# 15th International Christmas Tree Research and Extension Conference

## June 5-9, 2022

## Fallen Leaf Lake, California

# Contents

## Conference sponsors

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# Conference Schedule

## Sunday, June 5, 2022

| | |
|---|---|
| 13:00 | Stanford Sierra Conference Center (SSCC) open to CTRE participants |
| 13:00-19:00 | CTRE registration open |
| 15:00 | SSCC room check-in open |
| 18:00 | Welcome to CTRE 2022! Bert Cregg, Michigan State University, Dept. of Horticulture, Dept. of Forestry, Conference Chair<br><br>Invited reception keynote: "The Tahoe Basin in a Time of Climate Change". Patricia Maloney, Associate Director and Project Scientist-Forest Ecology, UC Davis Tahoe Environmental Research Center |
| 19:00 | BBQ reception dinner on patio |

## Monday, June 6, 2022

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|---|---|
| 6:00-7:00 | Coffee, self-serve breakfast items available |
| 7:00-8:00 | Breakfast |
| 8:00-8:40 | Integrating forest health genomics with traditional tree breeding to rapidly advance conifer genetics<br>*Justin G. A. Whitehill*, Joerg Bohlmann* |
| 8:40-9:10 | Towards marker-aided selection for Fusiform rust disease in *Pinus taeda* breeding<br>*Fikret Isik*, Yu-Ming Lin, Eddie Lauer, Nasir Shalizi, Trevor Walker* |
| 9:10-9:40 | Grower needs assessment of Pacific Northwest Christmas tree and allied product producers<br>*Chal Landgren*, Holly Ober, Gary Chastagner* |
| 9:40-10:05 | Break |
| 10:05-10:35 | Identification of top performing trees for establishing Turkish and Trojan fir clonal seed orchards<br>*Gary Chastagner*, David McLoughlin, Kathy Riley, Don Sherry* |
| 10:35-11:05 | Variation among Nordmann fir somatic clones in the needle disorder 'bare shoulders', needle color and interrelation to nutrient content<br>*Jing Xu, Morten Ingerslev, Ulrik Braüner Nielsen** |
| 11:05-11:35 | Genetic variation in Christmas tree quality of somatic embryo plants of Nordmann fir<br>*Jing Xu*, Ulrik Braüner Nielsen (virtual)* |
| 11:35-12:00 | A national progeny test (CoFirGe 2)- A discussion about next steps (Interested parties will continue discussion over lunch)<br>*Chal Landgren*, Gary Chastagner, Rick Bates* |
| 12:00-13:00 | Lunch |
| 13:00-14:00 | Round table discussion: Christmas tree seed orchards |
| 14:00-16:30 | Networking/Outdoor break |
| 1630-18:00 | Poster session and reception |
| 18:00-19:30 | Dinner |

* = presenter

## Tuesday, June 7, 2022 - Field tour

Discussion of California wildfires with UCCE Forestry and Natural Resources Advisor Susie Kocher at the site of the 2021 Caldor fire

McGee's Christmas Tree Farm. Mike, Phyllis and Eli McGee, hosts

US Forest Service Institute of Forest Genetics

Rapetti Farms. Randy Rapetti, host

Lunch at Lava Cap winery

## Wednesday, June 8, 2022

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|---|---|
| 6:00-7:00 | Coffee, self-serve breakfast items available |
| 7:00-8:00 | Business meeting (over breakfast) |
| 8:00-8:30 | Genomic and genetic approaches to improve Christmas tree health<br>*Justin G. A. Whitehill** |
| 8:30-9:00 | Potential Impacts of climate change on diseases and the postharvest quality of Christmas tree<br>*Gary Chastagner** |
| 9:00-9:30 | *Botrytis spp.* obtained in Norwegian forest nurseries are resistant to fungicides<br>*Katherine Ann Gredvig Nielsen*, Magne Nordang Skårn, Venche Talgø , Martin Pettersson, Inger Sundheim Fløistad, Gunn Mari Strømeng, May Bente Brurberg, Arne Stensvand (virtual)* |
| 9:30-9:45 | Break |
| 9:45-10:15 | Reaching new and established Christmas tree growers through webinars<br>*Heidi Lindberg*, Bert Cregg, Debalina Saha, Riley Rouse (virtual)* |
| 10:15-10:45 | Deer repellent research and deer browse management in North Carolina<br>*Jeffrey Owen** |
| 10:45:11:15 | Improving conifer establishment using sustainable pest management and soil health practices: First year results.<br>*B. Brown, A. Dunn, B. Eshenaur, E. Lamb*, L. Sosnoskie* |
| 11:15-11:45 | *Rhizoctonia butinii* on spruce Christmas trees<br>*Venche Talgø*, Martin Pettersson, Inger Sundheim Fløistad, Iben Margrete Thomsen (virtual)* |
| 11:45-12:00 | Wrap-up/discussion |
| 12:00-13:00 | Lunch |
| 13:00-15:00 | Round table discussion: Climate change and Christmas tree extension |
| 15:00-18:00 | Networking/Recreation |
| 18:00-19:30 | Dinner |

* = presenter

## Thursday, June 9, 2022

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|---|---|
| 6:00-7:00 | Coffee, self-serve breakfast items available |
| 7:00-8:00 | Breakfast |
| 8:00-8:30 | Christmas tree needle retention in response to 1-MCP and dark chamber storage treatments<br>*Jeffrey Owen*, Justin Whitehill* |
| 8:30-9:00 | Postharvest treatments for spotted lanternfly<br>*Austin Lourie, Stephen Corbett, Spencer Walse** |
| 9:00-9:30 | Improving transplant success in Abies fraseri Christmas tree plantations<br>*Riley Rouse*, Bert Cregg* |
| 9:30-10:00 | S-Abscisic Acid (ConShape) for Christmas tree leader control<br>*Jozsef Racsko** |
| 10:00-10:15 | Break |
| 10:15-10:45 | Improving first year noble and Douglas-fir seedling survival and growth in PNW Christmas tree plantation<br>*Judy Kowalski*, Chal Landgren* |
| 10:45-11:15 | Conclusion of spring cone control research in North Carolina<br>*Jeffrey Owen** |
| 11:15-11:45 | Managing cone formation in Fraser fir Christmas tree plantations: Highlights from the Michigan experience<br>*Bert Cregg*, Riley Rouse* |
| 11:45-12:00 | Wrap-up/discussion |
| 12:00-13:00 | Lunch |
| 13:00 | Depart conference center |

* = presenter

## Posters

Presenters will be with their posters Monday, June 6, 16:30-18:00

Abies spp. somatic embryogenic tissue culture pipeline development
*Angela Chiang, Robert Thomas, Justin G. A. Whitehill**

Efficacy of eFume and Bluefume (HCN) fumigation in eradicating elongate hemlock scale on Christmas trees
*Gary Chastagner, Jill Sidebottom, Robert Jetton, Spencer Walse*, Stephen Corbett*

Heat treatment - A potential approach of killing Megastigmus larvae in imported conifer seeds
*Thomas Whitney, Allison Casciola, Gary Chastagner**

Insecticide toxicity, application efficacy, and degree-day modelling of an emergent Christmas tree pest, the Douglas-fir twig weevil (*Cylindrocopturus furnissi*)
*Thomas Whitney, Allison Casciola, Gary Chastagner**

Controlling glyphosate-resistant weeds with alternative herbicides in Fraser fir Christmas trees
*Jeffrey Owen*, Joseph Neal*

Strategies to address emerging weed management challenges in Christmas tree production using herbicide and organic mulch combinations
*Greta C. Gallina*, Bert Cregg, Debalina Saha*

Controlling weeds by non-chemical methods in Christmas tree production
*Manjot Kaur Sidhu*, Debalina Saha*

Inoculation experiment with subalpine and Fraser fir seedlings planted in a stand of old subalpine fir heavily infested by *Neonectria neomacrospora*
*Venche Talgø*, Inger Sundheim Fløistad, Martin Pettersson (virtual)*

Diseases on fir (*Abies spp*.) Christmas trees in Scandinavia
*Venche Talgø*, Martin Pettersson, Iben Margrete Thomsen (virtual)*

Diseases on spruce (*Picea spp*.) Christmas trees in Scandinavia
*Venche Talgø*, Martin Pettersson, Iben Margrete Thomsen (virtual)*

Regional variation in postharvest needle loss from trees in CoFirGE planting sites
Gary Chastagner*, David McLoughlin, Kathy Riley, Don Sherry

A final look at bud break variation in families of Turkish and Trojan fir trees in the CoFirGE plots in Washington
*Gary Chastagner, David McLoughlin**

Effect of moisture content on the viability and vigor of Nordmann, Turkish and Trojan fir seeds
*Thomas Whitney, Allison Casciola, Chal Landgren, Gary Chastagner**

Nitrogen stabilizers do not improve growth or foliar nutrition of Fraser fir Christmas trees
*Bert Cregg*, Jill O'Donnell, Dana Ellison-Smith, Riley Rouse*

* = presenter

# 15th International Christmas Tree Research and Extension Conference

Oral Presentation Abstracts

## Integrating forest health genomics with traditional tree breeding to rapidly advance conifer genetics

Justin G. A. Whitehill[1], Joerg Bohlmann[2]

1. North Carolina State University (NCSU), Department of Forestry and Environmental Resources, Raleigh, NC 27695, USA
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Insect pests are part of natural forest ecosystems contributing to forest rejuvenation but can also cause ecological disturbance and economic losses that are expected to increase with climate change. The white pine or spruce weevil (*Pissodes strobi*) is a pest of conifer forests in North America. Weevil-host interactions with various spruce (*Picea*) species have been explored as a genomic and molecular reference system for conifer defense against insects. Interactions occur in two major phases of the insect life cycle. In the *exo-phase*, adult weevils are free-moving and display behavior of host selection for oviposition that is affected by host traits. In the *endo-phase*, insects live within the host where mobility and development from eggs to young adults is affected by a complex system of host defenses. Genetic resistance exists in several spruce species and involves synergism of constitutive and induced, chemical and physical defenses that comprise the conifer defense syndrome. Here, we discuss how conifer defenses disrupt the weevil life cycle and the mechanisms by which trees resist insect attack. We highlight molecular and genomic aspects and a possible role for the weevil microbiome. Knowledge of conifer defense systems support forest health strategies and tree breeding approaches to rapidly integrate pest resistance. The spruce weevil-spruce interaction can serve as a model to facilitate the integration of traditional forest genetics approaches with functional molecular studies. We explore ways that conventional tree breeding programs can integrate knowledge of functional genomics and chemical ecology studies to deploy pest resistant trees effectively across impacted forest landscapes.

## Towards marker-aided selection for fusiform rust disease in *Pinus taeda* breeding

Fikret Isik[1], Yu-Ming Lin[1], Eddie Lauer[2], Nasir Shalizi[1], Trevor Walker[1]

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2. Research Geneticist at PEAK Genetics, Madison, WI

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Fusiform rust is the most impactful disease affecting pine plantations in the southeast United States. The disease is caused by the endemic fungus *Cronartium quercuum* f. sp. *fusiforme*. We discovered three major QTL that confer effective immunity against diverse samples of pathogen genotypes, both in controlled inoculation experiments and field trials. Our group is implementing a plan to stack these QTL using marker-assisted selection for developing homozygous resistance donors. For cost-effective genotyping, we developed a low-density platform based on AgriSeq Targeted GBS panel by Thermo Fisher Scientific. Most of the markers were selected from the *Pinus taeda* Axiom array (Pita50K). Additionally, a subset of markers were designed to target candidate rust resistance transcripts discovered in RNAseq experiments. The panel contains 1002 markers evenly distributed across the twelve linkage groups of *P. taeda*. The panel was validated with 192 samples with known pedigree. The sample call rate was 85.9%, the sample uniformity was 89.1% and average coverage of sequencing was 201x. Genomic relationships and clustering of pedigree based on low-density panel markers corresponded well with Pita50K array markers.

## Grower needs assessment of Pacific Northwest Christmas tree and allied product producers

Chal Landgren[1], Dr. Holly Ober[2], Dr. Gary Chastagner[3]

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The refilling university positions either in research or extension in the PNW is never a given. For background, Chal Landgren, OSU Christmas Tree Specialist retired in 2020 and has been working part-time. Gary Chastagner, Research Plant Pathologist at WSU, is planning to retire in the next 1 to 2 years. University administrators are looking for an objective assessment of current and future industry needs relating to the research and extension to hopefully, configure positions to meet future needs.
To that end, we conducted an industry wide needs assessment survey in January 2022. There were 147 responses from Oregon, Washington, and Idaho participants. The study objectives for the assessment were:

A. Identify industry concerns in the near-term (next 10 years), to set research agendas.

B. Establish preferences for information dissemination, to determine Extension priorities.

C. Characterize the industry (e.g., size, location, future intent).

We will summarize survey results and strategies for refilling Christmas tree related research and extension positions.

## Identification of top performing trees for establishing Turkish and Trojan fir clonal seed orchards

Gary Chastagner[1], David McLoughlin[1], Kathy Riley[1], Don Sherry[1]

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Recent research trials, such as the Collaborative Fir Germplasm Evaluation (CoFirGE) Project, have shown that certain sources of Turkish and Trojan firs have the potential to make excellent Christmas trees, particularly in the Pacific Northwest. The CoFirGE project consists of a series of common garden plots which were established in the U.S. during 2013 to evaluate the regional adaptability and quality of Turkish and Trojan fir Christmas trees. Each planting contains approximately 3,500 trees and includes progeny from 55 Turkish firs (3 provenances), 34 Trojan firs (2 provenances) from Turkey, and seedlings from proven Christmas tree sources of balsam, Fraser, grand, Korean, noble, Nordmann (3 provenances and 2 Danish seed orchards) and white fir. One of the objectives of the CoFirGE project is to identify top performing trees that could be used to establish clonal Turkish and Trojan fir seed orchards. During the past 8 years, we have collected bud break (2014-2019), annual growth rate, final grade and "consumer" acceptability (2021), and postharvest needle retention (2017-2020) data for each of the trees in the Nisqually CoFirGE plots in western Washington. How these data have been used to identify the top performing individual Turkish and Trojan fir trees that will be used to establish grafted seed orchards will be discussed during this presentation.

## Variation among Nordmann fir somatic clones in the needle disorder 'bare shoulders', needle color and interrelation to nutrient content

Jing Xu[1], Morten Ingerslev[1], Ulrik Braüner Nielsen[1]

1. University of Copenhagen, Department of Geosciences and Natural Resource Management. Rolighedsvej 23, 1958 Frederiksberg C, Denmark.

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For Nordmann fir Christmas trees dark green needles are an important characteristic and fertilization is mandatory during cultivation, but still variation is seen among individual trees as well as nutrient related needle disorders occurs.

The objective of the study is to investigate clonal variation in needle color and the needle disorder 'bare shoulders' and their interrelation with needle nutrient content supplemented with soil samples describing soil nutrient content.

The plant material used for the study was 152 somatic clones, from 25 families of Ambrolauri origin, 1639 trees allowing a strong phenotyping of clones as well as an efficient tool for characterizing the micro-geographic variation using spatial analyses. Trees were evaluated for needle color and bare shoulders in two consecutive growing seasons. Three groups of material comprising 8 clones was selected based on estimated breeding values - top, medium and low, respectively for both traits of concern after the first measurement and a needle sample from each tree was analyzed for nutrients. Strong clone differences were seen for color and bare shoulders and micro-geographical patterns was documented by spatial analyses. Based on a multivariate canonical analysis of variance for all selected clones the standardized loadings showed that nitrogen (N) as expected had a strong impact on color, but also strong positive loadings were seen of sulphur (S), potassium (K) and iron (Fe) all meaning darker green color (can1 describing 68 % of the variation in color). For 'bare shoulders' negative loadings meaning less damage was found for sufficient magnesium (Mg) and cupper (Cu) (can1 describing 55 % of the variation in 'bare shoulders'). Interestingly several micronutrients seems to play an important role in distinguishing clones for both traits. Soil samples for nutrient analyses based on maps from the spatial analyses will be presented and discussed (currently under analyses).

## Genetic variation in Christmas tree quality of somatic embryo plants of Nordmann fir

Jing Xu[1], Ulrik Braüner Nielsen[1]

1. University of Copenhagen, Department of Geosciences and Natural Resource Management Rolighedsvej 23, 1958 Frederiksberg C, Denmark.

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Christmas trees represent a unique forest product that commands high prices for trees with desired characteristics. To increase the levels of improvement potential from tree improvement programmes, attention has turned to somatic embryogenesis (SE), which is a vegetative propagation method that potentially can produce clonal material that grows at a uniform rate, making management more predictable as well as producing a more uniform and higher quality product.

In Denmark, SE clones were achieved in Nordmann fir (*Abies nordmanniana*), which is the most popular used Christmas tree species in Europe. Several clonal field trials have been established at autumn 2014 and 2015 in Denmark. The seeds underlying the clonal material were originated from a direct import from 27 trees grown in the Ambrolauri/Tlugi region in Georgia. Furthermore, seeds harvested from Danish seed orchards (originated from Borshomi area in Georgia) were also used for producing SE clones. This study aims at evaluating the field performance of 255 Nordmann fir SE clones, a total of 3828 trees, with regards to Christmas tree production in three sites. Christmas tree quality and growth traits were measured in all three trials, and additive and non-additive genetic variances are partitioned in each site. The first results in general indicate a large family variance (additive), but also important clone variation (non-additive). Clonal performance stability was also explored by multi-sites analysis. Fairly high additive genetic correlations were seen across sites (range 0.56~0.99) for all traits except Christmas tree quality score (range from 0.11 to 0.79), indicating strong genotype by environment interaction for Christmas tree quality. Results and implication for breeding and production potential will be discussed in the presentation.

## A national progeny test (CoFirGe 2)- A discussion about next steps

Chal Landgren[1], Gary Chastagner[2], Rick Bates[3]

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A progeny test, modeled after the Cooperative Fir Germplasm Evaluation trial, (CoFirGe) is scheduled for planting in Spring 2023, after 2 years of greenhouse growing. The trial is comprised of 12 Trojan fir families, 11 Nordmann fir families plus a mix of seed orchard and provenance collections including Canaan, Fraser, Balsam firs for a total of 34 sources.

The trial will be planted across the US. I'm hoping to use some time at the conference to get input from participants about next steps. Some topics include- Should we consider fall rather than spring planting, what is the best design for field planting and evaluation, how do we coordinate field measurements, what should be "measured" and when, how best to get trees to the sites, what tagging system is best, how/who will get the best trees into seed orchards?

## Genomic and genetic approaches to improve Christmas tree health

Justin G. A. Whitehill[1]

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Fir (i.e. *Abies* spp.) species are the premiere conifer for Christmas tree use around the world. However, firs are extremely sensitive to the global impacts of climate change. Unfortunately, increasing evidence suggests that overall global temperatures are rising at an accelerated rate which is resulting in increased maladaptation of local conifer populations. Firs are generally adapted to cool, moist environments and geographically constrained to high elevation montane ecosystems. When grown as Christmas trees, firs are planted well below their natural elevational range and associated climatic niche. This stresses trees, decreases productivity, and increases sensitivity to pests and pathogens. Traditional genetic improvement methods cannot keep pace with climate change and the associated challenges of increased damage from pests. Instead, improved tree breeding strategies that accelerate the domestication process are needed. To mitigate the future impacts of climate change, the NC State Christmas Tree Genetics (CTG) program is implementing a multi-pronged approach using several genomic strategies. Strategies include both functional and quantitative genomics approaches. Specifically, the Whitehill lab is focusing on identifying key genomic associations in Fraser fir (*A. fraseri*) with important Christmas tree traits such as needle retention and pest resilience. Key pests and pathogens include: (1) *Phytophthora* root rot and the causal agent *P. cinnamomi*; (2) piercing/sucking insects such as elongate hemlock scale (EHS; *Fiorinia externa*); and (3) grazing ungulates like the white-tailed deer (*Odocoileus virginianus*). Christmas trees with natural resilience to these threats are being developed through somatic embryogenesis and identified through genomic selection approaches from existing breeding programs. Genomic approaches have the potential to generate genetically elite Christmas trees in a matter of years instead of several decades. Ultimately, genetic resistance/resilience is the only viable long-term pest management solution that will ensure the continued success of conifers around the world as climate change continues to accelerate.

## Postharvest treatments for spotted lanternfly

Austin Lourie[1], Stephen Corbett[1], Spencer Walse[1,2]

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The objective of this research is to evaluate a suite of postharvest fumigation treatments to limit the geographic spread of spotted lanternfly (SLF). SLF lays eggs masses on a variety of plant and non-plant material, so the need for postharvest fumigation treatments extends beyond the scope of horticultural interests such as those of the Christmas tree industry. The research will be conducted in three Phases: Phase 1 - lab-scale exploratory fumigations, Phase 2 - commercial-scale confirmatory fumigations, and Phase 3 - technology transfer with regulatory and operational outreach. As such, the research will result in efficacious phytosanitary treatments, which can be applied to goods harboring SLF and its egg masses prior to movement from infested areas. Results of Phase 1 trials involving methyl bromide, phosphine, propylene oxide, sulfuryl fluoride, hydrogen cyanide, and ethyl formate will be presented and discussed. In addition, physiological and biochemical features of SLF eggs will highlighted, with focus on relevance to treatment efficacy.

## *Botrytis* spp. obtained in Norwegian forest nurseries are resistant to fungicides

Katherine Ann Gredvig Nielsen[1,2], Magne Nordang Skårn[1], Venche Talgø[1], Martin Pettersson[1], Inger Sundheim Fløistad[3], Gunn Mari Strømeng[1], May Bente Brurberg[1,2], Arne Stensvand[1,2]

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Gray mold, caused by *Botrytis* spp., is a major challenge for forest nurseries producing Norway spruce (*Picea abies*) seedlings. Losses are common despite the use of fungicides for gray mold control. A total of 53 *Botrytis* isolates were obtained from *P. abies* seedlings in Norway from 2013 to 2019. Between November 2018 and June 2019, 68 *Botrytis* isolates were obtained from various locations indoors in three forest nurseries. *Botrytis* isolates were obtained from the air using open agar plates and from various surfaces in production areas using sterile cotton swabs. In addition, four *Botrytis* isolates were obtained from weeds in the genera *Epilobium* and *Chenopodium* growing near *P. abies* seedlings.

*Botrytis* isolates were identified to species level; 90% were *B. cinerea* and more than 60% of these were further characterized as *Botrytis* group S. *Botrytis pseudocinerea* was obtained from *P. abies*, and in a pathogenicity test it infected *P. abies* seedlings, causing development of necrotic tissue and conidiation. Results demonstrate that *B. pseudocinerea* can cause gray mold in *P. abies* seedlings, a *Botrytis* species not previously reported in this host. In addition, four isolates obtained from forest nurseries were similar to *B. prunorum* in regions of the *g3pdh* and *nep2* genes used for species identification.

A mycelial growth assay was used to test for fungicide resistance, and resistance to the following fungicides was detected (percentage of resistant isolates in parentheses): boscalid (8.8%), fenhexamid (33.6%), fludioxonil (17.6%), pyraclostrobin (36.0%), pyrimethanil (13.6%), and thiophanate-methyl (50.4%). The *cytb*, *erg27*, *mrr1*, *sdhB*, and *tubA* genes were analyzed for the presence of known resistance-conferring mutations and those leading to G143A, F412S, ΔL497, H272R, and E198A/F200Y were detected, respectively. Detection of fungicide resistance in the gray mold pathogens in forest nurseries illustrates the need for fungicide resistance management and inoculum control.

## Reaching new and established Christmas tree growers through webinars

Heidi Lindberg[1], Bert Cregg[2], Debalina Saha[3], Riley Rouse[4]

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Webinars provide easy-to-access, convenient, and cost-effective training options for Christmas tree growers. MSU Extension has hosted seven Christmas tree winter webinar series since 2016 covering nutrient, disease, insect, and weed management topics for both new and established growers. The webinar series has been increasingly popular where a total of 694 people participated over the first four years total to the following number of participants in 2020, 2021, and 2022, respectively: 350, 356, and 476. The most recent webinar series during 2022 reached 476 participants from 33 US states and 4 providences of Canada, representing 138,438 acres of Christmas tree production throughout North America. Short term impacts were evaluated at the conclusion of the yearly series and participants received a long-term impact survey a year after the program where they could report the changes in practices and the number of acres affected by the management change. For the 2022 webinar series on weed management, 92% of survey respondents planned on making a change to their weed management strategy, impacting 20,439 acres of production. The webinar series has been successful in distributing information to wide audience of both new and experienced Christmas tree producers and is an important avenue for outreach in the 21st century.

## Deer repellent research and deer browse management in North Carolina

Jeffrey Owen[1]

1. North Carolina State University (NCSU), Department of Forestry and Environmental Resources, Mountain Horticultural Crops Research & Extension Center, Mills River, NC 28759

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Deer browse of young Christmas trees is a devastating problem for many Christmas tree growers in North Carolina and elsewhere. Injury results in culling and replanting of young trees, permanent degradation of tree quality, harvest delays, and eventual abandonment of farms with severe deer browse pressure. Growers have employed hunting, fencing, and repellents to deter deer from browsing with mixed results. Research conducted in North Carolina from 2002 to 2012 resulted in widespread use of inexpensive bulk deer repellents made of inedible egg or spray-dried red blood cell powders. However, these bulk materials were difficult to mix and spray, sometimes limited in availability, and only effective if re-applied on time. Conversations at the 2019 CTRE meeting in Quebec City, Canada led to new deer repellent research using Trico, a European product manufactured from sheep fat. Trico was tested alongside bulk egg and blood repellent treatments in 2020. In 2021, Trico, Bobbex, and Thiram repellents were tested. Results suggest that all repellents tested were effective when re-applied according to recommendations. Trico was noteworthy for still protecting trees at the end of a six month reapplication period rather than the more common two month duration. Adding a new deer repellent to growers' wildlife management strategies is a measure of success, but may not be adequate in the long term. A discussion of rotation-long deer browse management is crucial to sustainable Christmas tree production. Grower decision-making must involve cost of application, treatment duration, and risk management considerations. Repellents represent a relatively inexpensive treatment, but may be inadequate over a ten-year crop rotation.

## Improving conifer establishment using sustainable pest management and soil health practices: First year results.

B. Brown[1], A. Dunn[1], B. Eshenaur[1], E. Lamb[2], L. Sosnoskie[3]

1. New York State Integrated Pest Management Program, Cornell AgriTech, 630 W North Street, Geneva NY 14456
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Seedling establishment continues to be a major loss point in Christmas tree production in New York State. Some growers report using soil additives but have no information on success. In this project, we are evaluating the benefits of alternative weed management practices – comparing conventional herbicides with mulching, cultivation, mowing a grass underseeding and no weed management – and disease management at planting – using RootShield Plus WP, ProPhyt, Subdue Maxx and water- on tree height, trunk diameter, foliage color, and survival, and weed biomass.

The trial used Fraser fir, planted in May 2021, with 4 replicate rows of each weed management treatment, and one plot of seven trees for each root treatment within each row.
Although results from a single season will not show the whole picture, there are some trends. Survival was 82% or higher in each plot. Sample dead trees tested positive for Phytophthora, indicating its presence in the field. Highest overall survival was in ProPhyt and Rootshield treated plots and with cultivation and mulching. Greatest change in height was for water and RootShield treated plants and for untreated and herbicide treated plots. Growth in tree diameter was greatest for trees treated with ProPhyt and RootShield, and where weeds were managed with herbicide and cultivation.

Overviews of installation and first year results can be found in the Biocontrol Bytes blog.

## *Rhizoctonia butinii* on spruce Christmas trees

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*Rhizoctonia* spp. are soilborne fungi that may attack both woody and herbaceous plants, among them conifer species. In Norway, a *Rhizoctonia* sp. used to be an aggressive pathogen on Norway spruce (*Picea abies*) seedlings in forest nurseries (Roll-Hansen & Roll-Hansen 1968), a problem that ceased when the production was shifted from bareroot to plug plants. However, in Denmark serious attacks by *Rhizoctonia* have recently been observed in Norway spruce Christmas trees in western Jutland, Denmark. Sequencing (ITS rDNA) revealed that the damage was caused by *Rhizoctonia butinii*. This fungus has also been reported on white spruce (*P. glauca*) in Slovenia (Hauptman & Piškur 2013) and on several conifers in the USA (Chastagner & LeBouldus 2018).

A laboratory inoculation test with *R. butinii* on Norway spruce seedlings confirmed the aggressiveness. In an ongoing trial in a growth chamber at NIBIO, soil from beneath heavily infected Danish Christmas trees has been used for both Norway spruce seed germination and as growth medium for seedlings obtained from a Norwegian forest nursery.

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## Christmas tree needle retention in response to 1-MCP and dark chamber storage treatments

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The US market share of real Christmas trees has shrunk to less than 20% of that held by artificial Christmas trees. “Messiness” resulting from needle drop is a frequent criticism of real trees. Early harvest, storage, and distribution of wholesale Christmas trees can contribute to poor performance. Identification of treatments to improve Christmas tree needle retention during farm storage is a critical research need of real tree growers. Among plant growth regulator compounds, those that block or otherwise interfere with ethylene influence on needle abscission such as 1-MCP are of particular interest.

1-MCP treatments were made to branches and whole Fraser fir Christmas trees in several postharvest needle retention studies in North Carolina spanning 2010 through 2018. A pattern of slightly better needle retention associated with 1-MCP was observed across different years, experimental designs, and storage conditions. In 2019, dramatically improved needle retention occurred to branches of poor-performing Fraser fir clones treated with 1-MCP. However, this occurred after branches were unintentionally left in their dark 1-MCP gas chamber an extra two weeks.

Studies conducted in 2020 and 2021 sought to repeat 2019 conditions and results. Three rates of 1-MCP gas chamber and spray-applied treatments were tested in 2020 across different storage durations using clones with known needle retention performance. After mixed results in 2020, a full matrix of 1MCP rates and dark storage durations were implemented in 2021 using six clones selected for differing needle retention performance. As in earlier pre-2019 studies, 1-MCP treatments revealed a slight positive rate response in needle retention. However, durations of dark chamber storage without 1-MCP (2, 7, and 14 days) revealed a more significant contribution to differences in needle retention. Results have implications for both future postharvest research and farm storage of Fraser fir Christmas trees.

## Potential Impacts of climate change on diseases and the postharvest quality of Christmas trees

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Our climate and weather patterns have changed dramatically and so have the terms used to describe weather events. Forecasters and the media now use terms such as "atmospheric river", "polar vortex", and "heat dome" to describe meteorological events typically associated with extreme weather. Christmas tree growers are already dealing with the consequences of changes in weather patterns that have altered “normal” precipitation and temperature patterns in many production regions. Growers in areas experiencing drought and extreme heat have already encountered increasing problems related to seedling survival and direct heat damage to larger trees. Changes in our climate and weather patterns are also likely to affect disease development and the postharvest quality of trees. The ways in which climate and weather may affect fungal needle cast diseases, Phytophthora root rot, and postharvest needle retention will be discussed.

## Improving transplant success in *Abies fraseri* Christmas tree plantations

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In the Great Lakes region, of the United States Christmas tree plantations are established by planting seedlings or transplants. Limiting plant moisture stress after planting is crucial to successful establishment of these small conifers. A myriad of products have been marketed to Christmas tree producers with claims to improve transplant success by limiting transplant shock. The objective of this study was to determine the effect of various root dips and cultural treatments on survival and subsequent performance of *Abies fraseri* seedlings. In 2021, we initiated trials at four Christmas tree farms in Michigan. Root dip products applied at planting included 1) DieHard™ Root Dip (endo/ecto mycorrhizae + polymer), 2) MycoApply® Injector Ecto (ectomycorrhizae), 3) SoilMoist™ Fines (polymer), 4) Roots® Terra-Sorb® Fine Planting Gel (polymer), and 5) control. Cultural treatments applied following planting include 1) foliar anti-transpirant spray (Wilt-Pruf® [25% di-1-p-menthane]), 2) organic mulch (varied by location), 3) shade block (20.3 cm x 30.5 cm mesh screen), 4) mulch + shade block, or 5) control. First year survival was excellent (>97%) across all farms. Survival of untreated control trees was 100% at all farms, demonstrating that products and techniques used could not further improve survival. When examined across all farms, leader growth was unaffected by root dip treatments while the combination of mulch + shade blocks improved leader growth compared to the untreated control. The application of Wilt-Pruf reduced transpirational water loss but also reduced photosynthetic rate; otherwise, treatments did not affect gas exchange rates. While plots treated with mulch consistently maintained higher soil moisture, foliar nitrogen was lower for mulched seedlings at one farm compared to non-mulched trees. This result may suggest possible nutrient tie-up related to mulch use, or the lower foliar N values may be in response to growth dilution. Overall, first year survival and outplanting performance of *A. fraseri* seedlings was largely unaffected by root dip or cultural treatments.

## S-Abscisic Acid (ConShape) for Christmas tree leader control

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Leader growth control of the tree is one of the most important production technology elements in Christmas tree production. It greatly impacts tree size, shape and ultimately the value of the tree. In the past, mechanical leader control was practiced by manual shearing which effectively reduced leader height, but also removed most of the buds from the leader. Therefore, multiple chemical treatment options (e.g., NAA, ethephon, S-Abscisic acid) have been tested in the last decade. Among the treatments evaluated, S-Abscisic Acid, a naturally occurring plant growth regulator, appears to provide the most consistent results. This presentation gives a historical background on the development of S-Abscisic Acid for Christmas tree leader control, marketed under the brand name ConShape. The presenter will also discuss application techniques of the product and summarize efficacy data on various Christmas tree species from Europe and the US, where ConShape has been registered and successfully used for leader control.

## Improving first year noble and Douglas-fir seedling survival and growth in Pacific Northwest Christmas tree plantations

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The Pacific Northwest (PNW) has seen increasingly dry and hot summers over the past decade resulting in high mortality rates of newly planted noble fir seedlings in Christmas tree plantations. The majority of Christmas trees grown in the PNW are dry-land produced. In late June of 2021, a prolonged period of excessive heat, referred to as a heat dome, caused temperatures to soar to record breaking highs in Washington and Oregon. Temperatures reached 118 °F (48 °C) in major Christmas tree production regions of Oregon. Past trial data indicates typical noble seedling mortality ranges 10-15%, during the first year. Many PNW growers experienced significantly higher mortality percentages in 2021. Many growers suffered 70-80% mortality and some complete crop losses.

To explore options of improving seedling survival, trials were established in March 2022 to increase survival and growth of first year noble fir (*Abies procera*) and Douglas-fir (*Pseudotsuga menziesii*) at three grower sites in the PNW. The trial is investigating three promising pre-plant treatments and wood chip mulch, which has proven to increase seedling survival in past trials at some locations. Two-year old noble and Douglas-fir seedling plugs were hand planted at all sites. Pre-plant treatments include: 1. Mix of, Puric Prime 1-0-2, Nutrio Unlock, Till-It Blue Zone Max 6-24-6, Tricoderma Ecto mycorrhizae, 2. Nucleus 0-0-21-13 and O-Phos, 3. Best Paks 20-10-5. Post-planting treatment: Wood chip mulch applied 2 inch depth (5 cm) in a 12 inch (30 cm) circle around tree. A non-treated control is included for comparison. Height measurements at initial planting, mid-season and at conclusion of trial are planned. Air temperature and tree bio-mass data will be collected throughout the growing period. Seedling mortality and root volume evaluations are planned after fall rains begin in October 2022.

## Conclusion of spring cone control research in North Carolina

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Fraser fir Christmas trees can produce unwanted female cones prematurely after periods of environmental stress. Manual removal of cones can be one of the most expensive practices growers incur over a crop rotation. After 10 years of Fraser fir cone control research in NC, efforts narrowed to killing tender emerged cones in the spring using contact herbicides. Of more than twenty products tested, herbicidal soaps (fatty acid/alcohols) were the most effective at killing cones. Killed immature cones dry to small persistent brown cones. Additional rate and spray coverage work was conducted with two organic herbicides, Axxe (ammoniated pelargonic salts) and Scythe (a fatty acid). Rate and timing studies progressed from testing back pack sprayer to high pressure hose sprayer applications. Treatment success was a function of spray coverage. Both herbicides have potential to injure new growth if applied at the wrong time. Used at the right time – after all cones have broken bud, but before any foliage buds emerge, all rates of Axxe (4 oz., 6oz., 8 oz., 10 oz., 13 oz., and 15 oz.) were used safely. Tree injury occurred in North Carolina with all but the lowest Scythe application rates. A 6% rate of Axxe was effective at killing nearly 100% of cones when full coverage was achieved. Eight percent and 10% rates of Axxe were more consistent at killing cones across less favorable treatment conditions. Volumes of spray needed to achieve full coverage were measured. Estimated cost of treatment using a 6% application rate was less than the estimated cost of manual cone removal currently employed by growers.

## Managing cone formation in Fraser fir Christmas tree plantations: Highlights from the Michigan experience

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Precocious coning is a frequent issue in Fraser fir Christmas tree plantations in the United States. Individual trees can produce hundreds of cones, which are a major sink for photosynthate reserves of trees and result in unsightly cone stalks that reduce tree salability. As a result, cone picking has become a major labor expense for growers. Our research on managing cone formation has focused on three principal approaches: post-emergent control of cones using herbicides, reduction of cone formation using plant growth regulators (PGRs), and selection of late-coning genotypes.

We achieved high rates of post-emergent control of cones (>90% cone kill) with backpack applications of d-limonene (Avenger®), ammonium nonanoate (Axxe®), and pelargonic acid (Scythe®). For all products, proper timing of application and good spray coverage were essential for good cone kill.

Application of PGRs, specifically gibberellic acid (GA)-inhibitors, reduced cone formation by up to 55% compared to untreated control trees. Paclobutrazol reduced cone formation when applied as either a soil application (Cambistat®) or as a foliar application (Trimtect®). In a current trial, we are investigating whether combining soil and foliar treatments can provide additive reduction in cone formation.

We are currently cultivating trees in our container nursery from seed collections from our delayed-coning seed orchard. The seed orchard was established in 2008 with trees that were phenotypically selected from operational plantations for late or sparse coning and excellent tree form. The selected trees were transplanted to the MSU Horticulture Teaching and Research Center to form a research seed orchard. We collected seed from open-pollinated families in 2017 and 2019 and seedling transplants were produced by Peterson's Riverview Nursery in Allegan, MI. We are currently growing the transplants in our container nursery and will evaluate coning of the various families along with nursery-run seedlings from Peterson's Nursery.

# 15th International Christmas Tree Research and Extension Conference

Poster Presentation Abstracts

## *Abies* spp. somatic embryogenic tissue culture pipeline development

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Fir (i.e. *Abies* spp.) species are the premier conifer used for Christmas tree production around the world. Conifers are unique as both an agricultural and forestry crop. Christmas tree production is facing significant challenges due to the effects of accelerated climate change. These challenges include increased pressure from pests and pathogens as well as maladaptation to historic geographic planting ranges. Novel approaches are needed to rapidly advance genetic improvement efforts in order to address the current and future threats to Christmas tree production around the world. One such approach is the use of clonal production of Christmas trees through plant tissue culture. This includes a suite of techniques that employ sterile conditions to propagate plant cells, tissues, or organs on a culture medium supplemented with defined nutrients. Tissue culture methods include: (1) propagation from meristematic tissues; (2) organogenesis; or (3) somatic embryogenesis (SE). SE is widely used in basic research to study plant cells, tissues, organs, and complex systems in a controlled environment. SE can be used to generate clonal lines of genetically identical plants for more extensive analysis. SE techniques must be specifically tailored to the plant species under investigation. In conifers, tissue culture has only been successfully reported through SE approaches. Here, we present experimental timelines and potential future research applications for the development of a robust pipeline for SE production of *Abies* spp. through tissue culture. We also discuss genetic applications including transformation and the potential of CRISPR to modify Christmas tree genomes. SE represents an essential tool for the study of resistance/resilience of fir species to both abiotic and biotic threats.

## Efficacy of eFume and Bluefume (HCN) fumigation in eradicating elongate hemlock scale on Christmas trees

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The elongate hemlock scale (EHS), *Fiorinia externa* Ferris, is an exotic, armored scale insect pest of Christmas trees and other conifers. It is native to Japan and eastern Asia and was first detected in the U.S. in 1908 in Queens, NY. Since then, it has spread throughout most of the eastern U.S. and has become a key pest of true firs (*Abies spp.*) grown as Christmas trees during the past 30 years. EHS has a complex life cycle and can overwinter in several developmental stages. Only the mobile crawlers, which can be present throughout the year can infect new plant material. Movement of infested plant material is the principal way EHS is spread long distances. Although not know to occur in the western U.S., in 2019 EHS was detected on Fraser fir Christmas trees that were shipped from North Carolina to a number of western states. While there are questions about the ability of the EHS life stages found on Christmas trees to spread to other hosts, regulatory agencies issued stop sale notifications and ordered infested trees to either be returned or destroyed. Since 2020, we have evaluated the effectiveness of postharvest ethyl formate (EF), sold commercially as eFume, and hydrogen cyanide (HCN), sold commercially as Bluefume, fumigations for killing EHS life stages on infested Fraser fir branches and determined the effects of these fumigants on the postharvest quality of commonly-grown Christmas tree species, such as balsam fir, Canaan fir, Fraser fir, grand fir, noble fir, Nordmann fir, Turkish fir, and Douglas-fir. The efficacy of EF and HCN in killing EHS was rate and/or fumigation duration dependent. The highest rate of EF and longest exposure to HCN significantly reduced numbers of crawlers that emerged from the scales on treated branches, but they did not eliminate the release of crawlers from EHS-infested shoots. In addition, conifer species varied greatly in their tolerance to fumigation treatments.

## Heat treatment - A potential approach of killing *Megastigmus* larvae in imported conifer seeds

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The production of Nordmann fir and Turkish fir Christmas trees is increasing, particularly in the Pacific Northwest where they now account for approximately 10% of the total trees grown. Domestic conifer nurseries mostly rely on the importation of seeds from natural stands in the Republic of Georgia, Russia, and Turkey to produce the planting stock of these species. Insect pests currently threaten the consistent supply of imported seeds and planting stock, and none are more common than conifer seed wasps from the genus *Megastigmus*. These insects lay eggs within premature seeds while still in the cone, and the larvae nourish themselves on resources meant for the seed embryo. They can lie dormant within seeds for several years even after the cone has matured. Within the past few years, APHIS PPQ has returned or destroyed considerable numbers of imported seed shipments due to the detection of live *Megastigmus* larvae. There is currently no APHIS approved post-entry treatments for *Megastigmus*-infested conifer seeds, so importers have no recourse. Previous work on Douglas-fir, indicates that heat treatment of seeds may be an effective way of killing larvae in seeds. Given the lack of information on the effectiveness and crop safety of heat treatments to mitigate insect pests on Nordmann or Turkish fir seed, studies were conducted to determine threshold temperatures and durations that effectively kill larvae infesting Nordmann and Turkish fir seeds. After heat treatments ranging from 35 to 50 °C for either 24 or 48 hours, seed from infested seed lots were dissected after 7 days to assess larval mortality. Only temperatures $\geq$ 45 °C for 48 hours consistently killed 100% of larvae. While heat treatment appears to be a promising approach of killing *Megastigmus* larvae in seeds, research is currently underway to determine if these treatments have any adverse effects on seed germination and growth of seedlings.

## Insecticide toxicity, application efficacy, and degree-day modelling of an emergent Christmas tree pest, the Douglas-fir twig weevil (*Cylindrocopturus furnissi*)

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The Douglas-fir twig weevil (*Cylindrocopturus furnissi*) is a problem on virtually all species of Christmas trees grown in the Pacific Northwest. Historically it has been a sporadic problem on Douglas-fir Christmas trees, particularly on trees planted on sites that are prone to moisture stress. However, during the past few years, this pest has emerged as a significant export issue and affects growers' ability to develop a quality tree for both domestic and export markets. It is also affecting the marketability of noble fir boughs in low elevation production stands. Twig weevil is the number one insect pest causing load rejections into Mexico. From 2014 to 2018 over 50% of the rejected Christmas tree loads shipped from Oregon to Mexico were rejected due to twig weevil. In an effort to develop a pest management strategy on adult weevils, the most susceptible life stage to contact insecticides, we (1) conducted laboratory experiments to determine which commonly used pesticides are most effective, (2) compared the effectiveness of aerial vs grand-based application of esfenvalerate in killing twig weevils, and (3) developed a degree-day model for adult emergence. Two pyrethroids, bifenthrin and esfenvalerate, were the superior chemistries, killing weevils faster on contact and more reliably after a long residual period than the organophosphates we tested. Both aerial and ground-based applications of esfenvalerate were highly effective in killing weevils upon exposure to current-season and one-year-old growth from treated trees. The number of growing degree days (base 50 °F, January 1$^{st}$ biofix, single sine method) for 50% of the adult weevil population to emerge ranged from 1000 to 1200, with the entire emergence window ranging from 500 to 1500. Results have provided a springboard for further research into Douglas-fir twig weevil management in Pacific Northwest Christmas trees. Field testing the efficacy of the optimal insecticides and timing from this research will be a future focus.

## Controlling glyphosate-resistant weeds with alternative herbicides in Fraser fir Christmas trees

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Christmas tree growers in North Carolina and across the US struggle to control glyphosate (Roundup) resistant weeds. NC growers have recurring glyphosate treatment failures with three annual weeds: horseweed or marestail, *Conyza canadensis* L., common ragweed, *Ambrosia artemisiifolia* L., and lambsquarters, *Chenopodium album* L. Not only are many populations of these weeds resistant to glyphosate, but in other cropping systems these species have been reported to have also evolved resistance to other families of herbicides. Control of herbicide-resistant weeds is particularly challenging in NC Fraser fir production fields where growers are trying to maintain living ground covers beneath trees to protect steep mountain soils.
The purpose of current research is to identify safe and effective pre- and postemergence herbicides with different modes of action that may control these target weeds without killing white clover (*Trifolium repens*) ground covers. Preemergence herbicides tested include Goal (oxyflurfen), Princep (simazine), Pendulum (pendimethalin), Esplanade (indaziflam), and Sureguard (flumioxazin). Initial research indicates certain products control certain problem weeds better than others and product selection must be based on weed populations. White clover tolerance of these herbicides is variable but better than expected. Postemergence herbicides tested include FirstRate (cloransulam-methyl), Harmony (thifensulfuron-methyl), 2,4-D amine, Frequency (topramazone), and Python (flumetsulam). FirstRate and Harmony continue to provide promising levels of horseweed and lambsquarters control, respectively, but are at risk of their own weed resistance issues. 2,4-D amine and Python applied prior to budbreak controlled horseweed and did not injure Fraser fir trees, but caused unacceptable injury when applied to actively growing trees. Additional research is underway to confirm efficacy on glyphosate tolerant ragweed. Product registrations continue to be sought, with assistance of the USDA IR-4 Environmental Horticulture Program.

## Strategies to address emerging weed management challenges in Christmas tree production using herbicide and organic mulch combinations

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Weed competition directly impacts rate of Christmas tree growth during the second and third years of establishment. The objectives of this study were to evaluate the weed control efficacy of organic mulch and herbicide combinations and determine phytotoxic effects on four species of Christmas trees during their establishment stage. The experiment was conducted at Christmas tree farms in Michigan. Christmas tree species studied were Fraser fir [*Abies fraseri* (Pursh) Poir], blue spruce (*Picea pungens* Engelm.), white pine (*Pinus strobus* L.), and Scotch pine (*Pinus sylvestris* L.). Initial and final tree growth indices were taken. The dominant weed species in each field was recorded before treatments. Twelve treatments consisted of herbicides (clopyralid, oxyfluorfen, and glyphosate) and organic mulch (cypress bark), either applied singularly or in combinations, and control (no herbicide and no mulch). The experiment was done in complete randomized block design with four replications of each treatment per field. Liquid formulations of oxyfluorfen, glyphosate, and clopyralid were applied at their highest labeled rates uniformly with a $CO_2$ backpack sprayer. Data collection included visual estimation of weed control and phytotoxicity at 30, 60, and 90 days after treatment (DAT) using a scale of 0% (no control/no tree injury) to 100% (complete control/death). At 90 DAT, results showed that mulch combined with herbicide combinations can provide 70-100% weed control in all cases. However, clopyralid showed 26% and clopyralid + oxyfluorfen + glyphosate combination provided only 19% weed control in the field where the dominant weed species was common ragweed (*Ambrosia artemisiifolia* L.). Combinations of mulch + clopyralid + glyphosate and clopyralid + oxyfluorfen + glyphosate showed phytotoxic effect on blue spruce and Fraser fir, respectively. Whereas combinations of clopyralid + oxyfluorfen + glyphosate and mulch + clopyralid + glyphosate caused injury to Scotch pine.

## Controlling weeds by non-chemical methods in Christmas tree production

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Weed control is an essential aspect for successful Christmas tree production from both aesthetic and biological perspectives, and for obtaining high quality marketable trees. Weeds interfere with tree growth at any time and can even interfere with pruning practices. Effective weed control is extremely important for initial conifer seedling survival and in the first three years after transplanting in the field, during their establishment phase. Growers mostly rely on mechanical mowing and applications of herbicides for weed control in Christmas tree fields. However, herbicides can be phytotoxic to Christmas trees, cause environment related issues, and their repeated applications can lead to herbicide-resistant weeds. Therefore, there is an immediate need to adopt alternative nonchemical weed control strategies in Christmas tree production. Foremost, introduction of weed seeds can be prevented by controlling weeds along farm roads, maintaining clean equipment, and eliminating new weeds before they start seeding. Mowing can reduce the number of seeds produced by the weeds and significantly reduce competition with trees. Shropshire sheep can be allowed grazing in Christmas tree plantations as they prefer grazing on grasses and weeds rather than coniferous trees. Organic mulching is another method for weed control, which improves soil moisture, maintains soil temperature, and enhances plant establishment and survival. Incorporating cover crops into Christmas tree plantations can improve tree growth and quality, soil fertility and can supplement conventional nitrogen fertilizers. However, if cover crops are not properly managed, they can be highly competitive with the trees. Flaming can cause suppression of many annual weed species. Several insects have also been used as biological agents to control selective weed species. However, further research is required to focus on several potential biological agents, different types and depths of mulching, cover crop types and their effects on seedling survival and growth.

## Inoculation experiment with subalpine and Fraser fir seedlings planted in a stand of old subalpine fir heavily infested by *Neonectria neomacrospora*

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Neonectria canker (*Neonectria neomacrospora*) is one of the most destructive diseases in Norwegian fir (*Abies* spp.) production. Delphinella shoot blight (*Delphinella abietis*) is another serious disease on fir, especially subalpine fir (*A. lasiocarpa*). A few growers are currently trying out Fraser fir (*A. fraseri*) as a potential Christmas tree under Norwegian conditions. It has been observed that Frasier fir is less susceptible to *D. abietis* than subalpine fir. To get a better understanding of potential tolerance of Fraser fir against the two diseases, inoculation experiments were initiated in 2020. Here we report from the *Neonectria* experiment.

Fraser and subalpine fir seedlings were planted under a more than 50-year-old subalpine fir stand heavily infested with *N. neomacrospora* (November 6). Most of the old trees were dead or dying. The seedlings were 2-year-old plug plants, and 45 of each species were planted in two circles around a dying subalpine tree in the center of the stand. There were approximately 30 cm between each seedling, and in both circles the two species were planted every other time. An additional ten plants (five per species) were planted as control a few km away. Unfortunately, they were destroyed, probably by roe deer.

The trial ended on November 18, 2021. All plants where cut at the stem base and investigated in a dissecting microscope. Of the Fraser fir and subalpine fir seedlings, 93% and 94% had red perithecia of *N. neomacrospora*, respectively. It was concluded that Fraser fir is equally sensitive to *N. neomacrospora* as subalpine fir. However, the disease pressure at the site was massive and much higher than it would normally be in a Christmas tree field. Nevertheless, the results suggest that Christmas tree growers that are shifting subalpine fir for Fraser fir should be aware that Fraser fir is susceptible to *N. neomacrospora*.

## Diseases on fir (*Abies* spp.) Christmas trees in Scandinavia

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A poster based on this abstract will present an illustrated overview of symptoms and signs of diseases on fir Christmas trees in Norway, Sweden, and/or Denmark. Below the diseases are alphabetically arranged by the scientific names of the causal organisms.
Foliar diseases: Herpotrichia needle browning (*Herpotrichia parasitica*), fir-willow rust (*Melampsora abieti-capraearum*), interior needle blight (*Phaeocryptopus nudus*), silver fir needle rust (*Pucciniastrum epilobii*), Rhizosphaera needle cast (*Rhizosphaera kalkhoffii*), and current season needle necrosis/CSNN (*Sydowia polyspora*).
Shoot, branch and stem diseases: grey mould (*Botrytis* sp.), Cytospora canker (*Cytospora* sp.), Delphinella shoot blight (*Delphinella abietis*), Brunchorstia dieback (*Gremmeniella abietina*), Neonectria canker (*Neonectria neomacrospora*), Phomopsis canker (*Phomopsis* sp.), and Sclerophoma shoot dieback (*S. polyspora*).
Root and butt rot diseases: Armillaria root rot (*Armillaria ostoyae*), annosus root rot (*Heterobasidion annosum*), and Phytophthora root rot (*Phytophthora* spp.).
The most serious diseases, i.e. resulting in mortality, are Armillaria root rot, annosus root rot, Phytophthora root rot, and Neonectria canker. However, severe attacks by *D. abietis*, *H. parasitica, R. kalkhoffii, S. polyspora,* and the rust fungi may destroy the aesthetical value and make the trees unsalable. Less prevalent diseases where only minor damage has been observed, are grey mould, Brunchorstia dieback, interior needle blight, Phomopsis canker, and Cytospora canker.

## Diseases on spruce (*Picea* spp.) Christmas trees in Scandinavia

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A poster based on this abstract will present an illustrated overview of symptoms and signs of diseases on spruce Christmas trees in Norway, Sweden, and/or Denmark. Below the diseases are alphabetically arranged by the scientific names of the causal organisms.
Foliar diseases: Chrysomyxa needle rust (*Chrysomyxa abietis*), Lirula needle cast (*Lirula macrospora*), web blight (*Rhizoctonia butinii*) - eventually killing branches, and Rhizosphaera needle cast (*Rhizosphaera kalkhoffii*).
Bud disease: Cucurbitaria bud blight (*Gemmamyces picea*).
Shoot, branch, and stem diseases: grey mould (*Botrytis* sp.), Cytospora canker (*Cytospora* sp.), Neonectria canker (*Neonectria fuckeliana*), Phomopsis canker (*Phomopsis* spp.), Sclerophoma shoot dieback (*Sydowia polyspora*), and cherry/spruce rust (*Thekopsora areolata*).
Root and butt rot disease: Armillaria root rot (*Armillaria* sp.).
The most serious disease, i.e. resulting in mortality, is Armillaria root rot. However, severe attacks by *G. picea, L. macrospora*, *R. butinii*, *R. kalkhoffii*, *S. polyspora,* and the rust fungi may destroy the aesthetical value and make the trees unsalable. Only minor damage has been observed by grey mould, Cytospora canker, and Phomopsis canker. However, *N. fuckeliana* seems capable of killing the upper whorls of spruce Christmas trees.

## Regional variation in postharvest needle loss from trees in CoFirGE planting sites

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Regional cooperators with Collaborative Fir Germplasm Evaluation (CoFirGE) Project common garden plots in CT, MI, NC, OR, PA (Connecticut Agricultural Experiment Station, Michigan State University, North Carolina State University, Oregon State University, and Pennsylvania State University), collected branches from families of Turkish fir (6) and Trojan fir (4), along with one source each of Nordmann, balsam and Fraser fir to determine if there was a good correlation in the ranking of needle loss (NL) patterns for the sources irrespective of where the trees were grown. These sources were selected because they exhibited a wide range of NL in preliminary tests of material from the plot in WA. Branches were harvested and shipped overnight to WSU Puyallup for early season NL testing in mid-October 2019 and 2020 to maximize NL differences. The branches were displayed dry in a lighted (24 hrs) display room at 20C, and the loss of 1 and 2-yr-old needles on each branch was rated on a scale of 0 to 7 over a 10 to 13-day period. There were significant differences in the NL ratings for the 13 sources of trees tested. For example, the family ratings for the branches from the different sites ranged from 3.16 to 0.30 in 2019. Balsam fir had the highest NL ratings at all of the sites. Rank mean correlation analysis of the data indicated that there was generally a significant correlation between the NL rankings from site to site. This suggests that NL rankings done at one site potentially can be used to identify sources of trees that will exhibit excellent needle retention over widely different production regions.

## A final look at bud break variation in families of Turkish and Trojan fir trees in the CoFirGE plots in Washington

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Bud break is an important attribute relating to the regional adaptability of species and seed sources of Christmas trees, particularly in more northern production areas. Early bud break predisposes trees to a greater risk of damage associated with late spring frosts. In 2013, a series of regional common garden plots were established in the U.S. as part of the Collaborative Fir Germplasm Evaluation (CoFirGE) Project to evaluate bud break as one aspect of the regional adaptability and quality of Turkish and Trojan fir Christmas trees. Each plot contained progeny from trees along an elevation gradient of three provenances of Turkish fir and two provenances of Trojan fir, along with several sources of Nordmann fir and single sources of common North American Christmas tree species. There are two CoFirGE plots in western Washington. The Nisqually plot contains a full set of trees, while a plot which contains a smaller subset of trees is located at WSU Puyallup. A one-time evaluation of bud break and shoot development was done on all the trees in the Nisqually plot every spring from 2014 through 2019. Ratings ranged from 0 (no bud swell) to 6 (shoots fully elongated). Weekly or biweekly assessments were also made on each of the trees at WSU Puyallup between 2016 and 2020 to obtain the specific date of bud break for each tree. Results indicate that Trojan fir consistently had the highest bud break ratings (broke bud the earliest), followed by balsam, white fir, and Turkish fir. Rank mean correlations indicate that trees and provenances that break bud early do so every year, and bud break ratings were not correlated with elevation of the mother trees. Overall, Trojan firs broke bud about 10 to 14 days before noble and Fraser fir. The tree-to-tree variation in bud break within given sources of trees indicates that even with provenances that tend to break bud early, there are trees that have delayed bud break. One criteria that could be used to identify promising trees is to compare the bud break timing of individual Turkish and Trojan fir trees to when 50% of the Fraser fir trees in the Nisqually and Puyallup plots have broken bud.

## Effect of moisture content on the viability and vigor of Nordmann, Turkish and Trojan fir seeds

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Conifer nurseries in the Pacific Northwest have reported that germination and vigor of two increasingly popular Christmas tree species, Nordmann and Turkish fir, degrade significantly after one or two years in cold storage. These nurseries rely heavily on imported sources of seed for these species, so improvements to storage longevity would greatly benefit the Christmas tree industry. The moisture content (MC) that seeds are dried to and temperature they are stored at are two important factors that affect the viability and vigor of stored seeds. Conifer seeds in the United States are mostly stored at moisture contents of 8-10% and temperatures of -10 °C. Several studies of *Abies* species, including one of Nordmann fir, indicate that a lower seed MC of 6-8% and a storage temperature of -18 °C can better maintain viability and vigor of stored seed. Seed importers have commonly noted that the MC of imported seed tends to be in the 10-12% range. This, along with potentially less-than-ideal storage temperatures may contribute to the limited success in storing seeds for extended periods of time. In 2021, a 3-year storage trial was initiated to test whether reducing seed MC and storage temperature can increase the lifespan of these valuable seeds. Four domestic [Turkish (2) and Nordmann fir (2)] and seven imported [Nordmann (6) and Trojan (1)] seed lots were obtained and depending on their initial MC were dried at 26.7 °C to MC ranging from 4 to 11%. To examine the influence of MC on initial seed quality, tests were conducted to assess germination, enzymatic activity, accelerated aging, and speed of germination. Results indicated that the MCs tested had very little, if any effect on seed quality. Aliquots of each of these seed lots are being storage at -10 and -18 °C to examine the interactions of MC and storage temperature to determine the optimal MC and storage temperature for sustaining seed viability and vigor.

## Nitrogen stabilizers do not improve growth or foliar nutrition of Fraser fir Christmas trees

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Nitrogen stabilizers are fertilizer additives that conserve nitrogen (N) applied as fertilizer by reducing volatilization of urea and/or inhibiting nitrification. In agronomic systems, N stabilizers often reduce N losses and improve crop yields. However, there are many differences between Christmas tree plantations and conventional agronomic farming that could affect the utility of N stabilizers in conifer production systems.

In spring 2016, we established trials at four tree farms in Michigan. Three of the trials were in Fraser fir (*Abies fraseri*) plantations and one trial was in a Black hill spruce (*Picea glauca* var. *densata*) plantation. In each trial, we established replicated plots of seven N fertilizer/stabilizer treatments. The treatments included an unfertilized control, two standard fertilizer treatments (urea or ammonium sulfate), one polymer coated urea product (ESN®), and three N stabilized products (Instinct®, Nitrain™ Express, SuperU®). We applied all fertilizer at a rate of 28 g (1 oz.) of N per tree. Fertilizer was applied in May 2016, and treatments were re-applied in 2017 and 2018. Current year shoot growth was measured in 2016, 2017, and 2018, and foliar samples were collected for N analysis in October 2016, 2017, and 2018.

There was no difference in shoot growth between unfertilized (control) trees and any fertilizer treatment. Fertilization increased needle N concentration compared to not fertilizing (control), but the coated urea and the stabilized-N fertilizers did not increase needle N compared to standard fertilization with urea or ammonium sulfate.

Alternative N sources did not provide any benefit over conventional sources of N despite their additional costs. Potential N losses due to volatilization are low in Christmas tree systems and can likely be addressed through standard best practices such as avoiding urea fertilization in hot weather and incorporating fertilizer when possible.

## Conference Registrants

(as of May 5, 2022)

### In-person attendees

| Name | | Title | Affiliation | e-mail |
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