pasquini, S.; Braidot, E.; Petrussa, E.; Vianello, A. 2011. Effect of different storage conditions in recalcitrant seeds of holm oak (*Quercus ilex* L.) during germination. Seed Sci. Technol. 39(1):165–177.

Richards, C.M.; Lockwood, D.R.; Volk, G.M.; Walters, C. 2010. Modeling demographics and genetic diversity in *ex situ* collections during seed storage and regeneration. Crop Sci. 50(6):2440–2447.

Sharrock, S.; Jones, M. 2011. Saving Europe's threatened flora: progress towards GSPC Target 8 in Europe. Biodiv. Conserv. 20(2):325–333.

Smith, P.; Dickie, J.; Linington, S.; Probert, R.; Way, M. 2011. Making the case for plant diversity. Seed Sci. Res. 21(1):1–4.

Teste, F.P., Lieffers, V.J.; Landhäusser. 2011. Viability of forest floor and canopy seed banks in *Pinus contorta* var. *latifiolia* (Pinaceae) forests after a mountain pine beetle outbreak. Am. J. Bot. 98(4):1–8.

Teste, F.P., Lieffers, V.J.; Landhäusser. 2011. Seed release in serotinous lodgepole pine forests after mountain pine beetle outbreak. Ecol. Appl. 21(1):150–162.

Williams, C.G.;von Aderkas, P. 2011. Marking live conifer pollen for long-distance dispersal experiments. Oecologia 165(1):249–254.