11th International Christmas Tree Research and Extension Conference

Proceedings

August 10 – 14, 2013

Faculty of Agriculture, Dalhousie Agricultural Campus,
Dalhousie University
Truro, Nova Scotia, B2N5E3

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Conference Organizational Committee

Executive Coordinator:	Rajasekaran Lada
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Executive Summary

The 11th International Christmas Tree Research and Extension Conference, which was held from August 10-14th, 2013 for the first time in Nova Scotia, Canada, hosted by the Christmas tree Research Centre, Faculty of Agriculture, Dalhousie University. Dr. Gray presented the inaugural address at the Conference. The Conference served as a model for integration of international researchers, extension specialists, students and industry. The scientific presentations touched various disciplines ranging from breeding, genetics, physiology, postharvest physiology, pathology, entomology, soil science and nutrition, marketing and economics dealing with real-world challenges that the industry across the world is facing.

In addition to various scientific presentations, the conference was also configured to have tours to various plantations, networking, poster presentations, and Scientist –Industry panel discussion. This platform provided opportunity for the industry to have conversations with global scientific community seeking solutions.

This Conference provided an excellent opportunity for the graduate students, post-doctoral fellows and technical staff of the Christmas tree Research Centre to participate and learn from the global scientific community at large and share their research findings. The tour has provided an opportunity for the scientists and extension specialist from various countries to see how Christmas trees in Nova Scotia are produced in truly an ecologically and environmentally sustainable way.

I would like to take this opportunity to thank the international executive advisory team, my research team in working with me to organize the Conference, the partners – Dalhousie University, Nova Scotia Department of Natural Resources, Christmas Tree Council of Nova Scotia for their contributions.

All in all, it was a great, memorable learning global experience.

Best regards,

Dr. R. Lada Ph.D. (Adelaide), U.M.C. (Manitoba), P.Ag.
Professor & Department Chair, Environmental Sciences
Founding Director, Christmas tree Research Centre.

Foreword

The 11th International Christmas Tree Research and Extension Conference was hosted by Dalhousie University in Bible Hill, Nova Scotia, Canada. Participants were treated to beautiful Canadian summer weather and, by all accounts, participants enjoyed local maritime scenery and food. This event marked the first time this conference was held in Canada in 16 years and was the most recent in the following series:

Date	Host	Location	Country
October 1987	Washington State University	Puyallop, WA	USA
August 1989	Oregon State University	Corvallis, OR	USA
October 1992	Oregon State University	Silver Falls, OR	USA
September 1997	British Columbia Ministry of Forests, Research Branch	Mesachie Lake, BC	Canada
July 2000	Danish Forest and Landscape Research Institute	Vissenbjerg	Denmark
September 2003	North Carolina State University	Hendersonville, NC	USA
October 2005	Michigan State University	Tustin, MI	USA
August 2007	Forest and Landscape, University of Copenhagen	Bogense	Denmark
September 2009	Oregon State University and Washington State University	Corvallis, OR and Puyallop, WA	USA
August 2011	Christmas Tree Growers Association of Lower Austria	Eichgraben	Austria
August 2013	Dalhousie University	Bible Hill, NS	Canada

The conference kicked off with a full day off presentations followed by a poster session. Then it was off to Lunenburg County the following day for a look at Nova Scotia's natural beauty and the Christmas tree capital. I think there are some people who never would have left our supper restaurant overlooking the ocean. Tuesday was our last full day and was split between presentations and round table discussion in the morning, and tours to Antigonish County in the afternoon. The evening banquet was the perfect way to end the day.

Overall the conference was a remarkable experience. There are so many people to thank for their contributions, but none of this would have happened without the conference coordinator, Rachel Kennedy. I'd like to extend a sincere thank you to her. Also, for someone like myself who is relatively new to Christmas tree research, it was a great pleasure to meet so many other people with much more experience. I am looking forward to the next meet in Norway in 2015.

Mason MacDonald, PhD, PAg
Proceedings Editor

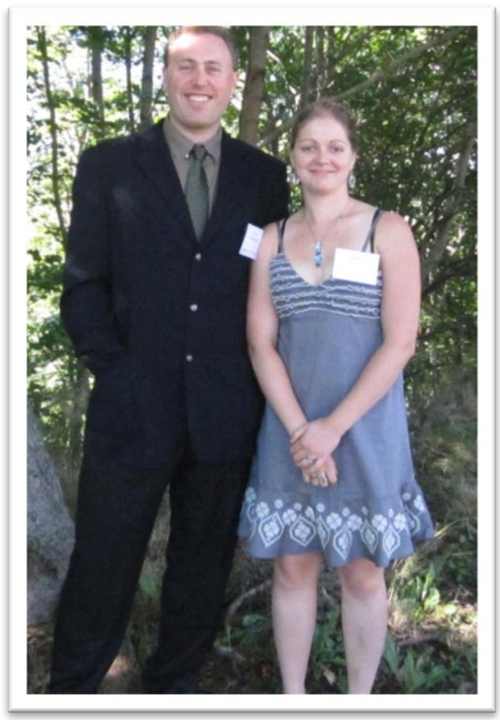
What an amazing experience you all provided for me to learn from and fondly remember this past August. Having the unique opportunity to work with you all and organize the 11th Annual International Christmas tree Research and Extension conference is something that I will forever carry with me.

I must take this time to thank Dr. Lada for “leading the charge” on this conference and getting it here for the first time on Canadian soil, a fact which we are very proud of. Thank you to Dr. Mason MacDonald, for all of his assistance with; set-up, take-down, organizing and the use of his editorially abilities to complete these proceedings. As well as a thank you to the rest of the CRC staff and students; Gaye MacDonald, Jane Blackburn, Dr. Arumugam Thiagarajan, Dr. Andrew Schofield, Scott Veitch and Melissa Georgeson. This conference would not have been possible without all their help.

A big thank you to the sponsors who’s generosity made the field tours and meal breaks possible; Nova Scotia Department of Natural Resources, The Nova Scotia Christmas tree Council, Mike Keddy and the Department of Environmental Sciences – Dalhousie University.

Knowing that this conference wasn’t as large as it has been in previous years, it was our hope to make up for that with the tours of our unique natural production systems, the producer interaction and the overall general experience. We may have been smaller in numbers, but the impact of having this conference and your expertise come to Nova Scotia holds great importance to us, our producers and supporters. The networking opportunities and information exchange will only further improve the Christmas tree industry in this area and those working in it, be it researcher, producer or hired hand. It was a great pleasure to be directly involved in this unique experience.

I anxiously await an opportunity to converse and work with you all again. Maybe I will even be lucky enough see you in Norway in 2015.



Proceedings editor Mason MacDonald and conference coordinator Rachel Kennedy

Kindest Regards,

Rachel Kennedy, BSc (Agr)
Conference Coordinator

Schedule

Guests were invited to stay in Chapman House on campus. All conference events were held overlooking the salmon river valley in the Riverview Room, Jenkins Hall, Dalhousie University Agricultural Campus. Tours left from the "horseshoe" parking area. Guests were encouraged to explore the beautiful campus, including highlights such as the rock garden, alumni gardens, and butterfly meadow.

Saturday, August 10

Time	Event	Location
17:00	Registration	Chapman Residence
19:30	Welcome Reception and Poster Set Up	Jenkins Building

Sunday, August 11

Time	Event	Moderator
7:00	Registration/Breakfast	
8:30	Welcoming address *Dr. David Gray, principal Dalhousie Agricultural Campus and Dean of Faculty of Agriculture* *Dr. Raj Lada, Director Christmas Tree Research Center and Department Head of Environmental Sciences*	
8:50	Effect of scion age on the marketability of Fraser fir grafts as Christmas trees *Anne Margaret Braham and John Frampton*	
9:20	Observation on the inspection of Christmas trees in Hawaii *Gary Chastagner*	
9:40	Managing nutrients and soil pH for Christmas tree production with soil and tissue testing: expectations and reality *John Hart*	
10:00	Nutrition Break – Sponsored by NS-DNR	Mason MacDonald
10:20	Confronting heavy cone production in plantation-grown Fraser fir trees *Brent Crain*	
10:40	Role of auxin in postharvest needle abscission in balsam fir (Abies balsmea L.) *Raj Lada*	
11:00	Physiological and metabolic characterization of postharvest needle abscission resistance of balsam fir after natural cold acclimation *Mason MacDonald and Arumugam Thiagarajan*	
11:20	Low temperature modulates postharvest needle retention in balsam fir (Abies balsamea L.) *Arumugam Thiagarajan*	

Time	Event	Moderator
11:40	Biophysical changes and a comparison of needle abscission resistant genotypes in postharvest balsam fir *Mason MacDonald*	Mason MacDonald
12:00	Lunch and Poster Set Up	
13:00	An emerging adelgid pest on Nordmann fir Christmas trees in western Washington *Gary Chastagner*	Arumugam Thiagarajan
13:20	Adelgid resistance *Ulrick Nielsen*	
13:40	Screening true fir for resistance to Phytophthora communities from Pacific Northwest Christmas tree farms *Kathleen McKeever*	
14:00	Use of shade netting strong reduces current season necrosis (CSNN) *Venche Talgo*	
14:20	Nutrition Break – Sponsored by NS-DNR	
14:40	*Neonectria neomacrospora* is threatening the true fir production in Scandinavia *Venche Talgo*	
15:00	Mechanical control of Epilobium sp. In Christmas tree plantations *Inger Floistad*	
15:20	Poster Session	
17:00	Supper	

Monday, August 12 (meet outside Jenkins hall after breakfast)

Time	Event	Organizers
6:30	Breakfast	Rachel Kennedy Ross Pentz
7:40	Leave for field tours (Lunenburg area)	
10:00	Stop 1: Mike Keddy, New Ross (Tree grower and exporter)	
11:00	Stop 2: Colin Hughes, New Ross (Tree grower and exporter)	
12:00	Lunch Break - Legion	
13:00	Stop 3: T&D Nurseries, New Ross (forestry and landscape stock)	
14:00	Stop 4: Seffernsville Experimental Lot, Seffernsville (Christmas tree experiment/production lot)	
16:00	Supper	
18:00	Return from field tours	

Tuesday, August 13 (in Riverview room)

Time	Event	Moderator/Guide
7:00	Breakfast	
8:00	Screening balsam fir genotypes for postharvest needle abscission resistance *Andrew Schofield*	Andrew Schofield
8:20	Genetic control of post-harvest needle retention in Fraser fir. *John Frampton*	
8:40	Results from common source trials of Nordmann and Turkish fir in Denmark and the Pacific Northwest, USA. *Chal Landgren, Gary Chastagner, Ulrick Nielsen*	
9:40	Round table discussion: Breeding Trials	Chal Landgren
10:20	Nutrition Break – Sponsored by CTCNS	
10:30	Leave for field tours (Truro area)	Rachel Kennedy
10:35	Stop 1: Balsam Fir Germplasm Center, Bible Hill	
10:50	Stop 2: Christmas Tree Research Center, Bible Hill	
11:30	Lunch at Perrenia Park	
12:15	Leave Perennia Park, travel to Saint Andrews	
1:45	Stop 3: Roger Trenholm's Lot, Saint Andrews (producer)	
2:20	Stop 4: Scott & Stewart Forestry, Saint Andrews (nursery)	
3:10	Stop 5: Elite Balsam Products, Saint Andrews (wreaths and specialty products)	
5:00	Return from field tours	
7:00	Banquet	

Wednesday, August 14 (in Riverview room)

Time	Event	Moderator/Guide
7:00	Breakfast	
8:00	Producer Scientific Engagement	Raj Lada
10:00	Nutrition Break	
10:20	Campus Tour	
12:00	Lunch	

Marketing and Plantation Management	Tree Physiology
Pest Management	Breeding and molecular biology
Tour	Other
Nutrition Break or Meal	

Presentations

Marketing and Plantation Management

Effect of Scion Age on the Marketability of Fraser Fir Grafts as Christmas Trees

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[2] Smoker Holly Tree Farm, 3452 Meadowfork Rd, Laurel Springs, NC 28644 USA
[3] Department of Forestry and Environmental Resources, North Carolina State University, Raleigh, NC 27695 USA

Grafted planting stock might be useful to mass produce select Christmas trees that display desirable traits such as faster growth, higher quality, increased pest resistance, or better color. Although ortet genotype, age, and quality can influence growth and development of grafts for many conifer species, this has not been investigated for Fraser fir [*Abies fraseri* (Pursch) Poir.] Christmas tree production. In 2004, a field trial was established near Independence, Virginia, with the objectives of assessing 1) the effect of scion age (stock plants = 6, 12, 18 years) on growth and quality and 2) the response of specific (old) selections to two shearing regimes: fixed (40 cm) versus variable leader length. Total height, USDA grade (0-4 scale), cone production (0-4 scale) and market value (USD) were assessed after 8 years in the field. Scions from Fraser fir Christmas trees 2 m or taller produced grafts that expressed maturation, resulting in lower tree grades, increased coning, and decreased market value. In contrast, the quality and market value of was similar when scions were collected from young Fraser fir Christmas trees. We recommend collecting scions from the upper whorls of trees no older than 2-3 years in the field (6 to 7 years from seed). The effect of age on Fraser fir clones varies so that pre-screening might identify some old selections suitable for use as scion donors. The overall effect of shearing regimes (fixed versus variable) was not substantial. However, there was a 'clone x shearing regime' interaction so that some individual clones responded noticeably better to one or the other regime.

Observation on the inspection of Christmas trees in Hawaii

Gary Chastagner[1]

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Insects are commonly found by Hawaii quarantine inspectors on Christmas trees, which are imported from the Pacific Northwest. To reduce the risk of importing yellowjacket (*Vespula* spp.) queens, other insects, and slugs, an inspection and tree shaking certification program was initiated in 1991, requiring exporters to shake all trees at destination using a mechanical shaker, or shake 10% of trees manually in the presence of an inspector, who would then require 100% shaking if yellowjackets were observed. For the period 1993-2006, the percentage of shipping containers rated by Hawaii quarantine inspectors as moderately or highly infested with insects following manual and mechanical shaking was 17.0% and 2.6%, respectively. Live yellowjacket queens and slugs continue to be intercepted in Hawaii from containers certified as manually shaken and from containers certified as mechanically shaken. During the past couple of years, the Hawaii Department of Agriculture (HDA) has given importers the option of treating trees in containers with intercepted regulated pests with a hot water shower treatment that was originally developed to treat plants to control the spread of the coqui frog, an invasive pest that is already present on a number of island in Hawaii. In an effort to better understand the inspection process and hot water treatment option, the HDA inspection of containers of PNW-grown Christmas trees was observed during November 2012. Facilities for the hot water treatment of trees were also examined. This presentation will provide a summary of these observations and discuss possible approaches the industry might use to reduce the risk of regulated pests being intercepted in exported trees.

Managing Nutrients and Soil pH for Christmas tree Production with soil and tissue testing: Expectations and Reality

John Hart[1]

[1] Department of Crop and Soil Science, Oregon State University, Corvallis, OR 97331 USA

Soil and tissue or needle analyses have been available to Christmas tree producers as a basis for plantation nutrient management. Growers use these analyses with expectations for rapid straightforward information about nutrient sufficiency or need. Their expectations are not always met. Soil and needle analyses changes with fertilizer and lime application during one rotation of a single field in an Oregon plantation will be examined addressing the question, “did the nutrient application change soil and needle analyses as expected and desired?”. Initially, soil pH, Ca and Mg increased beyond expectations with dolomitc lime application and collection of a soil sample from the surface to a 13 cm depth. A recent soil sample collected incrementally to 30 cm showed soil pH, P and K in the surface changed from application of N, P, and K fertilizer. Soil pH and Ca decreased more rapidly than expected near the end of the rotation. A single preplant application of B substantially increased soil test B only the year following application, but B needle concentration has been elevated for the entire rotation. Three annual late rotation topdress applications of 40 kg K/ha increased soil test values in the surface 5 cm of soil and needles, but less than expected. This data shows that increasing tissue nutrient concentration in large rapidly growing late rotation trees can be difficult with topdressing a nutrient not mobile in soil. Additional examples illustrating successes and limitations of soil and tissue analyses will be provided.

Nitrogen source does not affect growth of Fraser fir or Colorado blue spruce Christmas

Bert Cregg[1,2] and Dana Ellison[1]

[1] Department of Horticulture, Michigan State University, East Lansing, MI 48824 USA
[2] Department of Forestry, Michigan State University, East Lansing, MI 48824 USA

Maintaining proper soil fertility and tree nutrition is critical to ensure tree growth and tree quality, especially needle color. Among the 17 essential elements required for tree growth and development, nitrogen (N) is usually considered the most critical in a Christmas tree fertilization program. Nitrogen is the element which is most commonly limiting for plant growth. First, N is needed in relatively large amounts compared to other elements. At the end of a typical production cycle, the needles, stems and branches of a standing crop of Christmas trees may contain over 400 lbs of N per acre; more than all other nutrient elements combined. Secondly, in the nitrogen cycle, soil N goes through a series of chemical transformations and several forms of N are subject to losses from soil though leaching, ammonia volatilization, crop removal and de-nitrification. As with most crops, fertilization programs for Christmas tree plantations are largely focused on N additions. Fertilizer rates and timing are often common concerns when developing a fertilizer prescription, however, which source of N to apply can also play a role in the fertilizer decision-making process.

The Traditional View

Historically, scientists considered that plants take up N as either ammonium (NH4+) or nitrate (NO3-). The fact that N can be taken up as either a negatively charged form (anion) or a positively charged form (cation) makes N unique since all other mineral elements are taken up as either a cation or anion, but not both. More recently, research from a variety of forest systems, including studies of conifers by MSU's Dr. Pascal Nzokou and his students, suggest that N may also be taken up by plants as organic nitrogen in the form of amino acids (Wilson et al., 2013).

Background Biology

Nitrogen performs several key functions in plants, most notably as a fundamental component of amino acids, which are the building blocks of proteins, including all of the enzymes and co-enzymes that regulate a plant's biochemical machinery. From a plant metabolism point of view, NH4+ is often considered to be more efficient than NO3- since NO3- must be converted to NH4+ in order to be assimilated into amino acids (Fig. 1). Likewise, recent work on amino acid fertilization rests on the premise that amino acid fertilizers will save an additional energetic step and result in greater efficiency than applying either NO3- or NH4+. While investigations into amino acid fertilization are comparatively recent, the use of NO3- and NH4+ by plants has been well studied. In general, conifers are thought to prefer NH4+ as an N source since they often occur on sites with low soil pH and low rates of nitrification. In a trial comparing growth response of container-grown Fraser fir seedlings to varying ratios of NH4+ and NO3- supply, Rothstein and Cregg (2005) found that seedlings grown with high ratios of NO3- grew more than seedlings supplied with N as NH4+ only.

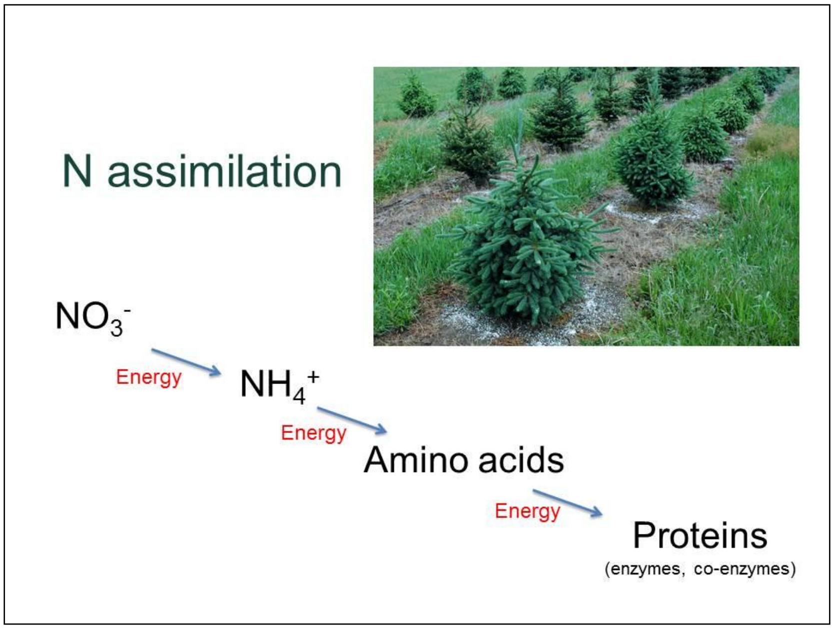

Figure 1. Simplified model of nitrogen assimilation. Conifers may take up N as NO_3^-, NH_4^+, or amino acids.

MSU Nitrogen Source Study

In order to determine the impacts of N source on Christmas tree production over a longer time-scale, we established a Nitrogen Source Study at the MSU Southwest Michigan Research and Extension Center near Benton Harbor, Michigan in 2009. The study was established in existing plots of Colorado blue spruce and Fraser fir trees that were planted in 2006. Tree density was 1210 trees/ac. Each spring from 2009 through 2012 we fertilized 5-tree row plots of each species at rate of 75 lb/ac of N (1 oz. N/tree) applied as either ammonium only or nitrate only. Ammonium was applied as ammonium sulfate (5.6 oz/tree); nitrate was applied as calcium nitrate (6.7 oz/tree). We counter-balanced the potential effects of each fertilizer source on soil pH by adding elemental sulfur to the calcium nitrate plots and adding lime to the ammonium sulfate plots (Table 1). The amount of each material required was converted to an ounces-per-tree basis and pre-measured scoops were used to apply the appropriate amount of material. Fertilizer was applied by hand around the drip line of each tree in early spring each year (Fig. 2). We assessed annual tree growth (stem caliper @ 2' above ground-line and height), foliar nutrients, and soil pH during the study (Fig. 3). Coning was assessed in 2012 when some of the trees began to produce cones.

Table 1. Fertilizer treatments for MSU Nitrogen Source Study

N source: Ammonium only

Fertilizer	lbs/ac product	N	Ca	S	$CaCO_3$ equivalents*
$(NH_4)_2SO_4$	357	75		86	-393
CaOH	180		90		245
Total or net		**75**	**90**	**86**	**-148**

N source: Nitrate only

Fertilizer	lbs/ac product	N	Ca	S	$CaCO_3$ equivalents
Elemental sulfur	86			86	-268
$Ca(NO_3)_2$	500	75	95		100
Total or net		**75**	**95**	**86**	**-168**

*Calcium carbonate equivalents reflect the relative effect of fertilizer on soil pH. Positive values indicates an increase in pH, and a negative values indicate a reduction in pH

Figure 2. Each fertilizer treatment was applied to 5-tree row plots.

Figure 3. Tree growth was assessed each fall.

Results

After four years of treatment, N source did not affect annual height growth or stem caliper growth of either species (Figs. 4 and 5; note height growth of Fraser fir and caliper growth of Colorado blue spruce are shown for illustration). Leader growth was consistent across all four years of the study while caliper growth was greatly reduced by the 2012 drought. Foliar nutrient concentrations were higher for Colorado blue spruce than for Fraser fir, however, color was good on almost all trees and there was no effect of treatment on nutrient concentrations (Table 2). Coning was relatively sparse in the Fraser fir trees. There was no effect of nitrogen source on either cone density (cones per tree) or cone frequency (percent of trees with cones). The results of this study suggest that any gains in efficiency of plant utilization of ammonium versus nitrate are relatively small for field-grown Fraser fir and Colorado blue spruce.

Table 2. Mean foliar nutrient concentrations of Fraser fir and Colorado blue spruce trees in MSU Nitrogen Source Study

		Foliar nutrient concentration			
Species	**N source**	**N (%)**	**P(%)**	**K(%)**	**Ca(%)**
Fraser fir	Ammonium	1.68	0.16	0.57	0.78
	Nitrate	1.68	0.15	0.58	0.76
Colorado blue spruce	Ammonium	2.06	0.20	0.46	0.79
	Nitrate	2.15	0.21	0.47	0.85

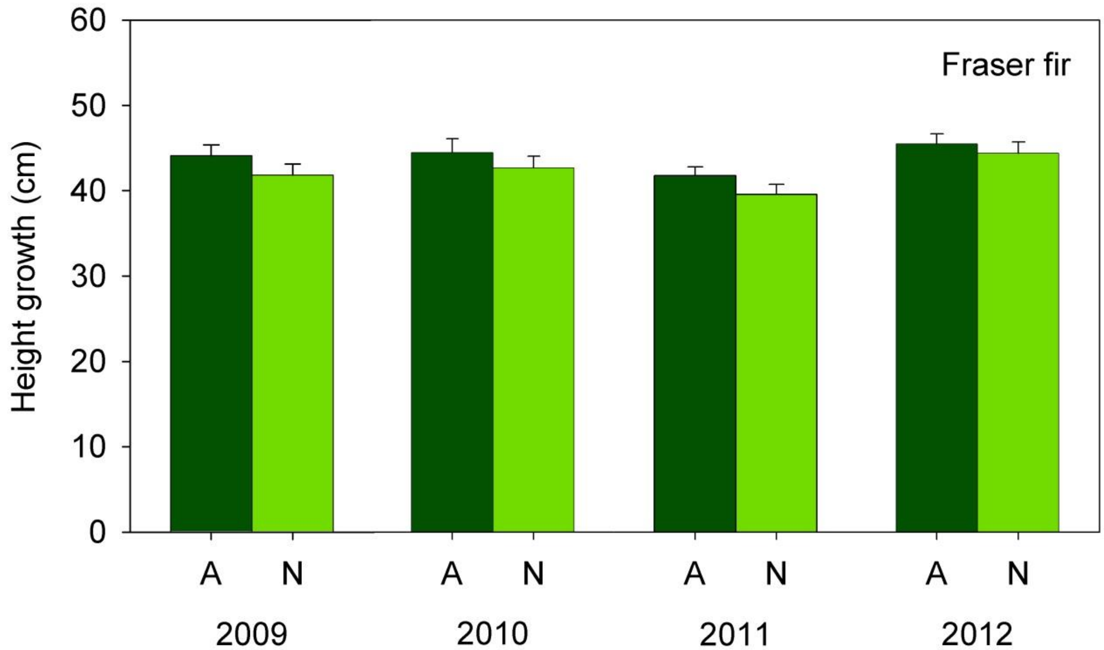

Figure 4. Mean annual height growth of Fraser fir trees in MSU Nitrogen Source Study 2009-2012. A = ammonium only; N = nitrate only.

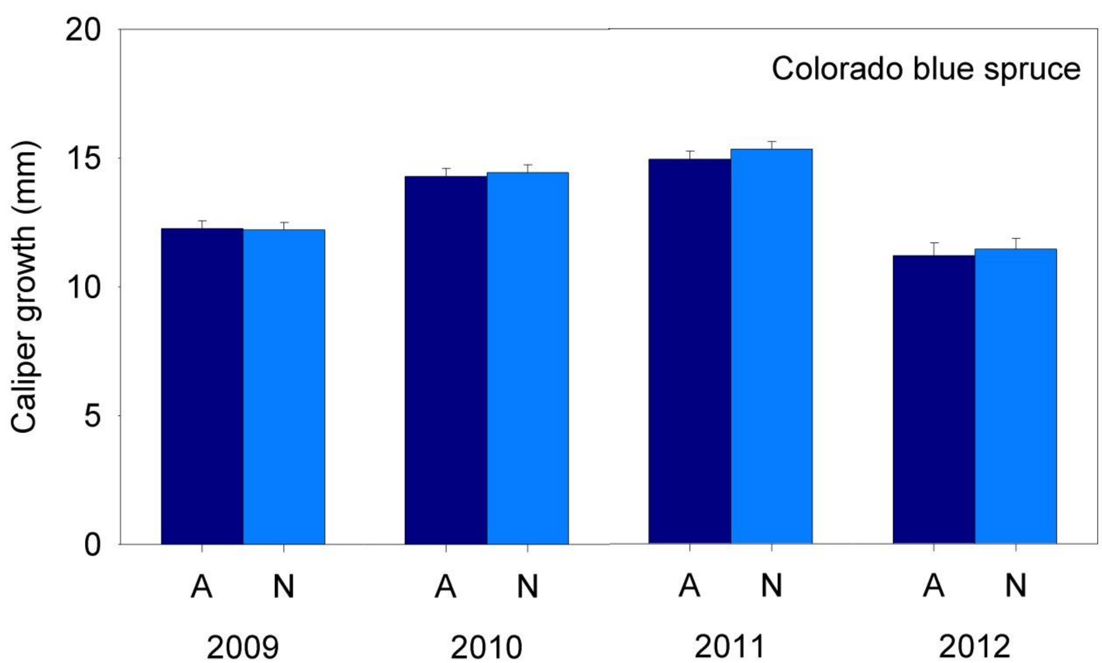

Figure 5. Mean annual height growth of Colorado blue spruce trees in MSU Nitrogen Source Study 2009-2012. A = ammonium only; N = nitrate only.

Conclusions and Recommendations

Growers can achieve sufficient N uptake and utilization in their crop by applying either nitrate or ammonium-based fertilizer. Other considerations such as price, availability and effects on soil pH should serve as the drivers for decisions on N source. Urea is a common choice for many growers because of cost and availability. When comparing price of N sources it is important to consider the fertilizer analysis or proportion of N in the fertilizer and consider costs in terms of price per pound of N. Also, consider that some N sources such as monoammonium phosphate (MAP) or potassium nitrate will supply other elements that may be indicated based on soil testing. In addition to price, soil reaction (the effect of a fertilizer source on soil pH) is a common factor in selecting a fertilizer. Ammonium sources and urea have net negative soil reaction (reduce soil pH), while nitrate sources will generally increase pH. Since acidifying soil pH is often a benefit in Christmas tree production, soil reaction is another reason urea and ammonium fertilizers are favored. Growers should monitor soil pH at least annually, however, to ensure that pH remains within the optimum for their crop. If pH declines too much they may consider applying lime or a different N source. A concern when using urea and ammonium sources is volatilization of ammonia. Volatilization occurs when fertilizer is applied during dry, warm weather. Volatilization varies with a variety of factors including soil pH (low pH decreases volatilization) and soil texture (volatilization is greater in loams the clay soils). Volatilization rates vary widely but agronomic studies indicate 10 to 30% of applied N may be lost from urea. Growers can reduce volatilization by fertilizing in cool weather during the spring (a few weeks before budbreak is optimal) and when rain is expected within a few days. Incorporating fertilizer or using coated formulations can also reduce N losses.

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Acknowledgements

This research was supported by the Michigan Christmas Tree Association Research Fund and MSU Southwest Research and Extension Center (SWMREC). We thank SWMREC farm manager Dave Francis and his crew for maintaining the plots and Brent Crain for assisting with treatment application and data collection. We thank Jill O'Donnell for her helpful comments on this article.

Tree Physiology

Confronting heavy cone production in plantation-grown Fraser fir Christmas trees

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Heavy cone production begins much earlier for plantation-grown Fraser fir Christmas trees in Michigan, compared with trees in native stands. Cone growth consumes resources and unsightly stalks persist after the cones disintegrate. Growers must remove young cones by hand at considerable expense. We developed a comprehensive approach to better understand and reduce early cone production in Fraser fir trees. We established 2-year observational studies at 10 farms located throughout Michigan. In addition, we established irrigation studies at three farms and mulch studies at two farms to investigate soil moisture and temperature stress as potential drivers of cone development. We also developed a phenology model of shoot growth, which allows us to predict when environmental factors and applied treatments will have the greatest influence on cone development. We used this model to time plant growth regulator treatments to inhibit differentiation of lateral buds into cone buds. Trees treated with gibberellin (GA) biosynthesis inhibitors had 28% fewer cones than in the previous year. Untreated control trees had 20% more cones and trees treated with Provide (GA4/7) as a positive control had 60% more cones. Across state-wide locations, maximum temperature, precipitation, radiance, PET, C13 discrimination, foliar nutrition, soil nutrition and pH showed little correlation with either coning density (number of cones per tree) or coning frequency (percent of trees with cones). Soil organic matter and clay content were inversely correlated with coning, and minimum air temperature was strongly positively correlated with coning. This suggests that warmer nights and decreased soil moisture holding capacity contribute to early cone development. In paired plots comparing areas of heavy and low coning within individual farms, minimum air temperature, C13 discrimination, soil organic matter and clay content were inversely correlated with coning, consistent with moisture stress as a factor in cone development.

Role of auxin in postharvest needle abscission in balsam fir (*Abies balsmea* L.)

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Postharvest needle abscission is a great challenge to balsam fir Christmas tree industry. Postharvest needle abscission is a consequence of changes in an array of phytohormones, including auxins and ethylene. In other species, the regulation of auxin and ethylene determine abscission of organs. While the link between ethylene and postharvest needle abscission in balsam fir is established, relationship between auxin and postharvest needle abscission remains obscure. Series of experiments were conducted to determine the role of auxin(s) and postharvest needle abscission dynamics. Synthetic auxin (Naphthalene acetic acid) was applied either by foliar, brushing or xylem feeding to two-year old balsam fir branches at various concentrations (5 to 50 ppm) at three selected intervals postharvest. Needle retention quality was monitored in terms of percent needle loss (PNL) on a fresh weight every 3 days for 100 days. Application of synthetic auxins either accelerated or showed no effect on the needle abscission when compared to controls ($p<0.05$) irrespective of mode of application, concentration and day of application. These results challenge the known relationships between auxin and abscission. It appears auxins have limited role in regulating or controlling postharvest needle abscission in balsam fir.

Physiological and metabolic characterization of postharvest needle abscission resistance of balsam fir after natural cold acclimation

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Earlier harvest dates have become necessary for Christmas tree producers to meet international demand. Unfortunately, a majority of those trees harvested early suffer from poor needle retention. The objective of this study is to understand the temporal changes in certain physiological and metabolic changes postharvest and needle abscission postharvest and establish possible linkage with cold acclimation. In one experiment, branches were collected in October and January and monitored for needle retention. This was repeated annually for three years. In a second experiment, 45 branches were collected each month from September to January and monitored for needle retention, xylem pressure, membrane injury, capacitance, and accumulation of galactose, raffinose, and ABA. Genotypes with high needle retention in October tended to have poorer needle retention in January while the genotypes with low needle retention in October tended to have improved needle retention in January. Between September and January there was also an 85% increase in raffinose, 147% increase in galactose, 80% increase in ABA, and 62% decrease in stem capacitance. It was concluded that early harvest is not detrimental for all genotypes.

Low temperature modulates postharvest needle retention in balsam fir (*Abies balsamea* L.)

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Balsam fir (*Abies balsamea* L.), the premier species of Atlantic Canada's Christmas tree and greenery industries suffers from severe needle abscission postharvest. Series of investigations were carried out to: (i) identify the optimum temperature and duration that prolongs postharvest needle retention duration (NRD), (ii) determine and characterize the phytohormonal changes in response to low temperature (LT) exposure, (iv) understand the interactive influence of genotypic and environmental factors on postharvest NRD and (v) investigate the temporal dynamics of LT-induced ABA accumulation and ascertain the effect of ABA on NRD. Exposure of balsam fir seedlings to 5^{o}C for at least 6h resulted in a 6% weight gain and presence of roots was beneficial. When balsam fir seedlings were exposed to 5^{o}C for 48h, the shoot ABA concentration increased by 2.5x (2007 ng g^{-1} DW) and Gibberellic acid $(GA)^{44}$ declined by 3.5x (9.85 ng g^{-1} DW). Root phytohormones did not respond to LT treatment. Of the two contrasting genotypes investigated (AB-NSD-184 and AB-NSD-004), a negative correlation existed between the postharvest NRD and selected weather factors (average daily photoperiod hours (PP) and average daily maximum temperature) (R^2=0.75; P=0.001). The needle ABA concentrations (R^2=0.38; P=0.001) also correlated with NRD in genotype AB-NSD-184. A maximum (180 days) and a minimum NRD (41 days) were observed in October and June, respectively. Environmental conditions strongly modulated LT effects on postharvest NRD. Benefits of LT-induced changes in NRD involve alterations in shoot ABA and this response strongly varied with genotype, harvesting month and environmental conditions.

Biophysical changes and a comparison of needle abscission resistant genotypes in postharvest balsam fir

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It was hypothesized that significant biophysical changes, such as changes to water status, color, and membrane stability, occur postharvest in balsam fir and that these factors are linked to observed genotypic differences in needle retention. Factors such as needle loss, water use, xylem pressure potential, relative water content, capacitance, membrane injury index, needle break strength, and chlorophyll index were monitored in balsam fir branches every 5 days after harvest. Peak needle abscission occurred at day 24. All other response variables were significantly different during abscission compared to initial values. A comparison of genotypes ranked as having low, moderate, or high needle abscission resistance found only a significant difference in initial needle break strength in those variables listed above, though it was counterintuitive to expectations. Clones with low needle abscission resistance tended to have high initial break strength and vice versa. There were also differences in needle density and branch diameter between clones.

Pest Management

An emerging adelgid pest on Nordmann fir Christmas trees in western Washington

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During the past 10 to 15 years there has been an increased interest in growing Nordmann and the closely-related Turkish fir as Christmas trees in the Pacific Northwest (PNW). Research has shown that these species have excellent postharvest moisture and needle retention when displayed in water and are tolerant or have limited susceptibility to *Phytophthora* root rot, *Annosus* root rot, spider mites, and balsam woolly adelgid. Since 2004, an average of 500,000 Nordmann/Turkish firs has been planted per year in Oregon. Although data are not available, a similar increase has taken place in western Washington and the Inland Empire. Currently, these species are the third most widely planted Christmas trees in the PNW. Most of the Nordmann and Turkish fir are being planted in areas where true firs, such as noble fir, can't be grown because of *Phytophthora* root rot. During the past two years, an unidentified adelgid has been detected on Nordmann and Turkish fir trees in regional genetic trials located at WSU Puyallup. Large numbers of crawlers attack the foliage, which leads to discoloration and severe distortion of the needles on infested shoots. In Europe where Nordmann fir is widely grown for Christmas trees, the silver fir woolly adelgid [*Adelges* (Dreyfusia) *nordmannianae*] is a serious pest on this host. Although this adelgid is not known to occur in the PNW, the damage to trees in Puyallup is very similar to what has been reported for this adelgid in Europe. During this presentation information will be presented on attempts to identify the adelgid, its rate of spread, its distribution, egg laying, and the emergence of crawlers. Preliminary information on the susceptibility of different sources of Nordmann and Turkish fir in the trials at Puyallup to this pest will also be presented.

Adelgid resistance

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The adelgid (*Dreyfusia nordmannianae*) is a severely damaging insect causing yellowing on Nordmann fir needles on Christmas trees as well as bough production stands. An early study (Nielsen et al. 2002) showed remarkable differences among open pollinated progenies after artificial infestation. Re-evaluation of the same experiment after 10 years reveals still significant differences, and confirms the early test method as a potential tool for breeding more resistant/tolerant genetic material for Christmas tree production. Further the species *Abies bornmülleeriana* will be discussed, which was included as a reference. Clonal observations in seed orchards will be presented as well.

Screening true fir for resistance to *Phytophthora* Root Rot and Structures of *Phytophthora* Communities from Pacific Northwest Christmas Tree Farms

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Phytophthora root rot causes significant losses in true fir trees, which are important components of Christmas tree plantations and are particularly susceptible to *Phytophthora*. Mitigation options are limited and efficacy varies widely. My research will contribute to the construction of a marker-assisted selection system for identifying resistance to *Phytophthora*. My main research objectives include assembly of a culture collection of *Phytophthora* species from major fir growing regions around the U.S., a phenotype screening of true fir seedlings for resistance to various *Phytophthoras* conducted under two ambient temperatures, and histology of fir roots during host-parasite interactions. Compiling a collection of *Phytophthora* species will provide information about the community structures and habitats of soilborne *Phytophthoras* from different geographic regions within the U.S. and will serve as the source of the inoculum for the resistance screening study. Current collections have been conducted throughout the U.S. Pacific Northwest in states including Oregon, Washington, Idaho, and California. *Phytophthora cambivora* has been associated with the majority of noble fir mortality in Christmas tree plantations in Western Washington and Oregon, and P. *megasperma* has been isolated from grand fir in North Idaho. Isolations from Nordmann, white, and Trojan firs in Northern California yielded *P. cinnamomi*, which is an important pathogen of orchard trees and agricultural crops in the surrounding region. It is intended that the survivors of the fir phenotype screening project will be employed in a genomics study to identify molecular markers associated with resistance to *Phytophthora*. This research will increase our understanding of the population structures and behaviors of root rotting *Phytophthoras* in the United States, yield information regarding host-specific interactions between firs and *Phytophthoras,* and embark on new knowledge to contribute to the Christmas tree and forest nursery industries.

Use of shade netting strongly reduces current season needle necrosis (CSNN)

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In 2012, CSNN caused exceptionally large amounts of damage on Nordmann fir (*Abies nordmanniana*) in Denmark, UK and some other European countries. Chlorotic spots on the needles approximately 2-4 weeks after bud break is a typical symptom of CSNN. Observations during the last decades in USA and Europe have clearly shown that the chlorotic tissue turns necrotic when there is a sudden change in weather conditions from wet and cool to warm and dry. Probably due to cool temperatures and frequent rain during shoot elongation in Norway in 2012, the Norwegian Christmas tree industry was not affected by CSNN. In laboratory trials in Norway, the fungus *Sydowia polyspora* has changed the appearance of the wax layer around the stomata on Nordmann fir needles (Talgø et al. 2010). Thus, our hypothesis was that spots or sections of needles associated with presence of *S. polyspora*, dry out when exposed to sunny, warm weather. Based on results from Washington State, showing a reduction of CSNN if fir trees were placed under shade screen (Chastagner et al.1997), a field trial was established in a Danish pot-in-pot Nordmann fir production field in 2012. A total of 96 trees damaged by CSNN in 2011 were collected and organized in a randomized block design with four blocks, and six trees per treatment in each block. In addition to an untreated control, treatments were either shade netting (50 % light reduction) or weekly applications during shoot elongation with latex and the fungicide Signum (boscalid and pyraclostrobin). Latex was intended to protect the needles from drying out, and Signum was included because it had effectively controlled *S. polyspora* in seed treatments (Høst et al. 2012). Covering trees with shade netting reduced CSNN significantly (Talgø et al. 2013). Signum and Latex did not show any significant effect. The shade trial is currently (2013) being repeated, but results are not yet available.

Neonectria neomacrospora is threatening the true fir production in Scandinavia

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The bark parasite *Neonectria neomacrospora* is currently causing a canker epidemic on true fir (*Abies* spp.) in Norway and Denmark. Due to the extensive trade with transplants within the Christmas tree industry, we expect that the disease will spread to other countries in Europe. The fungus is very aggressive both under field conditions and in inoculation tests in controlled environment. We have also found it to be seed borne on Nordmann fir (*A. nordmanniana*), and seed trade between countries and continents may spread the disease. Thus far, we have found the fungus on grand fir (*A.grandis*), Noble fir (*A. procera*), Nordmann fir, Pacific silver fir (*A. amabilis*), Spanish fir (*A.pinsapo*), Siberian fir (*A. sibirica*), subalpine fir (*A. lasiocarpa*), and white fir (*A. concolor*). Especially worrying are heavy attacks on Nordmann and subalpine fir, our major Christmas tree species. Typical symptoms are dead shoots, flagging (dead branches), canker wounds, heavy resin flow, and often completely dead trees. The fungus produces white mycelia on incubated material and on artificial media (agar). Under humid conditions, characteristic red perithecia are occasionally found on dead plant material. Prior to recent sequencing (Cabral et al. 2012) of an old Dutch isolate from white fir that had been deposited to Centraalbureau voor Schimmelcultures (CBS) in The Netherlands in 1961, the fungus had only been reported from USA, Canada and Norway (Roll-Hansen 1962). Sequencing of material from Norway and Denmark revealed that they were identical to the Dutch isolate.

Mechanical control of *Epilobium* sp. in Christmas tree plantations

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In the production of Christmas trees, weed control is commonly one of the most expensive operations. Weeds may influence tree health by restricting air movement, hosting damaging agents like the rust fungus *Pucciniastrum epilobii* (Talgø et al. 2008) and competing with the trees for water and nutrients. Several species of *Epilobium* are usually present in Christmas tree fields, and as this species also act as a host for an important rust fungus, the spread of these plants are especially undesirable. The aim of our study was to obtain knowledge on regrowth of *Epilobium* following simulated cutting regimes. The study was performed under outdoors conditions at Ås (59°40' N, 10°46' E, 90 m asl). Root sections were plantet in containers in autumn and overwintered under snow cover. Perennial weeds may be controlled efficiently by exploiting their weak growth stages. Cutting was performed twice in each container, with either two or four weeks interval, with the first cutting in late June or mid July. Preliminary results indicate highest root dry weight by the end of the experiment, and least effect when cutting is done shortly before flowering and replicated two weeks later, compared to cutting earlier in the growing season.

Breeding and Molecular Biology

Screening balsam fir germplasm for postharvest needle abscission resistance

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Christmas tree producers competing on national and international markets are facing increasing pressure to deliver high quality trees with low incidences of postharvest needle abscission. In addition, as more intensive agricultural practices are being adopted profit margins are reduced by the rising cost of inputs such as shearing, fertilization, and pest management. These challenges can be partially addressed by the selection of germplasm with high needle abscission resistance (NAR) that also exhibit a naturally full architecture thereby requiring fewer years of inputs to produce a saleable tree. The present screening of Atlantic Canadian Balsam fir germplasm focused on Department of Natural Resources' clonal orchards in New Brunswick and Nova Scotia, as well as trees in commercial lots throughout Nova Scotia. Postharvest NAR of dehydrated branches was described by the number of days required to exceed a specified threshold of % needle abscission (cumulative weight of abscised needles / initial branch fresh weight). Of the total number (n=212) of genotypes assayed the highest NAR individuals (n=17) experienced 1% needle loss after ten days, and a second tier of individuals (n=29) experienced 1% needle loss after eight days. In contrast, the lowest NAR individuals (n=35) experienced 1% needle loss before the fourth day. When evaluated at higher thresholds of % needle abscission, the top individuals experienced 10% and 20 % needle loss after 15 and 16 days, respectively. Each of the four sample populations contained a range of individuals with varying NAR abilities; however, some populations had a stronger representation of high-NAR genotypes. Candidates were also evaluated for biometrics such as leader growth, internode branch number and length, branch fullness and overall architecture. Only unsheared trees were selected for evaluation. Trees that were naturally full without any shearing tended to exhibit a number of desirable architectural biometrics that helped to quantify the selection of superior trees. Combining NAR and architectural evaluations it was possible to identify some genotypes with both good needle retention and superior architecture.

Genetic Control of Post-Harvest Needle Retention in Fraser Fir

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Surveys consistently indicate that "messiness" due to needle loss is a key reason that consumers buy artificial rather than real Christmas trees. Research and experience has demonstrated that fir species vary considerably in needle holding ability. This trait has been shown to be under genetic control in some fir species. While Fraser fir [*Abies fraseri* (Pursch) Poir.] generally exhibits excellent needle holding ability, there are no reported investigations about its within-species variability. A study was conducted to rank the needle retention ability of 30 Fraser fir clones in a seed orchard located in Ashe County, NC, and managed by the N.C. Premium Fraser Fir Seed Cooperative. A detached branch technique was employed to assess needle retention of all 30 clones. For three years, branches were collected and their needle loss evaluated in both October (2010-2012) and November (2009-2011). Needle loss was greater in October (6.9%) than November (3.3%). Clones ranged from 0.2 to 21.9% needle loss when averaged over all six assessments. Overall, clonal mean correlations between the October and November assessments were not significant (0.15, p=0.4278). Correlations among the October assessments (0.48, 0.58) were significant but lower than those among the November assessments (0.74, 0.84). Growers managing the orchard can employ two strategies for improving the genetic quality of collected seeds: 1) avoiding collection of seeds from poorer clones and/or 2) rogueing poorer performing clones from the orchard.

Results from common source trials of Nordmann and Turkish fir in Denmark and the Pacific Northwest, USA

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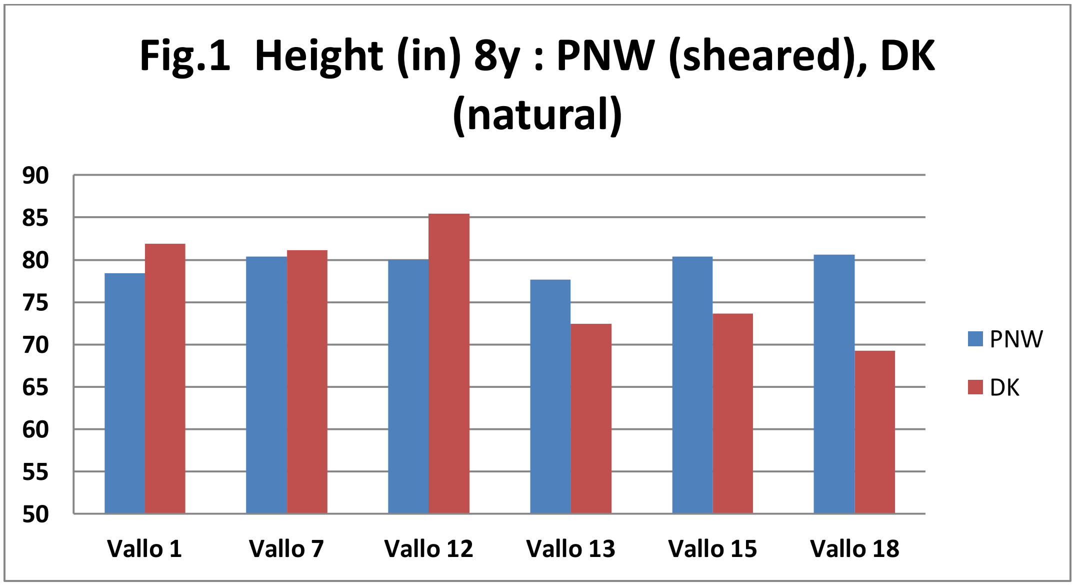
Our presentation will cover a number of subject themes all of which relate to common studies of Turkish and Nordmann fir. These experiments have been conducted over many years in both Denmark and the Pacific Northwest and include both post-harvest investigations and a variety of growth, quality and physiological traits. A number of common sources (half- sibling families and provenance collections) were used in a wide number of test settings with very different culturing and growth environments. Dr. Ulrik Nielsen will provide an overview of the sources of Nordmann and Turkish fir included in common tests. In addition he will discuss results relating to the performance of the sources in Danish field trials and discuss observations of growth and quality important to Danish Christmas tree producers. Chal Landgren will discuss field performance of these common sources as they relate to growth and value results from a trial planted on seven locations in the Pacific Northwest extending from Corvallis, Oregon to Puyallup, Washington. He will discuss results and observations important to PNW Christmas tree producers.

Introduction
Nordmann fir is the dominant Christmas tree species in production throughout Europe. In the Pacific Northwest (Oregon and Washington), testing and production is just ramping up. Denmark has a long history of progeny and provenance testing for Christmas tree production and a number of established seed orchards. That testing is just beginning in the PNW. Progeny (½ sibling) from the Vallo Orchard in Denmark have been tested both in the PNW and Denmark at various times and locations. Six families from the Vallo Orchard were common to both areas.

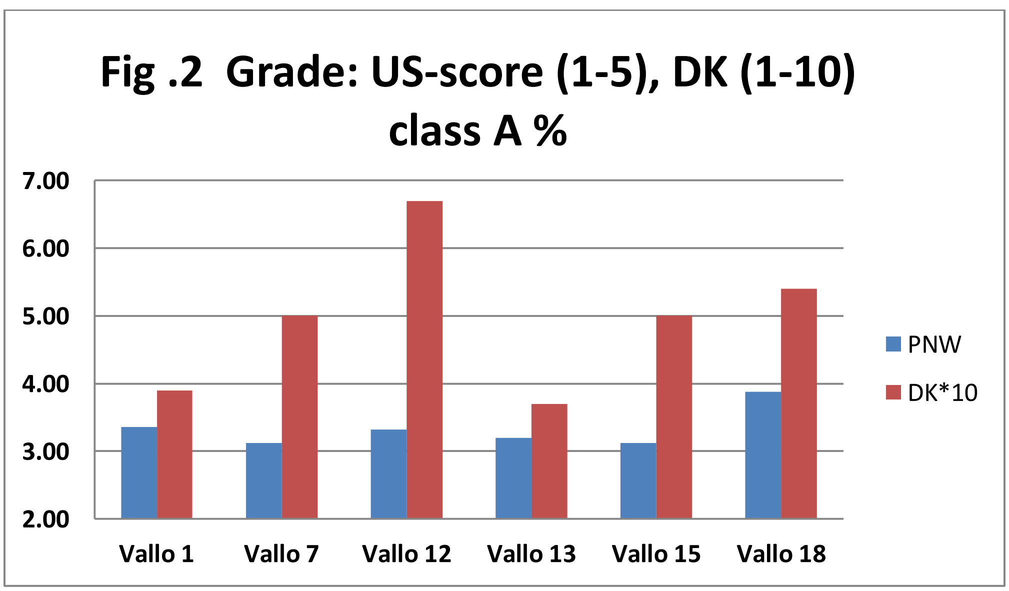
Methods
Independently, progeny test sites were established in Denmark and the PNW. In the PNW sites, the test sites were planted in 2004 using 3-year-old (plug+1) seedlings. Six sites were established in production fields ranging from Puyallup, WA to Corvallis, OR. Sites were set on well-known grower fields and each grower cultured the trees in the manner commonly used on each site. This included shearing and leader cutting. Evaluations on each site were conducted when the trees reached harvest size. Final evaluations were conducted between 2009-2011 and included tree height, grade, color, any damages or problems including Current Season Needle Necrosis.

Results
We report on conclusions around those 6 common seed sources Vallo Family #s 1,7,12,13,15,18.The evaluations were conducted in different years, but common to each was a summary of height, grade and resulting values for Christmas tree purposes. In each country/region the common production practices were utilized in tree production.

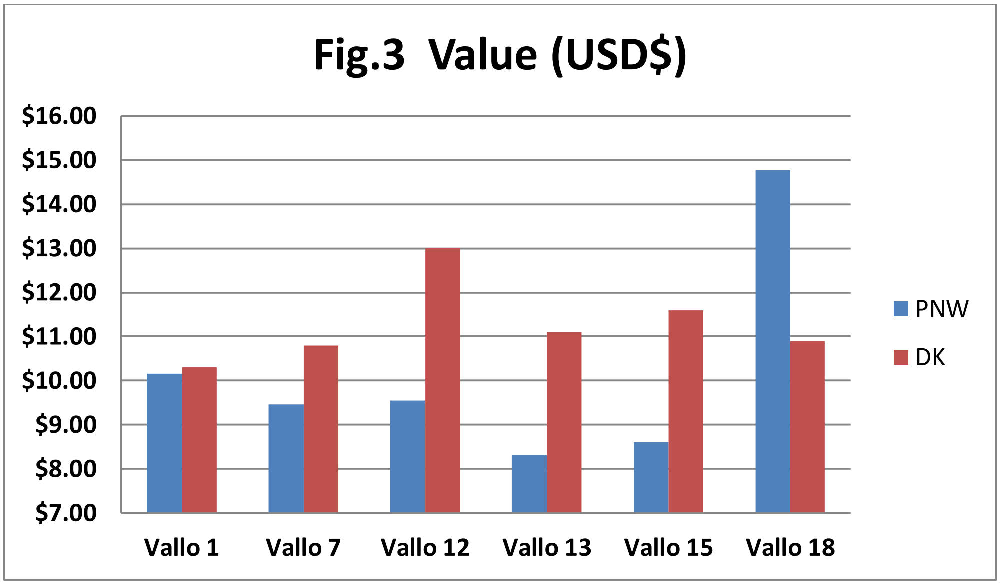
In the case with the PNW, tree height is commonly controlled by leader cutting. This practice provides for increased tree density and more uniform production sizes. In Denmark, natural trees are more common with no top cutting. Tree height differences in the PNW are minor compared to Denmark (Fig. 1).



Grade difference between Denmark and the PNW are somewhat exaggerated due to the different scales used in the two areas (Fig. 2). In both regions the higher the grade number, the "better" the family. In Denmark the relative ranking (high to low) is 12,1,7,15,13,18. In the PNW the ranking is 18,1,12,13,15,7. In short, there was little correlation between the grade ranking in the 2 countries for the same families.



As value is fundamentally a product of tree height and grade there similarly is little correlation between the preferences of the Vallo families based on this ranking (Fig.3)



Discussion

The fact that there was little consistency in any of the important characteristics measured in the two countries is likely a direct result of the varied production techniques and the differences in what constitutes a “top quality” tree. In the PNW case, the preferred tree is dense and uniform from top to bottom. In the case of Denmark, a more open tree is preferred with layered branches.

The Vallo seed orchard: History and results from Danish field trials

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The Vallo seed orchard is the oldest existing Danish clonal seed orchard of Nordmann fir (*Abies nordmanniana*). The orchard was grafted in 1966-68 originally 854 grafts and a total of 23 clones using European silver fir (*Abies alba*) as root stock and a spacing of six by six meters. The clonal material was selected in Danish stands focusing on bough production quality. In Denmark a combined breeding and seed orchard program was initiated in 1992, and the Vallo orchard became the guinea pig of the Danish program due to its potential to the first data-based genetic estimates for traits of interest for Christmas tree production. Information urgently needed in the program's juvenile phase for designing further breeding efforts. The seed orchard gave rise to the first progeny test in Denmark based on the seed harvest in 1986 and results after a full rotation was reported in 2000 (Nielsen and Hansen 2000) – showing large differences in Christmas tree quality, economic revenue and preliminary result for needle retention. Post-harvest needle retention was tested on the grafted material as well as the progeny (Nielsen and Chastagner 2005). In a second seed harvest in 1992 seed from all 23 clones was collected, and included in a test across 11 sites and 128 open pollinated progenies planted in 1997. Results from this will be reported. Based on commercial seed harvest the orchard has been tested in provenance trials (Nielsen and Chastagner 2005; Nielsen et al. 2010) and compared to a number of Danish seed sources, and imports from Georgia, Russia and Turkey. The Vallø material was in general fast growing and was among the provenances showing the best post-harvest needle retention. However, the quality of natural grown trees is rather low, mainly due to the fast growth unless chemical leader length control was applied. Comparisons of results from the different studies will be presented for growth, quality traits and post-harvest needle retention, and further Danish genotype-site interactions will be evaluated.

Grey mould (*Botrytis cinerea*) on Christmas trees in Norway

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Grey mould is causing problems on both herbaceous and woody plants worldwide, and all our Christmas tree species may get attacked. On conifers, severe damage has been observed in nurseries, but also under field conditions. The plants are most prone to damage when they are attacked during shoot elongation. Dense stands and high humidity are favourable conditions for infections. We have detected grey mould on conifer seeds, transplants, and both young and old trees under field conditions. Sporulation on needles and shoots is often abundant and sclerotia are commonly found on infected needles. In 2012, we also found that sclerotia had formed under the bark and girdled the stems of newly planted subalpine fir (*Abies lasiocarpa*) Christmas trees (Talgø & Fløistad 2012). We found the same on Nordmann fir (*A. nordmanniana*) and Norway spruce (*Picea abies*) transplants, the former direct from a nursery and the latter after transport under unfavourable conditions for the plants. Since fungicides are used against grey mould in nurseries, the stem damage made us wonder if resistance had built up. Thus, we are currently collecting isolates that we want to screen for possible resistance against the fungicides that are used against grey mould in Norwegian nurseries; Topsin (tiofanatmethyl), Rovral (iprodion), and Teldor (fenheksamid). A grant proposal to the Norwegian Research Council is due in September 2013.

Grey mould (*Botrytis cinerea*) on Christmas trees in Norway

Venche Talgø[1], Gunn Mari Strømeng[1] & Inger Sundheim Fløistad[1,2]

Norwegian Institute for Agricultural and Environmental Research

Grey mould is causing problems on both herbaceous and woody plants worldwide, and all our Christmas tree species may get attacked. On conifers, severe damage has been observed in nurseries, but also under field conditions.

Conditions for infection

The plants are most prone to damage when they are attacked during shoot elongation, which is before the needles have a well-developed wax layer and before the shoots are lignified. Tissue wounded by biotic or abiotic agents may also become infected by grey mould. Dense stands and high humidity are favourable conditions for infections.

Grey mould may attack all age classes

We have detected grey mould on conifer seeds **1**, transplants, and both young and old trees under field conditions. Sporulation on needles and shoots is often abundant **2**.

1 *Abies nordmanniana*

2 *Abies lasiocarpa*

Fungal resting structures (sclerotia)

Sclerotia are formed by the fungus when it needs to survive unfavourable conditions like frost or drought. They are commonly found on infected needles **3**, and can also be seen on the underside of the seed above **1**.

3 *Abies nordmanniana*

In 2012, we also found that sclerotia had formed under the bark and girdled the stems of newly planted subalpine fir (*Abies lasiocarpa*) Christmas trees (Talgø & Fløistad 2012) **4**. We found the same on Nordmann fir (*A. nordmanniana*) and Norway spruce (*Picea abies*) **5** transplants, the former direct from a nursery and the latter after an extended transport at too high temperature.

Further work

Since fungicides are used against grey mould in nurseries, the girdling of the stems may indicate that resistance has built up. Thus, we are currently collecting isolates that we want to screen for possible resistance against the fungicides that are used against grey mould in Norwegian nurseries; Topsin (tiofanatmethyl), Rovral (iprodion), and Teldor (fenheksamid). A grant proposal to the Norwegian Research Council is due in September 2013.

4 *Abies lasiocarpa*

5 *Picea abies*

Literature

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Clone differences in *Neonectria* sp. damage in a Danish Nordmann fir seed orchard

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During spring 2013 a severe epedemic outbreak of damages caused by *Neonectrai* sp. were seen in Danish Christmas tree production stands, and in some of the seed orchards too. A preliminary visual evaluation of the Tuse Næs seed orchard showed strongly significant differences among clones, and also among rows. The clone damage pattern was ranging from hardly any damage trees (no damaged) to all trees were damaged.

Leader length control impacts choice of provenace in Nordmann for Christmas tree production

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In recent years applying chemical leader length control have been common practice, and this treatment was therefor included in two provenance trials established in 2003. Full rotation data were analysed and number of saleable trees and first grade trees were analysed. The best provenances grown without leader length control was still the best after applying growth control, but for a set of second generation Danish material showing faster growth leader length control was obligatory to secure economic revenue. The two sites showed large differences in benefit from the leader length control. Provenance results will be presented.

Variation in spring and autumn frost tolerance in provenances of *Abies lasiocarpa*

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Spring and autumn frost tolerance was measured on 25 different provenances of subalpine fir (*Abies lasicarpa*) ranging in latitude from 60°N to 34°N. The aim of the project was to rank the provenances depending on freezing tolerance in spring and autumn. Shoots were collected from a two-years-old provenance field trial in Hallormsstadur in Iceland. Collection was done on May 7, 2001 when the buds generally showed swelling and Sept. 12, 2001 when most of the trees had finished height growth. The shoots were frozen to –4, -8, -12 and –16°C. Damage to cambium, needles and buds was assessed visually after development under ideal conditions for 2-3 weeks. Southern provenances from high elevations in New Mexico and Arizona showed most swelling on buds when testing for spring frost hardiness was carried out. These provenances and others from higher latitude in Wyoming, Utah and Colorado showed most damage on buds. Only the 3 most damaged provenances were significantly different from the least damaged provenances. Correlation between swelling score and frost damage was generally low. Differences between provenances in cambium and needle damage were small and slightly significant in the spring. Variation in frost damage between provenances was larger in the autumn than in spring. The far-north provenance from Alaska had least damage in the autumn freezing test. The interior provenances from Wyoming, Utah and Colorado and the northern provenances from British Columbia had generally less autumn frost damage compared to the provenances from Washington and Montana. The provenance Apache National Forest from Arizona showed the greatest autumn damage, while other provenances from New Mexico and Arizona had moderate damage.

Variation in spring and autumn frost tolerance in provenances of Subalpine fir (*Abies lasiocarpa*)

Brynjar Skulason

Abstract

Spring and autumn frost tolerance was measured on 25 different provenances of subalpine fir (*Abies lasiocarpa*) ranging in latitude from 60°N to 34°N. The aim of the project was to rank the provenances depending on freezing tolerance in spring and autumn. Shoots were collected from a two-years-old provenance field trial in Hallormsstadur, Iceland. Collection was done on May 7th 2001, when the buds generally showed swelling and on September 12th 2001, when most of the trees had finished height growth. The shoots were frozen to –4, –8, –12 and –16°C. Damage to cambium, needles and buds was assessed visually after development under ideal conditions for 2–3 weeks. Southern provenances from high elevations in New Mexico and Arizona showed most swelling on buds when testing for spring frost hardiness was carried out. These provenances and others from a higher latitude in Wyoming, Utah and Colorado showed most damage on buds. Only the 3 most damaged provenances were significantly different from the least damaged provenances. Correlation between swelling score and frost damage was generally low. Differences between provenances in cambium and needle damage were small and slightly significant in the spring. Variation in frost damage between provenances was greater in the autumn than in spring. The far-north provenance from Alaska had the least damage in the autumn freezing test. The interior provenances from Wyoming, Utah and Colorado and the northern provenances from British Columbia had generally less autumn frost damage compared to the provenances from Washington and Montana. The provenance Apache National Forest from Arizona showed the greatest autumn damage, while other provenances from New Mexico and Arizona had moderate damage.

Introduction

In the year 1999 a three year Nordic project started with subalpine fir, "Abies lasiocarpa for Christmas tree production in the Nordic countries". The project was cooperation between scientists in Norway, Denmark, Finland and Iceland. The aim was to find usable provenances and develop cultivations methods to produce valuable Christmas trees of subalpine fir (Madsen and Sigurgeirsson, 1998). Three years results from the provenance trials were first published 2004 (Hansen et. al., 2004). In this part of the project 25 different provenances were tested for spring- and autumn frost tolerance ranging in latitude from 60°N in Alaska to 34°N in New Mexico.

Materials and methods

24 provenances from a Danish seed-collection in USA and Canada in the years 1991–1993 were cultivated in the Danish research station at Humlebæk. In the spring 1999 these were planted as 3/2 bareroot plants in the Nordic countries into provenance trials, also in Hallormsstadur in Iceland (65°14'N, 14°67'W, 35m a.s.l.). One provenance, Arapaho, was produced in Hallormsstadur for comparison. The provenances from New Mexico and Arizona are of the variety corkbark fir (*Abies lasiocarpa var. arizonica*).

Table 1. Provenances included in the joint Nordic provenance test. Provenances are listed in order of latitude, with the most northern provenances being in the top of the list. In provenances where the identification number is marked with asterisk the number of trees from which seed have been collected are low (6 or below).

Identification No.	State	Latitude/longitude	Elevation m a.s.l.	Locality/provenance
183	Alaska	59°50'/135°30'	800	Seed zone A16, Skagway
166	Br. Col.	59°20'/133°45'	800	Atlin
217	Br. Col.	55°48'/129°10'	320	White River
168	Br. Col.	50°50'/119°45'	1400	Adams Plateau
218	Br. Col.	50°43'/115°27'	1525	Albert River
219	Br. Col.	49°14'/118°30'	1300	
196*	Wash.	48°37'/120°38'	-	Okanogan N.F., Mile Marker 172, Rt. 20
194*	Wash.	48°29'/119°58'	1300	Okanogan N.F., For. Rd. 42, Looploop Campg.
195*	Wash.	48°26'/119°50'	1500	Okanogan N.F., For. Rd. 42, Rt. 20
191*	Montana	48°10'/113°30'	1200	Flathead N.F., West of Marias Pass
170	Montana	48°00'/115°30'	-	Kootenai N.F.
171	Montana	48°00'/114°15'	-	Flathead N.F.
192*	Wash.	47°55'/117°07'	1400	Mt. Spokane
193*	Wash.	47°55'/117°07'	1500	Mt. Spokane
81	Montana	47°30'/113°30'	-	Flathead N.F., Hungry Horse
199*	Wash.	46°47'/121°40'	-	Mt. Rainier N.F., Before Stevens Creek Cross.
182	Wash.	46°10'/122°15'	1200-1400	Seed zone 440, South-west of Mt. St. Helens
202*	Wyoming	41°21'/106°32'	2400	Medicine Bow N.F., East of F.S. Work Camp
203*	Wyoming	41°21'/106°32'	2400	Medicine Bow N.F., East of F.S. Work Camp
201*	Utah	40°15'/112°00'	-	Wahsatch N.F., Rt. Cottonwood Canyon
2	Colorado	38°30'/106°10'	-	Arapaho N.F.
204*	New Mexico	35°11'/106°25'	2900	Cibola N.F., Sandia Crest
205*	New Mexico	35°15'/107°40'	2900	Cibola N.F., Mt. Taylor
67	Arizona	34°00'/109°38'	-	Apache N.F., Hannagan Meadows
140	Arizona	34°00'/109°38'	2800-3200	Apache N.F., Hannagan Meadows + Big Lake

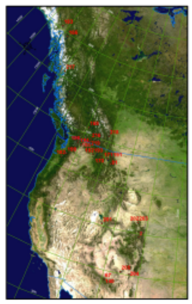

Figure 1. Distribution of the provenances from the Danish seed collection in North America (Esri Data & Maps 9.3, 2001–2008).

Collection of cuttings

Shoots were collected from a two-years-old provenance field trial in Hallormsstadur in Iceland. The timing of the sprout collection and the value of freezing stress was chosen to get maximum variation in freezing tolerance in the whole material. Collection was done on May 7th 2001, when the buds generally showed swelling and September 12th 2001, when most of the trees had finished height growth. The shoots were frozen to –4, –8, –12 and –16°C. 7 cm long cuttings were taken from the same year growth, 4 cuttings in second whorl from the top of each tree, one for each freezing treatment. Usually there were 15 trees for each provenance. The sprouts were kept in 6°C until the freezing test was carried out on May 9th, and September the 12th.

Scoring of the frost damage

Damage to cambium, needles and buds was assessed visually by cutting the shoots lengthwise.

Needles: Scale 0–11 (Johnsen, 1989)
0 = No discoloration of needles
1 = Up to ten percent brown or discoloured needles
2–10 = Ten percent intervals between classes (brown or discoloured needles)
11 = All needles completely brown

Cambium: Scale 0–11 (Johnsen, 1989)
0 = No discoloration of cambium
1 = Up to ten percent brown or discoloured cambium
2–10 = Ten percent intervals between classes (brown or discoloured cambium)
11 = All cambium is brown

Buds: Scale 0–3 (Edvardsen, 1995)
0 = No damage
1 = Damage in lateral buds
2 = Damage in terminal bud
3 = Damage in both lateral buds and terminal bud

Statistical analysis

Statistical analysis was done using the statistical program R (R Development Core Team, 2008). All data for frost damages was changed to binomial where each shoot was either damaged or not damaged, separately for different tissue. Effects of the factors, frost and provenance, on the depending variable damages were tested using glm and anova for binomial data. When significant differences were indicated ($p<0.05$), pairwise comparison was done using glht and Tukey letters from the multcomp package in R (Horton et.al. 2008). Kruskal Wallis and Wilcoxon rank sum test was used to decide differences between provenances in bud burst ($p<0.05$).

Scoring of flushing

Flushing was scored when the cuttings was prepared for freezing. Scoring was done by following scale (Krutzsch, 1973):
0 - Dormant buds
1 - Buds slightly swollen
2 - Buds swollen, green to grey-green in colour, bud scales still closed
3 - Burst of bud scales, tips of needles emerging
4 - First elongation of needles to about double bud length

Figure 2. A shoot cut lengthwise to make the possible freezing damage visible.

Figure. 3. An example of a completely damaged as well as a fresh shoot.

Freezing test

The cuttings were placed into wet sphagnum moss and sprayed with water to prohibit drying under the freezing process. The shoots were frozen to –4, –8, –12 and –16°C into 4 computer controlled freezers where the temperature was lowered 2°C pr. hour until minimum temperature occurred. Lowest temperature was kept for 3 hours and then raised again 2°C pr. hour. After thawing, the shoots were kept into high vapour, constant light and temperature about 20°C. Scoring of the damage was done on June 1st and October 1st which is 2–3 weeks after freezing and when damage had become visible.

Results and discussion

Generally damage in the freezing tests

In the freezing test in the spring, needles and buds are more damaged than cambium. The damages increase rapidly between –12 and –16 °C. In the freezing test in autumn needles were less damaged than buds and cambium.

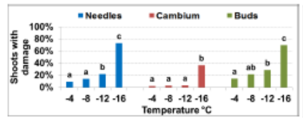

Figure 4. Damage of various tissue depending on freezing temperature, freezing test on May 9th.

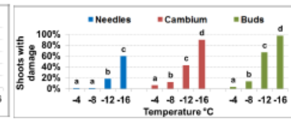

Figure 5. Damage of various tissue depending on freezing temperature, freezing test on Sept. 13.

Spring frost tolerance

Damage by late frost in spring is usually related to date of budbreak (Jones & Cregg, 2006a). Compared to other *Abies* species, *Abies lasiocarpa* is known for early budbreak and will easily be damaged by late frost in spring, especially in an environment with unstable temperatures in winter (Jones & Cregg, 2006a).

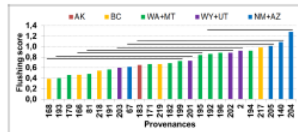

Figure 6. Average flushing for each provenance when the freezing test on May 9th was done. AK=Alaska, BC=British Colombia, WA=Washington, MT=Montana, WY=Wyoming, UT=Utah, NM=New Mexico, AZ=Arizona.

Hansen et.al. (2004) found significant correlation between latitude and flushing. The northernmost provenances did flush first. This was not the case in this project and difficult to see any geographic tendency in the rank of the provenances. Barney et. al. (2013) found that subalpine fir did break bud less than 1.5 days earlier than corkbark fir so the difference is not large.

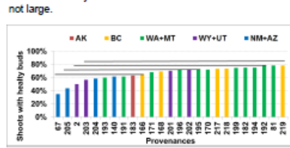

Figure 8. Percentage of shoots with no damage on needles for all four test temperatures on May 9th. Provenances under each horizontal line did not differ significantly in damage ($p<0.05$). AK=Alaska, BC=British Colombia, WA=Washington, MT=Montana, WY=Wyoming, UT=Utah, NM=New Mexico, AZ=Arizona.

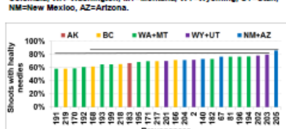

Figure 9. Percentage of shoots with no damage on buds for all four test temperatures on September 13th. Provenances under each horizontal line did not differ significantly in damage ($p<0.05$). AK=Alaska, BC=British Colombia, WA=Washington, MT=Montana, WY=Wyoming, UT=Utah, NM=New Mexico, AZ=Arizona.

Damage on cambium did not show significant differences between provenances. Only the provenance no. 205 had significantly less damage than four other provenances for damages on needles. Provenance no. 67 and 205 had significantly more damages on buds than most of the others. In general there is not a big difference between provenances in frost damage on May 9th. Selection for late flushing and spring frost hardiness based on differences between individuals might be more effective than selection based on differences between provenances.

Autumn frost tolerance

Ranking of provenances depending on their autumn frost hardiness was more distinct than in the spring. The interior provenances from Wyoming, Utah and Colorado and the northern provenances from British Columbia had generally less autumn frost damage compared to the provenances from Washington and Montana. This can be explained by similar effect of higher latitude and higher elevation on increasing maximum frost hardiness in midwinter as well as early budset (Jones & Cregg, 2006b). The provenance Apache National Forest from Arizona showed the greatest autumn damage, while other provenances from New Mexico and Arizona had moderate damage. Hansen et. al. (2004) found similar ranking for budset of the same provenances and high significant correlation with latitude and elevation. These results are promising for the possibilities for selection for autumn frost hardiness based on differences between provenances.

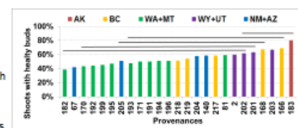

Figure 9. Percentage of shoots with no damage on buds for all four test temperatures on September 13th. Provenances under each horizontal line did not differ significantly in damage ($p<0.05$). AK=Alaska, BC=British Colombia, WA=Washington, MT=Montana, WY=Wyoming, UT=Utah, NM=New Mexico, AZ=Arizona.

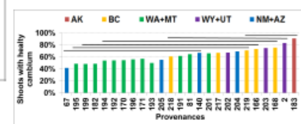

Figure 10. Percentage of shoots with no damage on cambium for all four test temperatures on September 13th. Provenances under each horizontal line did not differ significantly in damage ($p<0.05$). AK=Alaska, BC=British Colombia, WA=Washington, MT=Montana, WY=Wyoming, UT=Utah, NM=New Mexico, AZ=Arizona.

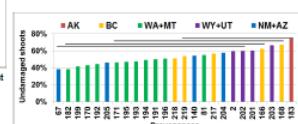

Figure 11. Percentage of shoots with no damage on any tissue (buds, needles, cambium) for all four test temperatures on September 13th. Provenances under each horizontal line did not differ significantly in damage ($p<0.05$). AK=Alaska, BC=British Colombia, WA=Washington, MT=Montana, WY=Wyoming, UT=Utah, NM=New Mexico, AZ=Arizona.

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Mid-rotation growth and postharvest needle retention characteristics of balsam fir grown in western Washington

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In 2008, a replicated common garden field trail was established at the Washington State University Research and Extension Center in Puyallup, WA to evaluate the growth and postharvest characteristics of 26 provenances of balsam fir (*A. balsamea*) and eight progeny collections of 'bracted' balsam fir (A. balsamea var. phanerolepis). A single source of Fraser fir (A. fraseri) was included in the trial as a standard. Seed was obtained from the Canadian Forest Service's National Tree Seed Center and P+2 seedlings were out-planted in February of 2008 in a 1.08 acre plot at 6 ft x 6 ft spacing. The plot design was a randomized complete block with five blocks. Five trees of each source were planted in a row within each block. To obtain information on the mid-rotation growth characteristics; tree heights were measured, bud break growing-degree days (GDD) were calculated, and data were collected on the color and form of the trees during the past two years. In 2012, tree heights ranged from 133 to 191 cm. All of the balsam sources broke bud prior to Fraser fir and the bud break GDD ranged from 208 to 437 among the balsam sources. Color was rated on a scale of 1 (poor) to 3 (excellent) and ranged from 1.7 to 2.7. Form was rated on a scale of 1 (poor) to 5 (excellent) and ranged from 2.3 to 4.1. Branches were harvested for trees and displayed dry in early October to also obtain preliminary information on differences in needle retention amoung the sources of trees. Needle loss was rated on a scale of 0 (none) to 7 (91-100% loss) and ranged from 1.3 to 4.8. These and previous early-rotation growth data indicates that there are significant growth and postharvest needle retention differences among the 34 sources of balsam fir in this trial.

A link between water quality and bacterial growth in Christmas tree stands with postharvest needle abscission in balsam fir

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Post-harvest needle loss in Christmas trees is a complex phenomenon regulated by genetic, environmental, management and post-harvest factors affecting physiological processes. Typically, the initial water consumption of a freshly cut Christmas tree is 0.20 mL g^{-1} d^{-1}, but follows an exponential decline until a steady state of approximately 0.05 mL g^{-1} d^{-1} is reached. It is hypothesized that bacteria growing in standing water of Christmas tree stands inhibits water flux and, ultimately, contributes to poor needle retention. A total of 100 branches were collected and placed in water. Each week ten branches were randomly selected and assessed for percent needle loss, water use, xylem pressure potential (XPP), and relative water content (RWC). In addition, the stand water was collected and analyzed for bacterial count and percent transmittance at 600 nm wavelength. In general, it was found that water use, RWC, XPP, and transmittance all decreased over time; percent needle loss and bacterial count increased over time. Bacterial counts were only able to be monitored over the first three weeks, which followed an exponential growth and a logarithmic transformation of this data had a significant ($P < 0.001$) linear negative relationship with transmittance (R^2 = 86.0%). Over the duration of the experiment, transmittance had a significant ($P < 0.001$) positive linear relationship with water use (R^2 = 62.5%) and XPP (R^2 = 62.1%). None of the factors studied was directly related to percent needle loss, but that was likely due to the fact that no needle loss occurred in the first few weeks. A comparison of the number of days until needle loss commencement and the number of days for water use to reach the steady state of 0.05 mL g^{-1} d^{-1} revealed a strong positive linear relationship (R^2 = 87%). It is suggested that the overall water quality, as indicated by transmittance, is strongly linked to water use. A quick decline in daily water use, due either to poor water quality or other reasons, can promote needle abscission. There is evidence to suggest that bacterial growth in standing water may perhaps be a contributor to the poor water quality and needle retention postharvest.

SMART Atlantic Balsam Christmas Tree Research Centre

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A Link Between Water Quality and Bacterial Growth in Christmas tree stands with postharvest needle abscission in balsam fir

Introduction

Balsam fir is the primary Christmas tree species in Atlantic Canada, controlling about 99% of the total natural Christmas tree market. Postharvest needle abscission remains a major challenge for the industry. It's been shown repeatedly that fresh Christmas trees consume about 0.20 $mLg^{-1}d^{-1}$, which gradually decreases to 0.05 $mLg^{-1}d^{-1}$. It's speculated that the decrease in water flux contributes to postharvest abscission, but the reason for the decrease is unknown. It's hypothesized that deteriorating water quality in Christmas tree stands due to microbial growth is linked to decreased water use promoting postharvest abscission.

Methods

Direct effect of poor water quality

A total of 20 balsam fir branches we collected from known genotypes available in a clonal orchard. Half of these branches were placed in water (control) while the other half were placed in water from stands with Christmas trees in them for 1 week (dirty). Branches were compared for water use and needle abscission.

Water quality link with abscission

A total of 100 branches were collected. Each week 10 branches were randomly selected and assessed for needle abscission, water use, relative water content, and xylem pressure potential. The water provided to these branches was analyzed for bacterial count and percent transmittance at 600 nm. Data was submitted to repeated measures analysis to identify trends over time. Data was also submitted for regression analysis to determine trends between key parameters.

Results

Direct effect of poor water quality

There were significant differences in both water use and needle abscission over time between treatments. Water use declined to a steady rate in only a few days in branches provided dirty water, while it took several weeks in control branches (Fig. 1). Similarly, needle abscission began on day 12 in branches provided with dirty water and day 18 in control branches. There was also a significant difference in the length of time required to complete abscission; branches provided dirty water completed abscission in 38 days while control branches completed abscission in 60 days (Fig. 2).

There was a strong, positive, linear relationship between the time required to decrease to a steady state of water use and the length of time required for abscission to commence (Fig. 3).

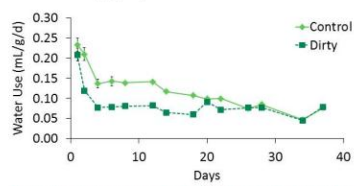

Fig. 1. Average water use for balsam fir branches placed in fresh water (control) and previously used water (dirty).

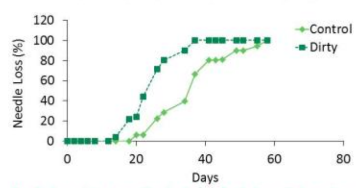

Fig. 2. Cumulative needle abscission for balsam fir branches placed in fresh water (control) and previously used water (dirty).

Results

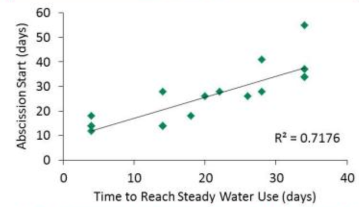

Fig. 3. Relationship between the length of time needed to reach a steady state of water use and the length of time needed to begin abscission.

Water quality link with abscission

Similar to the first experiment, postharvest needle abscission increased exponentially (Fig. 4) and water use decreased exponentially (Fig. 5). Bacterial growth increased exponentially as well, though was no longer measured after week 3 as counts had risen too high.

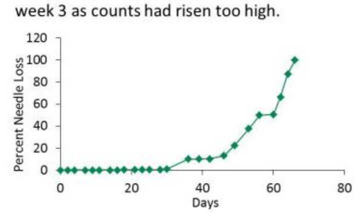

Fig. 4. Cumulative needle abscission for balsam fir branches placed in water.

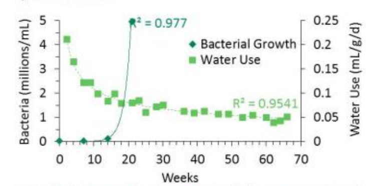

Fig. 5. Exponential decrease in daily water use and exponential increase in bacterial counts from Christmas tree stands holding balsam fir branches.

Results

There was some indication of slight drying in the branches. Over the duration of the experiment XPP decreased 3-fold and RWC decreased by 10% (Table 1). There was also discoloration of the water, which was noted by a change in transmittance of light (Table 1).

Table 1. Changes in XPP, RWC, and percent transmittance throughout the duration of the experiment with abscission.

Parameter	Initial	Final	P-value
XPP (MPa)	-0.21	-0.64	< 0.001
RWC (%)	81.7	72.3	< 0.001
Transmittance (%)	100	89.6	< 0.001

As noted in the previous experiment, there was a strong, positive, linear relationship between the length of time required for abscission to begin and the time required to hit a steady state of 0.05 mL g^{-1} d^{-1} of water (data not shown).

Conclusions

- Poor water quality directly decreased the length of time required for abscission and daily water use.
- There is a very strong relationship between the point at which water use stabilizes at a low rate and the time that abscission begins.
- Bacterial growth occurs rapidly immediately after placing the balsam fir in standing water and corresponds with decreased water use.
- There is evidence that the decreased water consumption leads to some degree of drying.
- Overall, poor water quality is detrimental to postharvest needle abscission. This may be linked to bacterial growth or other yet unidentified factors.

Effects of postharvest dehydration and cold acclimation on needle loss in various Balsam fir genotypes

Azure Adams[1], Rajasekaran Lada[1] and Mason MacDonald[1]

[1] Department of Environmental Sciences, Dalhousie University, Bible Hill, NS, B2N 5E3, Canada

Cold acclimation and postharvest dehydration can alter postharvest needle abscission response depending on the genotype. In our previous study, the critical level of post harvest moisture loss was determined to be between 15 and 20% fresh weight. For this study, 16 clones (12 high NRD, 4 low NRD) were selected from the NSDNR Tree Breeding Centre in Debert, NS and lateral branches (first set from terminal branch) were collected on October 22, 2012. The branches were allowed to equilibrate in water to ambient conditions in the lab overnight then given a fresh cut, brushed lightly to remove any loose/dead needles and weighed. Half of the branches were left to dry under lighted conditions until they lost approximately 17.5% moisture. The other half remained under un-hydrated conditions for the entire experiment. When branches dehydrated to the 17.5% level a finger run test was done and any dropped needles collected and weighed. Branches were then given a fresh cut, weighed, put in bottles with water and weighed again (branch+bottle+water). Needle loss and water use was monitored 3 times a week until complete needle loss had occurred. The experiment was repeated post-cold acclimation on January 29, 2013. Clones differed in the length of time they took to dehydrate to approximately 17.5% of their initial weight. Some reached that level in as little as 1 day, while others took up to 5 days. In the un-hydrated group, all of the clones had lost their needles by 35 days pre-cold acclimation and 28 days post-cold acclimation. Among the rehydrated group, NRD ranged from 46 to 108 days pre-cold and 30 to 93 days post-cold. Analysis of the data revealed that all two way interactions were significant. It appears that some clones do not benefit from rehydration. Two thirds of the clones did not show significant improvement in needle retention at either Needle Abscission Commencement (NAC) or Needle Retention Duration (NRD). Two clones actually experienced a decline in needle retention after rehydration. Significant improvement in needle retention was only seen in five of the sixteen clones (4 high NRD and 1 low NRD). Response to cold acclimation was split between the clones. Nine clones experienced an increase in needle retention after cold acclimation had occurred, while seven clones declined in both NAC and NRD.

Effects of postharvest dehydration and cold acclimation on needle loss in various balsam fir genotypes

Azure Adams, Rajasekaran Lada, Mason MacDonald

Department of Environmental Sciences, Faculty of Agriculture
Dalhousie University

Objective

To determine the role dehydration, rehydration, and cold acclimation may have in post harvest needle abscission of various balsam fir genotypes from a Nova Scotia providence trial.

Introduction

Needle abscission in balsam fir is known to have a high degree of variation between genotypes. For example, some clones may experience complete needle shed in 8 to 12 days, while others may retain needles for over 3 times longer. Factors such as dehydration, ability to rehydrate, and exposure to cold acclimation are all known to influence postharvest abscission. It is unknown how these factors may vary between genotypes differing in needle abscission resistance.

Methods

A total of 16 different genotypes available at the Debert Tree Breeding Center were selected for this experiment. Twelve branches were collected from each and considered a replicate. Half the branches were put on display dehydrated and the other half were allowed to dehydrate by 17.5% (a previously determined value) and then given a fresh cut and placed in water. Branches were then evaluated for percent needle drop. The number of days until needle abscission commencement (NAC) and needle retention duration (NRD) are reported. This was repeated again in January as a cold acclimation treatment.

Results - NAC

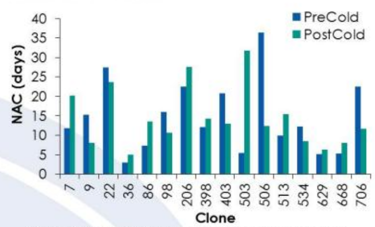

Figure 1. Interaction between cold acclimation and genotype on needle abscission commencement

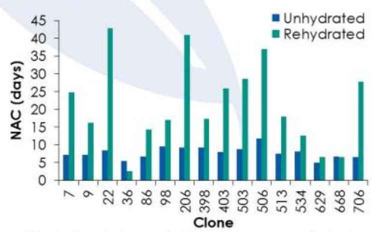

Figure 2. Interaction between hydration and genotype on needle abscission commencement

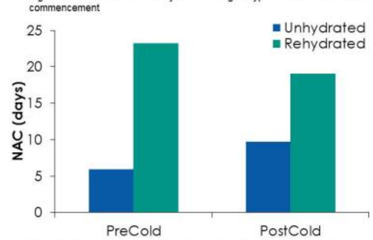

Figure 3. Interaction between hydration and cold acclimation on needle abscission commencement

Results - NRD

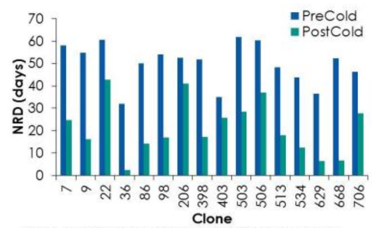

Figure 4. Interaction between cold acclimation and genotype on needle retention duration

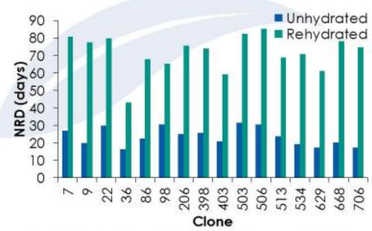

Figure 5. Interaction between hydration and genotype on needle retention duration

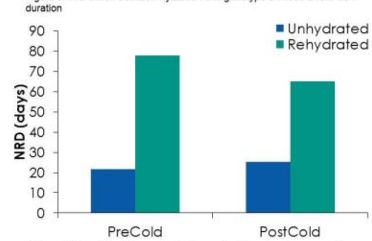

Figure 6. Interaction between hydration and cold acclimation on needle retention duration

Key Points

Cold acclimation generally did not improve needle retention in this study, although there was small improvement in unhydrated needle retention after cold. Genotypes showed very distinct differences in ability to rehydrate, especially in terms of needle abscission commencement.

Acknowledgements. We thank the Department of Natural Resources for use of the balsam fir clonal orchard in Debert, NS. We also thank our grant agencies NSERC, AIF, and ACOA for their support of this research.

The Relationship Between Soil, Needle Nutrient Content and Post-harvest Needle Retention

Melissa Georgeson[1], Rajasekaran R. Lada[1], Gordon R. Brewster[1], Claude D. Caldwell[2]

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Currently, we know little about the relationship between soil, needle nutrient content and post-harvest needle abscission in balsam fir. This study was conducted by obtaining branches from three different bio-environmental locations in Pictou, Colchester and Kings counties, Nova Scotia. Three trees were selected at each site with 5 branches that served as replications from each tree – a total of 15 branch replications per site. Soil samples were taken around each tree and soil moisture was taken with a TDR probe. All of the foliar nutrients were significantly different among locations except for boron. Significant relationship existed among locations for soil pH, CEC, calcium, magnesium, aluminum, iron and zinc contents. Needle retention duration (NRD) differed among the three locations. Needle retention duration was the highest with the branches that were collected from Kings county compared to Colchester or Pictou counties. Needle nutrient concentrations revealed that the higher N, P, K, Ca, Fe, Mn, Cu, Zn and B contents were found in Pictou and Colchester counties, which correlated with a low NRD, while a low nutrient status may have contributed to the higher NRD in Kings county. A Pearson's correlation was performed to see the relationship between the soil characteristics and needle nutrient content and NRD. It was found that none of the soil characteristics tested influenced the post-harvest NRD, although some of these characteristics did influence needle nutrient content. Four foliar nutrients, copper, nitrogen, iron and phosphorus, all had a significant negative relationship on NRD.

The Relationship between Soil, Needle Nutrient Content and Post-harvest Needle Retention

Melissa Georgeson, Rajasekaran R. Lada, Gordon R. Brewster, Claude D. Caldwell

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Introduction

Nutrients are essential for the maintenance of cellular metabolism, growth and the regulation of plant health (Campbell, 2005). Root severance can disrupt these physiological processes as the decline in nutrients and water uptake can cause needle senescence and/or abscission. While there has been previous research on tissue nutrient content of leaf and flower abscission in other plant species, there was no direct evidence that needle nutrient content alters needle retention in balsam fir. Therefore it is important to understand the relationship between soil fertility, needle nutrient content and needle retention.

The objective of this study was to determine the relationship, if any, between soil, needle nutrient content and post-harvest needle retention.

Methods

- Two-year old branches were collected from balsam fir orchards in Pictou , Colchester and Kings counties. From each location 10 sister branches were collected on the eastern side of the tree.
- From each location 5 of the 10 branches were analyzed at Harlow Institute, Truro, NS for their pre-harvest nutrient content.
- The other 5 sister branches were taken back to the lab for post-harvest observation.
- The post-harvest observations were:

1) needle retention duration (NRD), which is when 100 % of the needles dropped.
2) needle loss increments – which is where 1, 5, 10, 20, 40, 80 % of the needles fell off of the branch.

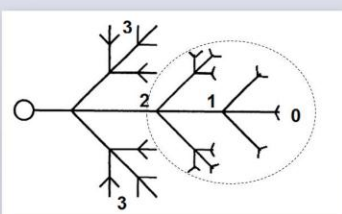

Figure 1: A diagram representing a branch of balsam fir. The dotted circle surrounds the branch sample size collected for the response variables. The dotted circle includes current year growth (0), first year growth (1) and second year growth (2). Sister branches are indicated by (3).

Results

Needle Loss:

Needle loss was significant at all increments, except at 1 %. The branches collected at Kings county had the highest NRD (53.5 days), Pictou county (34.5 days) and Colchester county (41.6 days) were statistically similar. Kings county also took the longest to lose needles at 5, 10, 20, 40 and 80 % .

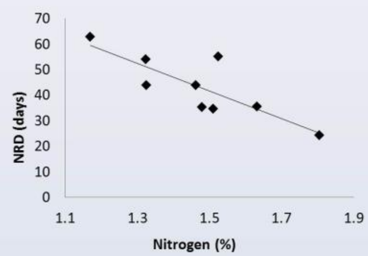

Figure 2: Foliar nitrogen levels (%) to NRD in balsam fir branches. A linear regression was preformed to demonstrate the relationship between increasing levels of nitrogen to decreasing NRD; with a p-value of < 0.0001 at an $\alpha = 0.05$ and a R^2 value of 0.43.

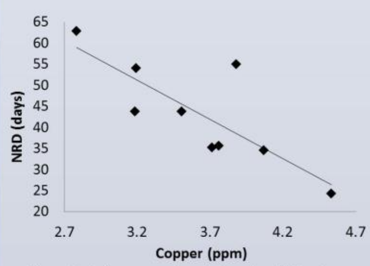

Figure 3: Foliar copper levels (ppm) to NRD of balsam fir. A linear regression was preformed to demonstrate the relationship between increasing levels of nitrogen to decreasing NRD; significant Pearson's correlation p-value of < 0.0001 at an $\alpha = 0.05$ and a R^2 of 0.271.

Results

Nutrient content:

Eight of the 9 nutrient contents, except manganese, were significantly different among locations. Pictou county's branches had the highest levels of nutrients, whereas Kings county had the lowest levels of nutrients.

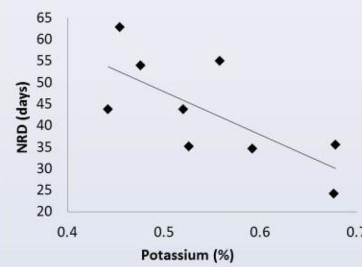

Figure 4: Foliar potassium levels (ppm) to NRD of balsam fir. A linear regression was preformed to demonstrate the relationship between increasing levels of nitrogen to decreasing NRD; significant p-value of < 0.0001 at an $\alpha = 0.05$ and a R^2 value of 0.274.

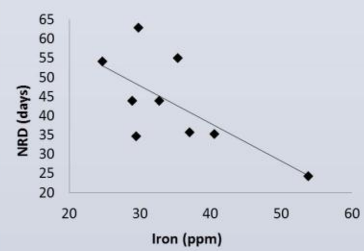

Figure 5: Foliar iron levels (ppm) to NRD of balsam fir. A linear regression was preformed to demonstrate the relationship between increasing levels of nitrogen to decreasing NRD; a significant p-value of < 0.0001 at an $\alpha = 0.05$ and a R^2 value of 0.297.

Discussion

Previous fertilization studies also showed that increased needle nutrient content reduced needle retention (Balster and Marshall, 1999). Conifers are known to grow in nutrient poor soils, to protect their nutrient resources, they have long foliage longevity. When conifers grow in nutrient rich soils, nutrient availability is not a limiting factor anymore and needle growth and abscission quickens (Balster and Marshell, 1999). They saw that fertilization increases above ground biomass, which causes self shading of lower and internal needles (which are closer to the trunk); this self shading promotes needle loss to the shaded needles (Balster and Marshell, 1999).

Interestingly, it was noted that the higher concentrations of iron and copper also reduced needle retention. Copper is a co-factor for several enzymes, in particular it mediates ethylene's binding as a transition metal cofactor (Burg and Burg, 1967). Ben-Yehoshua and Biggs (1970) believed that the acceleration of abscission by Cu and Fe chloride salts was related to the enhancement of ethylene or the inactivation of IAA as seen in citrus species. Ethylene is known to promote needle abscission in balsam fir trees (MacDonald et al., 2010).

Conclusion

The soil nutrient status had no significant influence on needle loss or retention. However, it was seen that the needle nitrogen, potassium, copper and iron content had a significant, but negative relationship with NRD. This indicates that the higher content of nutrients that a balsam fir tree may have, the lower its needle retention may be post-harvest.

Figure 1: An example of Pictou county's branches – they had long, thin, flat needles, which abscised quickly.

Acknowledgements

Funding was received from NSERC, ACCAF, ACOA (AIF), CTCNS and SMART Christmas tree Research Cooperative

Membrane lipid dynamics during abscisison in post-harvest balsam fir

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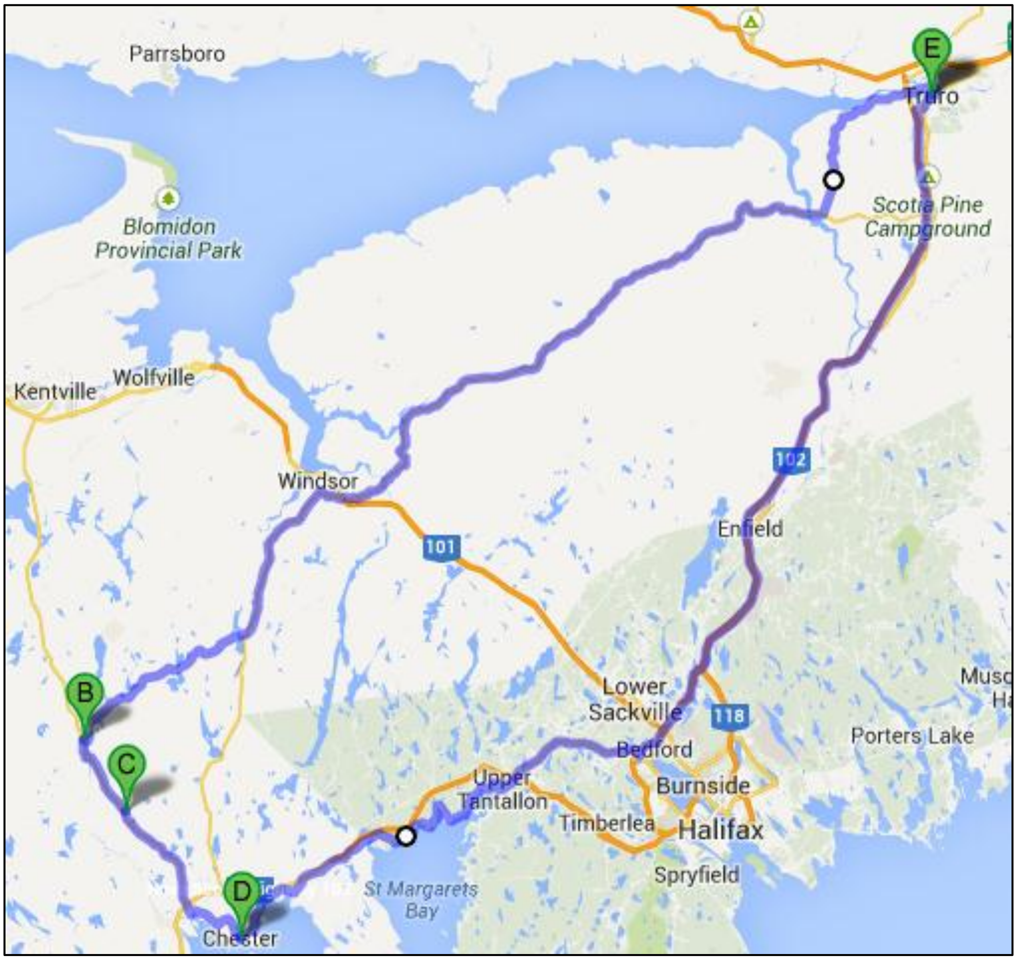
The balsam fir, *Abies balsamea* L., is the primary species of Christmas tree grown in Atlantic Canada, grossing approximately $56.6 million each year (Statistics Canada, 2011). It is the preferred species for Christmas trees and greenery due to its gratifying fragrance and rich green color (Burns and Honkala, 1990). Postharvest needle loss has been identified as a major challenge in the industry, limiting sales, particularly in situations where trees are harvested early, shipped out of the country, and sold in warm weather markets where they may have to be displayed for some time. Some progress is being made in revealing the underlying causes of abscission, but no one has ever looked at lipid and fatty acid (FA) changes postharvest as a possible signal for abscission in postharvest balsam fir. During this proposed research, the overall objective is to uncover the changes that occur in lipids and FAs from preharvest to postharvest balsam fir needles and establish a link between these changes and needle abscission, membrane breakdosn and senesence. If it is found that lipid and FA changes support membrane decay during abscission, possibly a membrane protectant will be the solution to this problem and provide the catalyst necessary for greater expansion of the balsam fir Christmas tree industry.

Lunenburg, Nova Scotia



Keddy Christmas Tree Company
Mike and Janet Keddy
586 Glendale Road, New Ross, NS

The Keddy Christmas Tree company was established in 1960 by Theodore (Bub) Keddy and Hibert Keddy to ship Nova Scotia Christmas trees to the Caribbean Islands. They continued this trade and established US customers durning the last 40 years and has shipped trees to areas stretching from Boston to Caracas Venezuela. The company is now owned and operated by Michael and Janet Keddy. Michael, Janet and their two children, James and Jacqueline, live and farm Christmas trees in New Ross, Lunenburg County, Nova Scotia, Balsam Fir Chirstmas Tree Capital of the World!

G & C Enterprises Limited
Colin Hughes
RR#2 New Ross, NS

Nova Scotia offers a cold moist climate which is ideal growing conditions for Balsam Fir Trees. Each tree is hand pruned to achieve the perfect shape. Nova Scotia Balsam Fir Trees have superior needle retention and a much sought after strong fragrance. We use Nova Scotia government approved grading methods to insure that you receive value and quality for your money.

T & D Nurseries
Thomas and Debbie Reeves
1503 Forties Road, New Ross, NS

T& D nurseries is a family owned business founded by the Reeves family of Forties Settlement in 1988. The nursery is the main supplier of quality tree seedlings for forestry and Christmas tree industries in western Nova Scotia with an annual production of about 150,000 seedlings per year. They also supply flowering and dead ending plants for local homeowners.

Seffernsville Experimental Lot
Lunenburg County Christmas Tree Producers Association
Hwy 12, Seffernsville, NS

This experimental lot is actually on crown land, but is leased for use by the Lunenburg County Christmas Tree Producers Association (LCTPA) since the 1960s. For the first two decades, the site was used for Christmas tree research by the provincial and federal governments, but has more recently been used as a training and demonstration site for LCTPA members. The experimental lot consists of about 6 acres of planted and natural growing balsam fir and is maintained by volunteers from LCTPA. Several hundred trees are harvested each year with profits used to help the association.

Tour Photos

Tour guide Ross Pentz vehicle

Conference participants at Mike Keddy's

Mike Keddy in his lot

Colin Hughes in his lot with Venche Talgo and Norm MacIsaac

Conference participants taking in the sights at Colin Hughes' lot

Raj Lada explaining something in Colin's lot

Overview of Colin Hughes back lot

Lunch at the legion with Nova Scotian flare provided by Mike Keddy

Greenhouses at T&D Nurseries

Conference participants gathered around one of the T&D greenhouses

Balsam seedlings at T&D nurseries

Conference participants viewing the 3-4 year old hardwood and fir trees at T&D nurseries

Chal Landgren and John Frampton in the exotics section at the Seffernsville lot

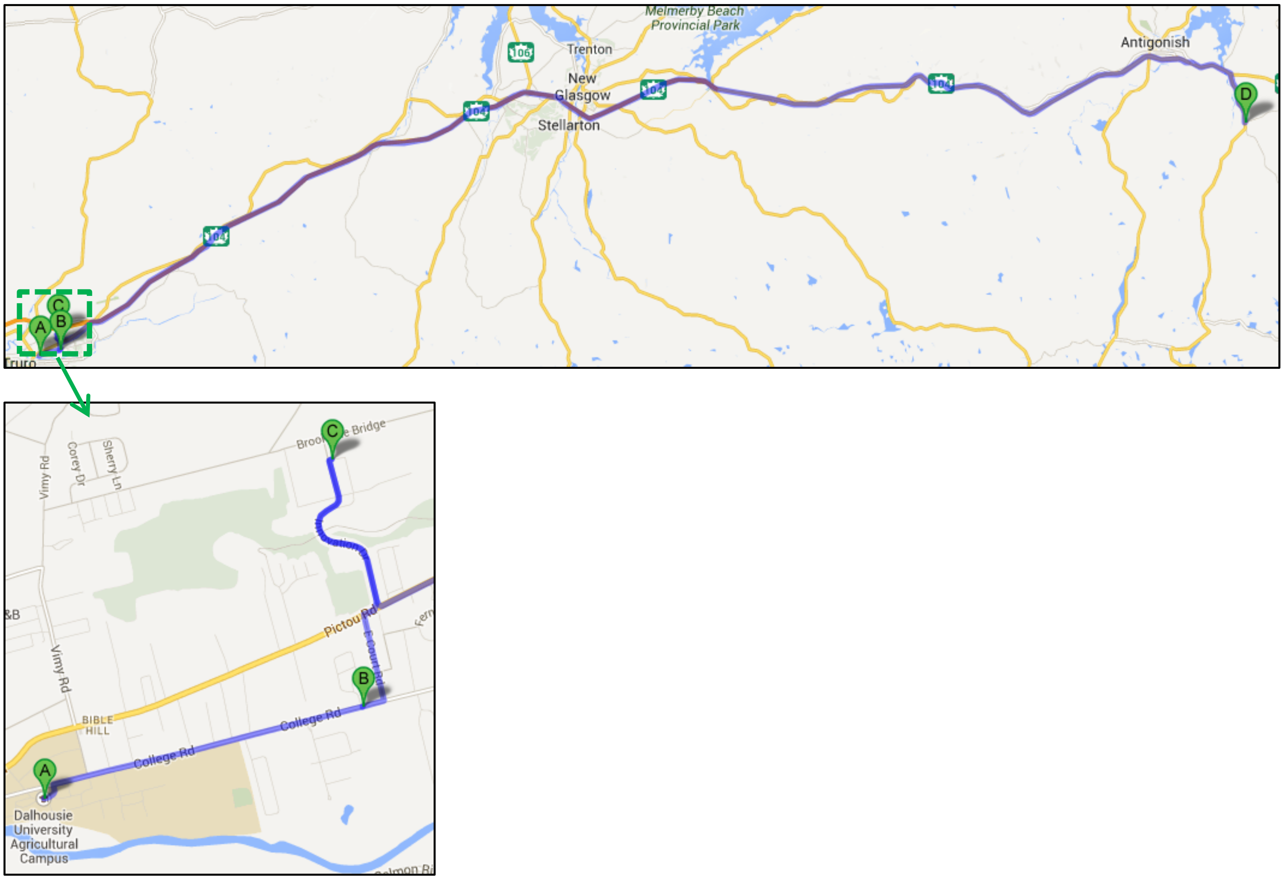
Conference participants in exotics stand at Seffernsville experimental lot

Group photo at Seffernsville lot

Supper at the ‘Rope Loft’ in Chester, NS

Admiring the view during supper at the end of the first tour day (Chester basin)

Antigonish, Nova Scotia



Balsam Fir Germplasm Center
Bible Hill, NS

The Balsam Fir Germplasm Center was established in 2009 by Christmas Tree Research Center, Christmas Tree Council of Nova Scotia and the Department of Natural Resources. It consists of a seed orchard which will be used for future breeding programs and seed source for the industry, and a research orchard which will be used to future experiments or branch collections. These orchards were planted with balsam fir from around Nova Scotia and were screened for superior needle retention, color, disease and pest resistant and architecture. When selections were made scion material was collected from trees and were then grafted onto rootstock in February and April of 2009, and planted in July and August of 2009. These orchards continue to be maintained by the Christmas Tree Research Center and the Christmas Tree Council of Nova Scotia. Approximately 800 trees have survived and are thriving.

Christmas Tree Research Center
Bible Hill, NS

The Christmas Tree Research Center was founded in 2010 by Dr. Rajasekaran Lada of Dalhousie University. The center's mission statement is to enhance Atlantic Canada's knowledge-based bioeconomy through the development of science-driven innovative technologies and products for increasing industry sustainability. Research is conducted on several platforms, including pest management, tree molecular breeding and germplasm, artificial root technologies, cold acclimation, and postharvest physiology. There is a staff of about 16 individuals working at the center, including graduate students, postdoctoral fellows, and administrative personnel.

Roger Threnholm
Saint Andrews, NS

Roger has approximately 43 acres of trees on a lot purchased by his family in 1978. Roger does most of his own work a plants 2000 seedlings each year. On this lot we saw Rogers shearing and the results of his fill planting.

Scott and Stewart Nursery
Saint Andrews, NS

At this stop Jackie MacDonald Nursery Manager showed the nursery operation which included recently seeded balsam fir, spruce seedlings including large stock, various hardwood seedlings, native scrubs and haskap berry plants.

Elite Balsam Products
Saint Andrews, NS

Scott is a grower, exporter of trees, wreaths and brush. At this stop we will viewed some of Scott newer plantations.

Tour Photos

Dr. Raj Lada introducing conference participants to the balsam fir germplasm center

Overview of the balsam fir germplasm center in Bible Hill, NS

Tree testing lab at Christmas tree research center

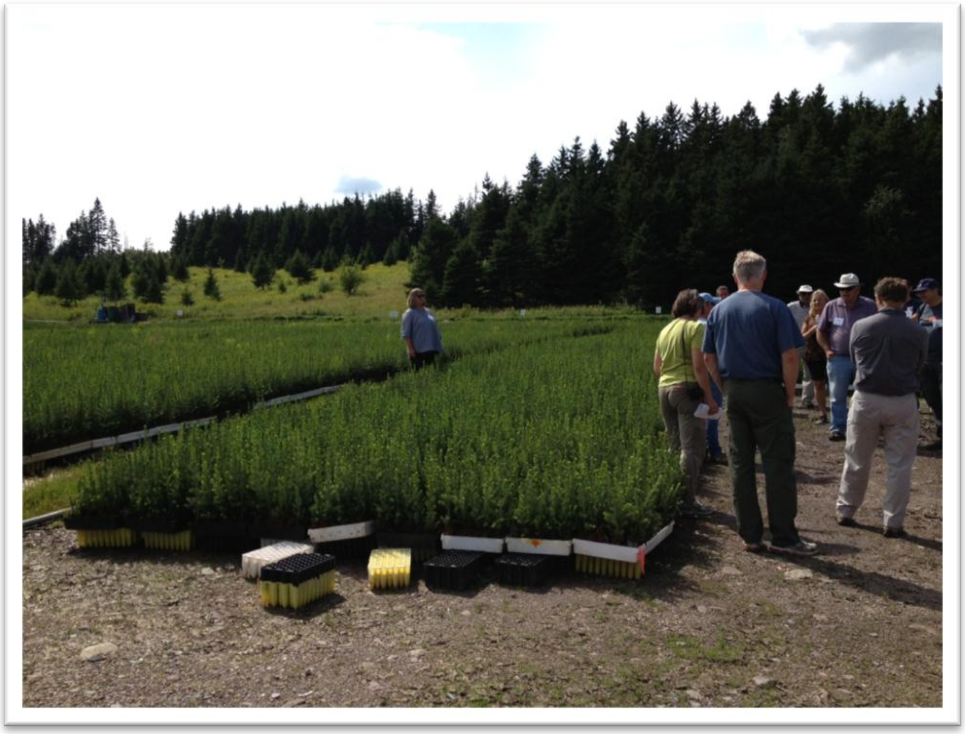
Raj Lada and Mason MacDonald talking about the physiology lab at the Christmas tree research center

Andrew Schofield introducing conference participants to his molecular biology lab

Arumugam Thiagarajan introducing conference participants to the instrumentation lab

Conference participants at Roger Trenholm's lot

Roger Trenholm engaging conference participants in discussion



Participants at Scott and Stewart nursery

Seedlings growing at Scott and Stewart nursery

Seedlings growing in an outdoor lot at Scott and Stewart nursery

Scott MacKinnon preparing to demonstrate tree shearing on one of his lots

Panel Discussions

On the final day of the conference, a panel of producers was available to field questions about issues that directly affect the Christmas tree industry.

Raj Lada introducing the panel members prior to discussion

Panel members (left to right): Colin Hughes, Bruce Turner, Murray Crouse, Richard Levy, Norm MacIsaac, David Sweet, Mike Keddy, and Matthew Priest

Conference participants in discussion during the producer panel presentation

Participants

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Name	Organization	Country	E-mail
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Young, Ron	NS Department of Agriculture	Canada	youngrv@gov.ns.ca

THANK YOU to all our wonderful sponsors for making this event possible!

Gold Level:

NS Department of Natural Resources

Bronze Level:

Department of Environmental Sciences, Dalhousie University
Christmas Tree Council of Nova Scotia
Christmas Tree Research Centre

Honorable Mention:

Mike Keddy, Keddy Christmas Tree Company
Nova Scotia Federation of Agriculture