Proceedings of the 10th International Christmas Tree Research & Extension Conference

August 21–27, 2011

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Title
Proceedings of the 10th International Christmas Tree Research & Extension Conference
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Held by the Christmas Tree Growers Association of Lower Austria

Editor
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Foreword

The 10th International Christmas Tree Research and Extension Conference was hosted by the Christmas Tree Growers Association of Lower Austria. By all accounts, both participants and spouses were treated to a fantastic week of research findings, great food, history, and scenic beauty. The conference included the presentation of 32 papers, 10 posters, and presentations and discussions at a number of farm tour sites across Austria. This conference was the most international of all, with 11 countries represented in attendance.

This conference was the most recent in the following sequence:

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

Thanks are in order to a number of groups, individuals, and tree farms. First, thanks to Karl Schuster and the Chamber of Agriculture. Without Karl's planning, superb organizational skills, and sense of humor, the conference would not have been possible. Ursula and Rainier Hass spent the week with us, organized the Spouses tour, provided a cultural perspective on Austria, and solved problems we never heard about. Our farm hosts shared their time, families, and homes to give all of us an inside view of Christmas tree farming in Austria.


Franz Raith, president of the Lower Austrian Christmas Tree Grower Association, Chal Landgren, and Maria Raith

The 2013 meeting, if all goes as planned, will be held in Nova Scotia, Canada.

Conference hosts

Karl Schuster, Chamber of Agriculture of Lower Austria
Chal Landgren, Oregon State University

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Early-rotation growth characteristics of balsam fir grown in western Washington

Gary Chastagner[1] and Gil Dermott[1]
[1]Washington State University, Puyallup Research and Extension Center

Balsam fir (*Abies balsamea* (L.) Miller) has historically been an important Christmas tree species, particularly in the southeastern portion of Canada and northeastern United States. It occurs naturally from northern Alberta to Labrador, southward to Pennsylvania. It is found from sea level to about 5,000 feet in elevation. This geographical distribution is larger than any other North American fir species. A variety of balsam fir, *Abies balsamea* var. *phanerolepis*, occurs as far south as West Virginia and Virginia. This variety is best described as an intermediate form between balsam fir and Fraser fir and is sometimes referred to as a “bracted” balsam fir or Canaan fir.

As a Christmas tree, balsam fir has several desirable characteristics. It has a dark-green appearance, an attractive form, and a long-lasting, pleasing fragrance. Balsam fir boughs are also used to make a number of evergreen decorations, such as wreaths and kissing balls. Post-harvest needle retention is an important characteristic of high-quality Christmas trees and evergreen decorations. However, unlike Fraser fir, balsam fir has variable post-harvest needle retention. Recent research on trees in several northeastern states and Nova Scotia has shown that there is significant tree-to-tree genetic variation in needle retention, suggesting that it should be possible to identify sources of balsam fir with superior growth and needle retention characteristics.

To examine variation in growth and post-harvest needle retention among sources of balsam fir, a replicated planting was established at WSU Puyallup. The following is a preliminary report on the early-rotation growth characteristics of 34 sources of balsam fir.

Methods

In 2008, a replicated common garden field trial was established at the Washington State University Research and Extension Center in Puyallup, WA to evaluate the growth and post-harvest characteristics of 26 provenances of balsam fir (*A. balsamea)* and 8 progeny collections of “bracted” balsam fir (*A. balsamea* var. *phanerolepis)* (Table 1 and Figure 1). Seed was obtained from the Canadian Forest Service’s National Tree Seed Center, and seedlings were plug-grown for one season by Kevin Potter at North Carolina State University before shipping to Puyallup, where they were grown in a transplant bed for two additional seasons. The P+2 seedlings were then outplanted in February of 2008 in a 1.08-acre (0.44-hectare) 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.

Table 1. Seed source index.

WSU#	Taxon	Location	State/Province	Elevation (m)
40	*A. balsamea*	Lincoln	Vermont	na
41	*A. balsamea*	na	Wisconsin	na
42	*A. balsamea*	Ottawa	Ontario	74
44	*A. balsamea*	North Grant	Nova Scotia	125
45	*A. balsamea*	Woodfield	Nova Scotia	200
46	*A. balsamea*	Spar Lake	Nova Scotia	61
47	*A. balsamea*	Granville Ferry	Nova Scotia	40
48	*A. balsamea*	Sheephouse Brook	New Brunswick	450
49	*A. balsamea*	Bay d’Espoir	Newfoundland	200
51	*A. balsamea*	West River Station	Nova Scotia	170
52	*A. balsamea*	Onslow Mountain	Nova Scotia	155
53	*A. balsamea*	Carleton	Nova Scotia	61
54	*A. balsamea*	North River	Nova Scotia	425
56	*A. balsamea*	Lac Rerock	Quebec	395
57	*A. balsamea*	Castaway	New Brunswick	40
58	*A. balsamea*	Bishop Mountain	Nova Scotia	175
59	*A. balsamea*	Mermaid	Prince Edward I	8
60	*A. balsamea*	Williamsdale	Nova Scotia	250
61	*A. balsamea*	Central Blissville	New Brunswick	40
62	*A. balsamea*	Harewood	New Brunswick	100
63	*A. balsamea*	Mechanic Settlement	New Brunswick	300
64	*A. balsamea*	Canoose	New Brunswick	100
65	*A. balsamea*	Marie	Prince Edward I	30
66	*A. balsamea*	Plaster Rock	New Brunswick	200
68	*A. balsamea*	Acadieville	New Brunswick	80
71	*A. balsamea*	Lac Etchemin	Quebec	800
74	*A. balsamea* var. *phanerolepis*	Sheet Harbor	Nova Scotia	30
77	*A. balsamea* var. *phanerolepis*	Big Salmon River	New Brunswick	165
79	*A. balsamea* var. *phanerolepis*	Fairview	New Brunswick	120
81	*A. balsamea* var. *phanerolepis*	Fairview	New Brunswick	120
82	*A. balsamea* var. *phanerolepis*	Fairview	New Brunswick	120
85	*A. balsamea* var. *phanerolepis*	Fairview	New Brunswick	120
86	*A. balsamea* var. *phanerolepis*	Fairview	New Brunswick	120
87	*A. balsamea* var. *phanerolepis*	Fairview	New Brunswick	120

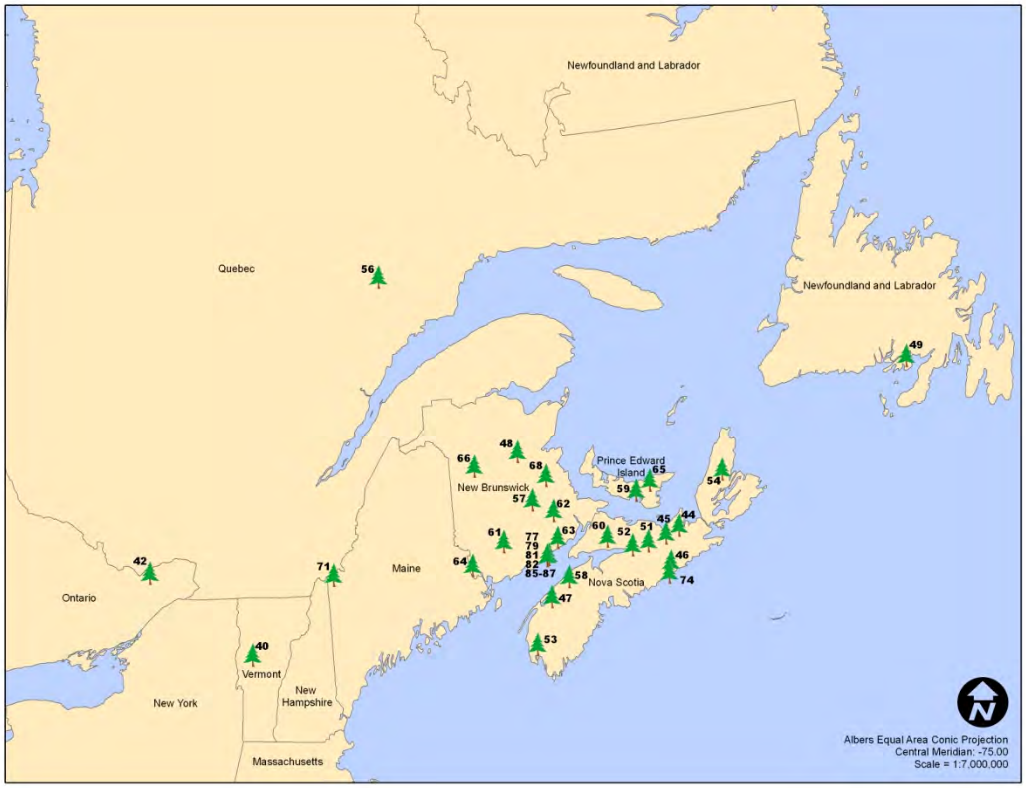

Figure 1. Seed source locations.

Data collected

To obtain a preliminary view of the growth characteristics of the trees in this test, the following data were collected.

- Tree height was measured in August 2010.

- Color was rated on a scale of 1 to 3 in August 2010.
  1 = poor (yellow to pale green)
  2 = average (pale to medium green)
  3 = excellent (medium to dark green)

- Form was rated on a scale of 1 to 5 in August 2010 using the following scale:
  1 = poor (undesirable taper, asymmetry in growth, uneven density)
  3 = good/average
  5 = excellent (good taper, symmetry, and density)

- Budbreak was rated on May 12, 2011 using the following scale:
  0 = tight bud, no bud swell (winter condition)
  1 = buds swelling/elongating, no needle emergence
  2 = bud burst (needles emerging out of scales)
  3 = emerging shoot less than 1" long, needles still “brush-like”
  4 = elongating shoot less than 3" long, needles still soft
  5 = elongating shoot greater than 3" long, needles still soft

Results

There were significant differences among the sources with respect to tree height, budbreak, color, and form. Results were as follows:

- Height ranged from 81.6 to 126.2 cm. Overall, the average height of the eight "bracted" balsam fir progeny (110 cm) was significantly greater than that of the balsam fir (105 cm) (Figure 2).
- There was a wide range in budbreak ratings (1.2–4.2) among the sources, with a higher rating for the balsam fir provenances (3.5) compared to the "bracted" balsam fir progeny (3.2). This difference was small, but significant (Figure 3).
- Color ratings ranged from 1.8 to 2.4 among all the sources, but there was no difference in color among the balsam fir provenances (2.1) and the "bracted" balsam fir progeny (2.1).
- Form ratings ranged from 1.6 to 3.0, and the balsam fir provenances had a higher rating (2.2), compared to the "bracted" fir progeny (2.0). This difference was small, but significant (Figure 4).

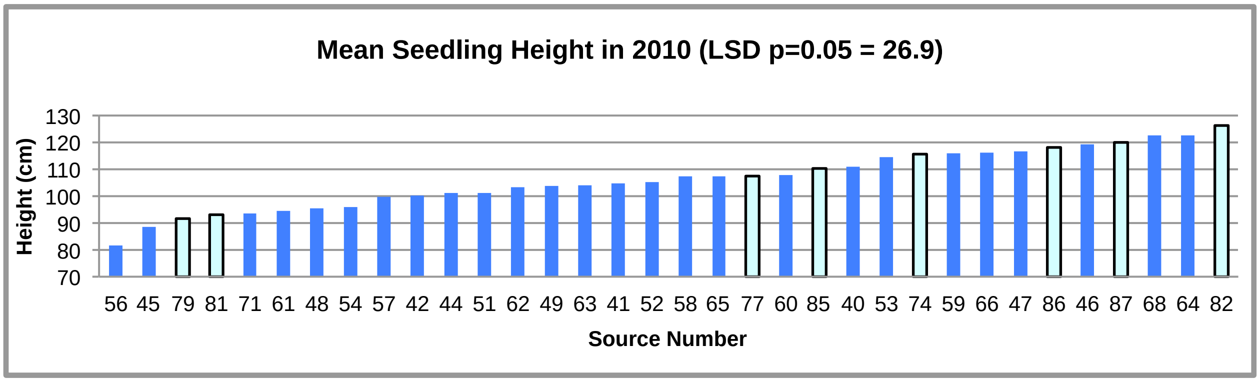

Figure 2. Tree height at the end of the 2010 growing season.

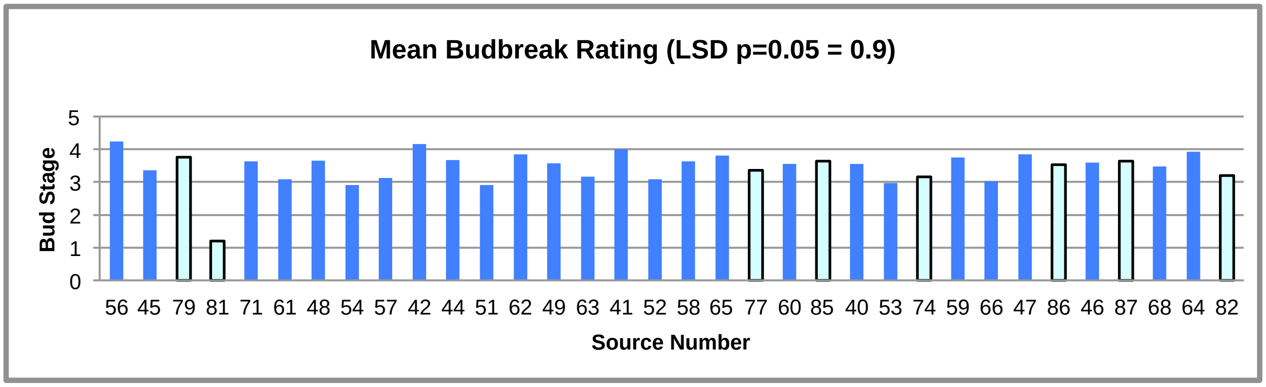

Figure 3. Budbreak rating (May 12, 2011).

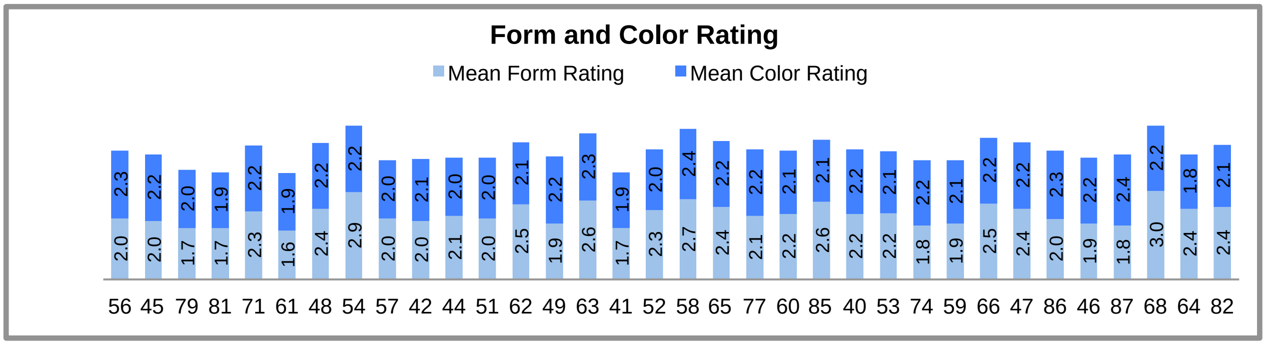

Figure 4. Form and color ratings at the end of the 2010 growing season.

Summary

Limited information is available regarding genetic variation in the growth and post-harvest quality of different sources of balsam fir that are grown as Christmas trees. Although the provenances and progeny included in our trial represent only a very small portion of the natural range of balsam fir, the early-rotation growth data indicate that there are significant differences among the sources when grown in western Washington. To determine the suitability of these seed sources for use as Christmas trees, post-harvest needle retention and additional growth data will be collected over the next 3 years.

Nordmann and Turkish fir production in the U.S. Pacific Northwest: Preliminary budbreak and post-harvest needle retention evaluations

Gary A. Chastagner[1)], Gil Dermott[1)], Kathy Riley[1)], and Chal Landgren[2)]
[1)]Washington State University, [2)]Oregon State University

In 2004, a series of replicated provenance/progeny trials were established in Washington and Oregon to identify sources of Nordmann and Turkish firs that are regionally adapted to Pacific Northwest climatic and production conditions and also exhibit superior post-harvest needle retention characteristics. In this paper, we are reporting on preliminary budbreak and needle retention evaluations that have been conducted on trees in some of these plantings.

Budbreak evaluations

Budbreak data were taken on ~3,700 trees in May, 2011 at 6 of the 2004 Nordmann/Turkish fir planting sites (Nos. 1, 2, 3, 4, 5, and 9) in Washington and Oregon (Figure 1). In addition, a second set of data on ~1,700 of those trees was taken at the 2 Washington State University (WSU)-Puyallup sites (Nos. 1 and 2) on June 6. Each of these sites contained 25 to 50 trees from each of 19 sources of Nordmann and Turkish firs (Table 1).

Figure 1. Location of the 2004 Nordmann and Turkish fir regional genetic trials.

Table 1. Nineteen sources of Nordmann fir (NF) and Turkish (TF) firs from Denmark and Turkey included in 2004 regional genetic trials.

Species	Source
TF	Adapazan-Akyazi
TF	Bursa-Komursu
TF	Adapazan-Hendek
TF	Bolu-Bolu-Kokez
NF	Artvin-Yayla
NF	Trabzon-Torul
NF	Vallo #7
NF	Vallo #9
NF	DSP Nordjylland, Tversted
NF	DSP Aabenraa, Saltberg
NF	Vallo #1
NF	Vallo #12
NF	Vallo #13
NF	Vallo #15
NF	DSP Berritzgaard, Hildesvig
NF	DSP Koberhavn
NF	DSP Randbol 053/00
NF	DSP Randbol 221a + 222
NF	Vallo #18

On each evaluation, the extent of budbreak and shoot growth on each tree was rated on a scale of 0 to 5:

- 0 = tight bud, no bud swell (winter condition)
- 1 = buds swelling/elongating, no needle emergence
- 2 = bud burst (needles emerging out of scales)
- 3 = emerging shoot less than 1", needles still “brush-like”
- 4 = elongating shoot < 3" long, shoots and needles still soft
- 5 = elongating shoot > 3" long, shoots and needles still soft

Results of these evaluations indicate that there was significant tree-to-tree variation in budbreak (Figure 2) and that budbreak also varied by site and rating date (Table 2).

Figure 2. Tree-to-tree variation in budbreak.

Table 2. Variation in budbreak ratings by site and date.

		Rating (0–5)*			
Site no.	**Name**	**May 16–27**		**June 6**	
2	PuyValley	1.19	c	4.19	b
1	PuyHill	0.97	d	4.29	a
4	Scholls	2.10	a		
5	Sublimity	1.18	cd		
3	LaCenter	1.67	b		
9	Kings	1.15	cd		

*Means followed by the same letter are not significantly different (*p*=0.05) Tukey’s Studentized Range (HSD) test.

Overall, there were also significant differences in budbreak rating for the different sources of trees in these trials (Table 3). In general, the Turkish fir tended to break bud earlier than the Nordmann fir. The individual budbreak ratings for each source were ranked from highest to lowest at each site. A Spearman rank order correlation analysis was then conducted to compare the rankings for each site to the rankings at the other sites. This analysis indicated that there was a highly significant correlation in the budbreak ranking from site to site (Table 4). This means that sources that broke bud earlier at one site also broke bud early at all of the other sites.

Table 3. Variation in overall budbreak ratings for sources of Nordmann and Turkish fir at six sites in Washington and Oregon.

Rating*		Species and source	
2.74	a	TF	Adapazan: Hendek
2.63	a	NF	Trabson: Torul
2.48	a	TF	Adapazan: Akyazi
2.43	a	TF	Bursa: Komursu
2.43	a	TF	Bolu: Bolu-Kokez
1.80	b	NF	Artvin: Yayla
1.74	b	NF	Vallo #7
1.34	bc	NF	Vallo #9
1.23	cd	NF	DSP Nordjylland, Tversted
1.20	cd	NF	Vallo #1
1.08	cd	NF	DSP Aabenraa, Saltbert
1.06	cd	NF	Vallo #15
0.90	cde	NF	DSP Aabenraa, Saltbjerg
0.86	cde	NF	Vallo #13
0.77	de	NF	DSP Randbol
0.76	de	NF	DSP Koberhavn
0.74	de	NF	DSP Berritzgaard, Hildesvig
0.56	e	NF	DSP Randbol, Ussinggard Sonderskov
0.55	e	NF	Vallo #12
0.48	e	NF	Vallo #18

*Means followed by the same letter are not significantly different (*p*=0.05) Tukey’s Studentized Range (HSD) test.

Table 4. Spearman rank order correlations for budbreak rankings.*

Site/Date	PH/J	PV/M	PV/J	LaCenter/M	Scholls/M	Sublimity/M	Kings/M
PHill/May	0.879	0.868	0.735	0.951	0.950	0.832	0.854
PHill/June	—	0.837	0.791	0.919	0.886	0.890	0.793
PValley/May	—	—	0.906	0.842	0.876	0.854	0.783
PValley/June	—	—	—	0.848	0.829	0.875	0.735
LaCenter/May	—	—	—	—	0.940	0.907	0.888
Scholls/May	—	—	—	—	—	0.909	0.896
Sublimity/May	—	—	—	—	—	—	0.792

*All *P* values are <0.001, except PH/M vs. PV/J, which is 0.0013.

Post-harvest needle retention evaluations

Needle retention testing was conducted on all of the trees in the two genetic trials at WSU-Puyallup (Sites 1 and 2) and at a grower site in southwestern WA (Site No. 3) to identify sources of trees and individual trees that exhibit superior needle retention characteristics. In order to determine variation in needle retention, 2-year-old branches were harvested between mid-October and mid-November. Branches were transported to WSU-Puyallup for post-harvest needle loss testing. Two branches were cut from each tree, one each from the north and south side. The branches were displayed in a post-harvest room at ~64°F, with continuous light, and were evaluated for needle loss after 10 days of display, using a subjective, 0–7 rating scale:

- 0 = no needle loss
- 1 = <1 percent needle loss
- 2 = 1–5 percent needle loss
- 3 = 6–15 percent needle loss
- 4 = 16–33 percent needle loss
- 5 = 34–66 percent needle loss
- 6 = 67–90 percent needle loss
- 7 = 91–100 percent needle loss

Needle loss ratings varied by species, source, site, and harvest date (Tables 5 and 6). Delaying harvest at the WSU-Puyallup site increased needle retention (Table 6). Overall, when branches were harvested on October 18, only 19.5 percent of the trees had needle loss ratings $\leq$ 1, which is the target for acceptable needle loss. This increased to 61.6 percent when branches were harvested 1 month later. There was also a significant effect of site on needle loss ratings. Only 4.7 percent of the trees at the grower site had acceptable needle loss, compared to more than 60 percent at Puyallup (Table 5) when branches were harvested in mid-November.

Table 5. Comparison of needle loss ratings (0–7 scale) of trees at WSU-Puyallup vs. grower site No. 3.*

WSU Valley site		**Grower site**		
Avg NL	**%≤1**	**Avg NL**	**%≤1**	**Species and source**
0.4	88.0	4.9	0.0	TF Bolu: Bolu-Kokez
0.4	88.0	4.1	4.2	TF Adapazan: Hendek
0.5	84.0	5.9	0.0	TF Bursa: Komursu
0.6	84.0	3.5	8.0	TF AdapazanL Akyazi
0.8	84.0	3.6	4.0	NF Artvin: Yayla
0.4	84.0	3.8	4.3	NF DSP Aabenraa: Saltbjerg
0.7	76.0	3.9	8.0	NF DSP Berritzgaard: Hildesvig
0.8	68.0	4.9	0.0	NF Trabzon: Torul
1.1	64.0	3.7	4.0	NF Vallo #1
0.8	64.0	3.7	12.0	NF Vallo #13
1.0	60.0	4.1	8.3	NF DSP Nordjylland: Tversted
1.2	60.0	3.6	4.2	NF Vallo #18
1.3	56.0	5.0	0.0	NF DSP Randbol
1.3	50.0	3.7	4.0	NF DSP Randbol: Ussinggard Sonderskov
1.7	44.0	3.9	4.2	NF Vallo #15
1.9	36.0	3.4	12.0	NF Vallo #9
1.6	36.0	3.7	4.2	NF DSP Koberhavn
1.8	28.0	4.8	0.0	NF Vallo #12
2.5	12.0	3.4	8.0	NF Vallo #7
1.1	**61.6**	**4.1**	**4.7**	**Overall average**

*Branches collected November 16–18, 2010.

Table 6. Effect of harvest date on needle loss ratings (0–7 scale) at Puyallup Valley site.

Oct. 18, 2010		**Nov. 18, 2010**		
Avg NL	**% ≤1**	**Avg NL**	**% ≤ 1**	**Species and source**
3.4	32.0	0.4	88.0	TF Bolu: Bolu-Kokez
3.0	32.0	0.4	88.0	TF Adapazan: Hendek
2.7	42.0	0.5	84.0	TF Bursa: Komursu
2.6	44.0	0.6	84.0	TF Adapazan: Akyazi
3.4	34.0	0.8	84.0	NF Artvin: Yayla
3.6	30.0	0.4	84.0	NF DSP Aabenraa: Saltbjerg
4.0	8.0	1.0	76.0	NF DSP Berritzgaard: Hildesvig
3.0	32.0	0.8	68.0	NF Trabzon: Torul
4.6	12.0	1.1	64.0	NF Vallo #1
4.9	*4.0*	*0.8*	*64.0*	*NF Vallo #13*
3.9	24.0	1.0	60.0	NF DSP Nordjylland: Tversted
4.1	14.0	1.2	64.0	NF Vallo #18
3.6	26.0	1.3	56.0	NF DSP Randbol
3.6	14.0	1.3	50.0	NF DSP Randbol: Ussinggard Sonderskov
5.0	4.0	1.7	44.0	NF Vallo #15
5.3	4.0	1.9	36.0	NF Vallo #9
5.0	2.0	1.6	36.0	NF DSP Koberhavn
4.2	12.2	1.8	28.0	NF Vallo #12
5.8	0.0	2.5	12.0	NF Vallo #7
4.0	**19.5**	**1.1**	**61.6**	**Overall average**

Additional information on the variation in budbreak and post-harvest needle retention will be collected from the trees in these plantings during the next 2 years. In May 2011, we installed environmental monitoring equipment at six of the Washington and Oregon planting sites where we are focusing our evaluations. The environmental data will be used to obtain a better understanding of the effect of climatic conditions on the yearly variation in budbreak and needle retention. We also plan on using these data to develop a degree-day model to predict the risk of needle retention problems.

Acknowledgments: The assistance of Rick Fletcher at Oregon State University and our industry partners is gratefully acknowledged. This project is being supported by a Washington State Department of Agriculture Specialty Crop Block Grant and the Pacific Northwest Christmas Tree Industry Advanced Research Fund.

The Collaborative Fir Germplasm Evaluation Project

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The Collaborative Fir Germplasm Evaluation (CoFirGE) Project was organized during the summer of 2010 to fund and implement the collection and evaluation of fir germplasm for use in the Christmas tree industry. This collaboration includes members from universities and grower associations in five regions of the United States (Connecticut, Michigan, North Carolina, Pennsylvania, and the Pacific Northwest) and Denmark. The initial focus of the CoFirGE Project is to obtain seeds of Turkish (*Abies bornmuelleriana*) and Trojan (*A. equi-trojani*) fir for evaluation as Christmas trees in a coordinated series of field trials.

During early October 2010, Gary Chastagner, Fikret Isik, Chal Landgren, and John Frampton travelled to Turkey for cone collection. Mr. Muzaffer Topak, who manages a commercial seed collection company in Turkey, served as guide and handled most of the logistics, including obtaining permission from the Turkish Ministry of Environment and Forestry, contracting climbers, reserving lodging, and providing transportation. About 60 cones from each of 20 trees, representing a range of elevations, were collected within each of three provenances of Turkish fir (Akyazı, Bolu, and Karabük) and two provenances of Trojan fir (Çan and Kazdagı).

The collected cones were processed in Ankara, and the extracted seeds were shipped to the U.S. during early 2011. Seedlings from each open-pollinated family and control seedlots of other fir species (Fraser, noble, and Nordmann) are currently being grown to establish a field trial series. Two test sites containing seedlings from each seed lot will be established in each of the five collaborating regions. The trials will be cultured according to regional Christmas tree practices. Throughout the rotation, survival, growth, and quality traits will be assessed using a common protocol.

Eight years after planting, each region can rogue their tests for seed production and/or collect scion material to establish a grafted clonal seed orchard. Additional seeds will be available from most seed lots, and it is anticipated that other collaborative studies involving this material will develop, including evaluating frost hardiness (date of budbreak), Phytophthora root rot resistance, and post-harvest needle retention.

Subalpine fir (*Abies lasiocarpa* ssp.) provenance testing in Denmark

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Abstract

As a potential new Christmas tree species for Danish producers, subalpine fir has been tested on three sites in Denmark. Mortality, forking, numbers of salable Christmas trees, post-harvest quality, damage due to balsam woolly adelgid, and top/branch dieback have been investigated for all provenances. Strongly significant provenance differences were seen. A northern British Columbia provenance, White River, had the overall best performance, and the top 30 trees in

this provenance were selected for establishment of a new seed orchard. The southern corkbark provenances from Arizona and New Mexico showed good potential for Christmas tree production, but suffered recently from severe dieback of tops and branches. This phenomenon is probably related to the fungi *Neonectria* ssp.

Introduction

Subalpine fir has been of interest in the Scandinavian countries for Christmas tree production, and preliminary results were published in 2004 (Hansen et al., 2004). Subalpine fir is naturally distributed in the western part of North America from the Yukon in the north to Arizona and New Mexico in the south (Fowells, 1965) (Figure 1). The species comprises two subspecies—subalpine fir and corkbark fir.

The aim of this study was to identify suitable provenances for Christmas tree production in Denmark based on the Danish test site in the Nordic series and two additional Danish sites.

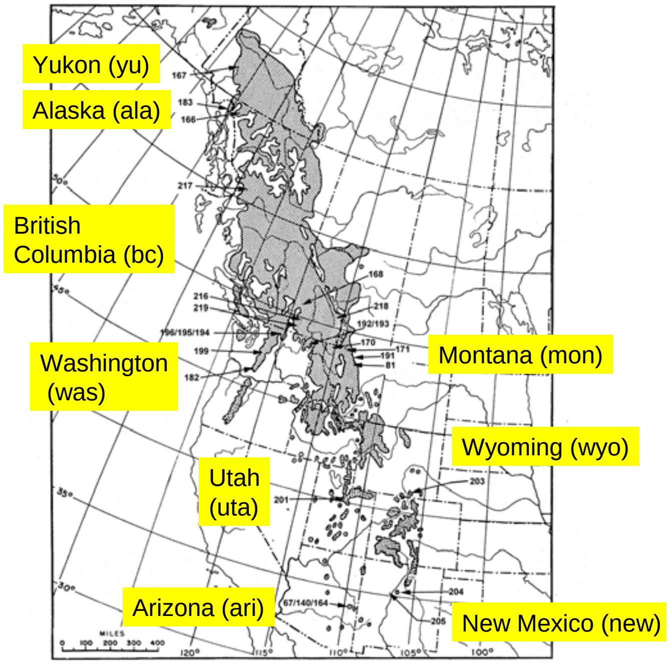

Figure 1. Natural distribution area of subalpine fir (Fowells, 1965). Numbers and arrows show origin of the 26 tested provenances (see Hansen et al., 2004).

Materials and methods

In the early 1990s, our late colleague Søren Flemming Madsen organized a seed collection that included 26 provenances covering most of the subalpine fir distribution area. Seed was received from several companies. This material was turned into a Nordic test series based on 5-year-old seedlings (2/3), including sites in Norway, Iceland, and Denmark (Hansen et al., 2004). A total of three Danish sites were established in the western part of the country (Figure 2), using randomized complete block designs, single tree plots, 1 tree per block, and 48 blocks per site. Trees were planted in 1999 and have been measured for a variety of characteristics:

- Accumulated mortality—2008 and 2011 (percent)
- Trees having double leaders (forks)—2003 (percent)
- Height growth—2008 (cm)
- Damaged trees—spring 2011 (percent):
  - Dead branches or dead tops (see Figure 3B for one of the most severely damaged trees)
  - Trees showing damage due to balsam woolly adelgid, *Adelges picea* (see Figure 3A)—2008 and 2010 (percent)
- Post-harvest needle loss (percentage of trees dropping needles after drying 10 days indoors, Figure 3C)
- Salable Christmas trees (percentage of planted)—2008 (after 10 growing seasons) and an adjusted value reducing salable numbers if trees were registered as further damaged in 2011.

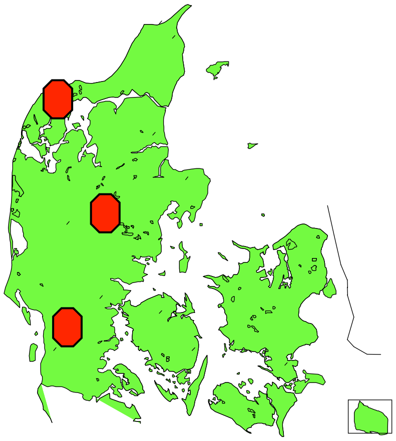

Figure 2. Location of test sites in Denmark.

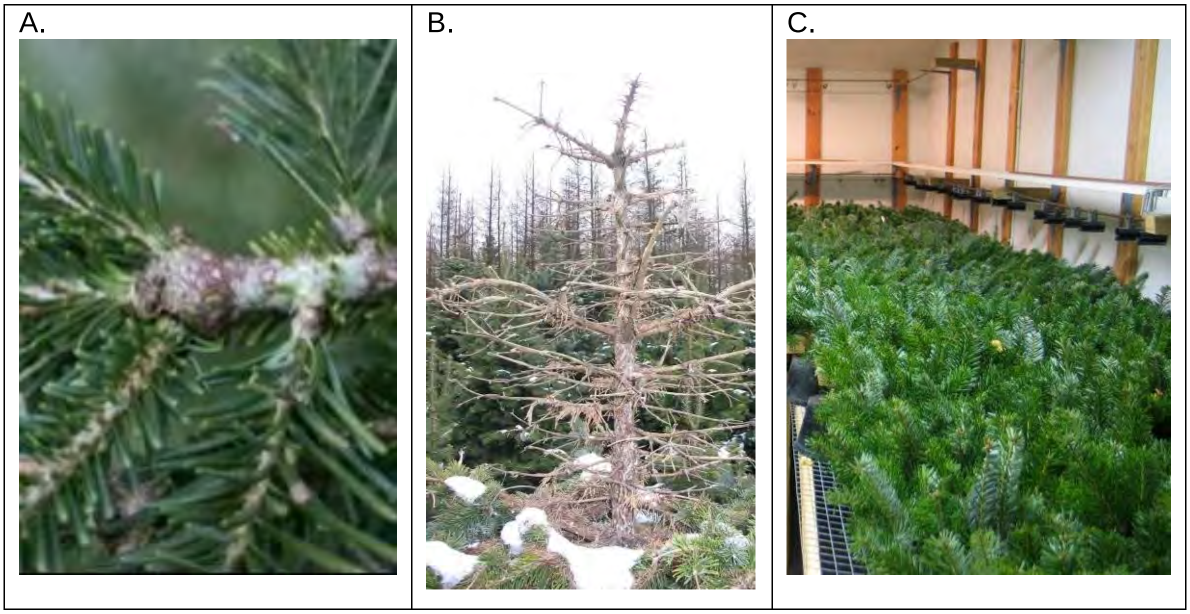

Figure 3. (A) Damage due to attack of balsam woolly adelgid. (B) Damage recorded during the years 2009–2011, probably related to attack of *Neonectria* ssp. (C) Test facility for the post-harvest needle retention studies.

Results

Results from the trials show a remarkably low output of salable trees across sites—3–26 percent in 2008 after 10 growing seasons (Table 1). Adjusting for damage occurring in the years after the first Christmas tree evaluation (Damage 2011 in Table 1) reduces the percentage of salable trees to 2–20 percent. Height after 10 growing seasons in the field approximates 2 meters.

The “damage 2011: top and branch” dieback occurred after 2008 and probably involved fungal attacks by *Neonectria* spp. (Talgø et al., 2011). The percentage of trees with damaged top or branches ranged from 2 to 26 percent and 24 to 60 percent respectively.

Besides this damage, attacks by balsam woolly adelgid (*Adelges picea*, or BWA) severely affected tree quality by deforming limbs and whole trees to various extents.

Forking, or double leaders, was recorded several times during the testing period, and the frequency of affected trees ranged from 24 to 58 percent. As expected, post-harvest needle loss was highest in the beginning of October (on average 20 percent), but even in November, 11 percent of the trees lost needles when allowed to dry.

Table 1. Site means for mortality (2008 and 2011), forks (2003), recorded damage (spring 2011), trees severely damaged by adelgids (2008 and 2010), height (cm, 2008), salable Christmas trees (autumn 2008 and adjusted by damaged trees 2011), post-harvest needle loss (October and November 2008).

	Mortality		Forks	Damage 2011		Adelgid	Height	Christmas trees		Needle loss	
Sites	**2008 (%)**	**2011 (%)**	**2003 (%)**	**Top (%)**	**Branches (%)**	**severe (%)**	**2008 (cm)**	**2008 (%)**	**2011 adj (%)**	**Oct. (%)**	**Nov. (%)**
A Hønning Plantage	13	14	54	26	60	50	188	3	2	27	10
B Thorsø Bakker	2	10	24	2	36	42	222	20	13	21	13
C Vilsbøl Plantage	7	7	58	5	24	35	187	26	20	11	11
Mean all sites	**7**	**10**	**45**	**11**	**40**	**42**	**199**	**16**	**11**	**20**	**11**

For all traits, significant differences were seen among provenances. The major findings were as follows:

- The provenance White River (55°48/129°10) from British Columbia had the highest Christmas tree production, a low number of damaged trees in 2011, and low sensitivity to BWA. It also had a rather low risk of post-harvest needle loss. Across all years, these results make it the most reliable and best performing provenance for these relatively harsh Danish site conditions (Figure 4A).
- The New Mexico and Arizona provenances showed good potential for Christmas tree production after 10 growing seasons and relatively low sensitivity to BWA. However, a rather high risk of post-harvest needle loss was seen for the Arizona provenances, ranging from 15 to 33 percent, whereas the risk for other provenances in November mostly ranged between 5 and 15 percent.
- Top and branch dieback, probably related to *Neonectria* ssp., was very severe on the southern provenances from Arizona and New Mexico (Figure 4B), but were not seen only in the variety *Arizonica* ssp. The Wyoming and Utah sources were also severely damaged. In general, a north-to-southeast cline could be seen, with the best trees originating from Alaska and British Columbia.

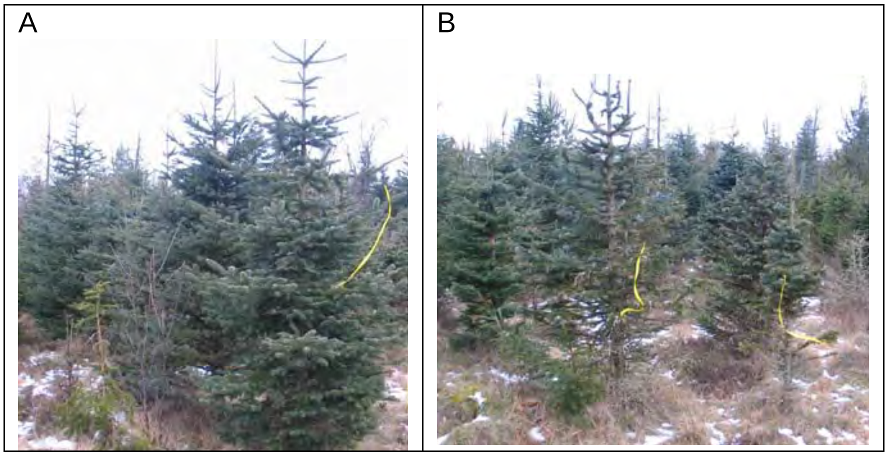

Figure 4. (A) The best provenance across sites was White River (55°48/129°10) from British Columbia. (B) Two New Mexico sources showing severe damage. Photos are from the Hønning plantage, which was the harshest site (site A in Table 1).

Based on the provenance results, it was decided to graft a new orchard based on the best performing material from the trials (Figure 5). Selecting the best trees within the best provenance (White River) yields an estimated within-provenance gain of 5–7 percent and pronounced gains compared to the mean of all provenances (Figure 5).

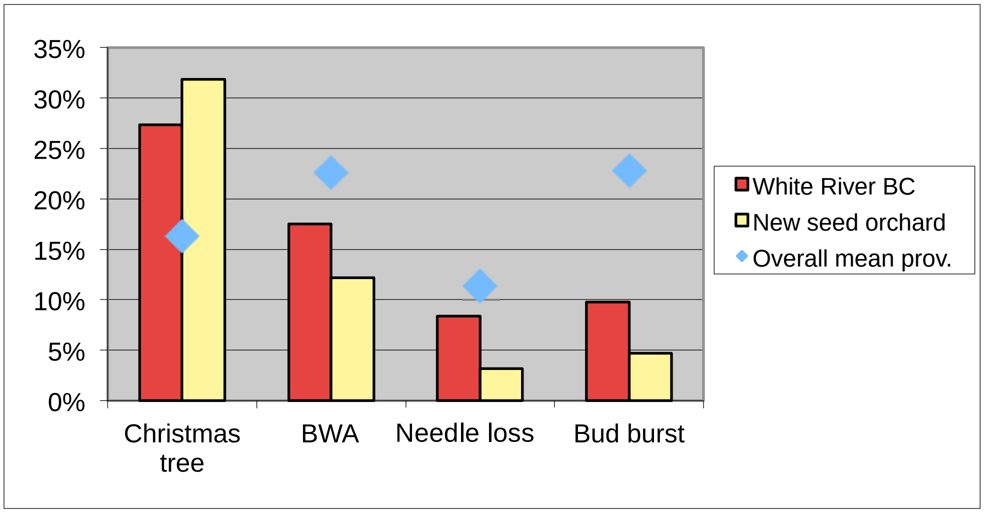

Figure 5. Estimated performance across all three sites of newly established seed orchards based on selection of the 30 best clones from the 146 trees of the best provenance (based on provenance BLUP [best linear unbiased prediction] values and best guess of heritabilities). Performance for salable Christmas trees (percent of planted), trees damaged by BWA (percent), trees showing post-harvest needle loss when allowed to dry in November (percent), and budburst (percentage of trees that have dropped bud scales and have visible emerging new shoots.

Some of the 26 tested provenances presumably comprised few trees (Hansen et al., 2004). To avoid inbreeding problems due to potential relatedness among selected trees when grafting a new clonal seed orchard, relatedness was investigated in a subset of the provenances. A minor study using DNA markers (five different SSRs) and bootstrapping was conducted and analyzed by a program package developed by Wang (2011). The White River provenance, #217, which was expected to be harvested on a large number of trees, was compared to a Washington source (Mt. Rainier, #199) with an expected narrow background—only one tree. A similar set of provenances was selected from among the corkbark provenances: Apache N.F., #164 (assumed to be harvested on a large number of trees) and Cibola N.F., #204 (presumably originating from one tree).

By use of the Wang (2011) program, the genetic relationship “r” (coancestry) was estimated (Table 2). The results confirmed the broad background of the White River source (r=0) and the narrow background of the Mt. Rainier collection, although more than one tree seemed to be involved in the latter (r=0.10). Theoretically, coancestry (“r”) equals 0.25 among half-sibs harvested from one mother tree. Results for the corkbark provenances showed that the Apache N.F. source seemingly had a broad background (r=0), and the single tree from the Cibola N.F. source was confirmed (r=0.27 to 0.29).

Table 2. Relatedness within each of the four tested provenances estimated by two methods: Wang and Lynch. ‘n’ is the number of pair-wise comparisons. Inbreeding is not accounted for.

Subalpine

Provenance =217

n=325	*(r) Wang*	*(r) LynchLi*
Mean	-0.04	-0.04
Variance	0.03	0.04

Provenance =199

n=136	*(r) Wang*	*(r) LynchLi*
Mean	0.11	0.1
Variance	0.09	0.09

Corkbark

Provenance =164

n=351	*(r) Wang*	*(r) LynchLi*
Mean	-0.07	-0.06
Variance	0.07	0.07

Provenance =204

n=351	*(r) Wang*	*(r) LynchLi*
Mean	0.29	0.27
Variance	0.07	0.08

Literature

Fowells, H.A. 1965. Silvics of forest trees of the United States. Agriculture Handbook No. 271, U.S Department of Agriculture, Washington, DC. 762 pp.

Hansen, O.K., U.B. Nielsen, Ø.M. Edvardsen, B. Skulason, and J.O. Skage. 2004. Nordic provenance trials with subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and corkbark fir (*Abies lasiocarpa* var. arizonica (Merriam) Lemmon)—3 year results. Scan. J. For. Res. 19:112–126.

Talgø V., I.M. Thomsen, U.B. Nielsen, M.B. Brurberg, and A. Stensvand. 2012. Neonectria canker on subalpine fir (*Abies lasiocarpa*) in Denmark. Proceedings of the 10th International Christmas Tree Research and Extension Conference, Austria.

Wang, J. 2011. Coancestry: A program for simulating, estimating, and analysing relatedness and inbreeding coefficients. Molecular Ecology Resources 11:141–145.

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Analysis of seed characteristics from 17 different populations in *Abies nordmanniana* subsp. *bornmülleriana* Mattf.

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Introduction

Uludağ fir (*Abies nordmanniana* subsp. *bornmülleriana*) has a special importance for Turkey because of its increasing economic value in the marketplace and its decorative characteristic in landscape architecture. Being an endemic species for Turkey, and a very decorative species, it is the most widely preferred Christmas tree (Şevik et al., 2011a). Uludağ fir is distributed from the Kızılırmak River to Mount Uludağ in the western Black Sea region, particularly in Ayancık, Ilgaz Mountains, Bolu Seben Mountains, Boyabat-Göktepe forests, Abant and Mount Uludağ. Stands of fir species occupy roughly 600,000 ha in Turkey (Anonymous, 2006).

Genetic variation is the fundamental component that ensures survival and thus the stability of forest ecosystems, as its quantity and quality determine the potential of a population to adapt to changing environmental conditions. This is particularly important with changing populations and climatic conditions and when the long-term stability of forest ecosystems is increasingly threatened by environmental stress. Thus, a genetic characterization of natural forest resources is the first step necessary for a better understanding of genetic resources for implementation of *in situ* and *ex situ* conservation activities (Turna et al., 2006; Şevik et al., 2010). The objectives of this study were to investigate the genetic diversity among Uludağ fir populations in Turkey and to determine the extent of between-population variation, using 13 different morphological characters.

Materials and methods

Open-pollinated seed materials were collected from the western Black Sea region. Locations and description of the studied population are indicated in Table 1.

Table 1. Description of the studied populations in Turkey.

Pop. no.	Population name	City	Number of sample trees	Altitude (m)	Longitude (E)	Latitude (N)
1	Bafra1	Samsun	10	828	35°21'18"	41°34'01"
2	Bafra2	Samsun	10	1,012	35°21'33"	41°33'28"
3	İskilip1	Amasya	20	1,673	33°46'11"	41°22'36"
4	İskilip2	Amasya	20	1,852	34°13'34"	40°49'01"
5	Türkeli	Sinop	13	1,348	34°16'15"	41°44'58"
6	Ilgaz1	Kastamonu	20	1,430	33°49'17"	41°09'27"
7	Ilgaz2	Kastamonu	20	1,624	33°49'11"	41°08'60"
8	Ilgaz3	Kastamonu	20	1,995	33°50'58"	41°07'47"
9	Ballıdağ1	Kastamonu	20	1,056	33°29'02"	41°37'11"
10	Ballıdağ2	Kastamonu	20	1,374	33°25'29"	41°34'12"
11	Ballıdağ3	Kastamonu	20	1,640	33°22'37"	41°31'58"
12	Samatlar	Kastamonu	20	1,497	33°15'32"	41°22'06"
13	Eflani	Karabük	20	1,102	32°51'45"	41°29'02"
14	Aladağ	Bolu	10	968	31°37'15"	40°40'21"
15	Kıbrıscık2	Bolu	20	1,499	32°00'42"	40°25'46"
16	Kıbrıscık1	Bolu	20	1,791	32°02'22"	41°28'43"
17	Göynük	Bolu	20	1,270	30°41'27"	40°30'08"

In this study, we determined width, thickness, length, and weight of seeds; carpel width, length, and weight; carpel scape width and length; and wings width and length. All length and width measurements were made with digital microcompass (0.01 mm) from 10 samples for each sample tree. All weights were measured with a digital weighing machine (0.001 g). Data were subjected to multiway analysis of variance, Duncan test, and cluster analysis with SPSS statistical package program.

Results and discussion

The analysis of variance showed that there were significant differences among populations at 0.01 for seed width and 0.001 for other characters (Table 2, pages 21–22).

The population of Kıbrıscık2 is in the first homogeny group according to all characters, and the population of Ilgaz1 is as well, except for wing length. These populations showed the lowest performance for 13 characters.

Populations of Aladağ, Ballıdağ1, and Ballıdağ2 showed the highest performance. The Aladağ population (except wing width) and the Ballıdağ1 and Ballıdağ2 populations (except carpel scape width) are in the last homogeny group according to Duncan test. These populations showed the highest performance for almost all characters.

Average measurements were as follows:

- Carpel length: 35.41 mm
- Carpel width: 30.27 mm
- Scale length: 26.96 mm
- Scale width: 5.32 mm
- Carpel scape length: 4.77 mm
- Carpel width: 1.56 mm
- Carpel weight: 304.58 mg
- Wing length: 16.7 mm
- Wing width: 15.3 mm
- Seed length: 11.64 mm
- Seed width: 5.89 mm
- Seed thickness: 3.97 mm
- Seed weight: 81.58 mg

According to results of variance, the percentage change from minimum values to maximum values was:

- Carpel length: 12.4 percent
- Carpel width: 16.4 percent
- Scale length: 16.2 percent
- Scale width: 17.2 percent
- Scale scape length: 14.4 percent
- Scale scape width: 25 percent
- Carpel weight: 45.9 percent
- Wing length: 42.4 percent
- Wing width: 15.2 percent
- Seed length: 16.1 percent
- Seed width: 13.4 percent
- Seed thickness: 16.4 percent
- Seed weight: 52.1 percent

The mean values, standard deviation and results of Duncan test of morphological characters by populations are shown in Table 2.

Table 2. Mean values and multiple comparisons of studied morphological characters.

Pop. no	**Carpel length (mm)**		**Scale length (mm)**		**Carpel width (mm)**		**Scale width (mm)**	
1	33.31±0.81	a	25.21±0.82	ab	28.7±1.01	abcd	4.87±0.14	a
2	33.32±0.98	a	24.7±0.92	a	27.63±1.12	a	5.12±0.21	abc
3	36.41±0.68	cdef	27.36±0.61	bcde	31.01±0.71	cde	5.08±0.11	abc
4	36.18±0.85	cdef	26.5±0.63	abcde	31.07±0.9	de	5±0.12	ab
5	33.54±0.87	a	25.69±0.5	abc	27.86±0.85	a	5.29±0.14	abcd
6	33.71±0.78	ab	25.33±0.66	ab	28.39±0.6	ab	5.18±0.13	abc
7	36.39±0.95	cdef	27.83±0.67	cde	29.87±0.82	abcde	5.41±0.12	bcd
8	34.86±0.64	abcd	26.95±0.65	bcde	28.47±0.82	abc	5.1±0.12	abc
9	36.99±0.73	ef	28.69±0.62	e	32.17±0.69	e	5.71±0.16	d
10	36.56±0.55	cdef	28.06±0.66	de	31.53±0.69	e	5.5±0.11	cd
11	36.3±0.56	cdef	27.73±0.53	cde	30.87±0.61	bcde	5.65±0.12	d
12	36.06±0.52	bcdef	27.77±0.52	cde	31.56±0.68	e	5.67±0.12	d
13	34.04±0.53	abc	26.34±0.58	abcd	29.97±0.63	abcde	5.18±0.12	abc
14	37.43±0.84	f	28.21±1.12	de	32.07±0.66	e	5.53±0.15	cd
15	34.12±0.76	abc	25.79±0.69	abc	30.86±0.64	bcde	5.29±0.17	abcd
16	36.65±0.7	def	27.93±0.58	cde	31.93±0.72	e	5.45±0.15	bcd
17	36.11±0.7	bcdef	28.15±0.68	de	30.67±0.72	bcde	5.45±0.11	bcd
Av.	35.41±0.72		26.96±0.65		30.27±0.74		5.32±0.13	
F	3,194*		3,007*		3,420*		3.42*	

*Significant at $P < 0.001$.

Table 2 (continued). Mean values and multiple comparisons of studied morphological characters.

Pop. no	Carpel scape length (mm)		Carpel scape width (mm)		Carpel weight (mg)		Wing length (mm)		Wing width (mm)	
1	4.79±0.12	bcdef	1.61±0.07	cdef	275.64±20.03	ab	15.31±0.47	bc	14.04±0.51	a
2	4.17±0.12	a	1.41±0.09	ab	245.6±22.69	a	14.74±0.91	ab	14.05±0.66	a
3	4.86±0.11	def	1.75±0.06	f	353.41±14.83	de	16.97±0.5	cde	15.85±0.42	c
4	4.96±0.13	def	1.7±0.05	ef	358.38±20.35	e	17.37±0.59	def	16.4±0.39	c
5	4.72±0.12	bcdef	1.62±0.05	cdef	273.34±18.87	ab	13.27±0.58	a	14.45±0.49	ab
6	4.41±0.11	ab	1.41±0.04	ab	252.23±11.26	a	16.25±0.43	bcde	14.47±0.3	ab
7	4.89±0.14	def	1.58±0.04	bcdef	299.35±16.62	abcd	16.97±0.64	cde	15.98±0.46	c
8	4.43±0.07	abc	1.51±0.06	abcd	251.07±12.66	a	16.31±0.55	bcde	15.64±0.3	bc
9	4.74±0.12	bcdef	1.54±0.05	abcde	330.65±14.27	cde	17.6±0.46	def	15.75±0.32	c
10	5.13±0.12	f	1.54±0.04	abcde	339.47±11.48	cde	17.65±0.52	def	15.81±0.26	c
11	4.58±0.12	bcd	1.62±0.05	cdef	299.12±12.54	abcd	16.56±0.41	cde	15.2±0.31	abc
12	4.84±0.15	cdef	1.51±0.04	abcd	325.96±17.56	bcde	17.09±0.46	cdef	15.38±0.32	bc
13	4.64±0.1	bcde	1.4±0.05	a	286.68±12.46	abc	16±0.46	bcd	15.1±0.36	abc
14	4.94±0.24	def	1.68±0.07	def	315.5±19.19	bcde	18.06±0.66	ef	15.63±0.49	bc
15	5.07±0.1	ef	1.49±0.05	abc	272.18±14.67	ab	17.6±0.54	def	14.39±0.4	ab
16	4.99±0.09	def	1.59±0.04	cdef	352.06±16.43	de	18.9±0.52	f	15.82±0.34	c
17	4.9±0.12	def	1.54±0.06	abcde	347.25±19.36	de	17.26±0.61	def	16.17±0.36	c
Av.	4.77±0.12		1.56±0.05		304.58±15.79		16.7±0.54		15.3±0.38	
F	3,808*		3,604*		5,675*		4,703*		3,376*	

*Significant at $P < 0.001$.

Table 2 (continued). Mean values and multiple comparisons of studied morphological characters.

Pop. no.	Seed length (mm)		Seed width (mm)		Seed thickness (mm)		Seed weight (mg)	
1	11±0.34	ab	5.74±0.11	abc	3.97±0.09	ab	81.58±5.41	abcde
2	10.84±0.39	a	5.78±0.12	abcd	3.82±0.14	a	85.84±7.66	abcde
3	11.63±0.28	abcd	6.12±0.13	de	3.92±0.08	ab	84.55±4.38	abcde
4	11.46±0.22	abc	5.93±0.12	abcd	3.9±0.07	ab	72.94±4.29	ab
5	11.44±0.18	abc	5.95±0.14	abcd	3.94±0.1	ab	79.97±4.85	abc
6	10.83±0.23	a	5.65±0.12	ab	3.73±0.08	a	74.71±3.73	ab
7	12.01±0.28	cdef	5.86±0.12	abcd	4.03±0.08	ab	95.57±4.6	defg
8	11.48±0.16	abc	5.65±0.07	ab	3.77±0.06	a	80.41±3.05	abcd
9	12.46±0.21	ef	6.07±0.09	cde	4.22±0.09	ab	103.29±4.53	fg
10	12.57±0.17	f	6.05±0.08	cde	4.33±0.08	b	109.11±3.82	g
11	12.36±0.22	def	5.85±0.09	abcd	4.05±0.07	ab	94.71±3.9	cdefg
12	11.77±0.25	bcde	5.85±0.08	abcd	3.83±0.09	a	91.68±4.66	cdef
13	11.16±0.24	ab	6.36±0.12	e	3.9±0.07	ab	87.96±4.29	bcde
14	11.99±0.26	cdef	5.99±0.12	bcd	4.07±0.14	ab	95.42±7.44	defg
15	11.06±0.19	ab	5.61±0.08	a	3.77±0.05	a	71.72±2.78	a
16	11.67±0.25	bcde	5.76±0.13	abcd	4.34±0.43	b	83.27±4.59	abcde
17	12.15±0.24	cdef	5.96±0.08	abcd	3.93±0.1	ab	96.8±4.65	efg
Av.	11.64±0.23		5.89±0.1		3.97±0.1		81.58±4.05	
F	5,123*		3,451*		1,789**		5,942*	

*Significant at $P < 0.01$; **significant at $P < 0.001$.

A cluster dendrogram was constructed on the basis of Euclidean distances, with the use of the nearest neighborhood method for 13 quantitative morphological traits. Two distinct groups can be noticed: the first is İskilip1, İskilip2, Ballıdağ2, Göynük, Samatlar, Aladağ, Kıbrıscık1, and the others. The second group contains two distinct groups, Ilgaz1 and others. According to these results, it can be said that there are three main groups (Figure 1).

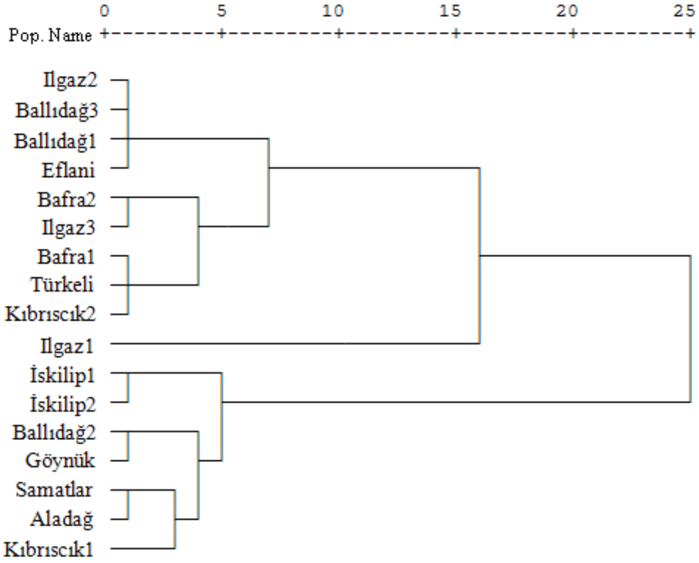

Figure 1. Dendrogram of 17 populations of Uludağ fir based on 13 morphological traits.

Some populations are geographically and genetically close to each other, such as the Bafra1 and Bafra2, Ilgaz2 and Ilgaz3, and İskilip1 and İskilip2 populations. Some are geographically close to each other, but genetically different (for example, the Ballıdağ1 and Ballıdağ, İskilip1 and İskilip2 populations). On the contrary, some populations are genetically close to each other, but geographically distant (for example, the Bafra1 and Kıbrıscık2, İskilip1 and Göynük populations).

According to results of the cluster analysis and variance analysis, the Ilgaz1 population is very different from other populations. The reason might be its longitude and different ecological and genetic factors. Results of the cluster analysis (Figure 1) were well in accordance with morphological distances. For instance, morphological distances of Ilgaz1 were the highest of all populations.

These results could be used in preparation of gene maps and in determination of seed transfer zones, breeding populations, gene conservation areas, geographic variation, and provenance trials. Preparation of forest gene maps and determination of seed transfer zones and geographical variation by morphological distance were also suggested by Yahyaoğlu et al. (2001). Results of this study could also be taken into consideration for silvicultural purposes (afforestation, artificial regeneration) and breeding strategies (i.e., determination of breeding populations, gene conservation areas, seed transfer zones, seed sources and geographic variation, provenance trials, and establishment of seed orchards).

Similar studies exist on *Abies* species (Messaoud et al., 2007): *Abies balsamea* (Okada et al., 1973), *Abies sachalinensis* (Parker et al., 1981), *Abies balsamea* and *Abies lasiocarpa*

(Kolotelo, 1998), *Abies amabilis*, *Abies grandis,* and *Abies lasiocarpa,* etc. However, there has not been enough study of Uludağ fir. Thus, it can be suggested that all populations, especially the Ilgaz1 population, be considered for a gene conservation program.

Also, future studies are necessary to provide deeper insights into the subject. It may be concluded from the present study that the studied characteristics were the important factors in morphological distance among populations. Ecological and geographical differentiation are other important factors that influence breeding and sampling strategies for tree crops. It is also essential to consider the relationship between population structure in natural and domesticated populations (Chalmers et al., 1992; Şevik et al., 2011b).

Generally, our results show that large genetic diversity exists in Uludağ fir, thus explaining its great ecological plasticity and evolutionary success. The results of this study showed that the populations are not homogeneous with regard to morphological characteristics. The existence of these groupings and differences, in terms of morphological characters, may indicate that different origins or varieties formed the Uludağ fir stands. Variation in most of these characteristics appeared to be related to altitude and to divergent gene and genotype frequencies.

References

Anonymous, 2006. Orman Varlığımız, T.C. Çevre ve Orman Bakanlığı Orman Genel Müdürlüğü, Orman İdaresi ve Planlama Dairesi Başkanlığı, Ankara, 160 s.

Chalmers, K.J., R. Waugh, J.I. Sprent, A.J. Simons, and W. Powell. 1992, Detection of genetic variation between and within populations of *Gliricidia Sepium* and *G. maculata* using RAPD markers. Heredity 69:465–472.

Kolotelo, D. 1998. *Abies* seed problems. Forest Nursery Association of British Columbia meetings, proceedings, 1995, 1996, 1997, pp.122–130.

Messaoud, Y., Y. Bergeron, and H. ve Asselin. 2007. Reproductive potential of balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), and black spruce (*Picea mariana*) at the ecotone between mixed wood and coniferous forests in the boreal zone of western Quebec. American Journal of Botany 94(5):746–754.

Okada, S., H. Mukaide, and A. ve Sakai. 1973. Genetic variation in Saghalien fir from different areas of Hokkaido. Silvae Genetica 22:1–2.

Parker, W.H., J. Maze, and G.E. Bradfield. 1981. Implications of morphological and anatomical variation in *Abies balsamea* and *Abies lasiocarpa* (Pinaceae) from western Canada. Botanical Society of America, 68(6):843–854.

Şevik, H., S. Ayan, İ.Turna, and Z. Yahyaoğlu. 2010. Genetic diversity among populations in Scotch pine (*Pinus silvestris* L.) seed stands of western Black Sea region in Turkey. African Journal of Biotechnology 9(43):7266–7272.

Şevik, H., D. Güney, and Ş Kulaç, 2011a. Difficulties of Uludag Fir (*Abies nordmanniana* subsp. *bornmulleriana* Mattf.) Seed Production and Some Recommendations, Türkiye IV. Tohumculuk Kongresi, Bildiriler Kitabı-1, 436–441, Ondokuz Mayıs Üniversitesi Ziraat Fakültesi, 14-17 Haziran 2011, Samsun.

Şevik, H. 2011b. Determination of Uludag Fir Populations Suitable for Cristmas Tree Production According to Branch Characteristics, Kastamonu Univ., Journal of Forestry Faculty, 11(1):102–107, Kastamonu.

Turna, I., Z. Yahyaoglu, F. Yüksek, F.A. Ayaz ve D. Guney. 2006. Morphometric and electrophoretic analysis of 13 populations of Anatolian black pine in Turkey. J. of Environmental Biology 27(3): 491–497.

Yahyaoğlu, Z., A. Demirci, N. Bilir, and M. ve Genç. 2001. Comparison of 22 taurus cedar (*Cedrus libani* A. Rich.) origins by seedling morphological distance. Turkish Journal of Biology 25, Ankara, 221, 224.

Current results of Czech-American fir hybridization research

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Interspecific hybridization is generally considered to be one of the most efficient methods in forest tree breeding. Interspecific hybrids of firs have been recommended as a substitute for declining silver fir (*Abies alba* Mill.) in central Europe. Its decline is ascribed primarily to the reduced genetic variability of the domestic populations during the last centuries. The results of many studies indicate that interspecific hybrids of exotic species of fir seem to be candidates for replacing silver fir in the region.

Current activities are connected to a traditional hybridization program within genus *Abies*, which has been recently extended by our cooperation with an American partner (North Carolina State University in Raleigh, NC). This experiment is based in the long run on bilateral international cooperation between Czech Republic and USA. The Czech side is supported by a grant from the Czech Ministry of Education within the program KONTAKT. In this particular case, there exists a concrete collaboration between the Czech University of Life Sciences in Prague (responsible researcher Professor Jaroslav Kobliha) and the NCSU Christmas Tree Genetics Program (responsible researcher Professor John Frampton).

Fraser fir (*Abies fraseri* (Pursh) Poir.) Christmas tree plantations in North Carolina are infested by root rot caused by *Phytophthora cinnamomi*. This disease kills almost 100 percent of Fraser fir material and leaves the soil indefinitely infested, thus unsuitable for replanting.

In the experiment, control crossings of Mediterranean fir hybrids *Abies cilicica* (Toros fir) x *Abies cephalonica* (Grecian fir) with *Abies fraseri* were performed to obtain possibly resistant hybrid material of desired Christmas tree parameters. Pollen of various clones of Fraser fir and two clones of the Mediterranean hybrid (CZ1 and CZ2) was exchanged between CULS and NCSU. Control pollinations were performed annually in April/May 2007–2011 in hybrid seed orchards as well as at Rattlesnake Knob clone bank in North Carolina. Annual cone collections were managed during September. After cones completely disintegrated, the dry seeds were processed within each facility.

For the Czech material, basic parameters of cones and seeds were assessed for each seed lot. Crosses by CULS produced 176,300 seeds during the study period. Samples of the individual seed lots were X-rayed during October and November for the final step of full seed assessment. Generally, obtaining 5 percent viable seeds in a sample can be rated as successful.

The average filled seed for each pollination year ranged from 1 to 3.6 percent. The best hybrid combination so far was CZ1 x NC73, yielding a predicted 16 percent viable seeds and 526 germinants (8.6 percent) in 2008. In comparison, the open-pollinated (OP) crossing of CZ1 and CZ2 clones within the seed orchards had a 29 percent germination rate. The most successful tri-hybrid of 2010 was CZ2 x NC81, with a predicted 7 percent viable seeds; however, germination of all the crosses was very low—0 to 10 seedlings.

The hybrid material has been grown at both the CULS Kostelec Forest Breeding Station and in greenhouses at NCSU. A subsample of seedlings grown from the 2008 control pollinations that were germinated in 2009 was measured for various traits in July of 2011. Open-pollinated seedlings of the parent species *A. cilicica*, *A. cephalonica,* and *A. fraseri* were included in the measurements, as well as OP F2 seedlings. Measured traits were growth by year (summed for total height), needle length, number of lateral and whorl branches for 2009 and 2010, and the number of lateral and whorl buds for 2011. As expected, the OP F2 had a greater average height than either parent species.

Growth traits of the tri-hybrid crosses when Fraser fir was the female parent followed a general pattern for all traits. The seedlings crossed with the Czech hybrids were intermediate between Fraser fir and the OP F2 in height, needle length, and branch and bud numbers.

When Fraser fir was the male parent of the tri-hybrid, the differences were more variable. All growth traits for tri-hybrids with Fraser fir as the male were lower compared to tri-hybrids with Fraser fir as the female. Tri-hybrid seedlings with Fraser fir as the male were taller than Toros or Grecian firs, but similar to the OP F2. Whorl branches and buds were less numerous than those of parents or OP F2, but lateral branches and buds were more numerous. Needle lengths for the tri-hybrids with Fraser fir as the male parent were most variable, with the tri-hybrids' needle length being greater than that of *A. cephalonica* and OP F2, but less than that of *A. cilicica*.

Overall comparison of the species and hybrids showed Fraser fir as the fastest growing, fullest seedlings. The tri-hybrids exhibited intermediate growth characteristics, usually exceeding growth of the Mediterranean and OP F2 seedlings. The most dramatic differences were seen in the lateral branch and bud numbers, while needle lengths showed the least dramatic differences. Needle lengths for *A. fraseri* and *A. cilicica* were very similar, averaging 24 and 23 mm respectively.

Breeding for resistance to Phytophthora root rot is a primary objective of the NCSU Christmas Tree Genetics Program. Parent species and samples of the tri-hybrids were included, along with momi fir (*A. firma*), in a Phytophthora inoculation trial in 2010. Mortality of seedlings from crosses of the Czech hybrids with Fraser fir as the male parent ranged from 50 to 81 percent. Fraser fir mortality was 100 percent, while the mortality rates of Grecian, Toros, and the OP F2 were more moderate. Momi fir has proved to be the most resistant in inoculation trials and had a 1 percent mortality rate in the 2010 trial. Resistance seems to be dominant, perhaps under simple genetic control of one or a few loci. More testing of larger numbers of seedlings and the reciprocal crosses needs to be undertaken.

CULS and NCSU plan to continue the exchange of pollen and hybrid seeds. Single nucleotide polymorphic (SNP) DNA markers will be used to verify the tri-hybrids. Field plantings and subsequent measurement of growth and survival are planned for both hybrid material and the parent species. Vegetative propagation by somatic embryogenesis and rooted cuttings should provide a sufficient amount of material for Phytophthora screening and future field trials. NCSU is also undertaking the hybridization of Fraser with momi fir in cooperation with a Christmas tree producer and nurseryman.

Acknowledgments: The investigators extend many thanks to the staffs of both universities and cooperating government entities.

Transcriptome analysis of Fraser fir

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An investigation using Fraser fir (*Abies fraseri* [Pursch.] Poir.) was initiated to (1) identify single nucleotide polymorphic (SNP) markers for use in breeding efforts of the North Carolina State University Christmas Tree Genetics (CTG) Program and (2) explore gene function.

Messenger RNA was extracted and cDNA libraries prepared from needle samples of 10 trees from each of 6 provenances, as well as from the shoot and root of an individual seedling. After a two-step sizing and amplification process to yield fragments 300 ±15 bp in length, DNA was sequenced via an Illumina GAII instrument. The single-tree sample and pooled samples of each provenance were run in separate lanes of a single flow cell. Sequence data were merged and assembled using Velvet, with post-assembly analysis using Oases.

The single reference individual's reads were mapped to the assembly using Burrows-Wheeler Aligner (BWA), and the assembly with >2x coverage was extracted using SAMtools. The pooled provenance samples were characterized by individually mapping to the entire assembly using BWA. SNPs between pooled provenance samples and the reference transcriptome were identified using SAMtools, with the requirement of at least three reads to support any alternative allele. A nucleotide BLAST to the GenBank nr database was conducted. Blast2GO was used to map, annotate, and data mine the resulting dataset.

The reference transcriptome contained about 13 million base pairs with 25,359 contigs longer than 200 bp. The number of candidate SNPs identified per provenance ranged from 13,700 to 15,800, with 5,944 SNPs in 1,842 different contigs being shared by all six provenances. About 35 percent of the SNPs resulted in a change in translation, and about 14 percent resulted in changes likely to be nonconservative in nature, i.e., an amino acid with different properties is translated. Target SNP loci obtained from Fraser fir could be successfully amplified in several other *Abies* species and hybrids. Blast2GO successfully annotated 14,186 of the 28,010 total sequences.

Needle retention is an important concern for Christmas tree consumers. Strong evidence suggests that ethylene signals needle abscission:

- Ethylene production increases prior to abscission.
- Exogenous application of ethylene accelerates abscission.
- Blocking ethylene delays abscission.

As an example of data mining, a search in Blast2Go for sequences with "ethylene" in the GO terms identified 68 transcripts. Drilling down further, searches for two ethylene precursors, SAM (S-adenosyl-L-methionine) and ACC (1-aminocyclopropane-1-carboxylic-acid) identified 27 and 12 sequences from 12 and 9 loci, respectively.

Current efforts and future plans include:

- Testing selected SNP markers on Fraser and other fir species, including hybrids
- Using tested SNPs in the CTG Program to (a) genetically fingerprint orchard and clone bank trees, (b) identify pollen parents in open-pollinated families, (c) identify both

parents in Christmas tree plantations established from seed orchards of genotyped parent trees, and (d) verify fir hybrids and backcrosses
- Assembling 454 sequences from a previous study with the Illumina sequences and annotating the resultant assembly
- Continuing functional genomics exploration

GROWTH CONDITIONS

Rotational biomass and nutrient accumulation of four Christmas tree species

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Successful Christmas tree nutrient management is based on adequate supply of nutrients in a timely manner. Both seasonal and rotational nutrient supply timing are critical for Christmas tree production.

Data for nutrient removal with tree harvest can be helpful for planning nutrient management for succeeding rotations. Webster et al. (1997) reported N data for Douglas-fir in the Pacific Northwest, USA. Pedersen and Christensen (2005) measured biomass and nutrient accumulation of Nordmann fir in Denmark. No comprehensive measurement of nutrient and biomass accumulation has been reported for a rotation in the U.S. Pacific Northwest.

To determine rotational biomass and nutrient accumulation, four Christmas tree species—noble fir, Douglas-fir, grand fir, and Nordmann fir—were harvested at four sizes, 0.6 to 0.9, 1.2 to 1.5, 1.8 to 2.1, and 2.4 to 2.7 meters. The Douglas-fir trees were harvested from a farm near Silverton, Oregon, and the other species from a farm near Mossy Rock, Washington.

All trees were harvested in the fall of 2008 by cutting the tree from the stump, then excavating the roots with the stump attached. Three trees were excavated for each height. Tree components were separated into roots, bole, and branches plus needles. The components were coarsely ground or chipped, dried, weighed, and subsampled. A portion of the subsample of each component from the 2.4- to 2.7-meter height category for each tree species was finely ground and analyzed for nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), and magnesium (Mg). Average data for each species height were calculated using nutrient concentration from the 2.4- to 2.7-meter height class. Calculations for nutrient content or accumulation assumed a spacing of 1.6 x 1.8 m or 3,580 trees/ha. Data are reported on dry weight basis.

Results

Total tree weight increased exponentially for all species (Figure 1). The exponential growth function was similar to the characterization of growth for Danish Nordmann fir (Pedersen and Christensen, 2005). Noble and Nordmann fir produced slightly more biomass than did grand fir or Douglas-fir. Nordmann fir produced 23.5 t/ha aboveground biomass.

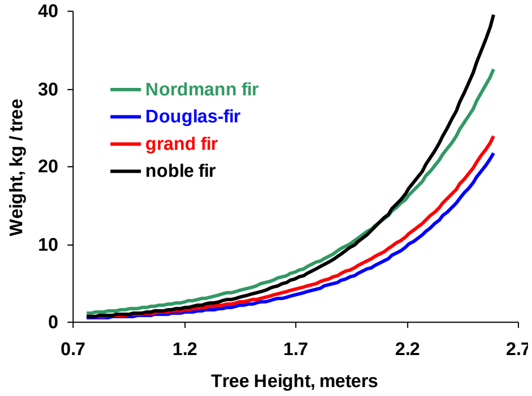

Figure 1. Average total tree weight increases with height in four species grown as Christmas trees.

At the 2.4- to 2.7-meter harvest height, stem and root biomass were equal and were half the branch biomass for Noble fir (Figure 2).

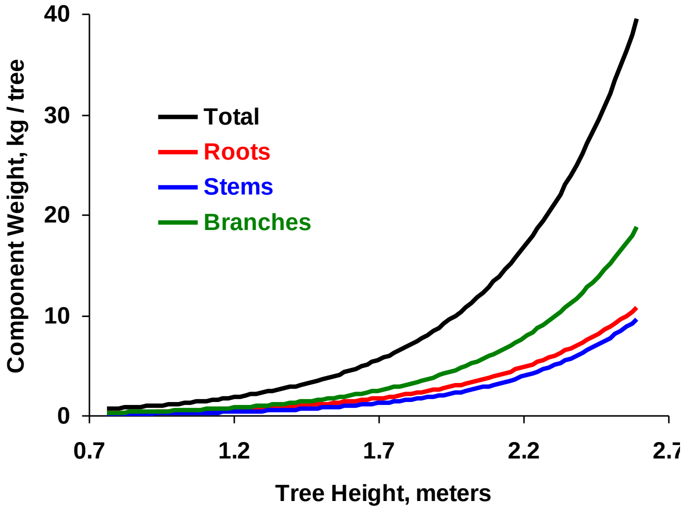

Figure 2. Comparison of noble fir Christmas tree component biomass with total biomass.

At the common harvest height, 1.8 to 2.1 meters, Douglas-fir and grand fir contained approximately the same amount of N, which was substantially less than Nordmann and noble fir (Figure 3 and Table 1). This outcome is driven by biomass, as average branch and needle N concentration was similar, 1.43 to 1.57 percent.

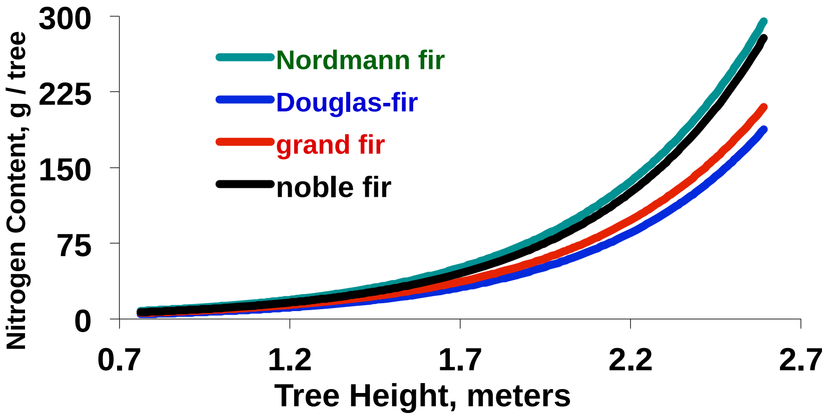

Figure 3. Average total tree N content increases exponentially with height in four conifer species grown as Christmas trees.

Table 1. Total (roots, stems, needles, and branches) nutrient content of 2-meter-tall Christmas trees.

	Species			
	Douglas-fir	**Noble fir**	**Grand fir**	**Nordmann fir**
Nutrient		**------ kg/ha ------**		
Nitrogen	225	410	265	300
Phosphorus	15	35	20	25
Potassium	80	240	145	140
Sulfur	10	20	15	15

Branches and needles contained most of the N (Figure 4), making the total and harvested amount of N similar. Reported nutrient accumulation is governed by biomass, as the nutrient concentration was constant.

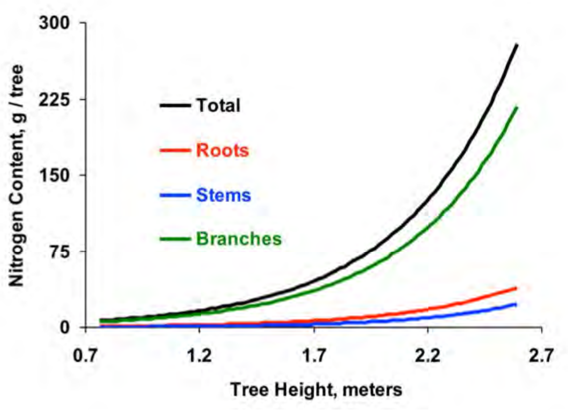

Figure 4. Total noble fir N content or accumulation, compared to accumulation in components—roots, bole, and small branches plus needles.

Douglas-fir accumulated less K than the other species (Figure 5). When harvested at approximately 2 meters, Douglas-fir Christmas trees contain approximately one-half the amount of K as do grand and Nordmann fir and one-third the amount of K as noble fir (Table 1).

Compared to N, root and bole K was greater for noble fir (Figures 4 and 6). The same pattern was measured for the other species.

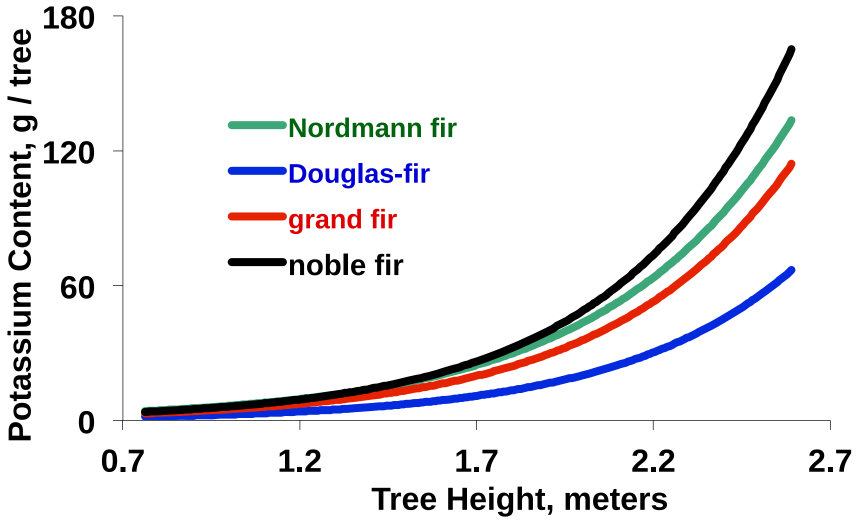

Figure 5. Total K content or accumulation for four Christmas tree species.

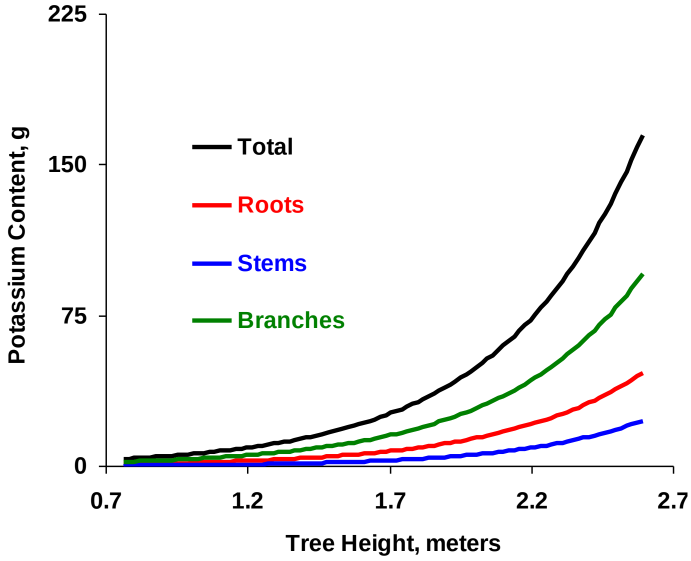

Figure 6. Total noble fir K content or accumulation compared to accumulation in components—roots, bole, and small branches plus needles.

Management implications

Christmas trees grow rapidly during the 2 to 3 years before harvest. The growth is accompanied by rapid nutrient accumulation. Lack of nutrients during this time easily creates unmarketable trees. To adequately supply nutrients, growers must anticipate tree nutrient need. Many growers approach nutrient supply for all species in the same manner. In addition, little differentiation of nutrient supply or need is given in the management guide (Hart et al., 2009).

The Christmas tree industry in western Oregon and Washington began by producing sheared Douglas-fir. As growers diversify species, management information about various species is needed, as tree species accumulate N and K at strikingly different annual rates (Table 2).

Table 2. Estimated annual N and K uptake of four conifer species grown for Christmas trees in the Pacific Northwest, USA as height increases from 1 to 2 meters. For the trees to increase from 1 to 2 meters, the time was assumed to be 3 years for Nordmann and noble fir and 2 years for the other species.

	Nordmann fir	**Noble fir**	**Douglas-fir**	**Grand fir**
Nutrient		**----- kg/ha -----**		
Nitrogen	50	100	50	75
Potassium	25	60	20	50

Nitrogen accumulation rate for grand fir is 50 percent greater than for Douglas-fir or Nordmann fir. Potassium accumulation rate for grand and noble fir is more than double that of Douglas-fir and Nordmann fir. Growers are more likely aware of the need for N than for K. Consequently, late-rotation K deficiency is a possibility for noble and grand fir. Potassium deficiency in Christmas tree production is uncommon, but the few problems brought to the attention of extension and research personnel in western Oregon and Washington have occurred late in a rotation of noble fir.

Most nutrients are removed with needles and branches as trees are harvested (Figures 4 and 6). Root removal would only add 1 to 3 percent additional N leaving a field. In contrast, a substantial amount of K is contained in roots. Root removal adds 5 to 10 percent to the total nutrient leaving a field for Douglas-fir and 20 to 30 percent for the other species. The increasing use of stump removal to control root diseases on true firs results in a need to consider the additional loss of K in true fir production.

Summary

Christmas trees grow rapidly during the 2 to 3 years before harvest. This growth is accompanied by rapid nutrient accumulation, with rates differing by species. Total tree weight increased exponentially for all species. Noble and Nordmann fir produced slightly more biomass than did grand fir or Douglas-fir. At the common harvest height, 1.8 to 2.1 meters, Douglas-fir and grand fir contained approximately the same amount of N, which was substantially less than Nordmann and noble fir. When harvested at approximately 2 meters, Douglas-fir Christmas trees contain approximately one-half the amount of K as do grand and Nordmann fir and one-third the amount of K as noble fir.

Most nutrients are removed with needles and branches as trees are harvested. Root removal adds 1 to 3 percent additional N leaving a field. Root removal of Douglas-fir adds 5 to 10 percent to the total nutrient leaving a field and 20 to 30 percent for the other species.

Lack of nutrients for Christmas tree production is critical, especially during the 2 to 3 years before harvest. To adequately supply nutrients, growers must anticipate tree nutrient need.

Literature

Hart, J., C. Landgren, R. Fletcher, M. Bondi, B. Withrow-Robinson, and G. Chastagner. 2009. Christmas tree nutrient management guide, western Oregon and Washington. Oregon State University Extension Service, EM 8856-E, Corvallis, OR.

Pedersen, L.B. and C.J. Christensen. 2005. A growth model for Nordmann fir: Biomass and nutrient consumption during one rotation. Program and abstracts for Seventh International Christmas Tree Research and Extension Conference, Tustin, Michigan.

Webster, S., C. Landgren, R. Fletcher, and M. Bondi. 1997. Nitrogen fertilizer: Where does it go? Christmas Tree Lookout (Summer):26–30.

Viewpoint: Causes of shoot damage and inhibited shoot growth of conifers in Christmas tree production

Jürgen Matschke

Editor's note: Dr. Jürgen Matschke has conducted research on physiology and genetics of Christmas trees for more than 20 years. He was appointed professor of the Academy of Agricultural Sciences in Berlin in 1988 and has published dozens of articles on conifers for ornamental and Christmas tree production. Dr. Matschke was unable to attend the 2011 CTRE due to health concerns; however, he submitted this synthesis of his observations of recent bud abortion and bud abnormalities in Nordmann fir in Germany for inclusion in the proceedings. We wish Jürgen the best in his cancer treatments and hope our edits maintain his intent.
—Bert Cregg and Chal Landgren

The ambition of every producer of Christmas trees is quality, marketable trees. However, the quality of the trees at the time of budburst—especially buds near the top region of the tree, may be influenced by genetics, especially provenances, and by management practices from the first year on (Figure 1).

Figure 1. Poor development of shoots of Nordmann fir.

In the northern region of Germany, growers reported poor budbreak, with many plantations in 2010 showing death of buds on more than 50 percent of the plants. Typically, investigation of poor bud performance focuses on recent environmental conditions, disregarding problems in cultivation from the seedling stage or provenances that are unsuitable for the site and the consequences of those factors. Consultants often focus on a single cause, forgetting that symptoms may result from different additive influences. Since physiological mechanisms and their long-lasting consequences for trees are not sufficiently understood as triggering factors, poor shoot development is attributed to frost damage, sun scorch, microorganisms and/or insect damage. Often, however, the problem has not started in the growing site (Figure 2), but rather in the seedling bed (Figure 3).

Figure 2. Often the problem doesn't start on the site of cultivation.

Figure 3. Growth problems may be traced back to the seedbed.

Unfortunately, wrong diagnoses results in wrong advice. Apparently, it is not quite clear to the producers that conifers will not always withstand permanent stress resulting for instance from top-application of herbicides during the growing season in combination with extreme wind and drought stress as well as intense solar irradiation. Consequently, weakened seedlings and plants undergo the phase of frost hardiness adaptation or the de-hardening phase in early spring.

Stress to conifers begins at the cellular level

Plant cells are genetically adapted to withstand natural stresses due to temperature (heat, cold), intense solar irradiation, water deficiency, and/or salt stress by protective or detoxication mechanisms. If these protective mechanisms are inhibited by additional stresses such as poor cultural management for long periods, detoxification processes become exhausted, followed by chronic damage and changes to physiological processes and morphology, as well as predisposition to secondary biotic agents. This anthropogenic stress is characterized by phases, where destabilization of metabolism and loss of function of organs occur.

Additive effects of the factors either lead to biochemical adaptation/tolerance or to destabilization of the system. The system is multi-causal; the visible damage is the effect of various factors. Among those, inhibition of the protein-metabolism as a consequence of misapplied herbicides is regarded as most common. It is related to the following: decreased water potential; changes in the pH-gradient in the cell-sap; decrease in turgor and the stability of the cells; accumulation of radicals destroying the cell membranes, especially following intense solar radiation; broken transport of carrier proteins through the membranes; and an uncontrolled redistribution of phytohormones in the cells

Consequences of changes in concentration of the phytohormones are: loss of the apical dominances of the meristems; growth disorders; reduced cambial activity as well as disturbed production of phloem and xylem tissues and reduced activity of plant metabolism.

Physiological adaptations to environmental conditions mean an increased conversion of metabolism, parallel with production of several phytohormones: Stress leads to an activation of abscisines and jasmonates triggering the following: premature closing of the stomata, increased content of sugars and proline, increased permeability of root cell membranes, enhanced senescence of the cells, insufficient development of meristems, and premature beginning of the rest period.

Stress to the cells induces activation of the aging hormone ethylene, leading to enhanced senescence of the cells; water deficiency, activating phytohormones (cytokinins) and nutrients and premature beginning of the rest period

Stress to the cells means a reduction in concentration of the physiological active cytokinins in the roots as well as a destabilization of the transport mechanisms leading to a range of problems including: reduced and/or disordered water- and nutrient uptake and transport; reduced tolerance of water deficiencies; reduced production and disordered transport of amino acids and proteins as carrier for transport of phytohormones and nutrients; insufficient formation of the bud meristems and consequently insufficient protection from frost—which is an effect of a reduced volume of the cavity below the collenchyma-tissues in the transition to the pith-tissue; reduced production and development of leader- and lateral buds; and reduced or lost budburst in the spring of the following year (Figure 4).

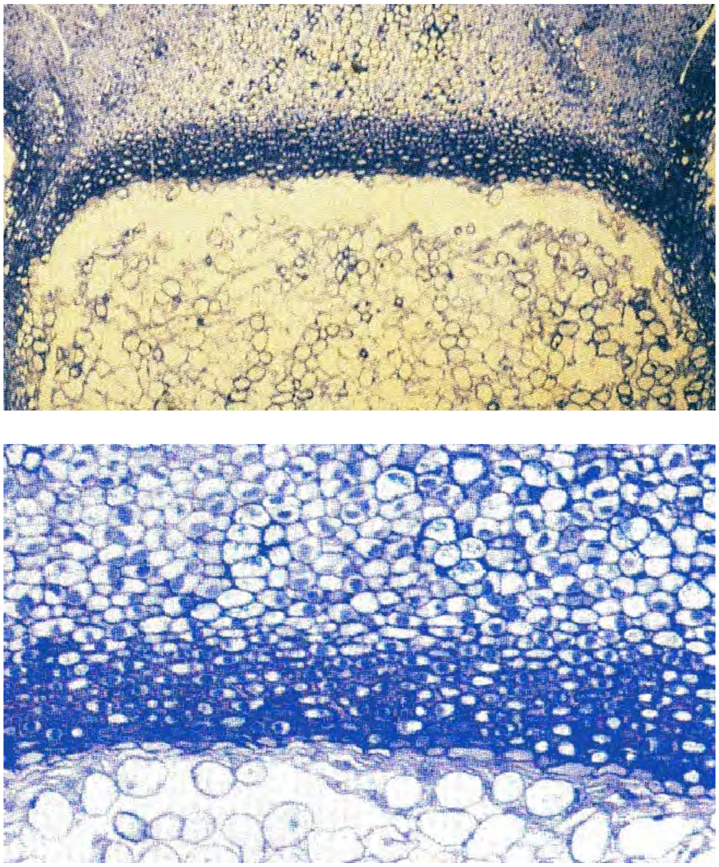

Figure 4. Cross section of unimpaired (above) and affected (below) terminal buds of a blue spruce during the dormant season. Compared to the unaffected bud, in affected plants the hollow space below the stabilzing tissue (collenchyma-plate), composed of nine cell rows (space), which protects the bud from winter frost, is lacking. Often the collenchyma plates of impaired buds are only composed of six cell rows. The cave/hollow and the collenchyma-plate above protect the bud meristem above from frost.

In total, the annually repeated stress as a result of various impacts leads to a premature senescence of the cells and therefore an insufficient formation of the buds meristems before the autumnal period. This condition is primarily triggered by misdirected biochemical metabolizing processes dependent on environmental conditions in relation to incompatible herbicides and therefore to an overstraining of the enzymatic detoxification system. This causes: accumulation of radicals and peroxides, especially during intense solar radiation leading to damage or destruction of the membrane systems; increase of the content of phytohormones, leading to senescence (apolar gibberellines, abscisines, jasmonates, ethylene), at the same time decreasing content of hormones conducive to vitality, the cytokinins; activation of the respiration metabolism with reduced output of photosynthesis; insufficient production of secondary defense compounds, protective amino acids and protein; reduced production of plant tissues and enhanced decomposition of protein; insufficient and retarded differentiation of tissues of the bud meristems and/or death of cells in the region of apical meristems, due to lack of acclimation-retarded budburst as a consequence of the inadequately developed bud meristems, caused by a deficiency of physiologically active cytokinins from the root tips and missing proteins for the transport of the hormones into the shoots.

The latter condition is a result of a deficiency of physiologically active cytokinins in the root tips, since these enzymes control the cleavage, activation of other enzymes, the growth and the budburst. The symptom of suppressed budburst is the result of lack of cytokinins and/or an insufficient transport of these substances to the top as well as a lack of transporting proteins. The reasons are mainly a disturbed and retarded growth of the root tips.

Impacts of chemical application

A deficiency of active cytokinins results in an insufficient content of proteins not only for cell production, but also for the transport of other enzymes and nutrients. This may be triggered by herbicides inhibiting protein synthesis and cleavage, such as sulfonyl-carbamides, and glyphosates or lufosinates. Recommendation of *Terano* for “maintenance” applied to seedlings and cultures is becoming more common. It has to be stated that the compounds Flufenacet and Metusolam show a similar function as sulfonyl-carbamides and Imidazolinones. Metosulam inhibits the essential key-enzyme ALS and therefore the cleavage in meristems. Flufenacet inhibits the formation of cell walls and suppresses the cell expansion in the meristems. In conifers, there are no mechanisms to detoxify these agents. Registered pre- and post-emergence herbicides show a wide range of efficacy against weeds inhibiting protein metabolism, cleavage, and cell expansion.

Recommendations to spray those compounds in minute amounts, even in tank-mixtures and/or in oily formulations without a protective shield may cause acute damage to conifers or, more commonly, in the following years. Symptoms develop at first as stunted shoot meristems and remain usually undetected by the producer of the trees, unless, during the following seasons, shortened and bleached needles and stunted buds appear. As early as the first half of July, meristems of buds for the following year can be seen on retarded shoots by use of a microscope. The production of new buds of affected plants may not be finished until the end of July, when days become shorter and natural senescence of cells and organs is initiated. This condition builds up, since there are no plant enzymes to metabolize the inhibiting herbicides.

Reducing stress to the plants

The acute biochemical stress resistance of the plants is linked to their anatomic adaptation to the various influences is decisive for the reaction against the combinations and interactions between the various stress triggering factors as well as their intensities. Christmas tree producers are well advised to consider those interactions and to keep the level of negative influences low from the initial seedling stage onward. This means:

- Avoidance of poor soil conditions or compaction and thus oxygen insufficiencies for the roots of the seedlings
- Avoidance of water deficit after lifting and planting on the site, as well as stress induced by lowering of the water potential as a consequence of salt-intoxication or through fertilizing, especially on poorly ventilated and cold soils, following herbicide impacts, cold, heat and/or osmotic salt-stress
- Avoidance of extreme solar and UV-irradiation, since the production of radicals in the cells, especially following impact of herbicides to young plants, i.e., protective fleeces against irradiation, excessive wind-exposure and drought; cultures should be protected initially by using shields or by sowing cover crops (Figure 5)
- There is no specific resistance of conifers to herbicides, at most conifers show selectivity/tolerance to some compounds in low concentration; therefore toxic reactions of the cells to incompatible herbicides should be excluded, mechanical control and shielded application of herbicides are preferable methods of weed control.
- Site-adapted species and provenances deriving from adequate altitudes and latitudes should be selected, and their optimal, unstressed growth should be ensured. This will help avoid retarded and reduced development and differentiation of the meristems giving rise to the shoots of the following year

Figure 5. Beside the shade-providing cultivation of cereals between the rows, green corridors between the rows have a temperature-balancing effect on the soil of the conifers.

Reducing frost damage

Cell bio-membranes may be inactivated by increased concentration of nutrient salts as well as salts of organic acids favoring a damaging dehydration. The functions of the membranes, especially those of the photosynthetic system, have to be maintained by osmotic substances as compounds rich in sugars or protective proteins in the cells, in order to enable adaptation of the woody plants to the extreme variations in temperature and the protection of frost-sensitive membranes and, as a consequence, the chloroplasts; probable frost damage is reduced by:

- An optimal nutrient-balance in the needles, especially potassium and phosphorus
- A close relation of nitrogen to other ions in the needles (N =<1.4%) is desirable
- Lowering of the freezing temperature by sugars, glycosides, pinoles, inositoles, free fatty acids, specific amino acids and proteins with stable chemical structures
- Optimal content of salts of organic acids
- Balanced relations of phytohormones to prevent from stress by low temperatures

Since stress caused by low temperatures increases the permeability of the cell-membranes, it is necessary to aim for unimpaired physiological processes, which favor tolerance against dehydration of the protoplasm, the stabilization of bio-membranes and the prevention from crystal nuclei of ice.

Extremely low temperatures and short photoperiods lead to inactivation of compounds in the cells, which function as osmo-regulators stabilizing the bio-membranes. These effects can only be avoided by the selection of adequate provenances from low altitudes, since these provenances mature during the vegetation periods on the production sites and are able to better equalize the extreme temperature-fluctuations. In addition, this requires an optimal maintenance of the seedlings to exclude growth disorders, i.e., the contact to herbicidal inhibitors. The latter can avoid the damage to “cold-hardiness-protectors” additionally, since only these membrane-protecting “cryoprotectives” are able to suppress the formation of ice-crystals in the cells and the loss of water and protect the buds.

The growth of poor-quality shoots should be avoided by an optimal fertilization, which must be adapted to the culture (*i.e., by needle and not only by soil analyses*). So the plants can withstand the hardening phase in autumn, the breakdown of temperature in winter and the gradual de-hardening in spring before shoot growth. That means a fertilization with phosphate, sodium, manganese and calcium with reduced admixture of nitrogen at the right time; the optimal relation in the needles should be: N to K: >0.55, Ca: 0.50, Mg:>0.13, P: >0.13, Fe:>0.010, B: 0.002, Zn: 0.003. A fertilization applied too late, a suboptimal one, and especially over-fertilization with nitrogen and low sodium should be avoided, as well as an excessive salt content, since this causes a reduction of the protective effects against frost by the sugars and the excess of competitive ions could become antagonistic to other essential ions.

Summary

The increasing number of observations of damaged shoots of conifers in Christmas tree production, and also in forests are the result of genetic and morpho-physiological causes. Owners of nurseries and producers of Christmas trees are well advised to use plant provenances from low altitudes which are well adapted to their specific sites. In addition, they should provide the plants with an optimal, site-related maintenance from the beginning. Only that may ensure early, undisturbed development of all bud meristems as well as the synthesis of necessary protective compounds against environmental impairments related to changing climate conditions, especially frost.

Editor’s note: (no literature references provided)

Effects of cover crop management on growth and nutrient dynamics in fraser fir (*Abies fraseri*) production systems

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Abstract

Fraser fir (*Abies fraseri*) is traditionally produced in high-input, intensively managed cropping systems for Christmas tree production purposes. Groundcovers have been used as an alternative approach to sustainable cropping in agriculture. Groundcovers can improve the sustainability of tree production systems by reducing nutrient loss, increasing soil organic matter content, and maintaining nutrient balance. However, adding groundcovers to a tree production system can lead to competition between the groundcover and trees for available resources, such as light, soil moisture, and soil nutrients.

The overall goal of this project is to investigate the effect of three groundcovers on the overall sustainability of Fraser fir Christmas tree production systems. The groundcovers investigated were alfalfa (*Medicago sativa*), Dutch white clover (*Trifolium repens*), and perennial rye (*Lolium perenne*). This paper reports on the effect of groundcover species and management practices on organic nutrient production, soil organic matter, and soil mineral nitrogen.

Intercropped groundcovers were mowed every 21 days, and the cut vegetation was returned to the ground as green mulch. The effects of cover crop species and management practices were evaluated by quantifying the cover crops' above-ground biomass production. The total amounts of organic nutrients, including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) were determined by chemical analyses of subsamples of materials from the cover crop biomass. The impact on soil fertility was evaluated by monitoring changes in soil organic C and soil mineral N.

Results obtained indicate that the species selection affected the amount of green manure produced and its total N and macronutrient content. The species choice affected tree height growth only in 2010 and not in 2009, while management practices significantly affected tree diameter and height growth in both years. Soil organic matter content was stable in the upper soil profile due to the relatively small quantities of organic matter added with the cropping system compared to the total stock of soil C. Mineral N decreased over the season due to the synchrony of cover crop decomposition, mineralization, and nutrient uptake by trees in the upper profile. These results indicate that intercropping cover crops can improve soil N fertility and organic matter. However, there is strong competition for other nutrients that needs to be carefully considered.

Introduction

In conventional agricultural and forestry production systems, inorganic fertilizers are widely used. However, approximately half of the applied fertilizers are lost from the systems before the cash crops can assimilate them (Drinkwater et al., 1998). In addition to their high cost, long-term use of fertilizers can also have serious negative environmental effects, such as increasing soil acidity, soil erosion, and degradation of soil biodiversity, eventually leading to loss of productivity for the target crop (Juo et al., 1995).

Conversely, using groundcovers can bring several potential advantages to the sustainability of intensive forestry and agricultural production systems. Groundcovers can contribute organic matter to soil and reduce soil compaction and crusting, thus improving water infiltration and, in some cases, moisture retention (MacRae and Mehuys, 1985). They also have the ability to reduce soil erosion by wind and water (Hargrove, 1991), add or retain soil N, facilitate the availability of other nutrients such as P and Ca (Kourik, 1986), suppress weeds, and improve chemical and physical characteristics of soil (Giller and Wilson, 2000).

The use of vegetative groundcovers has been extensively studied as one of the possible approaches to sustainable agriculture (Hartemink, 2005; Hänninen, 2002). In this practice, the soil under or around the main crop is covered with another plant species whose growth is managed to produce an optimal system for the target crop. Cover crops have been used for control of arthropod pests, to suppress weeds, and as a source for organic nutrients (Sanchez et al., 2007). Examples of perennial groundcovers in short-rotation production systems include palm oil and rubber plantations, and various orchard and vineyard production systems (Baumgartner et al., 2008). For example, the incorporation of cover crops has proven to significantly reduce nitrate leaching in rubber tree plantations (Schroth et al., 2001) and in cereal-grass-based systems, where they are reported to be more efficient in the uptake of residual soil N (Meisinger et al., 1991; Shipley et al., 1992). Brinsfield and Staver (1991) reported that perennial ryegrass exhibited the best response with regard to the absorption of unused soil N due to its quick-growing and fibrous root system.

Planting perennial cover crops between trees can improve soil physical, chemical, and biological properties and consequently lead to improved soil health and yield of the principal crop. The effect of crop residue on soil organic matter content depends greatly on the amount and type applied; therefore, the groundcover species' characteristics and management regime are key factors.

In short-rotation tree systems, regularly mowed groundcovers contribute significant amounts of organic matter that improve physical, chemical, and nutritional characteristics of the soil. For example, healthy stands of white clover and alfalfa produce between 140 and 160 kg N/ha^{-1} (Wilson et al., 2010). The low C:N ratio of their stems and leaves causes them to decompose rapidly and release N, making them first choices for "living mulch" systems planted between tree rows (Schroth et al., 2000). Cover crops also offer an important way to control and conserve excess soil nitrate during winter and to supply N when needed by the trees in the spring and summer (Bowman et al., 1998).

In addition to N, cover crops supply other essential nutrients to subsequent crops when their tissues decompose. The amount of mineral nutrients contributed by cover crops is also affected by environmental conditions, soil fertility, crop management practices, and the crop species (Fageria, 2007). For example, studies have shown that graminaceous cover crop species can improve the iron (Fe) nutrition of fruit trees grown on calcareous soils by enhancing Fe availability (Cesco et al., 2006).

However, intercropping systems are known to be complex ecosystems in which both facilitation and competitive interactions may occur. Groundcover plants normally use available soil resources such as water and mineral nutrients for their own growth and can decrease the growth of the target crop (Ong et al., 1991). In tree–cover crop systems with relatively wide spacing, the competition for resources is mainly below ground (Hänninen, 1998). In below-ground competition, plants reduce available soil resources, mainly water and mineral nutrients, and decrease the growth and success of their neighbors (Casper and Jackson, 1997). It has been suggested that root competition is more important than shoot competition and has a greater impact on plant performance (Wilson, 1988; Gerry and Wilson, 1995; Weiner et al., 1997).

Therefore, understanding organic nutrient flows provided by the management of living mulches is critical to the successful use of groundcovers in short-rotation cropping systems. The goal of this study is to determine the effect of cover crop species and management practices on organic macronutrient production, tree growth, and nutrient dynamics in a Fraser fir–cover crop intercropping system.

Materials and methods

The experiment was conducted in 2009 and 2010 at Sandhill Farm of the Tree Research Center (TRC) (42°65'N, 84°42'E) on the campus of Michigan State University, in East Lansing, Michigan. The field was 39 x 64 m in size, and the experiment was established as a randomized complete block design with three replications. Each experimental plot was 7.2 x 10.8 m and contained 35 trees established at 1.8 x 1.8 m spacing. Trees in border rows were used as a buffer and not included in measurements, therefore restricting data collection to the area of the remaining 15 interior trees in each plot.

The field was established in 2007 using Fraser fir transplants (plugs+2) obtained from a local commercial nursery (Peterson's Riverview Nursery, Allegan, MI). Transplants were machine planted on May 8, 2007. Two legume cover crops (Dutch white clover [*Trifolium repens*] and alfalfa [*Medicago sativa*]) and one grass (perennial rye [*Lolium perenne*]) were seeded between preplanted rows of Fraser fir trees. The cover crop seeds were purchased from Michigan State Seeds Company (Grand Ledge, MI) and hand broadcasted on May 15, 2007 at seeding rates of 28 kg/ha^{-1}. Cover crops were mowed regularly during the growing season in 2007 and 2008 to reduce competition with trees.

Management practices included combinations of banding and no-banding treatments of each species of cover crop, and a control or bare ground (BG) treatment where all weeds were removed by application of 35.84 kg/ha^{-1} of glyphosate with a CO_2-powered backpack sprayer (R & D Sprayers, Baton Rouge, LA). Banding consisted of maintaining a bare ground area 52 cm wide centered along the tree row. This was achieved by applying a directed spray of glyphosate with a custom-designed MANKAR sprayer (George F. Ackerman Company, Curtice, OH) at a rate of 3 liters/ha^{-1} three times during the season. The summary of the seven treatments includes: bare ground (BG), banded perennial rye (PR+B), non-banded perennial rye (PR+noB), banded alfalfa (ALF+B), non-banded alfalfa (ALF+noB), banded white clover (WC+B), and non-banded white clover (WC+noB).

Cover crops were mowed every 2 weeks during the growing seasons 2009 and 2010 using a mower equipped with side discharge, and the cut residues were returned as mulch to the ground. Cover crop biomass returned was determined by collecting biomass from randomly selected 0.55 m^2 quadrants in each plot. The green biomass collected in each treatment was weighed and oven dried at 65°C, and the dried biomass was determined. Subsamples from each treatment were used for chemical analyses.

Tissues were oven dried at 65°C and ground into a fine powder. Approximately 0.3 g of material was placed into a 75 ml digestion tube and digested with a mixture of sulfuric acid (4.5 ml) and hydrogen peroxide (1.5 ml).

Total N was determined as described by Wilson et al. (2010). Aliquots from the digested solution were buffered and chlorinated after dialysis to form a chemical complex measured at 660 nm on a SAN++ segmented flow analyzer (Skalar Inc., Atlanta, GA). Phosphorus content determination was based on an ammonium heptamolybdate and potassium antimony (III) reaction that forms in an acidic environment, and antimony-phospho-molybdate complex measured at 880 nm on the SAN++. Other nutrients, including K, Ca, and Mg were determined by Atomic Absorption Spectrometry.

Composite soil samples were collected from depths of 0–15 cm and 15–30 cm, within 1 foot of trees at two random locations within each plot using a soil auger. Samples were extracted using potassium chloride, filtered, and analyzed by segmented flow analysis to determine soil NH_4^+ and NO_3^-. Soil total organic matter content was determined by reduction of potassium dichromate by organic carbon compounds and subsequent determination of the unreduced dichromate by oxidation-reduction titration with ferrous ammonium sulfate (Walkley and Black, 1934).

Biomass production, nutrient content, soil nitrate and ammonia concentrations, and soil organic matter content were analyzed by two-way analysis of variance (ANOVA) to test the effect of the treatments on response variables. The means were separated by an LSD-test with $\alpha<0.05$. Pairwise comparison was run to compare each groundcover species and management practice combination to the conventional standard. The cumulated organic nutrient content data was analyzed using the mixed model for repeated measures procedures. All data analyses were performed using Systat 13 software (Systat Software, Inc., Chicago, IL). A level of significance of $\alpha<0.05$ was used to determine statistical significance.

Results

Cumulated biomass

Biomass production was greater in leguminous cover crops (white clover and alfalfa) compared to the grass cover crop (perennial rye). Within the same species, there was no statistically significant difference between treatments without bands and banded treatments (Table 1).

Table 1. Cumulated cover crop biomass (tons/ha).

Treatments	**2009**	**2010**
WC+B	1.07±0.19[a]	1.61±0.38[a]
WC+noB	1.07±0.07[a]	1.67±0.07[a]
ALF+B	1.17±0.14[a]	2.02±0.11[a]
ALF+noB	1.22±0.20[a]	2.21±0.23[a]
PR+B	0.87±0.18[a]	1.23±0.24[a]
PR+noB	0.58±0.34[a]	0.60±0.34[b]
p-value	*p= 0.326*	*p= 0.011*

ALF+B = Alfalfa with banding; ALF+noB = Alfalfa with no banding; PR+B = Perennial rye with banding; PR+noB = Perennial rye with no banding; WC+B = White clover with banding; WC+noB = White clover with no banding; BG = bare ground.

Soil organic matter

Soil organic matter values in soil samples from the upper soil profile (0–15 cm) were statistically higher than in samples from deeper in the soil profile (15–30 cm) in both 2009 (p=0.000) and 2010 (p=0.001). Within each sampling depth, soil specimens from cover crop plots were generally higher in soil organic matter than were bare-ground plots; however, the difference was not statistically significant (Table 2).

Table 2. Soil organic matter content (%) as affected by groundcover treatments.

	2009		**2010**	
	0–15cm	**15–30cm**	**0–15cm**	**15–30cm**
ALF	2.66±0.19[a]	1.86±0.26[a]	3.06±0.23[a]	1.64±0.20[a]
PR	2.78±0.23[a]	1.70±0.36[a]	2.69±0.29[a]	1.92±0.20[a]
WC	2.67±0.28[a]	2.25±0.45[a]	2.92±0.32[a]	1.83±0.25[a]
BG	2.12±0.24[a]	1.45±0.17[a]	2.24±0.34[a]	1.20±0.08[a]
p-value	*p=0.428*	*p=0.546*	*p=0.385*	*p=0.241*

ALF = Alfalfa; PR = Perennial rye; WC = White clover; BG = bare ground.

Organic nutrients

Quantities of organic nutrients returned to the ground through the mulching process were significantly affected by the treatments. Organic N varied from 5.3±0.2 to 17.3±0.6 g in 2009 and 6.7±0.3 to 26.6±0.8 g in 2010 (Table 3). As expected, organic N values obtained from the two legumes were two- to three-fold higher than those obtained for the grass cover crop species.

Table 3. Organic nutrient content returned to the ground through mulching of the various groundcovers.

	2009					**2010**				
	N	**P**	**K**	**Mg**	**Ca**	**N**	**P**	**K**	**Mg**	**Ca**
ALF+B	14.9±0.3^{ae}	1.7±0.0^{a}	4.6±0.4^{b}	0.3±0.1^{a}	1.7±0.2^{a}	26.3±0.5^{a}	4.9±0.1^{ab}	17.9±1.4^{ab}	0.9±0.0^{ad}	2.9±0.2^{a}
ALF+noB	17.3±0.6^{b}	1.6±0.1^{a}	4.1±0.7^{b}	0.3±0.0a^{b}	1.4±0.0^{a}	31.2±0.9^{b}	6.4±0.3^{ad}	22.0±1.4^{a}	0.9±0.0^{a}	2.3±0.1^{a}
PR+B	7.7±0.35^{c}	1.0±0.0^{c}	3.0±0.2^{ab}	0.2±0.0^{ab}	0.8±0.0^{b}	14.2±0.6^{c}	3.3±0.1^{bc}	12.8±0.3^{b}	0.5±0.0^{b}	0.9±0.2^{b}
PR+noB	5.3±0.2^{d}	0.6±0.5^{d}	1.9±0.3^{a}	0.1±0.0^{b}	0.9±0.0^{b}	6.7±0.3^{d}	2.1±0.2^{cd}	11.5±3.6^{b}	0.2±0.0^{c}	0.4±0.0^{b}
WC+B	13.8±0.5^{a}	1.1±0.1^{ac}	4.4±0.5^{b}	0.2±0.0^{ab}	2.2±0.0^{a}	24.4±0.7^{a}	5.0±1.1^{a}	16.3±0.3^{ab}	0.7±0.1^{d}	2.2±0.3^{a}
WC+noB	16.0±0.2^{be}	1.4±0.1^{a}	4.4±0.5^{b}	0.3±0.0^{a}	1.9±0.1^{a}	26.6±0.8^{a}	2.9±0.3^{bc}	18.3±1.3^{ab}	0.9±0.0^{ad}	3.0±0.1^{a}
p-value	*p=0.000*	*p=0.000*	*p=0.008*	*p=0.007*	*p=0.000*	*p=0.000*	*p=0.000*	*p=0.012*	*p=0.000*	*p=0.000*

ALF+B = Alfalfa with banding; ALF+noB = Alfalfa with no banding; PR+B = Perennial rye with banding; PR+noB = Perennial rye with no banding; WC+B= White clover with banding, WC+noB = White clover with no banding; BG = bare ground.

Phosphorus content varied from 0.6±0.5 to 1.7±0.0 in 2009, and 2.1±0.2 to 6.4±0.3 in 2010. Potassium content was also significantly higher for alfalfa and white clover treatments compared to perennial rye, both in 2009 (p=0.008) and 2010 (p=0.012). Similar to other macronutrients, magnesium (p=0.007 in 2009 and p=0.000 in 2010) and calcium (p=0.000 in 2009 and p=0.000 in 2010) were also significantly affected by cover crop treatments.

Soil nitrate

Soil nitrate concentrations at the 0–15 cm depth were statistically similar in all treatments in 2009, varying from 12.97±9.4 to 51.56±20.5 (p=0.376). However, the various treatments significantly affected nitrate concentrations, which varied from 2.81±0.42 to 18.82±4.23 (p=0.014) in 2010 (Table 4). At the 15–30 cm sampling depth, nitrate concentrations were significantly affected by the treatments in 2009 (p=0.040) but not in 2010 (p=0.076). Nitrate concentrations were generally lower in soil samples from the lower profile.

Table 4. Soil nitrate (NO_3^-) concentrations in upper soil profiles as affected by the groundcover species and management practice (µg/g)

	2009		2010	
	0–15 cm	**15–30 cm**	**0–15 cm**	**15–30 cm**
ALF+B	39.59±12.38^{a}	31.45±3.37^{ab}	4.20±0.67^{b}	3.52±0.23^{a}
ALF+noB	37.7±13.08^{a}	20.90±2.68^{ab}	7.67±3.12^{ab}	5.61±0.63^{a}
PR+B	32.58±4.96^{a}	16.72±5.87^{b}	9.23±4.74^{ab}	5.29±1.20^{a}
PR+noB	12.97±9.36^{a}	20.13±5.18^{ab}	2.08±0.17^{b}	5.80±0.12^{a}
WC+B	56.78±5.56^{a}	38.22±4.86^{ab}	8.38±2.26^{ab}	7.46±1.07^{a}
WC+noB	40.10±17.59^{a}	53.96±13.00^{a}	18.82±4.23^{a}	11.20±4.25^{a}
BG	51.56±20.46^{a}	33.74±10.68^{ab}	2.81±0.42^{b}	3.03±0.12^{a}
p-value	*p=0.376*	*p=0.040*	*P=0.014*	*p=0.076*

ALF+B = Alfalfa with banding; ALF+noB = Alfalfa with no banding; PR+B = Perennial rye with banding; PR+noB = Perennial rye with no banding, WC+B = White clover with banding; WC+noB = White clover with no banding; BG = bare ground.

Tree height and diameter growth

In 2009, tree height growth varied from 7.35 cm to 10.36 cm (Table 5) with no effect of groundcover species and management practice on height growth. However, management practices had significant effect on tree diameter growth, with lower diameter expansion observed in all no-band treatments compared to banded treatments where diameter values were similar to bare-ground plots. In 2010, species selection significantly affected tree height growth (p=0.018). Lower height growth values were observed in perennial rye compared to alfalfa plots, where growth was statistically similar to white clover and bare-ground plots. Height and diameter growth were also significantly affected by management (p=0.000 for height and diameter growth).

Table 5. Height and root collar diameter (RCD) growth as affected by groundcover species and management practice.

Treatment		2009		2010		2-year cumulative	
		Height (cm)	RCD (mm)	Height (cm)	RCD (mm)	Height (cm)	RCD (mm)
ALF	**Band**	9.95±0.86a	5.00±0.53a	14.70±1.60a	11.41±0.85a	24.65	16.41
ALF	**No band**	8.83±0.77a	2.58±0.33b	9.95±1.59a	4.60±0.56b	18.78	7.18
BG		10.36±0.89a	4.29±0.48b	11.11±1.26a	9.97±1.11a	21.47	14.25
PR	**Band**	8.59±0.99a	4.87±0.53a	10.85±1.15a	10.38±1.08a	19.44	15.25
PR	**No band**	7.35±0.85a	1.53±0.26b	4.55±0.81b	3.26±0.49b	11.89	4.79
BG		10.36±0.89a	4.29±0.48b	11.11±1.26a	9.97±1.11a	21.47	14.25
WC	**Band**	10.03±1.00a	4.62±0.49a	12.09±1.31a	9.11±0.88a	22.12	13.73
WC	**No band**	8.10±1.12a	2.59±0.39b	5.20±1.09b	9.17±1.03a	13.30	11.77
BG		10.36±0.89a	4.29±0.48b	11.11±1.26a	9.97±1.11a	21.47	14.25

Discussion

Effect on green manure production

The cover crop species affected the total amount of green manure biomass produced and returned to the system, with the two legumes (alfalfa and white clover) returning significantly more biomass than the grass species (perennial rye). This observation is in agreement with previous studies conducted on biomass quantification (Cline and Silvernail, 2001). The superior biomass production observed in legumes is due to their fast growth potential and their ability to fix atmospheric N.

Effect on organic nutrient production

The quantity of organic nutrients was directly correlated with the cumulated biomass production. As expected, species choice was critical in relation to the total organic N production. Legume species exhibited superior production of organic N, not only due to their higher biomass production, but also to their superior N concentration in plant tissues. This result is similar to previous findings and demonstrates that significant amounts of N can be added by the inclusion of N-fixing legumes to production systems (Rennie and Kemp, 1983). These organic nutrients returned to the soil add to the soil organic pool, which becomes available to the plant through mineralization (Pardo et al., 2009), thus increasing the overall fertility of the site.

The P, K, and Ca contributions from legume treatments were significantly higher than those of perennial rye treatments. Similarly, Mg content was also higher for legumes compared to the grass species, but not to the same extent as other macronutrients. Cover crops have been reported to improve several macronutrients in the soil budget (Cavigelli and Thien, 2003). In addition to direct contributions from nutrients contained in green mulches, residues of cover crops may recycle normally unavailable macronutrients into forms more available to the target crop.

The short-term effect of the cover crop species and management practices on soil organic matter was not very well defined. The addition of organic residues is the only way to increase soil organic matter levels (Fageria, 2007). The effect of crop residue on soil organic matter content is highly related to the amount and only weakly related to the type of residue applied (Fageria, 2007). The addition of green manure to the sites was expected to have a significant positive influence on soil physical, chemical, and biological properties.

In this study, soil organic matter values were significantly higher in the upper horizon as a result of the addition of green manure. However, soil organic matter values were very similar between treatments in the upper soil horizon. This was not surprising because it has been reported that when total stocks of C in the soil are of sufficient size, the differences in C input from treatments compared to controls are small (Griffin and Porter, 2004). For example, Collins et al. (1992) compared continuous wheat and wheat–pea rotations in place for 25 years and found no significant effect on soil organic carbon.

A possible explanation for the short-term stability in organic parameters is the C:N ratio of the green manure used. The C:N ratio of the residue plays an important role in the immobilization of soil N because the plant tissue is a primary sink for C and N (Fageria, 2007). Legume residues in our study contained considerable amounts of N and certainly a relatively low C:N ratio, leading to faster decomposition, mineralization, and release of N, compared to perennial rye treatments. C:N values were generally much higher in the upper horizon, indicative of superior fertility compared to deeper horizons. High C:N values allow slow mobilization of N (Snapp and Borden, 2005) as microbial populations grow, allowing organically fertilized treatments to release N at steady rates, as opposed to spontaneous rates observed in traditionally fertilized treatments (Poudel et al., 2002).

All treatments incorporating a cover crop showed decreases in mineral N (NO_3^--N) in the upper soil profile compared to bare ground treatments. This result could be due to the synchrony between cover crop decomposition, mineralization, and uptake by trees, or increased leaching below the tested upper soil profile. The latter hypothesis is a very strong possibility, since unexpected significant differences in mineral N were observed in the deep profile (15–30 cm) in 2009. Decreases in mineral N have been previously linked to greater demand for this nutrient by higher plants and microbes that grow vigorously during the season, as well as leaching, runoff, and erosion (Singh et al., 1989; Srivastava, 1992). This can be especially true for cover crops with highly degradable residues such as legumes, where the mineralization rate of plant-derived C and N can be as high as 80 percent (Griffin and Porter, 2004).

Effects of cropping systems on tree morphology

During the 2 years of the study period, tree height and diameter follow a similar trend. Species selection affected tree height growth only in 2010, with significantly higher growth in ALF plots compared to PR plots (p=0.018). Otherwise, height growth was statistically similar in all other groundcover plots and in BG plots. This result suggests that different groundcover species had no significant impact on tree growth in production systems compared to the conventional management. Similar results were achieved in Ctahr's (2009) study; improved tree growth and reduction in fertilizer use were reported when using living mulches with fruit trees. Also, these results agree with the previous growth study published by Wilson et al. (2010).

However, we found noticeable impacts of management practices on tree morphology growth (both diameter and height growth) during these 3 years. Significantly lower growth was found in all plots without band, and growth in banded plots was similar to BG treatments. This suggested there was competition for nutrients or water in groundcover–tree production systems. The competition between groundcovers and target crops was evidenced in many other studies (Walsh et al., 1996; Wilson et al., 2010; Wyland et al., 1995; Malik et al., 1996). Therefore, we conclude that appropriate management practices, such as creating bands between groundcovers and trees should be applied to avoid negative impacts on tree growth.

Conclusions

This study investigated the effect of cover crop species and management practice on accumulated organic nutrient production, soil organic matter, and mineral N, with the purpose of assessing overall impact on soil fertility. Biomass production was affected by the species choice, with alfalfa and white clover producing significantly higher amounts of biomass compared to perennial rye. Organic nutrients returned to the ground through regular mowing of the cover crops during the growing season followed the same pattern, and the two legumes performed much better in terms of organic N, P, K, Ca, and Mg contained in green mulches.

Measurement of soil organic matter showed no significant differences in the upper soil profile, certainly due to the relatively small quantities of organic matter added with the cropping system compared to the total stock of soil C. The difference in soil organic matter between the upper and lower soil profiles was statistically significant.

Year-to-year variations were observed for soil mineral N content in both the upper and lower soil profiles. We observed a decrease in soil nitrate concentrations over the seasons attributed to either the synchrony of cover crop decomposition, mineralization, and nutrient uptake by trees in the upper profile, or nutrient leaching below the soil profile. These results indicate that intercropping cover crops can significantly improve soil nutrient fertility, especially when fast-growing N-fixing species are used. The effect on organic matter, however, can be clearly defined only over a much longer term than the duration of the current reporting period. We will continue to assess soil organic matter over the 8–10 year rotation cycle of Fraser fir trees.

References cited

Baumgartner, K., K.L. Steenwerth, and L.Veilleux. 2008. Cover-crop systems affect weed communities in a California vineyard. Weed Sci. 56:596–605.

Bowman, A.M., D.M. Hebb, D.J. Munnich, and J. Brockwell. 1998. Rhizobium as a factor in the re-establishment of legume-based pastures on clay soils of the wheat belt of north-western New South Wales. Aust. J. Exp. Agric. 38(6):555–566.

Boyle, M., W.T. Frankenberger, Jr., and L.H. Stolzy. 1989. The influence of organic matter on soil aggregation and water infiltration. J. Prod. Agric. 2:290–299.

Brinsfield, R.B. and K.W. Staver. 1991. Use of cereal grain cover crops for reducing groundwater nitrate contamination in the Chesapeake Bay region. pp. 79–82. In W.L. Hargrove (ed.). Cover crops for Clean Water. Soil Water Conserv. Soc., Ankeny, IA.

Carter, M.R. and B.A. Steward (eds.). 1996. Structure and organic matter storage in agricultural soils. Advances of Soil Science. Lewis Publishers, CRC Press, Boca Raton, FL, USA, 477 pp.

Casper, B.B. and R.B. Jackson. 1997. Plant competition underground. Ann. Rev. Ecol. Syst. 28:545–570.

Cavigelli, M.A. and S.J. Thien. 2003. Phosphorous bioavailability following incorporation of green manure crops. Soil Sci. Soc. Am. J. 67:1186–1194.

Cesco, S., A.D. Rombola, M. Tagliavini, Z. Varanini, and R. Pinton. 2006. Phytosiderophores released by graminaceous species promote Fe-59-uptake in citrus. Plant and Soil 287(1–2): 223–233.

Cline, G.R. and A.G. Silvernail. 2001. Residual nitrogen and kill date effects on winter cover crop growth and nitrogen content in a vegetable production system. HortTech. 11:219–225.

Collins, H.P., P.E. Rasmussen, and C.L. Douglas Jr. 1992. Crop rotation and residue management effects on soil carbon and microbial dynamics. Soil Sci. Soc. Am. J. 56:783–788.

Ctahr. 2009. Perennial peanut. Sustainable Agriculture Cover Crop Database. College of Tropical Agriculture and Human Resources.

Drinkwater, L.E., P. Wagoner, and M. Sarrantonio.1998. Legume-based cropping systems have reduced carbon and nitrogen losses. Nature 396:262–265.

Fageria, N.K. 2007. Green manuring in crop production. J. Plant Nutr. 30:691–719.

Griffin, T.S. and G.A. Porter. 2004. Altering soil carbon and nitrogen sticks in intensively tilled two-year rotations. Biol. Fertil. Soils 39:366–374.

Gerry, A.K. and S.D. Wilson. 1995. The influence of initial size on the competitive responses of six plant species. Ecology 76:272–279.

Giller K.E., G. Cadisch, and C. Palm. 2002. The North-South divide! Organic wastes or resources for nutrient management? Agronomie 22:703–709.

Hänninen, K. 2002. Tree–cover crop interactions: Birch growth, competition and soil properties. Thesis dissertation. Oulu University.

Hargrove, W.L. (ed.), 1991. Cover Crops for Clean Water. Proc. of an Int. Conf., West Tennessee Experiment Station, Jackson, TN, 9–11 April 1991. Soil and Water Conservation Society, Ankeny, IA, XII+ 198 pp.

Hartemink, A.E. 2005. Nutrient stocks, nutrient cycling, and soil changes in cocoa ecosystems: a review. Adv. Agro. 86:227–253.

Juo, A.S.R., A. Dabiri, and K. Franzluebbers. 1995. Acidification of a kaolinitic Alfisol under continuous cropping with nitrogen fertilization in West Africa. Plant Soil 171:245–253.

Kourik, R., 1986. Designing and Maintaining your Edible Landscape Naturally. Metamorphic Press, Santa Rosa, CA.

MacRae, R.J. and G.R. Mehuys. 1985. The effect of green manuring on the physical properties of temperate-area soils. Adv. Soil Sci., 3:71–94.

Malik, R.K., T.H. Green, D. Mays, B.R. Bock, J.D. Joslin, F.C. Thornton, V.R. Tolbert, G.F. Brown, and K. Sistani. 1996. Cover crops for erosion control in bio-energy hardwood plantations. The Seventh National Bioenergy Conference: Partnerships to Develop and Apply Biomass Technologies, September 15–20, 1996, Nashville, Tennessee.

Meisinger, J.J., W.L. Hargrove, J.R. Mikkelsen, and V.W. Benson. 1991. Effects of cover crops on groundwater quality. pp. 57–68. In W.L. Hargrove (ed.). Cover Crops for Clean Water. Ankeny, IA, USA: Soil and Water.

Ong, C.K., J.E. Corlett, R.P. Singh, and C.R. Black. 1991. Above and below ground interactions in agroforestry systems. For. Ecol. Manage. 45(1-4):45–47.

Pardo, G., J. Cavero, J. Aibar, and C. Zaragoza. 2009. Nutrient evolution in soil and dry cereal yield under different fertilization type in dryland. Nutr. Cycling Agroecosyst. 84:267–279.

Poudel, D.D., W.R. Horwath, W.T. Lanini, S.R. Temple, and A.C.H. Ban Bruggen. 2002. Comparison of soil N availability and leaching potential, crop yields and weeds in organic, low-input and conventional farming systems in northern California. Agric. Eco. Env. 90:125–137.

Reeves, D.W. 1997. The role of organic matter in maintaining soil quality in continuous cropping systems. Soil & Tillage Res. 43:131–167.

Rennie, R.J. and G.A. Kemp. 1983. N_2-fixation in field beans quantified by ^{15}N isotope dilution. II. Effect of cultivars of beans. Agron. J. 75:645–649.

Sanchez, E.E., A. Giayetto, L. Cichon, D. Fernandez, M.C. Aruani, and M. Curetti. 2007. Cover crops influence soil properties and tree performance in an organic apple (*Malus domestica* Borkh) orchard in northern Patagonia. Plant and Soil 292:193–203.

Singh, J.S., A.S. Raghubanshi, R.S. Singh, and S.C. Srivastava. 1989. Microbial biomass acts as a source of plant nutrients in dry tropical forest and savanna. Nature 338:499–500.

Shipley, P.R., J.J. Meisinger, and A.M. Decker. 1992. Conserving residual corn fertilizer nitrogen with winter cover crops. Agron. J. 84:869–896.

Schroth, G., W.G. Teixeira, R. Seixas, L.F. da Silva, M. Schaller, J.L.V. Macedo, and W. Zech. 2000. Effect of five tree crops and a cover crop in multi-strata agroforestry at two fertilization levels on soil fertility and soil solution chemistry in central Amazonia. Plant and Soil 221(2):143–156.

Shiferaw, A. 1985. Perennial legume ground covers and augmentative releases of *Trichogramma* for low-input pecan management. Master's thesis. Humboldt University, Berlin, Germany.

Snapp, S.S. and H. Borden. 2005. Enhanced nitrogen mineralization in mowed or glyphosphate treated cover crops compared to direct incorporation. Plant Soil 270:101–112.

Srivastava, H.S. 1992. Multiple functions and forms of higher-plant nitrate reductase. Phytochemistry 31:2941–2947.

Walkley, A. and I.A. Black. 1934. An examination of Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37:29–37.

Walsh, B.D., S. Salmins, D.J. Buszard and A.F. Mackenzie. 1996. Impact of soil management systems on organic dwarf apple orchards and soil aggregates stability, bulk density, temperature and water content. Can. J. Soil Sci. 76:203–209.

Weiner, J., D.B. Wright, and S. Castro. 1997. Symmetry of below-ground competition between *Kochia scoparia* individuals. Oikos 79:85–91.

Wilson, J.B. 1988. Shoot competition and root competition. J. Appl. Ecol. 25:279–296.

Wilson, A.R., P. Nzokou, and B.M. Cregg. 2010. Ground covers in Fraser fir (*Abies fraseri* Pursh. Poir) production systems: Effects on soil fertility, tree morphology and foliar nutrient status. Europ. J. Hort. Sci. 75:269–277.

Wyland, L.J., L.E. Jackson, and K.F. Schulbach. 1995. Soil-plant nitrogen dynamics following incorporation of a mature rye cover crop in a lettuce production system. The Journal of Agricultural Science 124:17–25.

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Age-graded fertilization of Nordmann fir

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Seldom does growers' application of fertilizer reflect the actual nutritional demand of their Christmas trees. The main reason is a lack of knowledge about how to adjust fertilizer amount and composition based on the increasing demand of growing trees. The aim of this project was to illustrate the advantages of fertilization graded by age compared with the traditional fertilization method. The project provided fertilization recommendations that enhance the sustainability of Danish Christmas tree production, especially concerning preservation of soil fertility through better utilization of applied fertilizer. The recommendations also took into account the wish for better Christmas tree quality, i.e., reduced risk of inappropriate development of needle color in the last year before cutting. The project was sponsored jointly by the Growers' Production Fee Foundation; Forest and Landscape, University of Copenhagen; and the Danish Christmas Tree Growers Association.

The project compared:

- Fertilization graded by age versus traditional fertilization
- Fertilization by broadcasting versus needle fertilization
- Organic fertilizers versus mineral fertilizers
- Spring fertilization versus split fertilization
- Two fertilizer application amounts
- Fertilizer distribution in spring versus summer

The fertilization graded by age was based on a growth model that includes the uptake of nutrients (Figure 1).

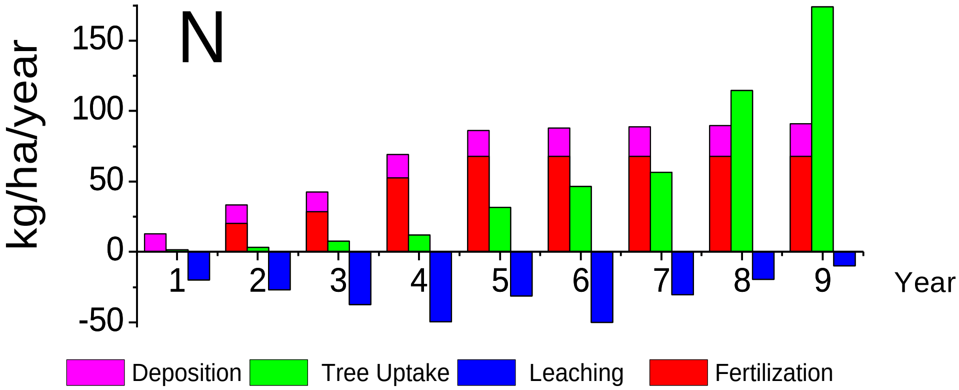

Figure 1. Nitrogen cycling model for a typical Danish Christmas tree stand.

The experiment was conducted on two different soil types:

- Nutrient-poor: meltwater sand from the Weichel glaciation (Rye Estate in Central Jutland)
- Intermediary: sandy clay loam from the Weichel glaciation (Clausholm Estate in Central Jutland)

The treatments included in this experiment are listed in Table 1, and Figure 2 provides an overview of the experimental design. On the sandy site at Rye, NPK 21-3-10 was used as spring fertilizer and NPK 23-3-7 as late-summer fertilizer. In the treatment with organic fertilizer, Binadan (produced from chicken manure) was used in the spring, followed by NPK 23-3-7 in late summer. At the more clayey site at Clausholm, NPK 21-3-10 was used as the spring fertilizer and NS 28-4 as late-summer fertilizer. In the treatment with organic fertilizer, Binadan was used as spring fertilizer, followed by NS 28-4 in late summer.

Table 1. Treatments in the experiment at the Rye site with fertilization graded by age in Nordmann fir stands. All fertilizer application was broadcast. Measurements related to nutrient cycling were carried out in the gray-shaded treatments. All fertilizers were merchandise mineral fertilizer.

No.	Treatment	Method	Fertilizer type	Age grading	N dose Kg/ha^{-1}/year^{-1}	Quota in spring (%)	Quota in autumn (%)
1	Control	-	-	-	0	0	0
2	Spring	Broad	Mineral	No	100	100	0
3	Split	Broad	Mineral	No	100	70	30
4	Split	Broad	Mineral	Grading	75	70	30
5	Split	Broad	Mineral	Grading	75	40	60
6	Split	Broad	Organic + mineral	Grading	75	70	30
7	Split	Broad + foliar	Mineral	Grading	75	70	30
8	Split	Broad	Mineral	Grading	100	70	30
9	Split	Broad	Organic + mineral	Grading	100	70	30
10	Split	Broad + foliar	Mineral	Grading	100	70	30

Instrumentation and methods

The plantations were established in 2003 (Rye) and 2004 (Clausholm) with Nordmann fir (Ambrolauri provenance), and the experiment began in the spring of 2007.

Bulk precipitation, air temperature (2 m), global radiation, and air humidity were logged approximately every 30 minutes. Bulk precipitation was sampled using three single collectors (Figure 2).

Soil water was sampled continuously below the root zone (depth 0.6 m) using Teflon suction samplers. Nine samplers were used in each treatment, three in each plot. Samples of both bulk precipitation and soil water were collected monthly.

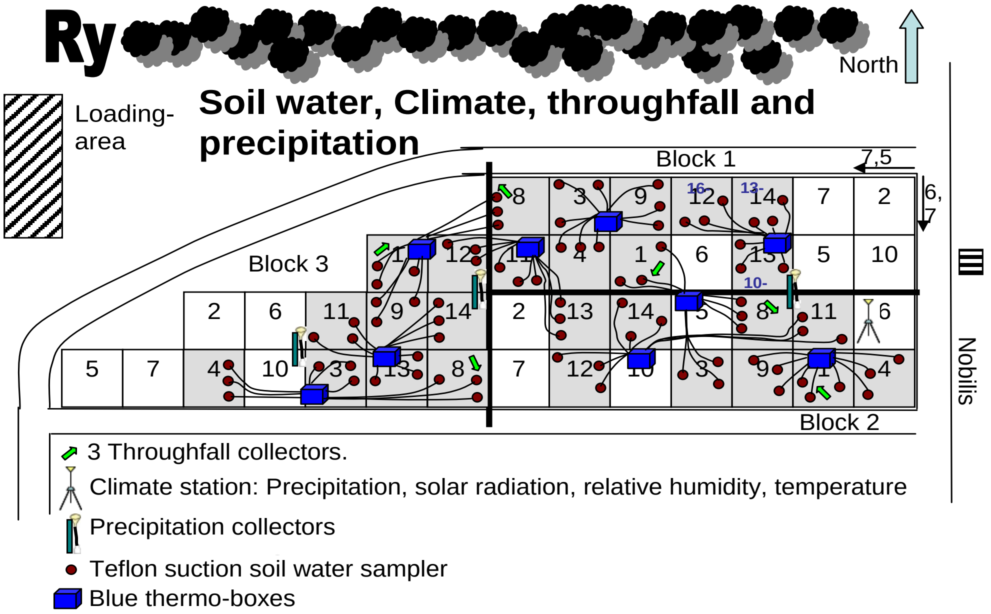

Figure 2. Soil water, climate, throughfall, and precipitation measurement, Rye experiment site.

Volumetric soil water content was measured by means of time domain reflectometry (TDR). We used two systems: an automatic one logging measurements of 32 pairs of probes approximately every second hour, and a manual system established to make monthly measurements on 20 different probe pairs.

Water samples were analyzed for ammonium (NH_4-N), chloride (Cl), nitrate (NO_3-N), sulfate (SO_4-S), Ca, Mg, Na, and K.

Input of N, K, and Mg was estimated by combining the fertilizer nutrient declaration with the amount of supplied fertilizer, as well as by combining the collected bulk precipitation with analyzed nutrient concentrations.

Soil percolation was estimated on a daily basis by hydrological modeling using a modification of the SIMPEL model (Hörmann, 1998) against the measured TDR data. The model was modified to calculate soil water percolation from the 0.6-meter depth corresponding to the root depth of Nordmann fir Christmas trees. Cl was used as a relative conservative anion to establish an overall confirmation of soil percolation. Monthly soil solute fluxes were obtained by multiplying monthly water fluxes by appropriate solute concentrations (mean values from blocs in the individual treatments).

Christmas tree quality included responses on growth (height and leader length), vigor (number of buds, [internodal] branches, and needle length), needle color, damage/health, and needle chemistry. These quality parameters were measured annually outside the growth period during the whole investigation period.

Results

Christmas tree growth is known to respond positively to fertilization. However, in this experiment the estate owners have used the TopStop® nipper to reduce leader length in such an inconsistent way that neither tree height nor leader length shows the usual correlations to the applied N dose, application time, or graded versus constant applied fertilization. The number of incisions does, however, correspond to treatment.

Christmas tree quality, mainly needle color and needle length, improved with increased dose of N. Hence, the graded application with increasing amount of N toward the end of the rotation resulted in the best Christmas tree quality (Figure 3).

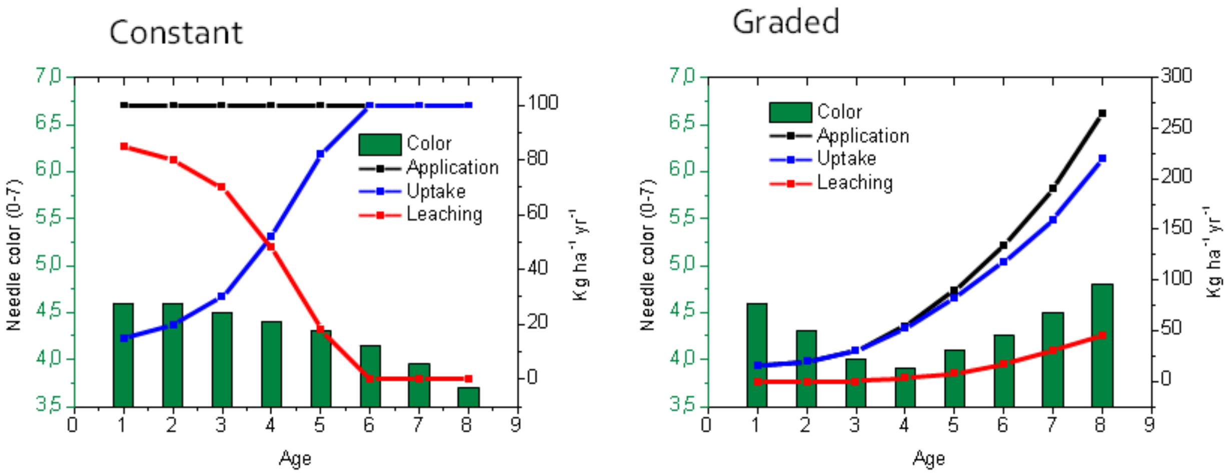

Figure 3. Application regime over a complete rotation period in relation to needle color, tree uptake, and leaching. Based on an application of 100 kg N/ha^{-1}/yr^{-1}.

Highest overall vigor appeared in the graded treatment. The number of buds and internodal branches improved with increased N dose, but was unaffected by fertilizer type, time of application, or regime.

From an environmental point of view, graded applications reduced N leaching and promoted increased N uptake. However, graded application increases the risk of high N leaching late in the rotation, especially after harvest has begun. N leaching from spring application of mineral and organic fertilizers is equal, but organic fertilizers have the potential for high leaching of other nutrients.

Biomass surveys indicate that a full-grown Nordmann fir has an N uptake rate between 190 and 250 kg/ha^{-1}/yr^{-1}.

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Budbreaking comparison of several *Abies nordmanniana* varieties cultivated in the Middle Ardenne (Belgium) since 2006

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General framework of the Middle Ardenne in Belgium

- Location: southern part of Belgium
- Medium altitude: from 350 to 550 m
- A lot of rain
- A lot of UV
- Heavy frost during the winter, frequent late frost during the spring
- Many hills with northern and southern exposure
- Major region for forests, including coniferous forest on acid soil; stony, shallow soil available for the roots system of trees, including Christmas trees

Union Ardennaise des Pépiniéristes (UAP)

- More than 50 members, including 30 big growers
- A lot of small growers with less than 2–3 ha (law)
- Annual production of 3,500,000 trees, in addition to 1,000,000 trees bought for resale
- 98 percent of the production in the southern part of Belgium
- Of this number, 95 percent of trees are produced by UAP members
- Between 4,000 and 5,000 ha in production
- 80 percent for export to France, Great Britain, Netherlands, and eastern countries
- Production is now 100 percent inside the Agriculture zone

Christmas tree species

- 1990: 70 percent Norway spruce, 10 percent Nordmann fir, and 20 percent other species
- 2010: 70 percent Nordmann fir, 15 percent Fraser fir, 10 percent Norway spruce, and 5 percent other species

Christmas tree propagation research

- Belgian nurseries are buying seeds to produce their own seedlings through the UAP and the CPSN (Pilot Center for Christmas Trees). The CPSN is funded by the Walloon Government, the province, and some private funds initiated by the UAP (commercial income).
- CPSN is responsible for all the experimentation in Belgium.

Goals of this research program

- To identify a variety or several varieties adapted to typical local conditions
- To stop production of *Abies nordmanniana* without a certified origin
- To select clones for installing a seed orchard in Belgium with good locally adapted *Abies nordmanniana*
- To initiate other programs for some other Abies species important for the Belgian market (*Abies fraseri, Abies lasiocarpa*, etc.)

The trial description

2006: Installation of 22 lines of 200 trees from various origins of *Abies nordmanniana*
2007: Installation of 30 lines of 200 trees from various origins of *Abies nordmanniana*

2006

L 1-8 Ambrolauri
Cl. Guiot
L 9 Borshomi
L 10 Ambrolauri Tlügi
L 11 Borshomi Netzvi
L 12 Apsheronsk
L 13 Bolu
L 14 Arkhys
L 15 Savsat (T)
L 16 Farum
L 17 Bachmarit
L 18-22 Ambrolauri
Cl. Guiot
S2R2
S2R2, but also S3/0 and S2R1

2007

1 *Abies Bornmülleriana* Bolu Koker
2 *Abies nordmanniana* Tversted 599D F566
3 *Abies nordmanniana* Borshomi Nedzvi NGR
4 *Abies nordmanniana* Salbjed 289 F690
5 *Abies nordmanniana* Tversted 623C F527
6 *Abies nordmanniana* Ambrolauri Tlügi
7 *Abies nordmanniana* Langesö F668
8 *Abies nordmanniana* Ambrolauri Borshomi Nedzvi
9 *Abies nordmanniana* Ambrolauri Tlügi
10 *Abies nordmanniana* Ambrolauri Tlügi GE
11–16 *Abies nordmanniana* Ambrolauri Tlügi
17 *Abies nordmanniana* Ambrolauri Borshomi Nedzvi
18 *Abies nordmanniana* Ambrolauri Tlügi
19 *Abies nordmanniana* Ambrolauri Borshomi Nedzvi
20 *Abies nordmanniana* Ambrolauri Tlügi
21 *Abies nordmanniana* Ambrolauri Tlügi
22 *Abies nordmanniana* Ambrolauri Borshomi Nedzvi
23 *Abies nordmanniana* Tversted F527
24–30 *Abies nordmanniana* Claude Guiot

Results of the budbreaking research

Figure 1. After 15 days.

Figure 2. After 3 weeks.

Figure 3. Budbreak (left and right) is complete after 1 month.

The process of budbreak

Figure 4. Phase 0—no buds breaking.

Figure 5. Phase 1—beginning of budbreak. Left: After 1 week. Right: After 10 days.

Results

Several budbreaking patterns have been observed:

- Very early and condensed: very risky for late frost
- Early but not condensed: risky
- Medium-term and condensed: risky
- Medium-term and not condensed: acceptable
- Late and condensed: acceptable
- Late and not condensed: acceptable

Analysis

- Only seeds with a certified origin (if possible with a field visit)
- Varieties Ambrolauri, Nikorstminda, Apsheronsk are acceptable
- No other variety without a 5-year budbreaking trial after planting
- Some varieties from certain seed orchards after a 5-year trial
- Some varieties are risky for late frost but have very good form
- New research on products to protect against late frost

Current research

We continue fertilization research with several mineral, organic, and chemical formulations to identify the best solution for the varieties selected and grown in our typical conditions. More than 20 programs are in process.

Dominique Raymackers, Master of Forestry Sciences, PhD in progress at the University of Liège, Faculty of Agro-Bio-Tech of Gembloux

A comprehensive approach to coning in Fraser fir Christmas trees

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Michigan State University: [1)]Department of Horticulture, [2)]Department of Forestry, [3)]MSU Extension, [4)]MSU Enviro-weather

Introduction

Fraser fir (*Abies fraseri*) trees in Michigan Christmas tree plantations produce cones at an early age. Cone production decreases the value of a tree by altering its structure and reducing its aesthetic appeal (Cregg et al., 2003). Cone removal is labor-intensive and expensive, costing growers thousands of dollars in heavy-coning years. One Michigan farm expended 9,000 hours on cone removal in 2010 (C. Maciborski, Dutchman Tree Farms, written communication, January 7, 2011).

The details of cone development have been reported for other *Abies* species (Owens, 1984; Owens and Morris, 1998; Owens and Molder, 1977; Owens and Singh, 1982) and are essentially the same for Fraser fir. Cone development follows a 2-year cycle. Near the time that vegetative growth ceases in the first year, newly formed lateral buds may differentiate into either vegetative or reproductive buds. In the second year, reproductive buds will produce either cones or pollen strobulli. It may be possible to reduce the number of cones that grow in the second year by manipulating environmental factors or applying cultural treatments in the weeks leading up to bud differentiation in the first year.

Goals and objectives

Long-term goal: To reduce or eliminate early coning of plantation-planted Fraser fir trees.

Specific objectives:

- ***To develop a growing-degree-based model of shoot phenology and bud development.*** Viable strategies to reduce cone formation depend on careful timing of treatments to coincide with bud differentiation. This necessitates the development of a reliable model to predict the timing of differentiation and identify the treatment window.
- ***To determine the effect of irrigation on cone development.*** Seed orchards often induce water stress to promote coning (Daoust et al., 1995; Owens and Blake, 1985); therefore, irrigation may have the opposite effect. Although many growers irrigate their plantations, irrigation is often inconsistent or may begin late in the season, after moisture stress may have already affected reproductive bud differentiation. We will begin irrigation earlier in the spring and continue past the time of lateral bud differentiation.
- ***To determine the effect of plant growth regulators (PGRs) on cone development.*** Several PGRs have potential to affect cone development. Gibberellins (GAs) are commonly used to promote cone development in seed orchards (Daoust et al., 1995; Eysteinsson and Greenwood, 1995; Smith and Greenwood, 1995; Kong et al., 2008), ostensibly by promoting reproductive over vegetative bud differentiation (Eysteinsson and Greenwood, 1995). GA inhibitors are employed in floriculture to disrupt GA biosynthesis, and they have the potential to inhibit reproductive bud differentiation. Ethylene treatments are used to thin fruit in apples and may serve to encourage

premature cone abscission, reducing cone removal costs. Plant hormone effects and interactions are complex, and it is presently unknown whether ethylene may promote or inhibit reproductive bud differentiation. We will apply GAs, GA inhibitors, and ethylene to determine their effect on cone formation.

- ***To determine the effect of cone removal on cone development for the following year.*** This is basic research to evaluate the biennial bearing tendencies of Fraser firs.
- ***To determine the effect of cone growth and development on carbon partitioning within the tree.*** Developing cones are expected to divert large amounts of energy from shoot and needle growth, but this has not yet been quantified.

Materials and methods

We have partnered with ten Christmas tree growers in Michigan (Figure 1). This geographic diversity provides a representative sample of seed sources, environmental conditions, and cultural practices typical of Michigan plantations. Our initial 2011 research will identify potential coning triggers and inform future treatments for 2012.

Observational studies

We randomly selected 25 trees from each of 10 farms across Michigan for a 2-year study. Trees selected were at least 2 years from harvest and varied in height from 0.95 m to 2 m. Cone production was highly variable between sites (Figure 2). We measured tree height and number of cones at the beginning of the season, followed by weekly measurements of leader growth (Figure 3). Our objective is to develop a growing degree day model for precisely timing cultural treatments to reduce cone bud formation.

Figure 1. Farm locations for 2011 coning surveys and phenology monitoring.

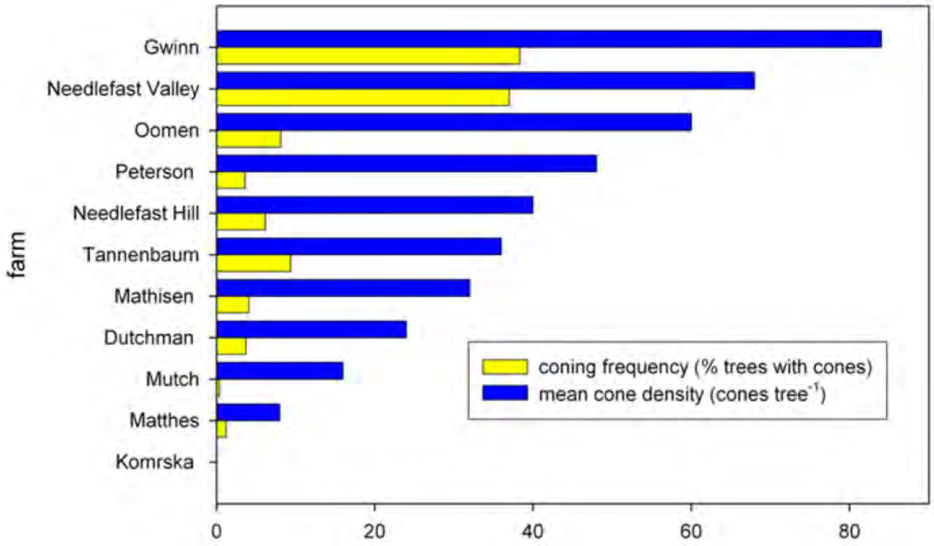

Figure 2. Coning frequency and mean cone density of Fraser fir trees in Christmas tree plantations across Michigan, 2011.

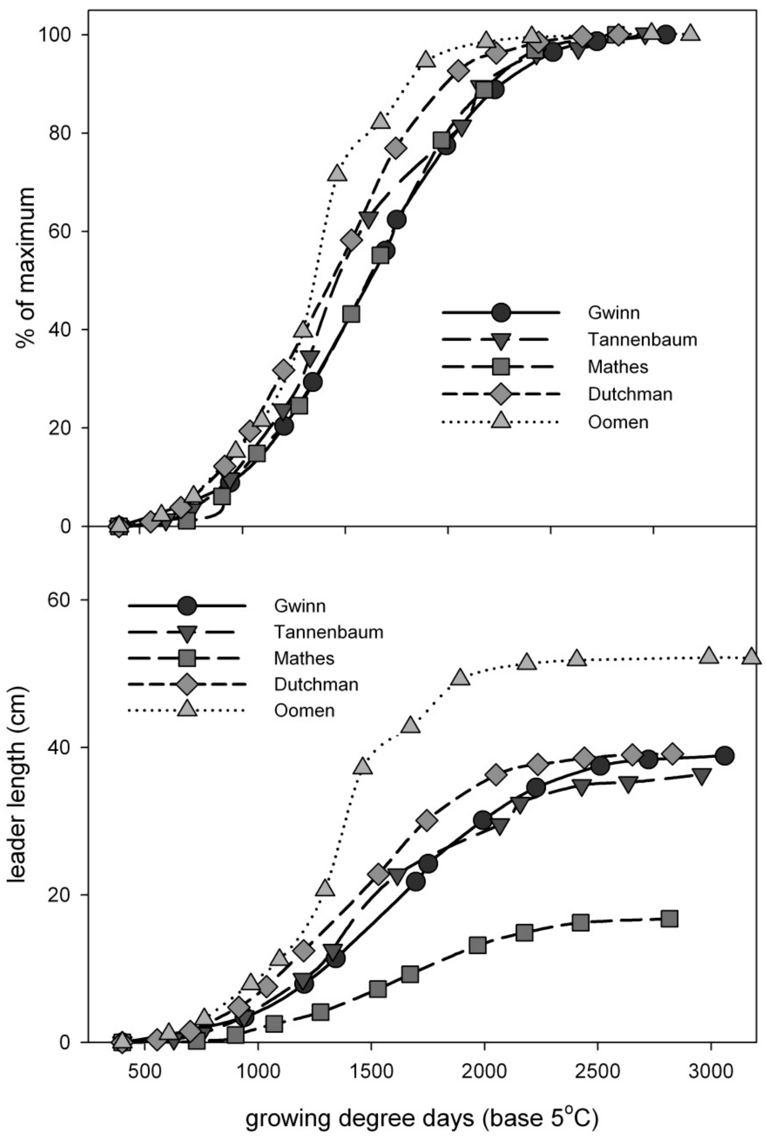

Figure 3. Mean leader growth in response to growing degree day accumulation for five Christmas tree farms in Michigan, 2011. Top: data normalized for final shoot length.

We will correlate current-year coning data with last year's climate data from Enviro-weather or onsite weather stations. We will also collect tissue and soil samples and perform the following analyses for each farm:

- ^{13}C foliar analysis
- Foliar nutrient analysis
- Soil pH, nutrient, and texture analyses

Preliminary data from a farm in south-central Michigan (Gwinn's) show an inverse relationship between soil moisture and coning (Figure 4). We will use ^{13}C foliar analysis to quantify the effects of moisture stress on cone formation. ^{13}C makes up about 1 percent of atmospheric carbon. During photosynthesis, plants favor ^{12}C over ^{13}C. During times of moisture stress, the stomata close, and discrimination against ^{13}C is reduced. Thus, the ratio of ^{12}C:^{13}C in plant tissue can serve as a measure of moisture conditions at the time the tissue was formed. Since bud differentiation for this year's cones occurred around the time needle expansion ended last year, we will correlate 2011 cone production with ^{13}C analysis of needles formed in 2010.

For a more detailed comparative analysis of areas of high and low coning pressure, we enlarged our initial sample to a full plot survey of 330 trees at a farm in south-central Michigan exhibiting high coning (Gwinn's) and 396 trees at a farm in eastern Michigan with low coning (Mutch's). Results are shown in Figure 5. We installed five soil moisture sensors and three soil temperature sensors at each farm, and we will perform detailed soil and foliar analyses to identify key differences between sites.

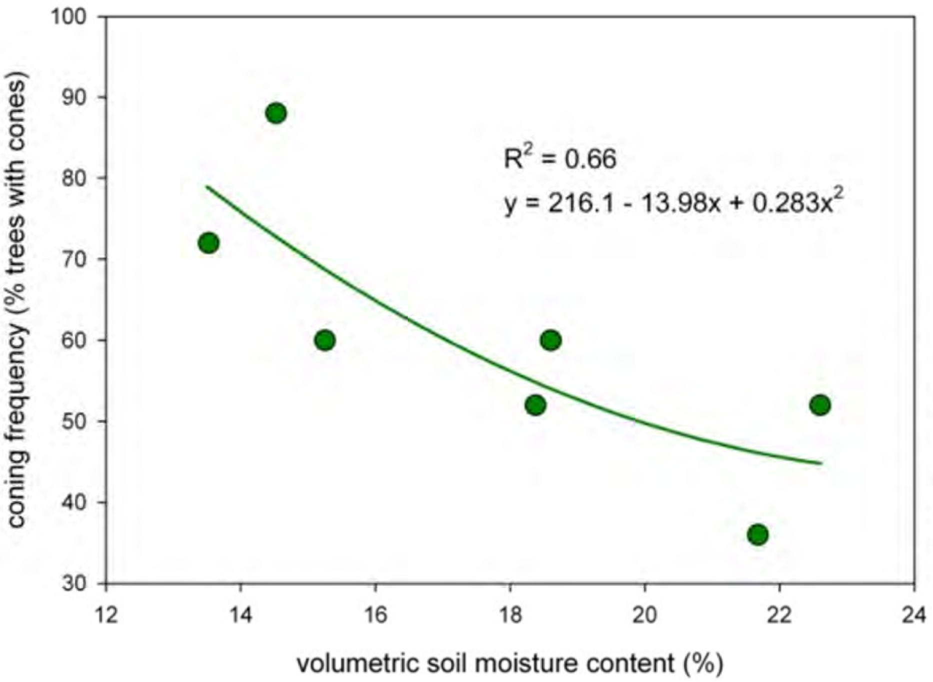

Figure 4. Coning frequency of Fraser fir Christmas trees in response to volumetric soil moisture, Gwinn's Tree Farm, Horton, MI, 2011.

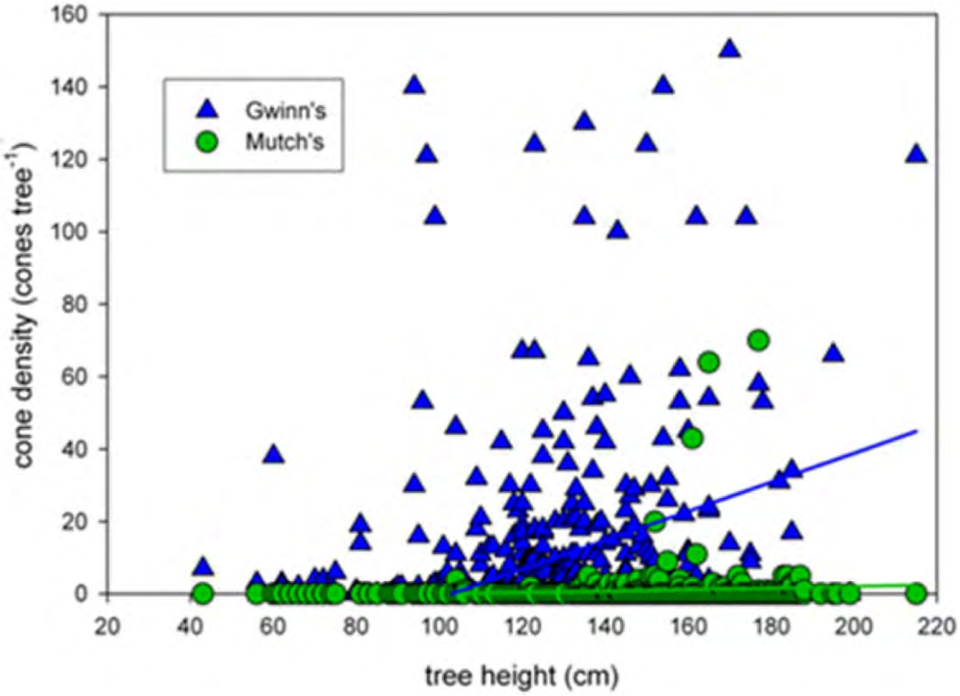

Figure 5. Cone density in response to tree height for Fraser fir Christmas trees at two locations in Michigan, 2011.

Manipulation studies

We applied treatments to trees at a farm in south-central Michigan (Gwinn's) in 2011 to study the effects on 2012 cone formation:

- ***PGR:*** We sprayed the upper one-third of 5 sets of 10 trees biweekly (four applications) with one of four plant growth regulators or control ($GA_{4/7}$ as Provide, 20 ppm; chlormequat as Cycocel, 1,375 ppm; paclobutrazol as Bonzi, 100 ppm; ethephon as Florel, 950 ppm; RO water). All treatments were augmented with 2 ml of CapSil adjuvant. Since ethylene is used in fruit thinning, we applied ethylene (Florel) as a spray directly to young cones on 10 trees, with no apparent abortive effect. As with all PGR treatments, timing and mode of delivery are critical, and further research is warranted.
- ***Irrigation:*** We are irrigating 6 of 12 rows of 25 trees in randomized, paired plots. We will use a pressure chamber to measure shoot water potential and a Li-6400 System to measure photosynthetic gas exchange, as a gauge of plant moisture stress.
- ***Biennial bearing:*** We picked cones on 60 trees and left cones on 60 trees to compare the impact on next year's coning.
- ***Carbon partitioning/Photosynthesis (Pn):*** We identified 20 large trees with heavy coning (2.05 m height, 117 cones average). We picked cones on 8 trees, left the cones on 8 trees, and selectively picked individual branches of 4 trees. We will assess the effects of cone development on Pn and carbon partitioning through periodic gas exchange measurements and by measuring shoot and needle length.

We have an additional irrigation study at a farm in northwest Michigan (Komrska's). They irrigate all of their trees, and none of their trees in our study (up to 1.65 m height) produced any cones. They anticipate that some of those trees will cone next year. We have doubled the irrigation on 25 trees (to 38 liters every 4 days) to determine the impact on cone production.

Literature

Cregg, B.M. J. O'Donnell, and M.R. Koelling. 2003. Precocious cone production in Fraser fir. In: Proceedings of the 6th International Christmas Tree Research and Extension Conference, Hendersonville, NC. pp. 98–105.

Daoust, G., A. Plourde, and J. Beeaulieu. 1995. Influences of crown size and maturation on flower production and sex expression in *Picea glauca* treated with gibberellin $A_{4/7}$. Tree Physiol. 15:417–475.

Eysteinsson, T. and M.S. Greenwood. 1995. Flowering on long and short shoots of *Larix laricina* in response to differential timing of GA applications. Tree Physiol. 15:467–469.

Kong, L., S.R. Abrams, S.J. Owen, H. Graham, and, P. Von Aderkas. Phytohormones and their metabolites during long shoot development in Douglas-fir following cone induction by gibberellin injection. Tree Physiol. 28:1357–1364.

Owens, J.N. 1984. Bud development in grand fir (*Abies grandis*). Can. J. For. Res. 14:575–588.

Owens, J.N and M.D. Blake. 1985. Forest tree seed production. A review of the literature and recommendations for future research. Environ. Can. Can. For. Serv. Inf. Rep. PI-X-53. 161 pp.

Owens, J.N. and M. Molder. 1977. Vegetative bud development and cone differentiation in *Abies amabilis*. Can. J. Bot. 55: 992–1008.

Owens, J.N. and S.J. Morris. 1998. Factors affecting seed and cone development in Pacific silver fir (*Abies amabilis*). Can. J. For. Res. 28:1146–1163.

Owens, J.N. and H. Singh. 1982. Vegetative bud development and the time of and method of cone initiation in subalpine fir (*Abies lasiocarpa*). Can. J. Bot. 60:2249–2262.

Smith, R. and M. Greenwood. 1995. Effects of gibberellin $A_{4/7}$, root pruning and cytokinins on seed and pollen cone formation in black spruce (*Picea mariana*). Tree Physiol. 15:457–465.

Growth, physiology, and nitrogen leaching of living Christmas trees with conventional and organic fertilization

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Introduction

Living Christmas trees represent an expanding niche market for Christmas tree growers in the United States and Europe. According to a recent survey in the United States, 17 percent of respondents had previously purchased a living Christmas tree (Kelly and Bates, 2007). Production of container-grown Christmas trees has grown rapidly in many parts of the United States, with several producers growing tens of thousands of units each year.

Shifting from production of field-grown Christmas trees to container production presents challenges and opportunities for growers. Container production systems are typically more intensive in terms of resource inputs and may have greater potential for adverse environmental impacts than field production systems. Container substrates have low inherent fertility so growers must rely on inorganic fertilizers, which may be subject to leaching (Juntunen et al., 2002; 2003). Likewise, certain pesticides may move more rapidly through container substrates than through field soil (Simmons and Kerr, 2007). Potential nutrient and pesticide leaching problems are further exacerbated by frequent irrigation in container nurseries (Colangelo and Brand, 2001; Ruter, 1997).

Another important trend in U.S. agriculture is the rise in organically grown products. For example, between 2001 and 2005 the number of USDA Certified Organic nurseries and greenhouses increased more than 15-fold (USDA NASS, 2007). In order to qualify as USDA Certified Organically grown, producers must follow USDA Organic Certification guidelines (USDA ERS). These guidelines prohibit application of inorganic pesticides or fertilizers 3 years prior to harvest. All fertilizers and pesticides used in production systems must be approved by the Organic Materials Review Institute (OMRI). Meeting crop nutrient needs without the use of inorganic fertilizers will be one of the largest challenges for organic nursery producers (Chong, 2005; Chong et al., 2008; Manas et al., 2009; Michitsch et al., 2007).

For the past 4 years, we have conducted research trials on improving nutrient and water management of landscape conifers and shade trees in Pot-in-Pot container production (Klooster et al., 2010; Taylor et al., 2009). The overall goals of the current phase of our Pot-in-Pot production research are to expand the capabilities of the system and evaluate components of production systems for container-grown conifers and shade trees that will enable growers to market plants as certified Organic or certified naturally grown.

Specific objectives of the current project are to:

- Compare growth and physiology of container-grown living Christmas trees fertilized with conventional and organic fertilizer
- Compare potential nutrient leaching of container-grown trees fertilized with conventional and organic fertilizer

Objective 1. Comparison of growth and physiology of container-grown trees grown under conventional and organic nutrition management.

We planted 100 conifers (50 Colorado blue spruce trees [*Picea pungens*] and 50 Fraser fir trees [*Abies fraseri*]) in 25-liter containers (Figure 1).

Figure 1. Overview of Pot-in-Pot living Christmas tree production system at Michigan State University.

All trees were planted in a standard container substrate of 80 percent pine bark and 20 percent peat moss (v:v) (Renewed Earth, Inc., Kalamazoo, MI, USA). Four rows of each species were assigned at random to receive either a conventional controlled-release fertilizer (Osmocote Plus 15-9-12, 5–6 month release, Scotts, Inc., Marysville, OH, USA) or an OMRI-certified organic fertilizer (Nature Safe 10-2-8 and Nature Safe 5-6-6, Griffin Industries, Cold Spring, KY, USA). The organic fertilizers were blended to provide approximately the same ratio of N-P_2O_5-K_2O as the conventional source (Table 1).

Table 1. Fertilizer additions (grams per container) for conifers in comparison trial of conventional (Osmocote) and OMRI-approved organic (Nature Safe) fertilizer.

Year: 2010

Product	**Product total (g/container)**			**Elemental totals (g/container)**		
	App 1 (July)		**Total**	**N**	**P_2O_5**	**K_2O**
Osmocote 15-9-12	80		80	12.0	7.2	9.6
	App 1 (July)	**App 2 (Aug)**	**Total**			
Nature Safe 10-2-8	50	30	80	8.0	1.6	6.4
Nature Safe 5-6-6	50	30	80	4.0	4.8	4.8
Total				**12.0**	**6.4**	**11.2**

Year: 2011

Product	**Product total (g/container)**				**Elemental totals (g/container)**		
	App 1 (June)			**Total**	**N**	**P_2O_5**	**K_2O**
Osmocote 15-9-12	170			170	25.0	15.0	20.0
	App 1 (June)	**App 2 (July)**	**App 3 (Aug)**	**Total**			
Nature Safe 10-2-8	63	63	63	170	16.8	3.4	13.4
Nature Safe 5-6-6	63	63	63	170	8.4	10.1	8.4
Total					**25.2**	**13.5**	**21.8**

We measured height and trunk caliper at the start of the study and at the end of each growing season. Foliar samples were collected for nutrient analysis in November. Net photosynthetic gas exchange of the conifers was measured on three dates (Aug. 8, Aug. 31, and Oct. 7) using a portable photosynthesis system (Li-6400, Li-Cor, Inc., Lincoln, NE, USA) equipped with a 0.25-liter cylindrical conifer chamber. Gas exchange measurements were collected on all conifers in the study between 10:00 and 16:00 on clear days (photosynthetically active radiation (PAR) >1,500 µmol m^{-2} s^{-1}). Gas exchange measurements were expressed on a projected shoot area basis.

Objective 2. Nutrient leaching

Leachate from eight containers in each row of the nursery was collected via an automated leachate collection system. (Figure 2).

Figure 2. Installation of leachate collection system. Each row of 8 trees drains to a single line. Run-off from each line was continually measured by tipping bucket rain gauges and an automated datalogger.

Container leachate from each row was collected, and total run-off was measured by a series of tipping bucket rain gauges and an automated datalogger (Zhu et al., 2005). Trees were irrigated daily at 09:00 via spray stakes (Netafim, Inc.) operated by an automated timer. Irrigation and rainfall in excess of daily plant water use leached through the containers and was collected by tipping buckets and recorded by the datalogger (Figure 2.) After an initial assessment and trouble-shooting period, irrigation rates were adjusted in order to achieve a target leaching fraction of 10–20 percent of irrigation applied. Samples of leachate water were collected weekly after irrigation. Leachate samples were subsequently analyzed for nitrate and ammonium at the Michigan State University Soils laboratory. Total amount of nitrogen (N) leached during each season was estimated by multiplying the amount of water leached each week by the N concentration of the samples collected that week and summing the totals over the growing season.

Results

Objective 1. Comparison of growth and physiology of container-grown trees grown under conventional and organic nutrition management.

Conventional fertilizer increased ($p<0.05$) height growth of Fraser fir trees compared to trees receiving organic fertilizer (Table 2). Fertilizer source did not affect height or caliper growth of Colorado blue spruce trees and did not affect caliper growth of Fraser fir trees. Conventional fertilizer increased foliar N of Fraser fir trees relative to trees receiving organic fertilizer, but did not affect foliar N of Colorado blue spruce trees (Figure 3). Fertilizer source and species affected ($p<0.05$) rates of net photosynthesis. Colorado blue spruce trees had higher rates of net photosynthesis than Fraser fir trees (Figure 4). Conventional fertilizer increased net photosynthetic rates of trees compared to trees fertilized with organic fertilizer.

Table 2. Mean (± standard error) 2-year caliper and height growth of *Abies fraseri* and *Picea pungens* trees fertilized with two fertilizer sources

	Caliper growth (mm)		**Height growth (cm)**	
Fertilizer source	***Abies fraseri***	***Picea pungens***	***Abies fraseri***	***Picea pungens***
Organic	9.22 (0.89)	9.10 (0.75)	46.4 (2.7)	34.6 (3.4)
Conventional	9.55 (0.45)	10.49 (0.51)	58.0* (4.3)	33.4 (2.7)

*Indicates effect of fertilizer source is significant at $P<0.05$ level.

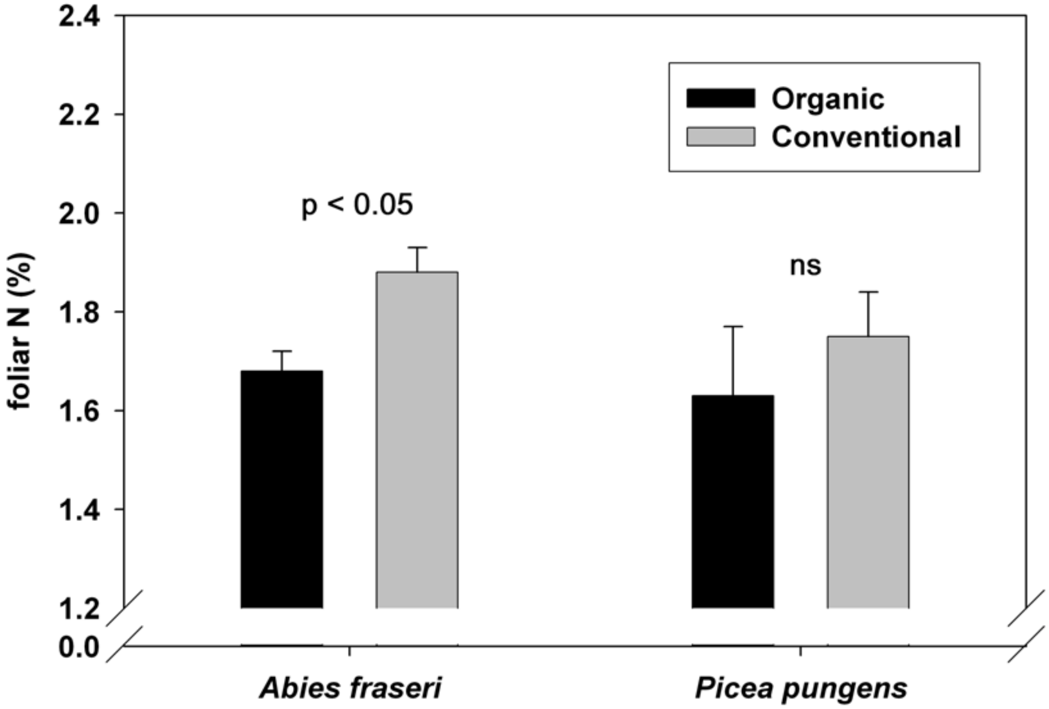

Figure 3. Mean (± standard error) foliar N concentration of needles of *Abies fraseri* and *Picea pungens* trees fertilized with organic or conventional fertilizer.

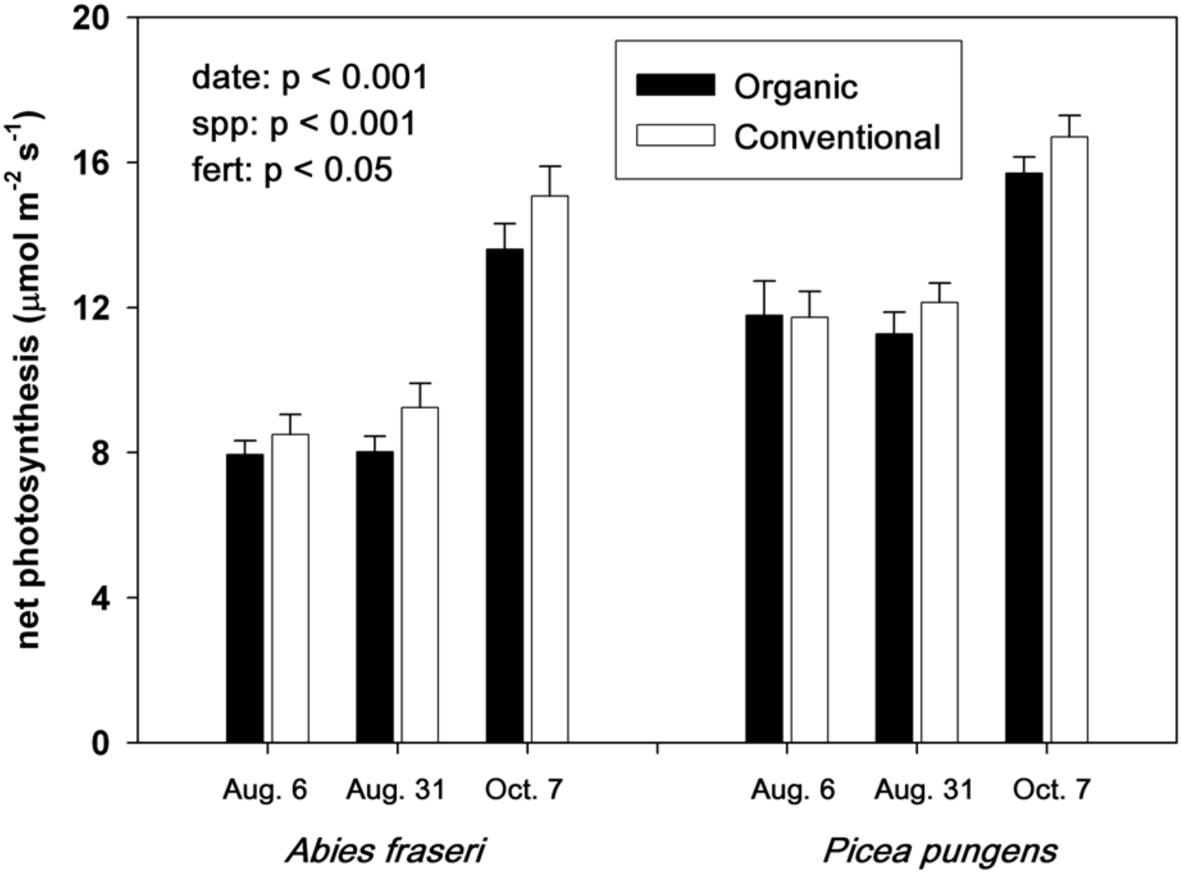

Figure 4. Mean (± standard error) net photosynthesis of *Abies fraseri* and *Picea pungens* trees fertilized with organic or conventional fertilizer.

Objective 2. Nutrient leaching

Nitrate and ammonium concentrations of leachate samples collected during the growing season were consistently higher for trees fertilized with conventional fertilizer than for trees receiving organic fertilizer or trees in an unfertilized check row (data not shown). As a result of the increased level of nitrate and ammonium, total N leaching was greatest for trees fertilized with the conventional fertilizer (Table 3).

Table 3. Estimated amount of N leached from tree containers in response to fertilizer source 2011.

Fertilizer source	Total N leached* (mg/container)
Conventional	129.4
Organic	56.9
None	16.5

*As of August 20, 2011

It is important to note, however, that the total amount of N leached was very small relative to the amount of N applied as fertilizer. For example, through August 2011 a total of 129.4 mg of N leached per container in the conventional fertilizer plots. This represents less than 1 percent of the total N applied (25 g N per container). This suggests the container production system is very efficient in terms of nutrient utilization. This is likely related to full utilization of the container substrate by tree roots.

Summary

Fertilizer source (conventional versus organic) had little effect on tree growth, except for height growth of Fraser fir trees. Conventional fertilizer increased foliar N of Fraser fir trees and resulted in higher photosynthetic rates for trees of both species. Casual observation indicated that color and quality of trees was comparable regardless of fertilizer source. Therefore, growers may be able to produce acceptable quality trees regardless of fertilizer source. Nutrient utilization appeared to be high, and relatively little applied fertilizer leached out of containers during the growing season.

References

Chong, C. 2005. Experiences with wastes and composts in nursery substrates. HortTechnology 15:739–747.

Chong,C., P. Purvis, G. Lumis, B.E. Holbein, R.P. Voroney, H. Zhou, H.W. Liu, and M.Z. Alam. 2008. Using mushroom farm and anaerobic digestion wastewaters as supplemental fertilizer sources for growing container nursery stock in a closed system. Bioresource Technology 99:2050–2060.

Colangelo, D.J. and M.H. Brand. 2001. Nitrate leaching beneath a containerized nursery crop receiving trickle or overhead irrigation. J. Environ. Qual. 30:1564–1574.

Juntunen, M., T. Hammar, and R. Rikala. 2002. Leaching of nitrogen and phosphorus during production of forest seedlings in containers. J. Environ. Qual. 31:1868–1874.

Juntunen, M., T. Hammar, and R. Rikala. 2003. Nitrogen and phosphorus leaching and uptake by container birch seedlings (*Betula pendula* Roth) grown in three different fertilizations. New Forests 25:133–147.

Kelly, K.M. and R.M. Bates. 2007. Containerized table-top Christmas trees: Interest among Pennsylvania consumers and attitudes concerning care and handling. Journal of Extension 45(1) http://www.joe.org/joe/2007february/rb7.php

Klooster, W.S., B.M. Cregg, R.T. Fernandez, P. Nzokou. 2010. Growth and photosynthetic response of Pot-in-Pot grown conifers to substrate and controlled-release fertilizer. HortScience 45(1):36–42.

Manas, P., P.E. Castro and J. de las Heras. 2009. Quality of maritime pine (*Pinus pinaster* Ait.) seedlings using waste materials as nursery growing media. New Forests 37:295–311.
Michitsch, R.C., C. Chong, B.E. Holbein, R.P. Voroney, and H. Liu. 2007. Use of Wastewater and compost extracts as nutrient sources for growing nursery and turfgrass species. J. Environ. Qual. 36:1031–1041.
Ruter, J.M. 1997. Pot-in-pot production and cyclic irrigation influence growth and evapotranspiration of ‘Okame’ cherry. HortScience 32:546.
Simmons, L.D. and J.F. Kerr. 2007. Pendimethalin movement through pine bark compared to field soil. Weed Technology 21:873–876.
Taylor, A., B. Cregg, R.T. Fernandez, and P. Nzokou. 2009. Growth and physiology of living Christmas trees under cyclic irrigation. 2009 ASH National Conference, St. Louis, MO.
USDA Economic Research Service. http://www.ers.usda.gov/Data/Organic/
USDA National Agricultural Statistics Service. 2007. Nursery Crops 2006 Summary.
Zhu, H., C.R. Krause, R.H. Zondag, R.D. Brazee, R.C. Derksen, M.E. Reding, and N.R. Fausey. 2005. A new system to monitor water and nutrient use efficiency in pot-in-pot nursery production system. Journal of Environmental Horticulture 23(1):47–53.

Establishment routines for *Abies nordmanniana* and *Abies lasiocarpa*

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Background

Christmas tree seedlings typically grow slowly during the first 2 or 3 years. A dense concentration of branches on the lower part of the tree tends to allocate a lot of resources to the tree base, which grows wide and heavy. Such trees are costly to cut and transport and difficult to sell. In Norway, 9 or 10 years are usually needed from planting to harvesting Christmas trees. Decreasing the time until harvesting by 1 or 2 years will increase the income of growers. Establishment routines that ensure rapid early growth are therefore important.

Hypothesis

Our hypothesis in this experiment was that planting in late summer and early autumn would give optimal establishment conditions and thereby result in rapid early growth.

Materials and methods

Field experiments have been established on three locations, representing both *A. lasiocarpa* and *A. nordmanniana* in the eastern inland and western coastal climates (Table 1 and Figure 1).

Table 1. Overview of locations of the planted species.

Species	**Locations**
Abies lasiocarpa	Ås, eastern Norway (59°40´ N, 10°46´ E) and Særheim, western Norway (58°44´ N, 5°38´ E)
Abies nordmanniana	Lier, eastern Norway (59°50´ N, 10°32´ E) and Særheim, western Norway (58°44´ N, 5°38´ E)

Figure 1. The experimental plot with *Abies nordmanniana* at Særheim.

Planting was performed six times at 3- to 4-week intervals from late April to late August in 2007 and 2008. We used winter-stored seedlings in weeks 17, 21, and 25 (spring). In weeks 29, 32, and 35 (summer), we planted seedlings directly from nurseries. In addition, winter-stored seedlings were planted at Ås and in Lier in week 29, 2008, and seedlings directly from the nursery were planted at Særheim in week 25, 2008. On each planting date and locations, 20 seedlings of each species were planted in 5 replicates, for a total of 1,200 seedlings of each species planted each year.

Measurements of height and root collar diameter, as well as registration on buds, were performed following planting and again following growth cessation each autumn from 2007 through 2010.

Results and discussion

Abies lasiocarpa

Due to massive frost damage at Særheim during the winter of 2007–2008, results from only three plots of *A. lasiocarpa* are presented (Figure 2). The results give little support to the hypothesis that planting in summer with growing seedlings results in increased growth. In fact, it seemed that seedlings planted in spring have increased growth the first growing season.

On seedlings planted at Ås (Figures 2A and 2B), there was no significant difference in the probability of having four or more buds among seedlings planted on the different dates. However, at Særheim in 2008 (Figure 2C), there was a significantly higher probability of four or more buds on seedlings planted April–June (76–87 percent), compared with seedlings planted in July or August (43–58 percent).

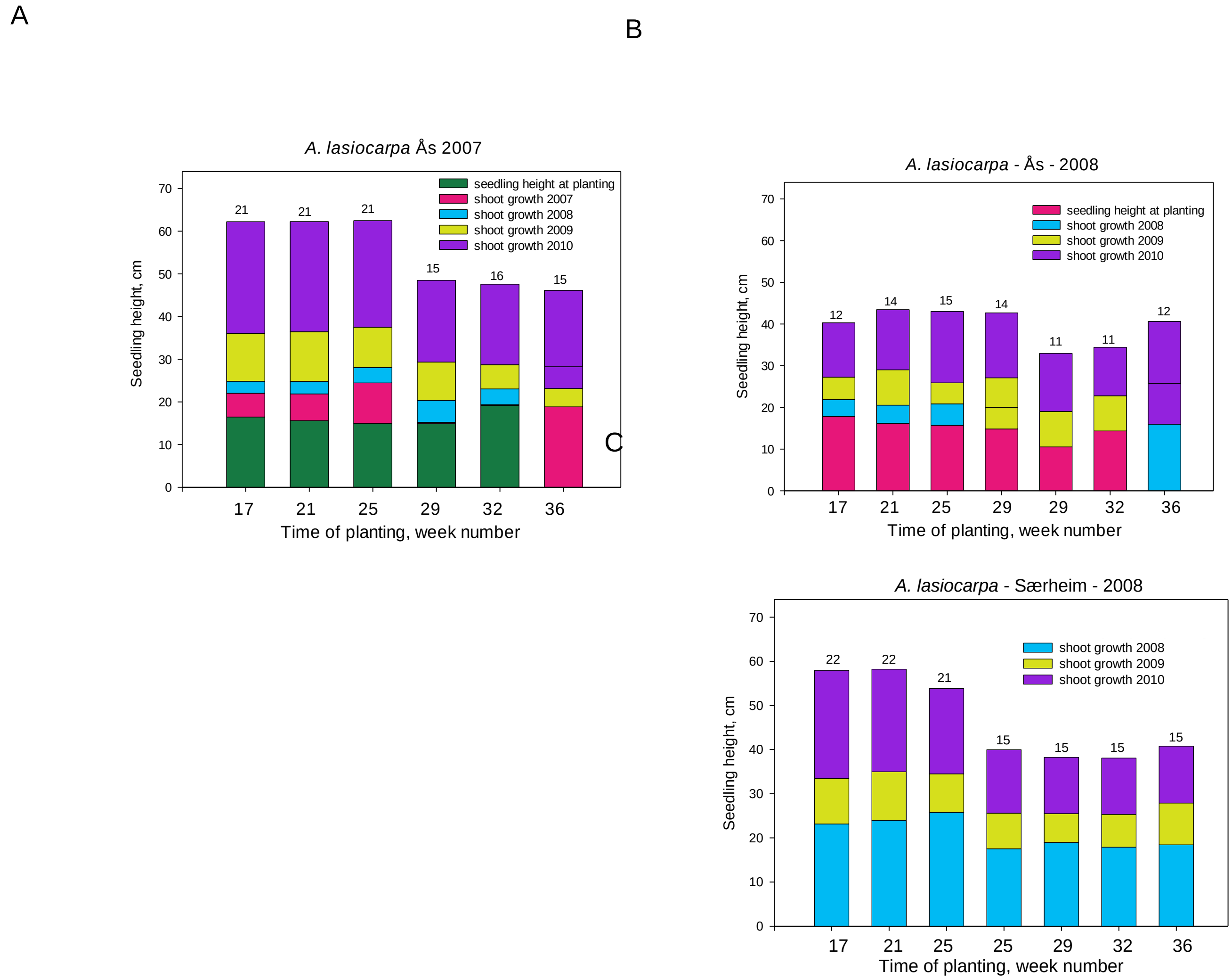

Figure 2. Seedling growth of *Abies lasiocarpa* following planting from April to August. Locations for the planting are presented in Table 1. In Figure 2C, shoot growth and seedling height at planting are combined for 2008, due to lack of registrations at the time of planting.

Abies nordmanniana

In Lier, the growth of *A. nordmanniana* was similar to that of *A. lasiocarpa,* with best growth in those seedlings planted in spring (Figures 3A and 3B). In contrast, seedlings of *A. nordmanniana* planted in late August 2007 in western Norway had a growth rate comparable to spring-planted seedlings (Figures 3C and 3D).

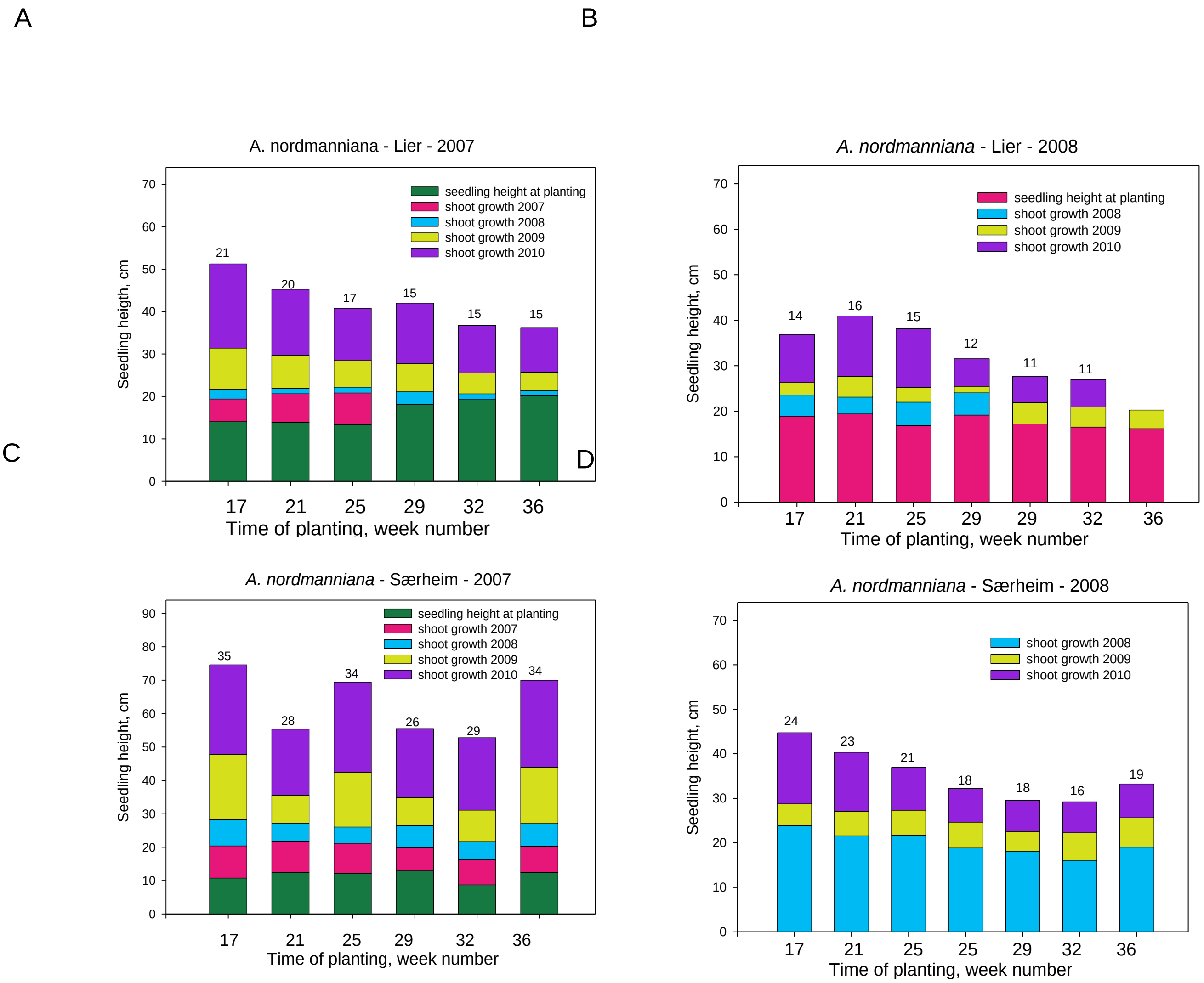

Figure 3. Seedling growth of *Abies nordmanniana* following planting from April to August. Locations for the planting are presented in Table 1. In Figure 3C, shoot growth and seedling height at planting are combined for 2008, due to lack of registrations at the time of planting.

For *A. nordmanniana* seedlings planted in 2007, there was no significant difference in the probability of having four or more buds among seedlings planted on different dates (Figures 3A and 3C). However, in seedlings planted in Lier in 2008 (Figure 3B), there was a significantly higher probability of four or more buds in seedlings planted April–June (88–92 percent), compared with seedlings planted directly from the nursery in July (35 percent). Likewise, seedlings planted at Særheim in April–June (Figure 3D) had a significantly higher probability of having four or more buds (68–88 percent), compared with seedlings planted in July or August (39–58 percent).

Our results indicate that there is no increase in growth following summer planting for *A. lasiocarpa.* For *A. nordmanniana,* there may be a possibility of increased growth following late-summer planting. Further analysis of the data will clarify these results.

Fertilization of Christmas trees: Comparing foliar- and soil-applied products

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Introduction

Over the past 5 years, Christmas tree growers in the Pacific Northwest have been applying a number of foliar fertilizer products and asking about the benefits/costs of this practice. Often the foliar products are used in addition to soil-applied products, so evaluation is difficult without some control of treatment options.

Christmas tree fertilization trials comparing foliar-applied, soil-applied, and combination treatments were conducted at the greenhouse at the North Willamette Research and Extension Center (NWREC) and at selected grower sites in the Willamette Valley of Oregon, USA. Results will be reported separately for each.

Materials and methods

Greenhouse/NWREC site

The study began with 4-year-old Nordmann firs grown in containers in inert soilless media being up-potted and grown for an additional 2 years during the treatment interval.

Treatments used in 2009 and 2010 are summarized in Table 1. Each treatment contained 9 trees in a completely random experimental design. A range of evaluation tools and tree measurements was used to determine response. Tree response measurements included needle length, tree height, leader length, and color (Royal Horticulture Color Chart System). Foliar nutrient analysis was conducted in 2009 and 2010.

In September 2010, four trees from each of the control, W-E, and Helena treatments of Nordmann fir were selected for a UreaSul application to investigate whether color could be improved by December 2010. These trees received one application of UreaSul on September 15, 2010.

In 2010, the soil-applied material used was multiple UreaSul applications. Also, a calcium-based foliar product from OrCal Inc. (Southern Oregon) was included.

Table 1. NWREC greenhouse treatments summary for year 1 and 2.

Tmt	Year 1—2009 Code/Product/Rate	Year 2—2010 Code/Product/Rate
1	Code H. Foliar only w/ Helena—3 products each. Applied at 1 qt/acre at budbreak (bb) and 3 weeks later.	Same
2	Code W-E. Foliar only w/ Wilbur-Ellis, berry mix. Applied at 2 gal/acre at bb and 3 weeks later.	Same
3	Code H+. Tmt 1, but foliar sprays were prevented from leaching into the pot.	UreaSul 112 kg/ha. Split (May, June, July).
4	Code Control. No treatment.	Same
5	Code CRF. Controlled release fert (CRF) 18-5-9. Applied at 186 g/pot.	Code U+. UreaSul 112 kg/ha. Split (May, June, July).
6	Code CRF+H. CRF +Tmt 1 foliar.	Code U+OrCal. UreaSul 112 kg/ha. Split (May, June, July). OrCal Calcium 2X 1.8 l/ha.
7		Code L1. 4 trees from Tmt 1 with UreaSul 56 kg/ha.
8		Code L2. 4 trees from Tmt 2 with UreaSul 56 kg/ha.
9		Code L3. 4 trees from Tmt 4 with UreaSul 56 kg/ha.

Field sites

Fertilization was evaluated in typical field plantings with noble and Nordmann fir. Here investigation focused on evaluating the impacts of foliar fertilizer applications on sites with and without soil-applied products at three locations.

Noble firs were grown at the two Stone Mountain sites, Nordmann fir on the Landgren Tree Farm. At all field locations, the grower made the product applications. At each location, foliar samples were collected from approximately 50 trees and bulked for analysis. Tree color and growth were observed, but not measured. The sites used are outlined below.

Stone Mountain Tree Farm manages the trees at two locations: one near Salem, OR, and the other on Mt. Rodgers, south of Sublimity (Stevenson Farm). Both are listed In Table 4. The Salem/Stone Mountain location had a soil-applied blended fertilizer applied across the entire field in both years. The Mt. Rodgers/Stevenson site had no soil-applied fertilizer. At both locations, the foliar products were applied at budbreak, and part of each site received a second foliar application about 4 weeks later. Foliar products were applied using an air blast ground sprayer at rates identical to those used in the NWREC greenhouse trial. Foliar tissue samples were collected in March of 2011 for both sites.

The Landgren Tree Farm site is located in Warren, OR, and treatments were conducted on 4-year-old Nordmann fir with no prior fertilization history. The data presented in Table 3 represent one growth season. The foliar applications were identical to the greenhouse trial in year 1 and were applied with a tractor PTO sprayer. The soil-applied fertilizer was UreaSul (at 112 kg/ha).

Results

Greenhouse/NWREC

Tree growth measurements were conducted at the end of the 2010 growing season and are shown in Table 2. The soil-applied materials produced taller trees, as well as longer leaders and needles. Likewise, 1 year of soil-applied UreaSul (treatment 3) did not seem sufficient to improve tree growth parameters.

Statistical analysis showed that the soil-applied treatments (5 and 6) produced 2010 needle lengths and leader lengths that were significantly different (longer) than all other treatments. The foliar materials showed no improvement over the control treatment. Regarding total tree height, the soil-applied treatments produced trees significantly taller than those in the control treatment, but were not different from those treated with either foliar product.

Table 2. Greenhouse Nordmann fir, final growth measure.

Tmt. labels	Avg. total height (cm)	Avg. leader height (cm)	Avg. needle length (mm)
1.H	89.1	4.6	13.7
2. W-E	91.6	4.9	15.8
3. H+	86.3	2.4	13.8
4. Control	84.6	2.6	14.3
5. CRF+U	98.6	15.9	31.1
6. CRF+ H	97.0	11.9	28.6

Foliar nutrient levels: The foliar nutrient levels for nitrogen (percent N) after 2 years of growth are shown in Figure 1 below.

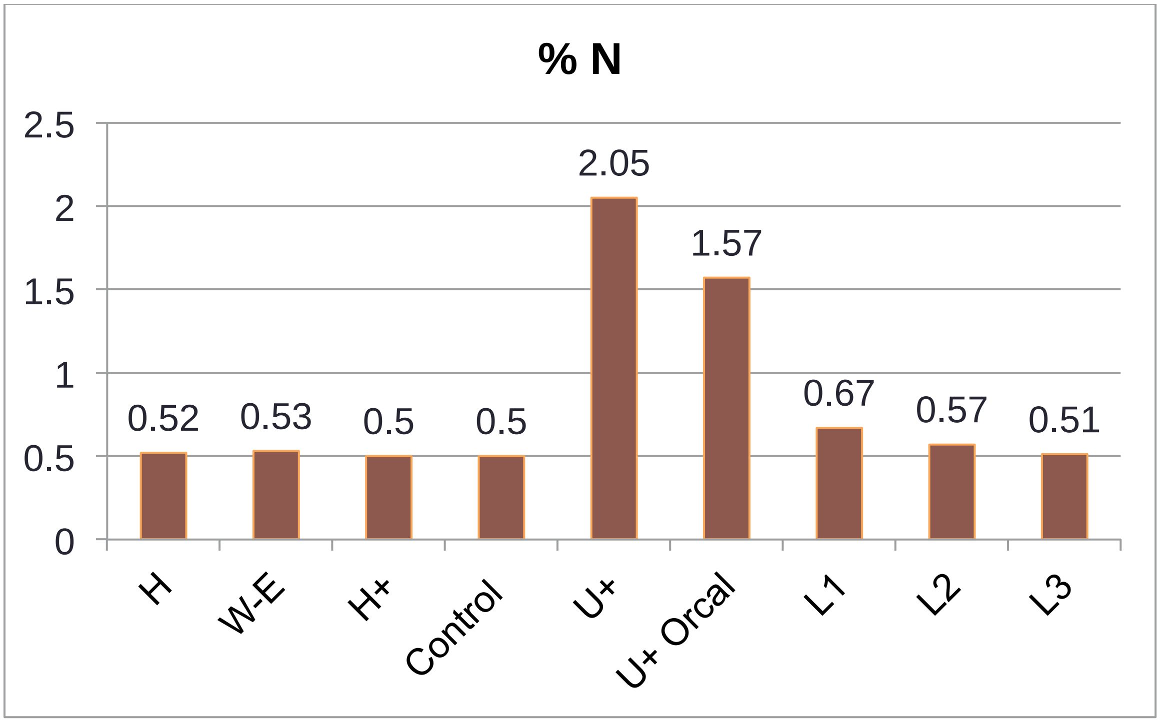

Figure 1. Foliar N levels in 2010.

Color: In year 1, the color differences were easily distinguished visually, but were difficult to "quantify." Soil-applied treatments (5 and 6) were dark green, while all others appeared yellow. The Royal Horticulture Color "chips" were used to evaluate color of each tree.

Results from field sites

Visual color evaluations and inspections of growth and needle characteristics revealed no obvious differences in treatments at any of the field sites. Individual measures were not conducted. The intent of these field trials was to determine whether fertilization practices make any "practical" difference; i.e., if you cannot see a difference, there is no merit in spending time trying to measure a difference.

Foliar nutrient levels: Foliar nutrient levels at the Landgren Tree Farm are shown in Table 3. Generally speaking, the N levels are all at or above 1.4 percent, the critical limit suggested in the OSU Nutrient Management Guide (EM 8865-E). Those treatments with UreaSul tended to have higher N levels than those without. No trends are evident when looking at the other foliar nutrients.

Table 3. Nordmann fir foliar nutrient levels by treatment, Landgren Tree Farm.

Tmt	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)
UreaSul (only)	2.2	0.20	0.63	0.87	0.11	0.13	29	46	269	3.9	33.1
UreaSul+H	2.2	0.19	0.67	0.74	0.10	0.13	39	50	280	3.7	31.5
UreaSul+WE	2.1	0.20	0.60	0.88	0.11	0.12	28	45	274	3.7	33.9
Foliar W-E	2.0	0.19	0.61	0.79	0.11	0.12	34	46	264	3.7	33.4
Foliar H	1.9	0.19	0.59	0.90	0.11	0.12	40	47	263	3.6	32.4
Control	1.9	0.19	0.60	0.79	0.11	0.12	30	44	246	3.6	29.5

Results from the Stone Mountain and Stevenson sites with noble fir are shown in Table 4 for N, P, K, and B. At the Stone Mountain sites (treatments 1–5), the foliar products appeared to provide no appreciable improvement in N level above the soil-applied material alone.

At the Stevenson site (treatments 14–19), where no soil-applied products were added, results are mixed. In one case, the foliar N level appeared slightly higher than the control; in another location, this was not the case.

Table 4. Noble fir foliar samples from selected field locations (bulk).

Tmt #	Location	Material	N (%)	P (%)	K (%)	B (ppm)	Comments
1	Stone Mt.	WE-1x	1.63	0.117	0.36	35.9	2 yrs of foliar & soil-applied
2	Stone Mt.	WE-2x	1.55	0.114	0.34	34.2	2 yrs of foliar & soil-applied
3	Stone Mt.	Helena-1x	1.38	0.112	0.36	31.2	2 yrs of foliar & soil-applied
4	Stone Mt.	Helena-2x	1.65	0.110	0.34	26.7	2 yrs of foliar & soil-applied
5	Stone Mt.	Soil-applied only—control	1.53	0.124	0.36	38.2	2 yrs of soil-applied product (no foliar)
14	Stevenson	WE-1x	1.65	0.144	0.53	31.6	2 yrs of foliar/no soil-applied
15	Stevenson	WE-2x	1.63	0.135	0.49	29.6	2 yrs of foliar/no soil-applied
16	Stevenson	WE—control	1.42	0.136	0.47	35.8	No soil or foliar fert.
17	Stevenson	Helena-1x	1.42	0.130	0.63	16.4	2 yrs of foliar/no soil-applied
18	Stevenson	Helena-2x	1.60	0.138	0.54	19.6	2 yrs of foliar/no soil-applied
19	Stevenson	Helena—control	1.54	0.137	0.54	19.2	No soil or foliar fert.

Conclusions

Greenhouse trial

Foliar treatments alone at the rates tested were not sufficient to maintain tree color or vigor over a 2-year period. The CRF and UreaSul treatments appeared to maintain growth and color during this period. Foliar treatments alone were little different than the controls for foliar N (percent). The addition of foliar treatments to the soil-based treatments did not appreciably improve results. Likewise, tree color improvement seems to be a slow process, based on the H+ and L1-3 treatments.

Field sites

Results here are much more variable, and definitive conclusions are more difficult. More definitive results would likely require more test sites and sites with more consistent initial fertilizer levels. Generally, the field results suggest that soil-applied products should be sufficient to supply nutrient requirements for N, if fertilizer is needed.

References

Hart, J. et al. 2009. Christmas tree nutrient management guide: Western Oregon and Washington. Oregon State University Extension publication EM 8856-E.

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Controlling leader length in Nordmann fir *(Abies nordmanniana)* in Germany

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Four to five growing seasons after planting, *Abies nordmanniana* often has a very long leader. As a result, the trees look slim and open. By using chemical growth regulator substances or mechanical methods, a reduction of leader length can be achieved. In Germany, no pesticide is registered for this purpose. The use of active ingredient Ethephon can be permitted by plant protection authority. In Denmark, therefore, the product Pomoxon, with the active substance 1-naphthylacetic acid (1-NAA), can be used. The use of 1-NAA will no longer be allowed in the EU beginning in 2012. Thus, the search for suitable products to control leader length is underway. The goal of the measures is to produce a shorter top leader than in the previous year. We hope to find a solution by the end of 2011.

Treatments

Products tested are listed in Table 1.

- First treatment date: June 17, 2010
- Second treatment date: July 1, 2010, nos. 1, 2, 6 only

Table 1. Tested products, 2010.

No.	Product/method	Active ingredient	Content	Dosage
1	(1) Alar 85 (2) Flordimex 420	Damonizide Ethephon	850 g/kg 420 g/l	0.15% 1.0%
2	(1) Alar 85 (2) Flordimex 420	Damonizide Ethephon	850 g/kg 420 g/l	0.30% 0.60%
3	Cycocel 720	Chlormequat	720 g/l	0.35%
4	Cycocel 720	Chlormequat	720 g/l	0.7%
5	Carax	Mepiquat + Metoconazol	210 g/l + 30 g/l	0.35%
6	(1) Flordimex 420 (2) Flordimex 420	Ethephon	420 g/l	0.8% 0.5%
7	Pomoxon + Spreader	Alpha-Naphthylacetic acid	15 g/l	2.0% + 0.05%
8	Top-Stop-pliers	—	—	2 cuts
9	Untreated check	—	—	—

Figure 1. Application of growth hormones by “Easy Roller” in June.

Figure 2. Top-Stop pliers with five knives.

Results

- Nearly all tested methods caused a decrease in the length of the top leader. See the line “Difference 2009/2010” in Table 2.
- Two of the treatments, Alar 85 (0.15%) and Flordimex 420 (1.0%), produced good effect, but unacceptable damage.
- Two of the treatments, Alar 85 (0.30%) and Flordimex 420 (0.6%), produced good effect, but also caused damage.
- One treatment, Cycocel 720 (0.35% and 0.7%), produced no effect on leader length, but caused some needles to turn yellow.
- One treatment, Carax (0.35%), had little effect, but caused some damage and yellowing of needles.
- Pomoxon (2.0%) + spreader (0.05%) had good effect and caused very little damage.
- Ethephon was most effective.
- Two treatments with Flordimex 420 (0.8% and 0.5%) caused too much damage (yellow and brown needles, bark necrosis, some needles dropped down).
- Top-Stop pliers were highly effective and caused no damage.

Table 2. Leader development, 2009–2010 (length, cm).

	Alar 85 0.15% + Flordimex 1.0%	Alar 85 0.30% + Flordimex 0.6%	Cycocel 720 0.35%	Cycocel 720 0.70%	Carax 0.35%	Flordimex 0.8% + Flordimex 0.5%	Pomoxon 2.0% + Spreader 0.05%	Top-Stop pliers 2 cuts	Untreated check
Leader length, 2009	40.0	43.0	39.0	43.0	43.0	41.0	41.0	46.0	33.0
Date of application June 17, 2010	12.8	12.0	12.7	13.2	13.2	14.2	13.6	13.2	10.6
End of growing season, September 30, 2010	18.2	21.2	30.7	33.4	27.2	11.6	16.3	28.0	23.8
Final length, 2010	31.0	33.2	43.4	46.6	40.4	25.8	29.9	41.2	34.4
% growing after treatment	59%	64%	71%	72%	67%	45%	55%	68%	69%
Difference 2009/2010	**77%**	**77%**	**111%**	**108%**	**94%**	**57%**	**73%**	**90%**	**104%**

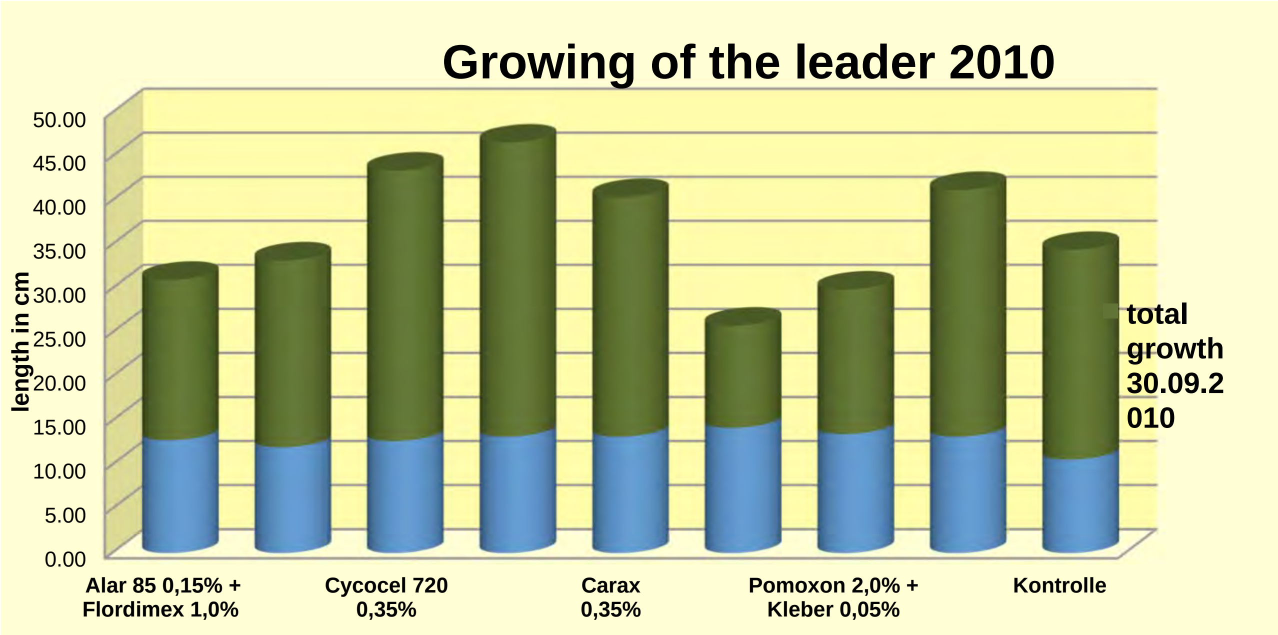

Figure 3. Leader growth, 2010.

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The impact of a full and complete Basamide recipe on Christmas tree growth

Dominique Raymackers[1)]
[1)]Union Ardennaise des Pépiniéristes

Why this question?

- Nursery growers have no or few herbicides to apply on seedlings at stages S1 and S2.
- Manpower is becoming more and more expensive.
- Growers must wait at least 4 (sometimes 5) years to sell Nordmann fir seedlings (S2R2, but sometimes S3R2).
- Many diseases, especially fungi, often occur during the nursery stage.

Research goal

The goal of this research is to find a technical answer to the problems of Belgian nursery growers by applying a new full and complete recipe that will provide a solution not only to weed and fungus problems, but also to the environmental conditions observed during the past few years in the Belgian Ardenne (dry weather during the spring, heavy frost during the winter, etc.). The chosen solution should also have the lowest impact on the surrounding environment.

Components tested

- Basamide
- Recolonization by various bacteria
- A copolymer to fix the water
- A root stimulant
- Mycorrhizae
- Various formulations of mineral fertilizer

Final solution adopted

A progressive combination of all the items mentioned above with a cost of 0.01 € per seedling produced in 3 years: S3/0

Field results

- Weeds are under-controlled.
- Fungi are under-controlled.
- Growth is very good for both size developments: aerial (x1.5) and rooting (x1.5).
- Seedlings are stronger: diameter is bigger (x2.0).
- It is possible to sell 3/0 seedlings with a reasonable size (25–35 cm).
- Less manpower is required.

Adoption by Belgian nursery growers

We have been testing this “recipe” for 3 years. Many nursery growers have visited our field to see our results; they didn’t believe our theoretical results without a field visit.

This year, 5 nursery growers are applying the recipe, including 2 with a full and complete procedure and 3 with a partial procedure (no copolymer to fix the water, no root stimulant, or no Mycorrhizae). They have been pleased so far. More nursery growers will apply the full methodology next year.

Grower experiences

- Appearance of small fungi (*Pithium* sp.), but easy to solve.
- A complete procedure was not always applied, and the difference in growth is not visible to the eye when compared to seedlings produced by a full and complete procedure.
- A new biological spectrum in the ground, including new colonization by 1,000,000 positive bacteria after 6 months.
- No seeds starting and stopping their germination development, even with a very dry spring.

Dominique Raymackers, Master of Forestry Sciences, PhD in progress at the University of Liège, Faculty of Agro-Bio-Tech of Gembloux

TREE HEALTH

Spread of *Phytophthora ramorum* inoculum from nurseries to streams: Implications for the Christmas tree and forestry industries in the Pacific Northwest, USA

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Phytophthora ramorum, the exotic water mold that causes sudden oak death and Ramorum shoot blight, was first detected on ornamental nursery stock in Washington in 2003. Since then, all three lineages (NA1, NA2, and EU1) have been detected in a total of 48 nurseries in western Washington. The swimming zoospores of water molds are commonly spread via water. In 2006, stream baiting revealed that *P. ramorum* had spread from a nursery in Pierce County into a nearby stream. Subsequent yearly stream baiting has resulted in the detection of *P. ramorum* in a total of 11 drainage ditches and/or streams in 5 western Washington counties. Genotype analysis indicates that all three lineages of this pathogen have spread into waterways and that contamination of waterways has typically resulted from spread of inoculum from nearby positive nurseries. Stream baiting has also shown that once a waterway becomes infested, it remains infested even after mitigation steps are taken to eliminate the pathogen from positive nurseries.

In the spring of 2009, infested ditch water resulted in the infection of salal (*Gaultheria shallon*) plants along the perimeter of a nursery. The furthest infected plants were located about 400 feet from the nursery. Genotype analysis of 12 salal samples and one water sample detected only the NA2 lineage. This represents the first time the NA2 lineage has been detected on plants outside of a nursery. In an effort to limit the spread of *P. ramorum*, regulatory officials removed the positive salal along the ditch during early fall 2009. In 2010, additional plants were positive on the nursery, and ditch water continued to be positive along its perimeter. Composite soil samples collected from along the ditch were also positive in 2010, making this the first location in Washington with evidence that inoculum has spread from a nursery, resulting in contamination of water and soil as well as the infection of natural vegetation.

The spread of the NA2 lineage onto salal plants illustrates the importance of this pathway for the spread of *P. ramorum* from nurseries to plants and soil in the landscape. In some areas, water from infested streams is used to irrigate a variety of horticultural sites. This also increases the risk that this pathogen will spread onto plants in the landscape. If this occurs, it will likely trigger a series of quarantines that have the potential to adversely affect the movement of regulated hosts, including a number of common Christmas tree and forestry conifer species. Regulatory agencies are continuing to monitor the spread of *P. ramorum,* and research is underway to identify effective ways to minimize its spread from nurseries into waterways.

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Variation in the development of current-season needle necrosis on noble, Nordmann, and Turkish fir Christmas trees in the U.S. Pacific Northwest

Gary A. Chastagner[1)], Kathy Riley[1)], and Chal Landgren[2)]
[1)]Washington State University, [2)]Oregon State University

Introduction

Current-season needle necrosis (CSNN) is a poorly understood disease on true firs (*Abies* spp.) grown for Christmas trees and boughs in Europe and North America. Early research suggested that CSNN was likely a physiological disorder that was associated with calcium deficiency and environmental stress. However, recent research in Norway has found that *Sydowia polyspora* may play a role in the development of this disease.

In the U.S. Pacific Northwest (Oregon, Washington, and Idaho) and British Columbia, CSNN is most commonly seen on noble fir (*A. procera*) and grand fir (*A. grandis*) grown at low-elevation sites. Similar needle damage has also been observed on white fir (*A. concolor*), Nordmann fir (*A. nordmanniana*), and Turkish fir (*A. bornmuelleriana*). In Europe, CSNN has also been observed on grand and noble firs, but the greatest economic impact has been on Nordmann fir, the dominant Christmas tree species.

Figure 1. Current-season needle necrosis symptoms on noble fir (top two) and Nordmann fir (bottom) needles.

Initial CSNN symptoms appear on needles during shoot elongation. Symptoms consist of tan to yellow bands and/or spots, which turn reddish brown during summer (Figure 1). Entire needles may become necrotic and, on some species, such as grand and Nordmann fir, are shed during early summer. Highly susceptible trees are often not marketable (Figure 2). Currently, there are no effective ways for growers to control this disease.

Figure 2. An unmarketable noble fir due to current-season needle necrosis damage.

A number of replicated regional provenance/progeny genetic trials have been established in western Oregon and Washington to identify sources of noble, Nordmann, and Turkish firs that have desirable Christmas tree characteristics. Two of the noble fir and two of the Nordmann/Turkish fir plots are located at the Washington State University Research Center in Puyallup, WA. This is a low-elevation (10–30 m) site that is very conducive to the development of CSNN and has provided an opportunity to examine yearly variation in development of CSNN and determine the variation in resistance to this disease among the different sources of trees in these trials.

Methods

The noble fir trials contain 37 (NT202) and 54 (NF104) sources of noble fir. Five trees from each of the sources were planted in each of five blocks during spring 2002 (NT202) or 2004 (NF104).

The two Nordmann/Turkish fir trials contain 15 sources of Nordmann fir and 4 sources of Turkish fir. One plot was planted in a “valley” site (NT104), and the other (NT204) was planted on a north-facing slope of a hill approximately 1 km away from the NT104 site. Ten trees from each of the sources were planted in each of five blocks during spring 2004.

CSNN initially appeared on trees in each of these trials about 2 years after planting. Once CSNN appeared, its severity on each tree was rated each summer/fall from 2004 through 2009. CSNN was rated on a scale of 0 to 10, where 0 = no CSNN, 1 = 1–10 percent, and 10 = 91–100 percent of the current-season needles had CSNN symptoms.

Results

Yearly variation in CSNN development

There was significant yearly variation in the overall average CSNN ratings for the trees in the four trials. Over 6 years, ratings for the 37 sources of noble fir in the 2002 plot (NF202) ranged from a low of 1.5 in 2009 to a high of 3.4 in 2006. Over 5 years, ratings for the 54 sources of noble fir in the 2004 plot (NF104) ranged from a low of about 1.1 in 2005 to a high of 3.3 in 2008. Compared to the noble fir, limited CSNN developed on trees in the 2004 Nordmann and Turkish plots (NT104 and NT204). Over 4 years, the average ratings for these trees ranged from 0.3 to 0.9.

Variation in susceptibility of sources to CSNN

There were significant differences in the susceptibility of the different sources of noble, Nordmann, and Turkish fir trees in these plots (Figure 3). In the 2002 noble fir plot, the percentage of trees that were resistant to CSNN ranged from 5 to 80 percent, depending on the source. In the 2004 noble fir plot, the range was 4 to 65 percent.

No CSNN developed on more than 80 percent of the trees from seven of the sources of Nordmann/Turkish fir at the hill and valley sites.

Figure 3. Five trees from a resistant source of trees in the 2002 noble fir plot.

Although there was significant yearly variation in the severity of CSNN, Spearman rank order correlation analysis indicated that there was a highly significant correlation between the yearly susceptibility rankings of the noble, Nordmann, and Turkish fir sources in each of these plots.

Effect of site on CSNN development

The effect of site on CSNN development was examined by comparing the severity of CSNN on trees in the 2004 noble fir genetic test plot at Puyallup to a grower site (Silver Mountain) near Sublimity, OR in 2009. Sublimity is located about 300 km south of Puyallup, in the Cascade Mountain foothills (elevation of about 370 m) along the eastern edge of the Willamette Valley. The overall CSNN rating for the trees at Silver Mountain was much lower than at Puyallup. More than 94 percent of the trees at Silver Mountain had no CSNN, compared to only 23 percent at Puyallup. Even though much less CSNN developed at Silver Mountain, Spearman rank order analysis indicated that there was a highly significant correlation in susceptibility rankings of the 54 sources at both sites.

Regression analysis of CSNN ratings from Nordmann and Turkish fir planted in the “valley” and “hill” plots at Puyallup also indicated that there was a highly significant correlation between the 4-year average ratings of the individual sources at these sites.

Summary

These trials indicate that there is considerable year-to-year variation in the development of CSNN and that significant differences exist in the susceptibility to CSNN of different sources of noble, Nordmann, and Turkish fir. More importantly, these trials show that susceptibility rankings of different sources of trees are consistent from year-to-year and site-to-site. This indicates that it should be possible to identify resistant sources of noble, Nordmann, and Turkish fir to CSNN after 1 or 2 years of evaluations at conducive sites, such as Puyallup, WA.

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Diseases, weeds, pests, and abiotic stress in Christmas tree plantations

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Background

The Christmas tree industry in Norway has evolved rapidly over the past 2 decades from being an additional source of income from young Norway spruce (*Picea abies*) forest stands to plantations where sophisticated cultural measures are implemented. Today, both fir and spruce, especially Nordmann fir (*Abies nordmanniana*), subalpine fir (*A. lasiocarpa*), and Norway spruce, are grown as Christmas trees in plantations on agricultural land. When entering strongly competitive domestic and export markets, high-quality, disease-free trees are a prerequisite.

Research cooperation

Bioforsk has been involved in several research projects on Christmas tree production. The projects are performed in close cooperation with the Christmas Tree Extension Service. Exchange of knowledge with our research colleagues abroad is important for improving the expertise of the Norwegian Christmas tree industry. In 2010, a new project entitled “An integrated approach to major disease and weed problems in an expanding Norwegian Christmas tree industry” was funded by the Research Council of Norway in cooperation with the Forest Owners Research Foundation, Norsk Juletreservice AS, and industry support from Washington State University and Copenhagen University. The overall aim of this project is high-quality Christmas trees produced for the domestic and European market using an integrated pest management (IPM) approach.

Diseases

The main focus in our new project is the serious disease current-season needle necrosis (CSNN). CSNN is a major problem on Nordmann fir all over Europe and the United States. For more than 25 years, CSNN was believed to be caused by abiotic factors (calcium deficiency and/or specific climatic conditions). In collaboration with research institutes in Austria, Denmark, Germany, and the U.S., we revealed that *Hormonema dematioides*, the imperfect stage of *Sydowia polyspora,* caused CSNN on Nordmann fir (Talgø et al*.,* 2010), but further research related to biology, epidemiology, and management was clearly needed. Phytophthora root rot and interior needle blight are also addressed in this project.

Weeds

Weeds may influence tree health by restricting air movement, hosting disease agents such as the rust fungus *Pucciniastrum epilobii*, and competing with the trees for water and nutrients. Thus, part of the project will focus on weed control. Due to high precipitation and steep fields in the main Norwegian Christmas tree production areas, a satisfactory ground cover is necessary to avoid erosion and soil-contaminated trees during harvest. Vegetation suppression for establishment of a noncompetitive groundcover is therefore a subgoal in our project.

Handbook

Through several previous projects, we have collected images of diseases, pests, and weeds in Christmas tree fields. Identification of damaging agents is very important in integrated pest management, which combines biological, cultural, physical, and chemical control methods into a more environmentally sensitive management approach than programs based entirely on the use of pesticides.

Based on a better understanding of the biology of the important diseases and weeds embraced by this project, our aim is to publish a handbook at the end of the project period. Symptoms, signs, and possible management measures relevant to damaging agents will be included. The handbook will combine new findings from our ongoing project with previous knowledge and thereby provide growers, advisors, and others with a good tool for identifying problems in the field. The book will also include nutrient deficiency symptoms and damage by mites and insects.

Literature

Talgø, V., G.A. Chastagner, I.M. Thomsen, T. Cech, K. Riley, K. Lange, S.S. Klemsdal, and A. Stensvand. 2010. *Sydowia polyspora* associated with current season needle necrosis (CSNN) on true fir (*Abies* spp.). Fungal Biology 114:545–554.

Analyzing plant vitality after application of the biocontrol fungus *Trichoderma harzianum* in a Christmas tree plantation of Lower Austria: Results of year one

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Abstract

Abies nordmanniana, established for Christmas tree production in northern Austria (48°28'N, 15°32'E), was treated with two different commercial products of the biocontrol fungus *Trichoderma harzianum*: *T. harzianum LC3 and T. harzianum* Vitalin®. As the damage caused by forest pests such as *Armillaria mellea* and *Kabatina abietis* has increased in European Christmas tree plantations during recent years, the project tests the potential of a biocontrol fungus to enhance the vitality of the trees and to prevent pest attack. For monitoring plant vitality and quality, common quality criteria were used, e.g., leader shoot length, number of whorl buds at the shoot tip, and root collar diameter. Additionally fresh and dry weights of roots and shoots were measured from a subsample for each of the experimental variants. All parameters showed nearly identical values for each of the experimental variants after the first year of observation. Causes and consequences of the findings are discussed.

Introduction

Christmas tree production is a growing business in Austria and an important factor for the regional economy. Increasing damage caused by fungal pests, e.g., *Armillaria mellea* var. ostoyae, *Kabatina abietis,* and *Pucciniastrum epilobii* (Cech, 2007; Perny et al., 2002; Talgø et al., 2007), in combination with the market relevance of organic farming, has led to the demand for an application of biocontrol organisms.

The concept of biocontrol includes the application of antagonistic organisms, e.g., fungi and/or bacteria, as an alternative to chemical pesticides (Swart and Wingfield, 1991; Harman, 2000).

Fungi of the genus *Trichoderma* are known for their ability to attack other fungal species (Harman et al., 2004). Early studies resulted in successful application of *Trichoderma harzianum* for controlling *Fusarium,* which was causing problems during nursery production of Douglas-fir and other shrub seedlings (Sivan and Chet, 1989; Mousseaux et al.,1998).

Austrian forestry and Christmas tree growers were not aware of these pest control options for a long time. Recent success in using biological agents to control the blue-stain fungus *Sphaeropsis sapinea* and increase the value of timber production (Gradinger et al., 2008) contributed to a general change in outlook in Austria.

Goals

Our goal was to test the potential of the biocontrol fungus *Trichoderma harzianum* for successful application in existing commercial Christmas tree plantations.

Materials and methods

The field trial was established in a regular Christmas tree plantation of Lower Austria (northern Austria: 48°2'N, 15°32'E) at an elevation of 470 m. *Abies nordmanniana*, provenance “Ambrolauri Tlugi,” is the most common provenance for this region, where annual precipitation reaches an average of 550 mm per year.

The experiment was started in spring 2010, 2 years after machine planting of the field. Chemical (Katana, Round Up) as well as mechanical (mulching machine) weed control was done. We used an experimental block design, where two rows of trees were exposed to one of the biocontrol organisms, followed by two rows of untreated trees (buffer zone). The same design was repeated for the second of the biocontrol organisms as well as for the “zero-variant.” Altogether, three experimental blocks were established.

Two different commercial products of the biocontrol fungus *Trichoderma harzianum* were used: *T. harzianum LC3* (yellow tags) and *T. harzianum* Vitalin® (red tags). The plants of the untreated “zero-variant” were marked with white tags. The treatment of the plants was done manually by application of a spore suspension two times at the beginning of the vegetation period.

Common tree quality parameters (e.g., Saebø et al., 2009) were used for monitoring tree vitality and quality: root collar diameter, total height, leader shoot length, number of whorl buds at the shoot tip, number of branches at the uppermost whorl, and length of three branches at the uppermost whorl. All parameters were measured from 100 tagged trees of each of the experimental variants, resulting in 900 trees being monitored before the start of the experiment as well as after the first vegetation period.

In addition, dry weight and fresh weight of roots and shoots were measured from a subsample of 10 trees of each of the experimental variants, so that 90 trees were excavated for laboratory analysis after the first vegetation period of the experiment. Data processing included the calculation of average values for each of the experimental variants and parameters, followed by a comparison of results and statistical tests (ANOVA).

Results and discussion

All calculated parameters resulted in similar values for all of the experimental variants, and even the distribution of the data was similar, so that no statistically significant effect was observed. The number of buds at the leader shoot tip of the observation period (2010), calculated for all three experimental variants and summarized over all three blocks, provides an example of these findings (Figure 1). The average number of buds at the leader shoot tip was 3.28 (red), 3.40 (yellow), and 3.43 for the control plants (white) in spring 2010 before starting the experiment. The number of buds reached a higher value after the first year of observation, which was obviously due to recovering from planting shock. The average values were nearly identical at 3.85 (red), 3.96 (yellow), and 3.99 for the control plants (white), respectively.

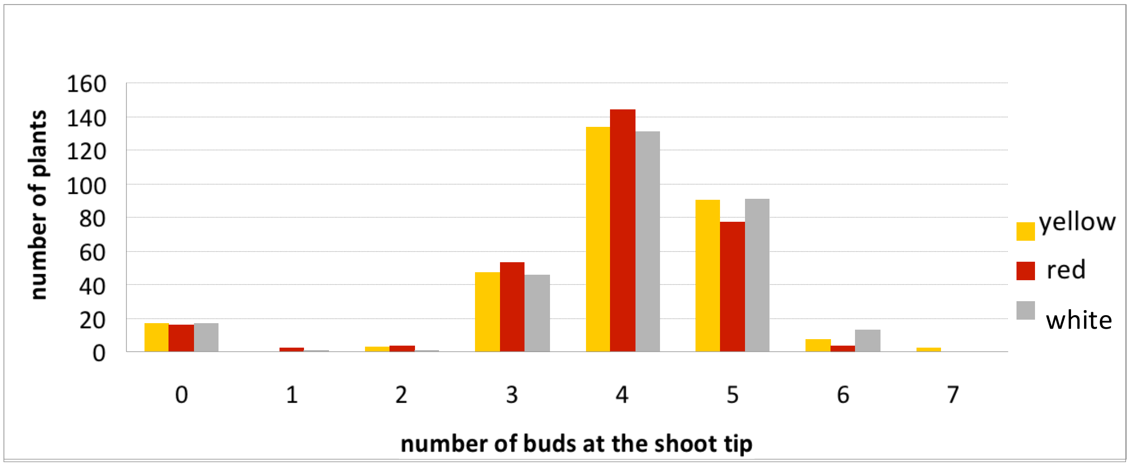

Figure 1. Number of whorl buds at the shoot tip after the first year (2010) of application of the biocontrol fungus *Trichoderma harzianum LC3* (yellow) and *T. harzianum* Vitalin® (red) in comparison to the performance of the untreated control plants (white).

We assume that the observation during one vegetation period was too short for a visible treatment response from the trees. Thus, the treatment and the measurement of the trees will be repeated during the second year of the experiment.

The positive effects of *T. harzianum* in raising Douglas-fir seedlings (Mousseaux et al., 1998) and the negative effects resulting from the application of *Streptomyces griseoviridis* for the same tree species (Dumroese et al., 1998) may indicate a species-specific interaction between the biocontrol organism and the host tree. Moreover, the most successful applications of biocontrol organisms in fruits have been demonstrated in greenhouse experiments or during postharvest storage, where environmental conditions can be controlled (see also Hjeljord et al., 2011), but field tests have failed (e.g., Hjeljord et al., 2011). Therefore, application of biocontrol organisms under controlled nursery conditions should be tested to see whether they may be more successful in the case of *Abies nordmanniana*.

Literature

Cech, T. 2007. Actual and new needle diseases of Christmas trees in Austria. Proceedings of the IUFRO WP 7.0202 conference Sopron 2007, Hungary. Acta Silv. Lign. Hung., Spec. Edition 2007. p. 264.

Dumroese, R.K., R.L. James, and D.L. Wenny. 1998. Interactions among *Streptomyces griseoviridis*, *Fusarium* root disease, and Douglas-fir seedlings. New Forests 15:181–191.

Gradinger, C., K. Fackler, K. Messner, and T. Boisselet. 2008. Biological control of the blue-stain fungus *Sphaeropsis sapinea* in the field. 10th EWLP 2008, Stockholm, Schweden, Vol. 400–403.

Harman, G.E. 2000. Myths and dogmas of biocontrol, changes in perceptions derived from research on *Trichoderma harzianum* T-22. Plant Disease 84:377–393.

Harman, G.E., C.R. Howell, A. Viterbo, I. Chet, and M. Lorito. 2004. *Trichoderma species*—opportunistic, avirulent plant symbionts. Nature Reviews 2:43–56.

Hjeljord, L.G., G.M. Stromeng, A. Tronsmo, A. Sonsteby, and A. Stensvand. 2011. Attempts to reduce strawberry grey mold (*Botrytis cinerea*) in Norway using fungal antagonists. The European J. of Plant Science and Biotechnology 5 (special issue 1):78–85.
Mousseaux, M.R., R.K. Dumroese, R.L. James, D.L. Wenny, and G.R. Knudsen. 1998. Efficacy of *Trichoderma harzianum* as a biological control of *Fusarium oxysporum* in container-grown Douglas-fir seedlings. New Forests 15**:**11–21.
Perny, B., T. Czech, E. Donaubauer, and C. Tomiczek. 2002. Krankheiten und Schädlinge in Christbaumkulturen. 2. Aufl. Bundesamt und Forschungszentrum für Wald, Wien. 239 S.
Saebø, D., I.S. Floistad, J. Netland, and O.M. Edvardsen. 2009. Weed control measures in Christmas tree plantations of *Abies nordmanniana* and *Abies lasiocarpa* on agricultural land. New Forests 38**:**143–156.
Sivan, A., I. Chet. 1989. The possible role of competition between *Trichoderma harzianum* and *Fusarium oxysporum* on rhizosphere colonization. Phytopathology 79: 198-203.
Swart, W.J. and M.J. Wingfield. 1991. Biology and control of *Sphaeropsis sapinea* on *Pinus* species in South Africa. Plant Disease 75**:**761–766.
Talgø, V., T. Cech, and A. Stensvand. 2007. Fungi found in Norway and Austria in association with Abies needles developing current season needle necrosis (CSNN). BIOFORSK EMA 2 (37).

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Neonectria canker on subalpine fir (*Abies lasiocarpa*) in Denmark

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Abstract

In 2011, Neonectria canker was found on subalpine fir in Denmark. The disease was caused by a different *Neonectria* species than the well-known *N. fuckeliana* previously reported on spruce (*Picea* spp.) from Denmark and other countries. It was more similar to *N. ditissima,* which is commonly found worldwide on apples and other broadleaf trees. To our knowledge, this new *Neonectria* species had previously been reported only in Norway. Koch's postulates were fulfilled.

Introduction

Neonectria canker is a well-known disease in many countries around the world, both on conifers and broadleaf trees. On conifers, *N. fuckeliana* has been reported from different hosts and locations, for instance, on Norway spruce and white spruce (*P. glauca*) in Norway (Jørstad, 1945), white fir (*Abies concolor*) in Europe and western North America (Callan, 1997; Schultz and Parmeter, 1990), radiate pine (*Pinus radiata*) in New Zealand (Dick, 2007), and subalpine fir in Canada (Funk, 1981).

In 2008, extensive dieback and canker wounds were found on white fir, Siberian fir (*A. sibirica*), subalpine fir, and Norway spruce in Norway. A *Neonectria* species new to the Norwegian fungal flora was obtained from all hosts (Talgø, 2009; Talgø et al., 2010).

In June 2011, severe canker and dieback symptoms were found on subalpine fir in Denmark. The aim of this work was to identify the disease-causing agent on the Danish subalpine fir and prove pathogenicity (fulfill Koch's postulates).

Materials and methods

Symptoms were found on subalpine fir in a forest plantation in northern Jutland, a provenance trial in mid-Jutland, and an arboretum in Copenhagen. Most trees in the Danish provenance trial investigated in June 2011, appeared healthy, but some dead and dying trees were found (Figure 1).

Figure 1. Subalpine fir (*Abies lasiocarpa*) in a provenance trial in Denmark in June 2011. Most trees looked healthy (left), but some patches of dead and dying trees were present (right).
Photos: Venche Talgø

Typical symptoms and signs were flagging (dead branches) and heavy resin flow (Figure 2). Red fruiting bodies (perithecia) were found on several diseased trees. No perithecia were found on current-year dieback or branches that obviously had been dead for a longer period. Perithecia were present only on branches that had died the previous year (brown needles still attached), and they were especially abundant where dead needles had accumulated on lateral branches (Figure 3). This was likely due to preservation of humidity after rain and dewfall, creating ideal conditions for fungal growth.

Figure 2. Typical symptoms caused by *Neonectria* sp. on a subalpine fir (*Abies lasiocarpa*) in a Danish provenance trial in June 2011: flagging (brown foliage, left) and resin flow (right)
Photos: Venche Talgø

Figure 3. Red fruiting bodies (perithecia, left) are typical signs after infection by *Neonectria* sp. Perithecia were present on dead branches where brown needles were still attached and were especially abundant where dead needles had accumulated on lateral branches (right). Photos: Venche Talgø

Samples, consisting of canker wounds on branches, branches with fruiting bodies (perithecia), and dead leaders and lateral shoots, were collected from all three sites and brought to Norway, where isolations took place. Small pieces (approximately 1 cm^3) from the leading edges (Figure 4, left) were dissected. They were surface sterilized (10 seconds in 70% ethanol + 90 seconds in 0.5% NaOCl), divided into smaller pieces, and plated on PDA agar.

Sequencing of the internal transcribed regions (ITS) of the ribosomal DNA was carried out on *Neonectria* cultures from all sites.

On 15 July 2011, an inoculation test was performed in Norway with a culture isolated from a tree in the Danish provenance trial. Top shoots/leaders on 34 three-year-old subalpine fir trees were inoculated with map pins containing *Neonectria* mycelium and spores, and 13 trees were kept as control (only wounded with autoclaved map pins).

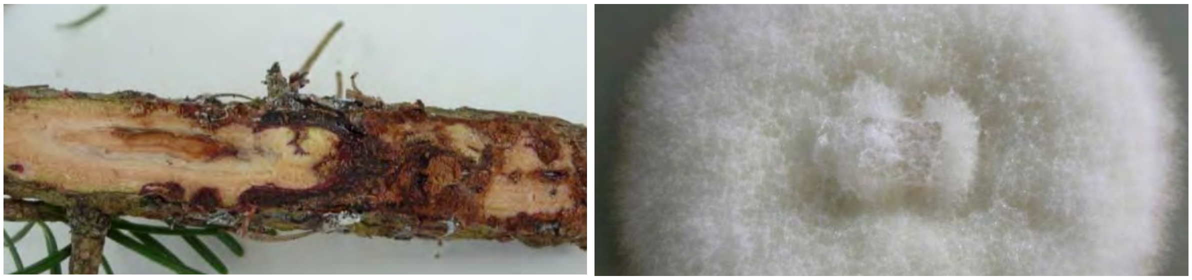

Figure 4. In June 2011, isolations were carried out from the area between healthy and diseased tissue (leading edges) (left) on subalpine fir (*Abies lasiocarpa*) samples from several Danish locations. Identical, fluffy, white *Neonectria* cultures were obtained (right). Photos: Venche Talgø

Results

A *Neonectria* sp. (Figure 4, right) was readily isolated from several samples per site. Sequencing of the rDNA stated that all isolates were most similar to *N. ditissima* (only 5 bp different from *N. ditissima* isolates reported to the GenBank), but very different from *N. fuckeliana* (> 20 bp different). The Danish isolates were identical to Norwegian isolates reported from true fir species and Norway spruce in Norway (Talgø, 2009).

By 11 August, needlecast and dead tissue occurred around the inoculation points (Figure 5). No canker was present on the control plants, only a slight discoloration of the tissue where the map pin had been present (Figure 6). The fungus was readily reisolated from the inoculated, dying leader shoots.

Figure 5. Dead leaders on subalpine fir (*Abies lasiocarpa*) less than a month after inoculation by map pins contaminated with *Neonectria* sp. isolated from Danish subalpine fir. Photos: Venche Talgø

Figure 6. Subalpine fir (*Abies lasiocarpa*) where autoclaved map pins were inserted (control) showed no canker symptoms. Photos: Venche Talgø

Discussion

The inoculation test resulted in needle cast and dead shoots within less than a month, indicating that the pathogen is very aggressive.

Since the disease spread in patches in the provenance trial in Denmark, frost damage is not likely involved. This is further indicated by the fact that trees from the same provenances looked healthy farther down the rows (the entire area was flat). In addition, the other locations where the fungus was isolated from subalpine fir had not been exposed to heavy frost.

In the future, this new *Neonectria* sp. found in Norway and Denmark may be classified as a new species. We are currently collaborating with researchers in other countries to find out whether the pathogen is present elsewhere.

References

Callan, B. 1997. Other canker diseases. In: Hansen, E. and K.J. Lewis (eds.). Compendium of conifer diseases. Pages 47–49. APS Press, St. Paul, MN, USA.

Dick, M.A. 2007. Nectria fruit canker. Forest pathology in New Zealand No. 23. http://www.ensisjv.com/ResearchCapabilitiesAchievements/ForestHealthBiosecurityandFire/ForestPestFactSheet/Nectriaflutecanker/tabid/433/Default.aspx

Funk, A. 1981. Parasitic microfungi of western trees. Canadian Forestry Service. 159 pp.

Jørstad, I. 1945. Parasitsoppene på kultur- og nyttevekster i Norge. I. Sekksporesopper (Ascomycetes) og konidiesopper (Fungi Imperfecti). Tillegg C til Landbruksdirektørens melding for 1943. Grøndahl & Søn Boktrykkeri, Oslo. 142 pp. (In Norwegian).

Schultz, M.E. and J.R. Parmeter. 1990. A canker disease of *Abies concolor* caused by *Nectria fuckeliana*. Plant Disease 74:178–180.

Talgø, V. 2009. Diseases and disorders on fir (*Abies* spp.) grown as Christmas trees, boughs, and landscape plants in Norway: from seed to site. PhD thesis 2009:28. Norw. Univ. Life Sci. 174 pp.

Talgø, V., M.B. Brurberg, and A. Stensvand. 2010. Neonectria canker on true fir and spruce in Norway. In: Proceedings of the 9th International Christmas Tree Research & Extension Conference (eds. Hart, J., C. Landgren, and G. Chastagner). Corvallis, Oregon, 14–18 September 2009. pp. 58–62.

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Sclerophoma shoot dieback on Nordmann fir (*Abies nordmanniana*) in Norway

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Abstract

Sclerophoma shoot dieback is an extensive problem on Nordmann fir (*Abies nordmanniana*) Christmas trees in Norway, and we have also seen damage on subalpine fir (*A. lasiocarpa*) and Norway spruce (*Picea abies*). Current-year shoots become chlorotic, bend, and eventually die. The disease is caused by the fungus *Sydowia polyspora* (syn. *Hormonema dematioides, Sclerophoma pithyophila,* and others). Pathogenicity was proven.

Introduction

In Canada, Sclerophoma shoot dieback has been found on pine (*Pinus* spp.), Douglas-fir (*Pseudotsuga* sp.), true fir (*Abies* spp.), spruce (*Picea* spp.), hemlock (*Tsuga heterophylla*), larch (*Larix* sp.), and cedar (*Thuja* sp.) (Funk, 1981). In Austria, Sclerophoma shoot dieback is commonly found on spruce and true fir and is considered a problem in the Christmas tree production (Perny et al., 2002). Also in Denmark, Sclerophoma shoot dieback has been found on Nordmann fir Christmas trees (Thomsen et al., 2009).

Under field conditions, initial Sclerophoma shoot dieback symptoms are small wounds on leaders and lateral shoots. As the disease develops, the shoots grow faster where they are not infected, and consequently result in malformation (bending). In severe cases, shoots become chlorotic and eventually die (Figure 1). The dead areas are often covered by black, leather-like pycnidia (Figure 2).

The aim of this work was to prove that *Sydowia polyspora* may cause Sclerophoma shoot dieback.

Figure 1. Sclerophoma shoot dieback on Nordmann fir (*Abies nordmanniana*) in a Christmas tree field in Rogaland County, Norway. Photo: Venche Talgø

Figure 2. A typical sign connected to Sclerophoma shoot dieback is the presence of numerous black, leather-like pycnidia covering the dead tissue. Photos: Venche Talgø

Material and methods

In June 2010, we inoculated new shoots of Nordmann fir before they were fully elongated. Since *Sclerophoma* spp. are described in the literature as weak pathogens attacking wounded plants, a few needles were removed per shoot. A spore suspension was transferred to the needle scars with a soft paintbrush. The culture we used (Figure 3) originated from a Nordmann fir sample collected in Rogaland County in southwestern Norway in April 2010. By sequencing the internal transcribed regions (ITS) of the ribosomal DNA, the culture was identified as *Hormonema dematioides*, which, together with *Sclerophoma pithyophila* and several other species, are classified as synonyms to the teleomorph *Sydowia polyspora*.

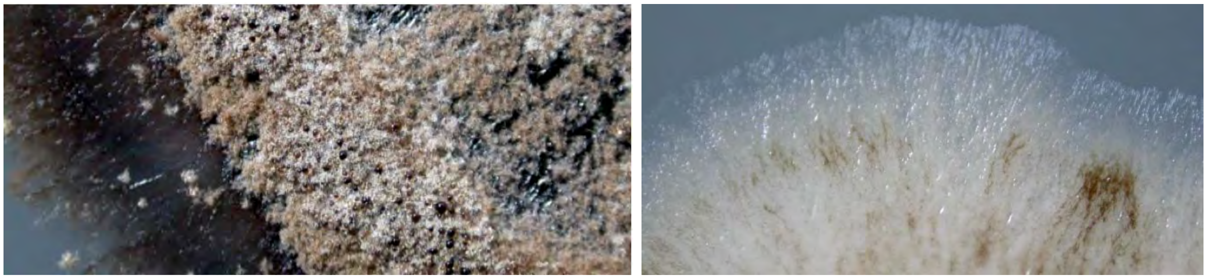

Figure 3. A 6-month-old, cold-stored culture from the isolate we used in this inoculation test (left), and the same culture 6 days after subculturing (right). The slimy appearance of the latter is due to abundant spore masses. Photos: Venche Talgø

To obtain high humidity, the plants were covered with a plastic sheet for 1 week after inoculation. The experiment took place in a high plastic tunnel where the plants were automatically watered by overhead sprinklers four times a day. Control plants received the same treatment, except that sterile water was used instead of spore suspension.

Results and discussion

We obtained classical Sclerophoma shoot dieback symptoms on inoculated Nordmann fir shoots (Figure 4); thus, *S. polyspora* is clearly pathogenic on young shoots. The fungus was readily reisolated. Isolations from control plants were negative.

Figure 4. Sclerophoma shoot dieback symptoms on Nordmann fir (*Abies nordmanniana*) approximately 4 months after inoculation with *Sydowia polyspora*. Photos: Venche Talgø

References

Funk, A. 1981. Parasitic microfungi of western trees. Canadian Forestry Service. 159 pp.

Perny, B., T. Chech, E. Donaubauer, and C. Tomiczek. 2002. Krankheiten und Schädlinge in Christbaumkulturen. Bundesamt und Forschungszentrum für Wald, Wien, Austria. 194 pp.

Thomsen, I.M., V. Talgø, and A. Stensvand, A. 2009. Skuddød og svampeangreb. Videnblade Pyntegrønt 5.6–19: 2 pp. (in Danish).

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Seed-borne fungi on conifers

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Abstract

In 2005, we investigated the fungal flora on seeds from true fir (*Abies* spp.). *Sydowia polyspora* was frequently found on investigated seeds, a fungus associated with Current Season Needle Necrosis (CSNN) and Sclerophoma shoot dieback. To determine whether *S. polyspora* was present on other conifer seeds, we made a new investigation in 2010, which included seed lots from the following genera: true fir, Douglas-fir (*Pseudotsuga*), pine (*Pinus*), spruce (*Picea*), hemlock (*Tsuga*), cypress (*Chamaecyparis*), and cedar (*Thuja*). *S. polyspora* was found on seeds from all genera except *Chamaecyparis*. Here we also report other fungi found on seeds in the test in 2010.

Introduction

Many fungi have been reported to be seed-borne on conifers (Litke and Browning, 1990; Mittal et al., 1990; Richardson, 1990). Some seed-borne fungi cause decay and reduce the germination of stored seeds, while others attack germinating seedlings or needles and shoots of seedlings in nurseries (Anderson, 1986). Some fungi are considered harmless saprophytes, but they may cause decay of seeds under improper storage conditions. Butin (1995) stated that biotic damage to seeds is almost exclusively caused by fungi attacking the outer seed coat or causing internal decay.

In Norway, a number of airborne fungi have been found to cause necrotic needles and dead shoots on Christmas trees and boughs (Talgø, 2009). Compared to forest production, there is hardly any tolerance for damaged foliage on such products. CSNN and Sclerophoma shoot dieback are especially troublesome. Both are associated with the fungus *S. polyspora* (Talgø et al., 2010b), which we found to be seed-borne on noble fir (*Abies procera*), Nordmann fir (*A. nordmanniana*), and subalpine fir (*A. lasiocarpa*) (Talgø et al., 2010a).

The objective of the current study was to determine whether *S. polyspora* was present on seeds from other conifer hosts than true fir.

Materials and methods

In 2010, 44 conifer seed lots representing 8 conifer host genera (Figure 1) were tested for presence of *S. polyspora* and other fungi. From each seed lot, 100 non-surface-sterilized seeds and 100 surface-sterilized seeds (1% NaOCl for 10 minutes, dried on sterile blotters) were plated on potato dextrose agar (PDA) and incubated for 7 days at 20 ± 2ºC under alternating 12 hours of NUV-light and 12 hours of darkness.

After incubation, each seed was examined for fungal growth under a dissecting microscope. Identification was based on morphological characters. When necessary for further identification, cultures were identified to species level based on sequencing of ITS (internal transcribed spacer) regions of the rDNA.

Figure 1. Seeds representing the 44 conifer seed lots that were included in the present work (I-III indicate different seed lots from the same host species): First/top row (from left to right): ***Abies** amabilis, A. balsamea, A. bornmuelleriana, A. concolor, A. fraseri, A. homolepis, A. koreana, A. lasiocarpa, A. nordmanniana, A. procera,* and *A. sachalinensis*. Second row: *A. sibirica, A. veitchii,* ***Chamaecyparis** lawsoniana,* ***Larix** leptolepis, L. sibirica* (I), *L. sibirica* (II), ***Picea** abies* (I), *P. abies* (II), *P. abies* (III), *P. engelmannii,* and *P. glauca.* Third row: *P. lutzii, P. mariana, P. omorika, P. pungens* var. *glauca, P. sitchensis,* ***Pinus** aristata, P. cembra, P. contorta* var. *contorta, P. contorta* var. *latifolia, P. mugo* var. *mughus,* and *P. mugo* var. *pumilio*. Fourth row: *P. mugo* var. *rostrata, P. mugo* var. *rotundata, P. pumila, P. sylvestris* (I), *P. sylvestris* (II), ***Pseudotsuga** menziesii, P. menziesii* var. *menziesii, P. menziesii* var. *glauca,* ***Thuja** plicata,* ***Tsuga** heterophylla,* and *T. mertensiana*. The seeds were placed in 1.2 cm x 1.2 cm squares. Photo: Erling Fløistad

Results and discussion

Several fungi were often present on the same seed (Figure 2), and it was sometimes difficult to obtain pure cultures. Here we present (in alphabetical order) only the seed-borne fungi we found that are known to be pathogenic in nurseries and/or production fields.

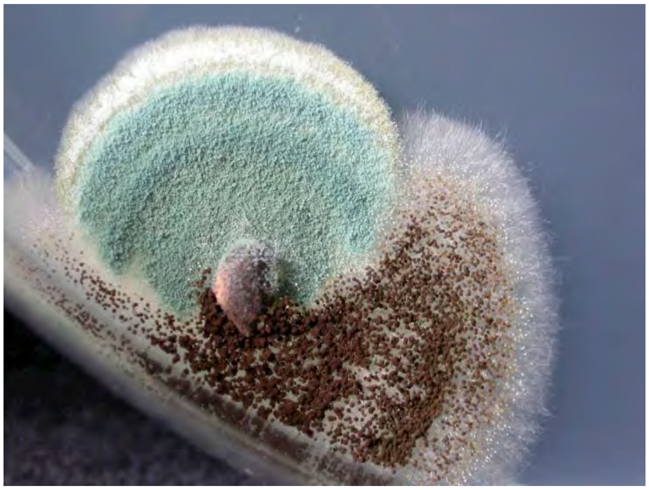

Figure 2. From this dwarf mugo pine (*Pinus mugo* var. *mughus*) seed, a *Penicillium* sp. (blue) and *Aspergillus niger* (brown) emerged. Both are considered secondary pathogens. Photo: Venche Talgø

Botrytis cinerea (grey mold) was found on seeds from noble fir and Siberian fir (*A. sibirica*), but grey mold is such a widely distributed fungus that it does not necessarily have to be seed-borne to cause problems in nurseries (Figure 3) or field production.

Figure 3. Subalpine fir (*Abies lasiocarpa*) attacked by grey mold (*Botrytis cinerea*) in a container nursery in Norway. Photo: Venche Talgø

***Fusarium* spp.** were detected on seeds from five host species: Veitch fir (*A. veitchii*), Nikko fir (*A. homolepis*), Siberian fir, Japanese larch (*Larix leptolepis*), and Siberian larch (*L. sibirica*). We have previously found damage by *Fusarium* spp. on conifers in nurseries and on Nordmann fir in a Christmas tree plantation (Talgø, 2009).

Pestalotiopsis cocculi was found on seeds from Nikko fir, and ***P. funerea*** was found on seeds from beach pine (*Pinus contorta* var. *contorta*) and western redcedar (*Thuja plicata*). *Pestalotiopsis* spp. are very common on woody plants in nurseries and elsewhere and are considered to be weak parasites. In an inoculation test with *P. funerea* on Nordmann fir in Norway, young needles dried out before they were fully elongated (Talgø et al., 2010b).

***Phomopsis* sp.** (teleomorph: *Diaporthe*) was found on seeds from Japanese larch, Siberian larch (Figure 4), and western redcedar. We have often found *Phomopsis* spp. on both fir and spruce (Figure 5) Christmas trees, including nursery stock (Talgø, 2009).

Figure 4. *Phomopsis* sp. emerged from a seed of Siberian larch (*Larix sibirica*). Photo: Venche Talgø

Figure 5. Spores (conidia) of *Phomopsis* sp. oozing out from pycnidia in the bark of an infected Norway spruce (*Picea abies*), forming thread-like structures. Photo: Venche Talgø

Sirococcus conigenus was found on seeds from Siberian larch. In the seed test in 2005 (Talgø et al., 2010a), we found *S. conigenus* on noble fir, but in nurseries and production fields we have detected the fungus only on spruce and pine.

Sydowia polyspora was found on seeds from seven of the eight tested conifer genera (in bold). Where pure cultures were obtained, the following hosts proved positive for *S. polyspora* by ITS sequencing of the rDNA: ***Abies** bornmuelleriana*, *A. lasiocarpa*, *A. procera*, *A. sachalinensis*, *A. sibirica*, *A. veitchii*, ***Larix** leptolepsis*, *L. sibirica*, ***Picea** abies*, *P. glauca*, *P. omorika* (Figure 6, left), ***Pinus** cembra*, *P. contorta* var. *latifolia*, *P. mugo* var. *mughus*, *P. mugo* var. *rostrata*, *P. mugo* var. *rotundata*, *P. pumila*, *P. sylvestris*, ***Pseudotsuga** menziesii* var. *menziesii*, *P. menziesii* var. *glauca*, ***Thuja** plicata,* and ***Tsuga** heterophylla*. Figure 6 (right) shows damage by *S. polyspora* (Sclerophoma shoot dieback) on Norway spruce.

Figure 6. *Sydowia polyspora* emerged from a seed of Serbian spruce (*Picea omorika*, left). Sclerophoma shoot dieback, caused by *S. polyspora*, on Norway spruce (*Picea abies*, right). Photos: Venche Talgø/Erling Fløistad

References

Anderson, R.L. 1986. Pathological problems in forest seeds. Journal of Seed Technology 10:138–139.

Butin, H. 1995. Tree diseases and disorders. Causes, biology and control in forest and amenity trees. Oxford University Press. 252 pp.

Litke, W.R. and J.E. Browning. 1990. Assaying for seed-borne fungi of Douglas-fir and true fir species. Proceedings from first meeting of IUFRO Working Party S2.07-09, Diseases and Insects in Forest Nurseries. British Columbia, Canada, August 22–30, 1990, pp. 253–258.

Mittal, R.K., R. L. Anderson, and S.B. Mathur. 1990. Microorganisms associated with tree seeds: World Checklist 1990. Information Report PI-X-96E/F. Petawawa National Forestry Institute, Forestry Canada. 57 pp.

Richardson, M.J. 1990. An annotated list of seed-borne diseases. The International Seed Testing Association, Zürich, Switzerland.

Talgø, V. 2009. Diseases and disorders on fir (*Abies* spp.) grown as Christmas trees, boughs, and landscape plants in Norway: from seed to site. PhD thesis 2009:28. Norw. Univ. Life Sci. 174 pp.

Talgø, V., G. Brodal, S.S. Klemsdal, and A. Stensvand. 2010a. Seed borne fungi on *Abies* spp. Seed Science and Technology 38:477–493.

Talgø, V., G.A. Chastagner, I.M. Thomsen, T. Cech, K. Riley, K. Lange, S.S. Klemsdal, and A. Stensvand. 2010b. *Sydowia polyspora* associated with current season needle necrosis (CSNN) on true fir (*Abies* spp.). Fungal Biology 114:545–554.

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INSECT AND VERTEBRATE PESTS

Major insect pests of Christmas trees in Canada

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Introduction

Like other crops, Christmas trees are subject to damage from insect pests, diseases, and weeds. However, the following paper focuses on major insect pests of Christmas trees in Canada.

Overview of Canadian Christmas tree industry

General information about Canadian Christmas tree industry

Canada was first introduced to the Christmas tree in 1781 in Quebec by a German immigrant, Baron Friederick von Riedesel. The Baron's tree was a balsam fir cut from a natural forest in Quebec and was decorated with myriad white candles.

Although Canadians have a long history of using Christmas trees, Canada is not presently a major Christmas tree producer in the world. In total, there are about 37,000 hectares of Christmas tree production in Canada. On average, 3 to 6 million Christmas trees are harvested annually. Farm gate value of Christmas trees is about $50 to 60 million. About 50 percent of annually harvested Christmas trees in Canada are exported, mainly to the United States, the Caribbean, and Central America.

Major Christmas tree species

True firs, pine, and spruce are all used for Christmas tree production in Canada. True firs include species of balsam fir (*Abies balsamea)*, Fraser fir (*A. fraseri)*, Canaan fir (*A. balsamea* var. *phanerolepis),* noble fir (*A. procera),* grand fir (*A. grandis),* white fir (*A. concolor)*. However, balsam fir is by far the predominant fir species for Christmas trees in Canada. In addition to these true fir species, Douglas-fir (*Pseudotsuga menziesii*) is also widely used for Christmas tree production, especially in western Canada.

Scots pine (*Pinus sylvestris*) and white pine (*P. strobus*) are two major pine species for Christmas tree production in Canada. European and Asian native Scots pine was one of the first plantation-grown Christmas trees in North America. A graceful evergreen, its fragrance and excellent needle retention have made it a popular Christmas tree for many years in Canada.

Among about 35 species in the genus of *Picea*, two are grown in Canada for Christmas trees, i.e., Colorado blue spruce (*P. pungens*) and white spruce (*P. glauca*). Both species are native to North America. Although Colorado blue spruce is a slow-growing tree, taking a few more years to bring to market, it is well worth the wait because of its shape and natural color as a Christmas tree.

Growing methods

Three growing methods have been developed over years of practice to grow Christmas trees in Canada.

Natural stand production: This production system relies mainly on natural regeneration of balsam fir in natural forest stands and is used mainly in eastern Canada, especially in the province of Nova Scotia. The seeds from mature trees of balsam fir are released, and young seedlings grow naturally from these seeds. In this production system, site preparation is not necessary. However, the dense seedlings need to be thinned. Initial investment in natural stand production for Christmas trees is less than that in plantation production. The crop rotation cycle is longer, however, and marketable Christmas trees per unit area are fewer than in plantation production.

Plantation production: Plantations allow for the production of high-quality marketable Christmas trees in a controlled environment and area. The choice of tree species and varieties to grow in a plantation varies according to growing zones, soil type, and market demand. Christmas trees are grown in the 1B–6A growing zones in Canada.

Stump culture: Stump culture is mainly used for Douglas-fir Christmas tree production in Canada. In this production system, the mature Christmas tree is cut at harvest in such a way that the stump is left with the bottom whorls or lower branches. These branches provide the stump with energy, allowing the tree to continue thriving. After several years, the best branch will be chosen to become the leader of the next tree (Figure 1). Stump culture reduces the time to harvest for a Douglas-fir by approximately 3 years. This production system is primarily found in the interior of British Columbia.

Figure 1. A future Christmas tree developed from a lower branch of the previous crop in the stump culture production system.

Major insect pests of Christmas trees in Canada

Based on feeding behavior and their damage to Christmas trees, insect pests may be classified into the following four groups.

Gall-forming insects

Balsam gall midge (*Paradiplosis tumifex*): This North American native species occurs throughout the range of firs. The midge overwinters as a mature larva, and adults emerge next May to coincide with the development of fir buds. The female adults lay their eggs between the tight needles of the opening buds. Each newly hatched larva crawls to the base of a needle to feed, initiating the growth of the gall tissue that ultimately completely encloses the larva. Thus, the gall is formed. There is usually only one gall per needle, but there may be more than one in a single needle if the population density is high (Figure 2). The larva leaves the gall in the fall and drops to the ground, where it overwinters. There is only one generation per year for this species in Canada. Although the insect does not kill the tree directly, it makes Christmas trees unmarketable because of the appearance of galls. Current control options include using an organophosphate insecticide that may be phased out soon in Canada. Using sex pheromone to manage this pest has been investigated in Canada.

Figure 2. Galls formed on balsam fir by balsam gall midge, *Paradiplosis tumifex.*

Douglas-fir needle midge (*Contarinia pseudotsuga*): Midge adults emerge in the spring and live for a short period. Eggs are deposited in groups on newly expanding buds. Larvae immediately bore into young needles after hatching and feed in the needles throughout the summer. A single needle may harbor more than one larva. Larvae mature in the fall and drop to the ground, where they overwinter. The Douglas-fir needle midge has only one generation per year in Canada. Damage to Christmas trees includes premature needle drop, making trees unmarketable. No chemical insecticide is registered for control of this pest in Canada. A pyrethroid insecticide (bifenthrin) may be effective in controlling this midge.

Defoliators

Balsam fir sawfly (*Neodiprion abietis*): Balsam fir sawfly is widely distributed in Canada, from Newfoundland to Alberta, and is a major forest pest as well. The insect overwinters as an egg inside of a current-year needle. Larvae hatch next June and feed vigorously in groups on second-year or older needles, but not on current-year needles (Figure 3). Adults emerge in the fall, and female adults lay their eggs in current-year needles, usually one egg per needle. The sawfly produces only one generation per year. The balsam fir sawfly seldom causes tree mortality, but damage to Christmas trees is significant because trees become unmarketable. A nuclear polyhedrosis virus was developed and registered in Canada for the control of the balsam fir sawfly.

Figure 3. Balsam fir branches damaged by balsam fir sawfly.

Spruce budworms (*Choristoneura fumiferana, C. occidentalis*): The spruce budworm is considered the most serious forest pest in North America. It was mistakenly identified as one species before 1965. There are actually two different species: eastern spruce budworm (*C. fumiferana*) and western spruce budworm (*C. occidentalis*). Both species have very similar life history and feeding behaviors. They overwinter as the second stage of larvae (L2). Larvae resume feeding in the spring. Adults emerge in late summer, and females lay their eggs in clusters of 10 to 30 under the needles. Larvae hatch in the fall and develop into L2 before winter. Spruce budworms prefer feeding on current-year shoots. There is only one generation per year. Severe infestations for a couple of years may kill trees. Much research has been conducted on spruce budworms by the Canadian Forest Service, and this pest is being monitored by provincial forest departments. Current control methods for spruce budworms rely mainly on use of biological insecticides, primarily *Bacillus thuringiensis* var. kurstaki (Btk).

Hemlock loopers (*Lambdina fiscellaria fiscellaria, L. f. lugubrosa*): Eastern hemlock looper (*Lambdina fiscellaria fiscellaria*) occurs in eastern Canada, while subspecies of western hemlock looper (*L. f. lugubrosa*) occur in the western part of the country. These species are also major forest pests. Eggs overwinter, and larvae hatch next June. There are four or five instar stages, depending on the region. Adults emerge in the fall. There is one generation per year. The main hosts of hemlock loopers are balsam fir in eastern Canada and hemlock in western Canada. Larvae prefer to feed on new growth and are waste feeders. Hemlock looper outbreaks develop and subside very suddenly and can cause death of balsam firs in the first year of infestation. Several natural enemies, including parasitoids and fungi, play an important role in hemlock looper population dynamics. Operational control of hemlock loopers relies mainly on *Bacillus thuringiensis*-based insecticides and insect growth regulator.

Sucking insects

Balsam twig aphid (*Mindarus abietinus*): This aphid has a complex life cycle that includes two forms of life stages (wingless and winged) and two modes of reproductive strategies (sexual and asexual). The aphid overwinters as eggs. There are three or four generations per year. Balsam twig aphids cause curling of needles and distortion of shoots. In Christmas tree plantations, balsam twig aphids can have a major economic impact because they reduce the aesthetic appearance of the trees. The aphid can be easily controlled by insecticides.

Conifer root aphid (*Prociphilus americanus*): Conifer root aphid has recently become a serious pest of Christmas trees. This aphid has two hosts: primary host of ash and secondary host of true firs. Like other aphids, conifer root aphid has two forms of life stages (wingless and winged) and two modes of reproduction (sexual and asexual). The aphid reproduces sexually on the primary host and asexually on the secondary host. The aphid feeds on roots of Christmas trees (Figure 4) and causes stunting, yellowing, and reduced growth. Currently there is no control measure available for this pest in Canada. Field efficacy trials have been conducted, and registration of imidacloprid insecticide for the control of this pest in Christmas trees is underway.

Figure 4. Wingless females of conifer root aphid (*Prociphilus americanus*) feeding on roots of Fraser fir Christmas tree.

Balsam woolly adelgid (*Adelges piceae*): This pest was introduced to North America from Europe and was first reported in eastern Canada in 1910. The adelgid overwinters as adults, reproduces asexually, and attacks only true firs. There are two to four generations per year.

Symptom of infection is the presence of white, woolly masses on branches. Damage to trees includes swelling and distortion of twigs. Prolonged attack hinders bud growth and height growth and may ultimately lead to tree death. No chemical insecticides are presently registered in Canada for control of this pest, although imidacloprid insecticides show some promise of effectiveness.

Spruce spider mite (*Oligonychus ununguis*): This North American native species overwinters as eggs. There are at least four generations per year. Like other phytophagous mites, populations of the spruce spider mite increase rapidly when it is dry. By sucking sap out of the needles while feeding, the spruce spider mite causes the foliage to discolor gradually. In addition, the adult mite secretes an abundance of silk threads and uses them to web together needles and twigs. Damage begins inside the branches located in the lower crown and gradually spreads outward and upward in the tree. A couple of miticides, such as Floramite (bifenazate) and Pylon Miticide (chlorfenapyr), are currently registered in Canada for control of this mite on Christmas trees.

Borers

Balsam shootboring sawfly (*Pleroneura brunneicornis*): This sawfly overwinters as a mature larva in the soil, and adults emerge next May. Female adults lay eggs at the base of terminal buds. Upon hatching, the larvae bore a tunnel into the new shoots. When mature, larvae drop to the ground and spin cocoons, in which they overwinter. Wilting current-year shoots with a reddish brown appearance are characteristic of attacks by balsam shootboring sawflies. If Christmas trees are heavily damaged, it is recommended that the annual shoots be pruned to improve the appearance of the trees. Control measures are not currently available against this insect in Christmas trees.

Fir coneworm (*Dioryctria abietivorella*): This European native insect was introduced to North America and first reported in Canada in 1939. Fir coneworm overwinters as mature larvae, and adults emerge in spring. There is only one generation per year. Larvae prefer to feed on cones, but also feed on terminal shoots. Thus, the fir coneworm is a major pest of seed orchards in Canada as well. Signs of an infestation include cones stuck together by frass mixed with webbing, chewed needles, and mined terminal shoots. An organophosphate insecticide is currently registered in Canada for the control of this insect in seed orchards and Christmas trees, but it may be deregistered soon. A newer insecticide, spinetoram, is being investigated for the control of this pest in Canada.

White pine weevil (*Pissodes strobi*): This North American native weevil attacks pine trees in eastern Canada and spruce species in western Canada. The weevil overwinters as adults. Although there is only one generation per year, the adults can live and continue laying eggs for several years. Adult females lay eggs from May through June in the bark of the previous year's leader. Eggs hatch, and larvae tunnel downward under the bark. The larvae may kill the top 1 to 2 feet of the tree (Figure 5). This pest causes serious damage to young Christmas tree plantations. Control strategies include mechanical and chemical controls. The mechanical control is mainly to cut the infected leaders at the level of the topmost whorl of unaffected branches. The lateral branches on the whorl will compete for apical dominance. Although one organophosphate insecticide is currently registered in Canada for the control of this insect, chemical control may not be an option soon because of potential loss of registration of this insecticide.

Figure 5. Young white spruce damaged by white pine weevil.

Monitoring midge emergence for timing insecticide applications

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Background

Over the past few years, we have seen an increase in midge damage in Michigan Christmas tree plantations. Douglas-fir trees are injured by *Contarinia pseudotsuga Condr.,* the Douglas-fir needle midge, and spruce trees have been affected by *Mayetiola piceae*, the spruce gall midge. Even moderate damage by these insects reduces tree quality, sometimes making trees unsalable. The incidence of damage has increased in recent years, and the range of these pests appears to be expanding in Michigan. Growers need to be able to predict the timing of pesticide application for optimal control.

Contarinia pseudotsuga Condr. The Douglas-fir needle midge (Figure 1) was first noticed in in Michigan in 2003. This insect is native to the Pacific Northwest but was not previously known to occur in the Great Lakes region. By 2007, we observed severe needle loss in plantations with high midge populations. Douglas-fir needle midge overwinters as larvae in the soil under infested trees. In early spring, larvae pupate, and adults emerge to mate. Females lay eggs in the needles of the expanding buds, and feeding by the larvae causes current-year needles to become bent and swollen. Damaged areas on needles are pale green or yellow, but darken to brown as the season progresses. These needles eventually drop from the tree. When trees are heavily infested, they may have few or no needles left by harvest time, making them unsalable for cut trees or even for the greens market.

Figure 1. Immature Douglas-fir needle midge (maggot) in needle. Photo: Howard Russell, MSU Diagnostic Clinic

Mayetiola piceae. Spruce gall midge adults emerge from galls in late April to early May. The adults are small flies about the size of a mosquito ($^1⁄_{16}$ of an inch long) and dull orange to brown. After mating, females lay bright orange eggs between the bud scales on new buds. Eggs hatch in 10 to 14 days. Newly hatched larvae move to the base of developing needles to feed, which alters the growth of current-year needles. Affected needles grow around the midge larvae as they continue to feed and develop inside small, individual chambers. The base of the needles swells as the chambers expand to accommodate the growing larvae. Affected twigs appear swollen (Figure 2), and needles may drop off or fail to fully develop. In most cases, the section of the shoot bearing the gall dies.

Figure 2. Gall caused by spruce gall midge on current-year spruce growth. Photo: Jill O'Donnell, MSU Extension

Methods

In *Biology and Control of Douglas-fir Needle Midge in Christmas Trees*, DeAngelis (1994) indicated that timing of pesticide applications is critical for effective control because adult midges must encounter treated foliage before they lay eggs. Emergence traps should be used to ensure appropriate timing.

In 2008 and 2009, we evaluated the efficacy of several trap types, including black and white 5-gallon buckets, cardboard boxes, and sticky traps (red, yellow, and blue). We placed traps under heavily infested trees in May to monitor adult emergence. Traps were checked daily to determine first midge emergence, peak emergence, and the end of the emergence period. We followed emergence for 3 years on 3 sites for Douglas-fir needle midge and two sites for spruce gall midge. Dates of midge emergence were associated with the corresponding accumulation of growing degree days (GDD base 50°F = 10°C) compiled by the nearest MSU weather stations and available from the MSU Enviroweather website (http://www.enviroweather.msu.edu/). The weather station used was 10 to 15 miles from our sites. Because spruce gall midge larvae overwinter in the gall, we also evaluated alternative methods to monitor midge phenology. Initially, we placed plastic bags over branches with galls to collect adults as they emerged in the spring. After success with using yellow sticky traps with Douglas-fir needle midge, we placed sticky traps adjacent to the previous year's gall to determine whether we could capture newly emerged adults.

Results

Determining growing degree days

We monitored Douglas-fir needle midge and spruce gall midge emergence in 2008, 2009, and 2010, along with cumulative GDD_{50} data compiled by local weather stations. We determined the following:

- Douglas-fir needle midge adults emergence began at approximately 200–225 GDD_{50} (May 20) and continued for 3–4 weeks in all three years.
- Spruce gall midge adults began emerging from the previous year's galls in late April to early May, at approximately 70–100 GDD_{50}. Adults began laying eggs immediately. Egg hatch began 10 to 14 days after adult emergence at approximately 130–145 GDD_{50}.

Trapping

Traps can be used effectively to monitor emergence of these small flies. We found that yellow sticky traps were just as accurate for trapping newly emerged adults as the box traps or bags. They were also easier to install in the field and held up well through the season. For Douglas-fir needle midge, place traps on trees in the mid and lower canopy of trees attacked the previous year. For spruce gall midge, place traps on the tree near a gall from the previous year. Place traps for both insects in the field by early to mid-April. Check the traps every other day until growing degree day accumulations reach approximately 25–50 GDD_{50} for spruce gall midge or 160–180 GDD_{50} for Douglas-fir needle midge. At that point, monitor the traps daily.

Alternative treatment

Insecticides can be used to effectively control midge, but application must be timed correctly. Delays caused by spring rain, wind, or other factors will result in poor control.

- In the fall of 2010, we conducted a trial to evaluate the effectiveness of clothianidin, a relatively new neonicotinoid systemic insecticide. This product is sold as Arena 50 WDG and is currently registered on ornamentals for insects in commercial and residential landscapes. We applied Arena 50 WDG to 30 trees at each of three locations (90 trees total). At two locations, we worked with Douglas-fir trees (7–8 feet tall; 1.5 to 1.75 inches in diameter) infested with Douglas-fir needle midge. At the third location, we had Black Hills spruce trees (5–7 ft. tall; 1.25 inches in diameter) infested with spruce gall midge. We selected 60 trees in each of two Douglas-fir fields that had midge damage in 2010. Trees were randomly assigned to be treated with the insecticide or to remain as untreated controls. We identified Control 1 trees that had needles damaged in 2010 and also selected Control 2 trees with no 2010 damage.

Prior to treatment we needed to determine how much water would be needed to adequately coat the trunk from ground level to 3 foot. We measured 64 ounces of water into a backpack sprayer and applied the water to 10 trees. The amount of water used was measured to determine the amount needed per tree. We did this three times and determined it would take 3.5 ounces of water per tree. Trunk drench applications were made with a Solo hand sprayer at the rate of 4.8 grams of Arena per diameter inch of the tree (measured 3 feet above-ground).

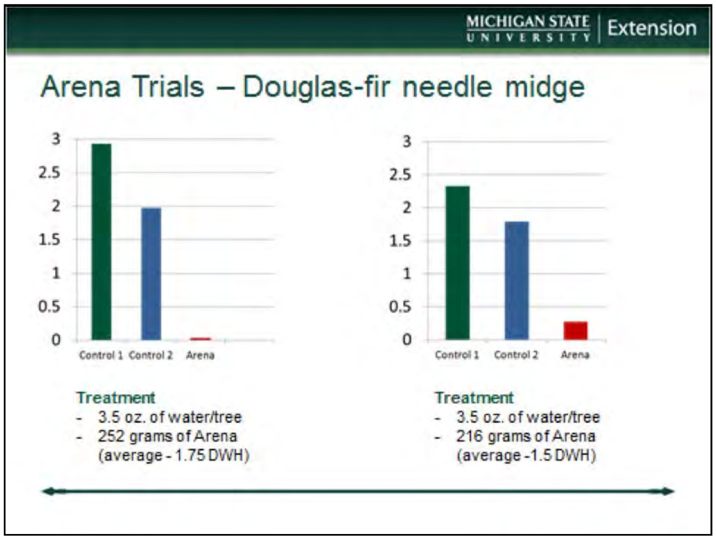
Trees were evaluated in fall 2011 to assess damage to the foliage. Each tree was visually examined and rated based on the degree of damage (Figure 3).

Needle damage rating

0	None
1	Slight damage (trees remained salable)
2	Moderate
3	Heavy (trees could not be sold)

Figure 3. Needle damage rating scale.

Arena effectively controlled Douglas-fir needle midge. This product provided nearly complete midge control in Field 1 (Figure 4) and reduced midge damage by 83–87 percent in Field 2. We also decided to establish two control treatments;



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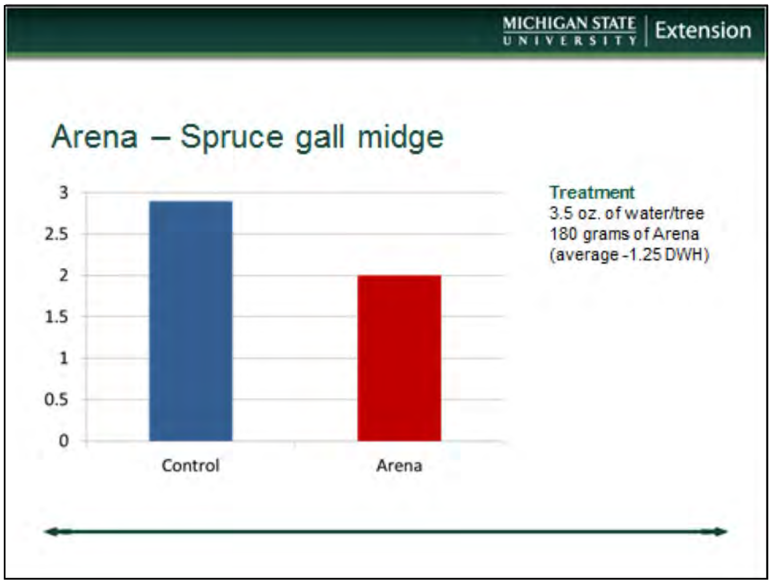
Arena Trials – Douglas-fir needle midge

Treatment
- 3.5 oz. of water/tree
- 252 grams of Arena (average - 1.75 DWH)

Treatment
- 3.5 oz. of water/tree
- 216 grams of Arena (average -1.5 DWH)

Figure 4. Results of Arena trials on Douglas-fir infested with Douglas-fir needle midge.

In the spruce gall midge trials, the Arena trunk spray was less effective. Trees treated with Arena had approximately 30 percent fewer shoots with midge damage than untreated controls (Figure 5), but numerous shoots had evidence of larvae. It's possible that we did not see the same results as with Douglas-fir needle midge because the spruce bark is scalier and rougher. We may need to increase the amount of water per tree or possibly use a higher rate of material to penetrate the bark. Another possibility is that the vascular system of spruce moves the insecticide differently to the needles.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Arena – Spruce gall midge

Treatment
3.5 oz. of water/tree
180 grams of Arena
(average -1.25 DWH)

Figure 5. Results of Arena trials on Black Hills spruce infested with spruce gall midge.

Summary

Monitoring growing degree days has been a useful tool to track the development of many insect pests in Christmas trees. Growers now have a range of growing degree days for Douglas-fir needle midge and spruce gall midge that should help them better determine when the adult midge is emerging. Yellow sticky traps can be used to effectively scout for Douglas-fir needle midge and spruce gall midge. A systemic neonicotinoid (Arena) was highly effective in controlling Douglas-fir needle midge, but provided relatively little control of spruce gall midge.

Literature cited

Carleo, J. The Douglas-fir needle midge. In Plant and pest advisory landscape: Nursery and turf edition. Rutgers Cooperative Research and Extension at the New Jersey Agricultural Experiment Station. http://njaes.rutgers.edu/pubs/plantandpestadvisory/2005/ln0728.pdf

DeAngelis, J.D. 1994. Biology and control of Douglas-fir needle midge in Christmas trees. Oregon State University Extension Service. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/19004/ec1373-e.pdf

Lehman, R.D. 2002. Pest alert: Douglas-fir needle midge. Pennsylvania State University and Pennsylvania Department of Agriculture. http://ento.psu.edu/extension/christmas-trees/information/pest-alerts/pest-alert-douglas-fir-needle-midge

Integrated pest management for Christmas tree production. Dec. 2010. pp. 37–38. http://pubs.cas.psu.edu/FreePubs/pdfs/agrs117.pdf

Damage to Christmas trees by larvae of *Melolontha melolontha* L. and control methods

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Introduction

Our firm has grown Christmas trees since 1988. The trees are grown on sandy soils in the eastern part of The Netherlands. The soil is partly loamy and moist (near a small stream), partly higher sand content with a thick humus-rich layer of 40–80 cm. Primary species grown are *Picea omorika* and *Picea abies*, but also *Picea pungens glauca*, *Abies nordmanniana*, *Abies nobilis, Abies koreana,* and *Abies fraseri.*

The plantations are generally established with 3-year-old seedlings of *Picea* species and 4- or 5-year-old seedlings of *Abies* species, raised by tree nurseries. The planting distance is about 1 x 1 meter. The soil is plowed before establishment. Planting is done mechanically. Weeds are usually controlled chemically.

Since 1992, larvae of *Melolontha melolontha* have been damaging Christmas tree plantations; first young trees died spotwise, after the larvae had consumed the fine roots and the bark of thicker roots. During the period 1992–2008, the percentage of damaged and dead trees increased, but we could live with it. In 2008–2009, the population of *M. melolontha* reached such a density that an entire parcel of trees of 1–1.5 m died.

This paper describes differences between the vulnerability of different Christmas tree species, the development of number of adult insects and larvae in 2010 and 2011, and difficulties associated with finding an effective control method.

Damage in 2009 and vulnerability of Christmas tree species

Table 1 shows the total numbers of trees per tree species and the percentage of damaged trees in a single parcel that was established in 2004. These numbers show that *Picea omorika* is very vulnerable to damage of Melolontha larvae. Height of these trees was 1–1.75 m. The larvae like the roots of *Picea omorika*, which are fine and numerous. They seem to have a lower preference for *Picea abies* and *Picea pungens* roots, which are much thicker and less numerous.

All *Abies* species suffered from the root-eating larvae, but *Abies fraseri* showed the greatest damage.

Table 1. Percentage of dead trees per tree species.

Tree species	Number of trees	Percentage dead or heavily damaged trees
Picea omorika	4,000	80
Picea abies	200	30
Picea pungens glauca	100	30
Abies koreana	200	50
Abies fraseri	200	70
Abies nordmanniana	50	40
Abies nobilis	50	40
Total	4,800	75

Adults in 2010 and larvae in 2011

To get insight into population density, adult insects were counted daily in the spring of 2010 and 2011. They were caught by a bright light (150 W), which was constructed on a vat with a thin layer of water. Insects were attracted by the light (which was turned on for 4 hours beginning at 21:00 hours), fell into the vat, and drowned.

Figures 1 and 2 show the numbers of adult insects caught in 2010 and 2011. The daily maximum and minimum temperatures recorded by a weather station within a distance of 10 km are also shown.

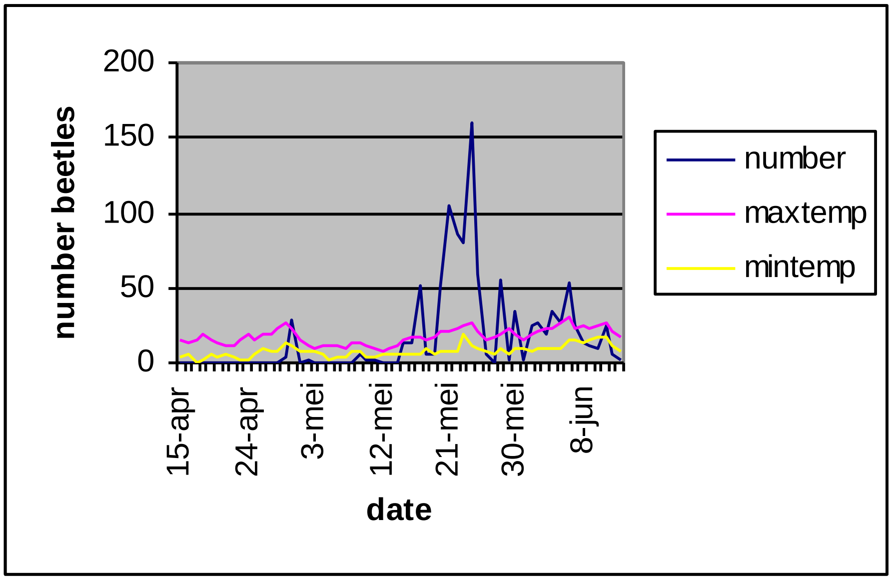

Figure 1. Number of trapped adults of *M. melolontha* in spring 2010.

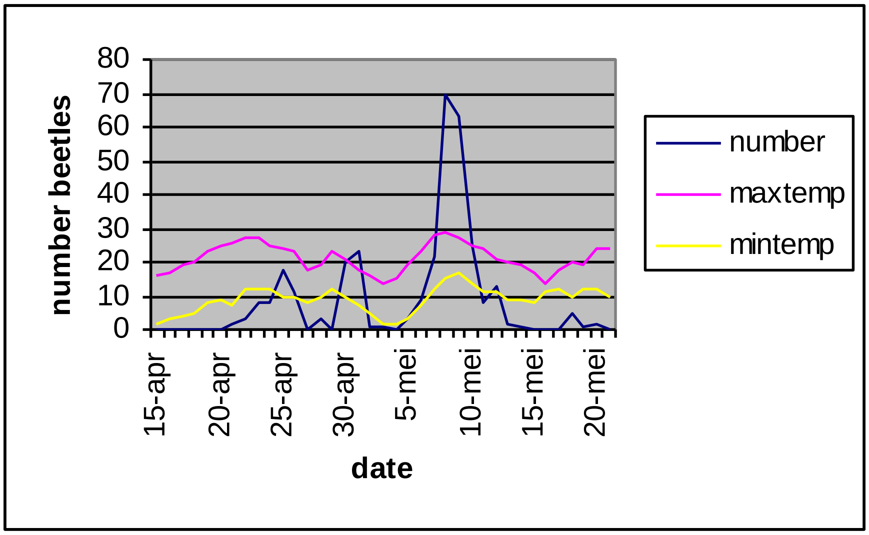

Figure 2. Number of trapped adults of *M. melolontha* in spring 2011.

In Figures 1 and 2, we can see that:

- The number of adults in 2010 was double the number in 2011.
- In 2010, the flight was very late. (Normally the peak of the flight is between 5 and 15 May, as in 2011.)
- The intense peak flight appears when the minimum temperature is above 10°C and the maximum temperature is above 20°C. According to Švestka (2010), peak swarming occurs when the mean temperature reaches 15°C.

In the summer of 2011 (end of June), 10 plots of 1 m^2 in a small meadow next to the Christmas tree plantations were investigated for the presence of larvae *of M. melolontha*. Table 2 gives the results.

Table 2. Number of larvae per square meter.

	Number per m^2 (10 plots)
L1	0
L2	70 (sd 3.4)
L3	2
Total	72

The results show a very high density of larvae—on average 72 larvae per square meter. Almost all of these larvae were L2 instars.

By the end of July, this density resulted in complete destruction of grass vegetation. Striking was the fact that the plant species *Ranunculus repens* and *Achillea millefolium* were almost not affected.

Control methods

In this section, the most relevant control methods are described and discussed in the context of our own experience and the Dutch situation.

Crop rotation

Until 2004, crop rotation with maize gave good results. But in that year it appeared that even in “clean” soil (after 20 years planted to maize) a new generation of beetles can deposit such a mass of eggs that the plantation is completely destroyed within 3 to 4 years.

Mechanical

Soil cultivation can disturb grubs in the topsoil. However, since the soil can be cultivated only between the rows, this method cannot be applied successfully in Christmas tree plantations.

Protection of the plantation by netting, which can prevent egg-laying by beetles, is difficult and expensive.

One solution might be to irrigate the field during the period of egg-laying. Mann (2004), on the contrary, advises keeping the soil dry.

Chemical

Use of chemicals to control *Melolontha melolontha* is not permitted in The Netherlands.

Biological

Animals

Moles (*Talpa europea*) and birds (e.g., crows, gulls, and starlings) are natural enemies, but seem to be unable to control dense populations of larvae of *Melolontha melolontha*.

Chickens like larvae of *Melolontha melolontha*. The practical problem in tree plantations is that serious tree damage has already occurred by the time the larvae can be caught by the chickens.

Nematodes

Treatment with nematodes of *Steinernema glaseri* and *Heterorhabditis bacteriophora* can reduce grub populations by 65 percent (Berner and Schnetter, 2002). However, it does not control L3 larvae. Success of nematode treatment is very susceptible to weather circumstances (temperature and moisture of the soil), and the costs are relatively high.

Fungi

A product based on the fungus *Beauveria brongniartii*, inoculated on barley kernels, exists. Applied to the soil, it can kill all development stages of the larvae, but results also depend on factors such as temperature and humidity. Its use is not permitted in The Netherlands.
It is already in use for control of *Melolontha* spp. in meadows and orchards in other European countries.

At a symposium in Germany in April 2011, biological methods appeared to be preferred, even in situations of heavy damage, but presentations made clear that the applicability depends also on the form of land use. Fields with trees have less possibilities than open fields (Bräsicke, 2011; Nordwestdeutsche Forstliche Versuchsanstalt und Julius-Kühn-Institut, 2011).

Root fungi can also play a role in protection against enemies (van Tol et al., 2001). Whether this mechanism can provide effective control has yet to be investigated.

Garlic-based products

Garlic-based products drive the grubs away temporarily, but do not eliminate the problem.

Selective weed control

Adults and larvae seem to have a preference for certain plant species, especially for *Taraxacum officinalis* and *Daucus carota* (Elberse et al., 2010). Beetles are capable of selecting these weeds in the field for egg deposition. Schutte (1996) even thinks that the dense cover of *Taraxacum* in meadows and pastures has favored the occurrence of *Melolontha*. Thus, it may be possible to use these plant species to attract beetles and larvae and pull them away from the trees.

Research has also shown that some other plant species have repellent effects, for example *Tanacetum vulgare* (van Tol et al., 2011). Whether this can be used as a practical method has to be further tested.

Pheromones

According to Griepink (Huiting et al., 2006), adult insects can be attracted with traps containing pheromones plus kairomones, but trapping is suitable only for monitoring.

Light

Light traps work better than pheromone traps (Huiting et al., 2006). However, it would be very difficult to reduce the population significantly by use of light traps.

Discussion

Most biological methods are focused on control of the larvae. In most cases, however, the larvae have already had their negative effects. Thus, it would be much more effective to search for a method of controlling the adult insects, preventing them from producing or depositing eggs.

An important question is why *Melolontha* populations grew so massively since 1990. Has population growth been caused by the warmer climate? Other possibilities are lower groundwater levels (Bräsicke, 2011) or the increase of certain plant species such as *Taraxacum* spp. (Schutte, 1996) and *Quercus rubra* (Bräsicke, 2011).

The most important question is when and how the large populations of *Melolontha* spp. will collapse and disappear. Will collapse occur soon, repeating a cycle of about 50 years? (The problem also faded away in 1910 and 1960.) Will collapse occur by a natural cause? According to Vlug (2010), the cause could be the *Tipulid iridescens* virus, which can be found in blue-purple colored *Tipula* spp. Larvae of *M. melolontha* with the same blue-purple color have been found.

Conclusions

- Larvae of *Melolontha melolontha* L. can damage Christmas tree plantations very severely.
- Most Christmas tree species grown in The Netherlands *(Picea abies, P. omorika, P. pungens glauca, Abies nordmanniana, A. fraseri,* and *A. koreana*) are susceptible.
- *Picea abies* and *Picea pungens glauca* seem to be less susceptible.
- Crop rotation with maize can reduce the risk of larvae damage, but cannot avoid a heavy attack when *M. melolontha* deposits its eggs the first year(s) after establishment of the plantation.

- Several mechanical and biological methods have proved to reduce the number of larvae, but for the Dutch situation there is no effective method for control of larvae in Christmas tree plantations.

References

Berner, M. and W. Schnetter. 2002. Field trials with the entomopathogenic nematode *Heterorhabditis bacteriophora* against grubs of the European cockchafer (*Melolontha melolontha*) in the southern part of Germany. IOBC/wprs bulletin, 25(7):29–34.

Bräsicke, N. 2011. Maikäfer-Symposium. Aktuelle Situation, Bekämpfungsmöglichkeiten and Perspektiven in Umgang mit Feld-ind Waldmaikäfer. Bericht zum Maikäfer-Symposium-12.bis 14. April 2011. Julius Kühn-Institut, Institut für Gartenbau und Forst. 4 pp.

Eilenberg, J. 2006. An ecological and societal approach to biological control. Progress in Biological Control, 2006, Volume 2, 247–255, DOI: 10.1007/978-1-4020-4401-4_12

Elberse, Y., A. Smits, R. van Tol, and H. Vlug. 2010. Control of grubs of cockchafer (in Dutch). Handout Praktijkonderzoek Plant &Omgeving, Wageningen UR.

Huiting, H.F., L.G. Moraal, F.C. Griepink and A. Ester. 2006. Biology, control and luring of the cockchafer, *Melolontha melolontha*, current control possibilities and pheromones. Applied Plant Research Unit AGV PPO no. 32 500475 00–I.

Mann, R.L. 2004. A review of the main turfgrass pests in Europe and their best management practices at present. Journal of turfgrass and sports surface science 80:2–18.

Nordwestdeutsche Forstliche Versuchsanstalt und Julius-Kühn-Institut 2011. Rückblick auf das Maikäfer–Symposium. Aktuelle Situation, Bekämpfungsmöglichkeiten und Perspektiven im Umgang mit Feld- und Waldmaikäfern

Ruther, J., A. Reinecke, K. Thiemann, T. Tolasch, W. Francke, and M. Hilker. 2000. Mate finding in the forest cockchafer, *Melolontha hippocastani*, mediated by volatiles from plants and females. Physiological Entomology 25:172–179. doi: 10.1046/j.1365-3032.2000.00183.x

Schutte, F. 1996. On the occurrence of the cockchafer (*Melolontha melolontha* (L.) dependent on the presence of dandelion (*Taraxacum officinale* Wiggers). Bulletin-OILB/SROP 19(2):27–33.

Švestka, M. 2010. Changes in the abundance of *Melolontha hippocastani* Fabr. and *Melolontha melolontha* (L.) (Coleoptera: Scarabeidae) in the Czech Republic in the period 2003–2009. Journal of Forest Science 56(9):417–428.

Tol, R. van, A.T.C. van der Sommen, M.I.C. Boff, J. van Bezooijen, M.W. Sabelis, and P.H. Smits. 2001. Plants protect their roots by alerting the enemies of grubs. Ecology Letters (2001) 4:292–294.

Tol, R.W.H.M. van, G.L. Wiegers, and W.J. de Kogel. 2011. Herbs attract and repulse white grubs also in practice (in Dutch). Kruiden lokken en weren engerlingen ook in de praktijk. Thema: Innovaties duurzame gewasbescherming BO-12.03-003.02-010.

Vlug, H. 2010. The white grub year 2010 (in Dutch). Het engerlingenjaar 2010. Greenkeeper, p. 20–21.

Weed control practices in the northeastern United States

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I have been involved in research on Christmas tree weed control for almost 50 years and have visited many farms in this region. These comments are based largely on my experience and observations. It is said that on any given site, at least 100 weed species can be competitive or otherwise detrimental to tree growth or quality. These species vary, depending on crop culture.

Growers of Christmas trees in the northeastern United States are fortunate to have a number of tools to control weeds in their plantations. Tables 1 and 2 list the products that are most commonly used. Pesticide labels must be approved by the U.S. Environmental Protection Agency (EPA) and, thereafter, by each state. Federal approvals are based on data submitted to the EPA by the manufacturers, using information from their own tests, by researchers at state and federal institutions, and, since about 1976, by IR-4. IR-4 is an inter-regional committee funded by the U.S. Department of Agriculture, state experiment stations, and industry to secure registrations of pesticides for minor-use crops and minor uses.

Currently, the components of most of the approved herbicides for Christmas trees have been labeled and approved by the EPA and the U.S. Food and Drug Administration (FDA) for use on some food crops. Since Christmas trees are not consumed by humans, however, the concerns of the EPA are largely based on safety to the crop and on environmental concerns.

Table 1. Preemergence herbicides for plantations in the northeastern U.S.

Chemical name	Trade name(s)	Weeds controlled
simazine	Princep, Sim-Trol, Simazine	annual broadleaves, short-term control of annual grasses
atrazine	Aatrex, Atrazine	annual broadleaves, quackgrass
oryzalin	Surflan, Oryzalin	primarily annual grasses
pendimethalin	Pendulum, Hurdle	annual grasses, some broadleaves
flumioxazin	SureGuard	annual weeds, broad-spectrum
S-metolachlor	Pennant Magnum	annual grasses, nutsedge
sulfometuron + hexazinone	Westar	broad-spectrum, most annuals, some perennials

Table 2. Postemergence herbicides for plantations in the northeastern U.S.*

Chemical name	Trade name(s)	Weeds controlled
glyphosate, isopropyl amine salt	Roundup Original, Glyfos, Glystar, Credit, etc.	most weeds and brush
triclopyr amine	Garlon 3A	broadleaves, brush
oxyfluorfen	Goal 2XL, Galigan 2E, Goal Tender 4F	certain broadleaves
clethodim	Envoy	grasses, including annual bluegrass
sethoxydim	Segment	grasses only
fluazifop-butyl	Fusilade	grasses only
clopyralid	Stinger	pea, aster, and smartweed families

*Oxyfluorfen, sulfometuron, hexazinone, and atrazine have both pre- and postemergence activity on certain weeds.

Products and techniques used by growers

Christmas tree growers in the northeastern United States are a diverse group and, as might be expected, their weed control programs are diverse also. Some growers, usually on small farms, use no herbicides and rely primarily on mowing to control weeds. Another technique used by smaller growers is to use herbicides very sparingly, by spot treating around individual trees with backpacks, applying noncalibrated sprays, or using wick wipers.

Glyphosate is widely used by this group because it controls a broad spectrum of weeds. Typically, glyphosate is applied as a directed spray to avoid conifer injury. Simazine, which has been available for more than 50 years and is inexpensive, also is widely used by these growers.

Although we and others have found that glyphosate is tolerated by true firs in the early fall or in early spring before budbreak, many growers prefer not to spray “over the top” with glyphosate. One of the reasons for grower resistance to “over-the-top” spraying with glyphosate, even during the dormant season, is that the old Roundup Original is no longer produced by Monsanto Chemical Company due to a loss of patents. Roundup Original was an isopropyl amine salt of glyphosate found to be safe on true firs and spruces in fall or spring at rates of 1 to 2 qt/acre (2.34 to 4.68 L/ha). Currently there are more than 40 formulations of glyphosate on the U.S. market, and only a few of them are equivalent to Roundup Original. Differences in type of surfactant, level of surfactant, and type of formulation (potassium vs. isopropyl amine salt) affect conifer tolerance to glyphosate.

Growers on larger Christmas tree farms mostly realize the importance of controlling weeds to shorten rotations and to achieve high tree quality. However, no single program is used by all growers. Efficacy, safety to conifers, and often economics are large concerns. Growers who calibrate their tractor-mounted or backpack sprayers may still apply what we call semi-directed sprays, where only the basal foliage of the Christmas trees is contacted. Off-center nozzle tips are frequently used and, when the sprayer is held too low, a strip of weeds remains untreated in the middle of the tree row where weed control is most needed. Good spray techniques are, therefore, quite important.

Most Christmas tree growers in the northeastern U.S. treat l8- to 36-inch (46- to 91-cm) herbicide bands over the tree rows and leave about half or more of the area between rows untreated. Native plants (including common weeds) or seeded hard or other fescues are grown between rows and are mowed three or more times during the season. Band treatment greatly reduces the amount of herbicide required, cools the soil, and greatly reduces the soil erosion potential. Broadcast treatment of herbicide is mostly used on flatter plantations where the potential for soil erosion is small.

Typical applications by larger growers usually involve preemergence herbicide(s) in the spring followed by glyphosate or triclopyr in September to control perennial weeds and brush. The spring treatments usually are combinations of herbicides to control the broad spectrum of annual weeds. Recently, SureGuard (flumioxazin) and Westar (sulfometuron + hexazinone) have been found to control a broad weed spectrum and are often used alone. If weeds are present in the spring, glyphosate is added to the mix, at 1 pt to 1 qt/acre (1.17 to 2.34 L/ha). Depending on the weed population, summer applications of clopyralid, oxyfluorfen, postemergence grass herbicides, or mixtures may be made. Frequent summer invaders include perennial vetch (*Vicia cracca*), common ragweed (*Ambrosia artemisiifolia*), and large crabgrass (*Digitaria sanguinalis*), but other annual grasses and broadleaf weeds also are common in summer.

One very selective method of applying glyphosate in plantations is with a wick wiper. Glyphosate formulations, diluted 1 part to 2 to 4 parts water, are wiped onto weeds. I know of one large grower who uses this technique because little applicator training is required. However, this method is time-consuming, and since glyphosate has no residual activity, it must be reapplied two or more times a season. Spot spraying of glyphosate (Roundup) at 1⅓ to 2 fluid oz/gallon (10.6 ml/L to 16 ml/L) is much faster, but requires more applicator care to avoid conifer injury. However, this method is used by most growers of a few thousand trees.

Importance of calibration

In our educational efforts with growers, we continually emphasize calibration of equipment, both tractor mounted and backpack. We published a method of equipping and calibrating backpack sprayers after researching this topic many years ago, so many growers in the northeastern U.S. and parts of Canada use this method. However, some managers of large Christmas tree farms prefer to use air blast sprayers (mist blowers) to apply herbicides because it is much faster. We discourage this practice because uniformity is more difficult to achieve. However, growers who successfully use this method determine the area covered by a given volume of water and put the required amount of herbicide for that area into the tank and spray their fields that way. They realize that the closest trees get an increased amount of herbicide and sometimes are injured, but the time saved in application by using this method compensates for the injured trees.

Weed suppression techniques

There seems to be increasing interest among growers in weed suppression rather than weed kill, largely because of the North Carolina experience with Fraser fir. Two systems have worked fairly well in the northeastern U.S. The first is similar to that used in North Carolina; low rates of glyphosate [8 to 12 fluid oz/acre (0.56 to 1.12 L/ha)] are broadcast three or four times a season. The second involves using low rates of a mixture of glyphosate, oxyfluorfen, and clopyralid—a method used by certain growers in Michigan. The dosages are glyphosate [Roundup Original at 4 fluid oz/acre (0.3 L/ha)] plus oxyfluorfen [Goal 2XL at 16 fluid oz/acre (1.2 L/ha)] or oxyfluorfen [Goal 4F at 8 fluid oz/acre (0.56 L/ha)] plus clopyralid [Stinger at 4 fluid oz/acre (0.3 L/ha)]. This mixture kills most annual weeds, suppresses perennial grasses, and is safely sprayed over conifers in June or later. It has advantages over glyphosate alone in that it controls legumes and a broader spectrum of annual weeds. The oxyfluorfen component also provides a month or more of residual control. Double rate applications have not injured conifers in our work. In the northeastern U.S., we suggest this approach for steep slopes where soil erosion can be a problem and for rocky fields that cannot be easily mowed.

References

Ahrens, J. 1979. Broadcast sprayer attachment simplifies application on confined areas. American Nurseryman, June 15, 1979.

Ahrens, J. and K. Bennett. 2011. 2011 New England guide to chemical weed and brush control in Christmas trees. http://extension.unh.edu/resources/files/Resource000845_Rep2560.pdf

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Early-rotation nonchemical weed management in *Abies nordmanniana* Christmas trees

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An increased level of interest in “Certified Organic” food and ornamental plants creates a market opportunity for Christmas tree growers. There are obvious challenges, however, to producing a quality tree without the use of chemicals. The susceptibility of common Christmas tree species to root, stem, and needle pathogens; insects; and mites; as well as early-rotation pressure from weed growth necessitate the development of alternate pest management options. Research trials have shown Nordmann fir (*Abies nordmanniana*) to be much less susceptible to damage from some common Pacific Northwest disease and pest problems than other true firs, potentially avoiding a need for pesticide applications to manage these pests. Nonetheless, even with the choice of a less insect/mite/disease-susceptible species such as Nordmann fir, nonchemical weed management remains a significant challenge early in the rotation.

Two recent studies in Michigan have focused on using a combination of integrated weed management strategies in Christmas tree production. Marshall et al. (2007) found that a living mulch such as hard fescue (*Festuca brevipila* ‘Aurora Gold’) or white clover (*Trifolium repens*) can reduce herbicide use in Christmas tree plantations by inhibiting the germination and growth of weed species. Cregg et al. (2009) also showed that mulches, including wood chip, plastic, and VisPore mats, enhanced early-rotation seedling growth and survival by suppressing the growth of competing vegetation, conserving soil moisture, and moderating soil temperature.

A trial was established at Washington State University’s Puyallup Research and Extension Center in the fall of 2009 to evaluate the effectiveness of different ground cover treatments in reducing weed growth. This WSU trial builds on information gathered in previous weed management studies and applies it to a Pacific Northwest Nordmann fir Christmas tree planting to gather data on effectiveness of weed suppression and effects on the growth of trees during the critical first growing season.

Methods

The following eight weed-management treatments were tested:

- No weed control
- Manual weeding
- Woven ground cover (DeWitt 3.2 oz. polypropylene)
- 2" of aged wood mulch (biofilter waste material)
- *Festuca trachyphylla* ‘Aurora Gold’ hard fescue sown at 80 lb/acre
- *Trifolium repens*, white clover, sown at 32 lb/acre
- 2" of compost + 2" of aged wood mulch (biofilter waste material)
- 2" of compost

Establishment of the 0.74-acre (0.3-hectare) study plot began in September 2009 with the planting of the fescue and clover living mulch treatments. These species were seeded in their designated treatment rows, and hard fescue was also sown in 3-foot-wide alleys between all treatment rows. The study plot was then irrigated regularly for several weeks. The treatment areas with no living mulch were lightly cultivated 1 month later in October, and the woven ground cover was put in place on treatment 3.

Nordmann fir seedlings (2+3 Vallo #18) were planted over a 2-week period in early February 2010 on a 6 ft x 6 ft spacing. The compost and/or mulch was applied to treatments 4, 7, and 8 in May 2010. Treatment 2 was hand weeded in April, June, and August of 2010.

The plot was a randomized complete block design with five blocks containing each of the eight treatments. Treatment areas consisted of a 3-foot-wide strip in which rows of seedlings were planted, and a 3-foot-wide fescue alley between all rows regardless of treatment. Each treatment had five “data” trees surrounded by a row of 16 border trees of the same treatment. The plot was not irrigated during the growing season.

Data collected

Weed species/density ratings (percent of ground cover) were collected in November 2010. The effect of treatments on the percent increase in seedling height and caliper was obtained from measurements collected in April 2010 and November 2010. A rating of seedling health was collected in May of 2011 using the following scale:

0 = dead seedling
1 = poor growth and color, some dead branches
2 = poor growth and color
3 = fair growth and color
4 = good growth and color

Results

The primary weed species that developed in this plot varied by treatment (Table 1). The most effective treatments in reducing weed establishment were the woven ground cover, white clover, fescue, and wood chip mulch (Table 1).

Table 1. Percentage of ground covered by weeds.

	Treatment	Mean[1]	Primary weed species	Secondary weed species
8	Compost	87 a	*Festuca* sp., *Stellaria media*	*Capsella bursa-pastoris, Solanum* sp.
1	No weed control	76 abc	*Festuca* sp.	*Taraxacum officinale, Capsella bursa-pastoris, Crucifer* sp.
7	Compost + wood chip mulch	61 abc	*Crucifer* sp., *Stellaria media, Taraxacum officinale*	*Vicia* sp.
2	Hand weeding	44 bcd	*Stellaria media, Capsella bursa-pastoris*	*Taraxacum officinale*
4	Wood chip mulch	33 cde	*Festuca* sp.,*Stellaria media*	*Taraxacum officinale, Vicia* sp.
5	'Aurora Gold' fescue	20 de	*Capsella bursa-pastoris*	*Taraxacum officinale*
6	White clover	1 e	*Panicum dichotomiflorum*	
3	Woven ground cover	1 e		

[1]Means followed by the same letter are not significantly different (p=0.05), Tukey's Studentized Range (HSD) test.

The seedlings growing in the woven ground cover, compost, compost plus wood chip mulch, hand-weeded, and wood chip mulch treatments had the highest health ratings (Figure 1). 'Aurora Gold' hard fescue was clearly a detriment to Nordmann fir seedlings where the two were interplanted (Figure 1). Unmanaged weed growth would be preferable to having tree seedlings interplanted with this grass species.

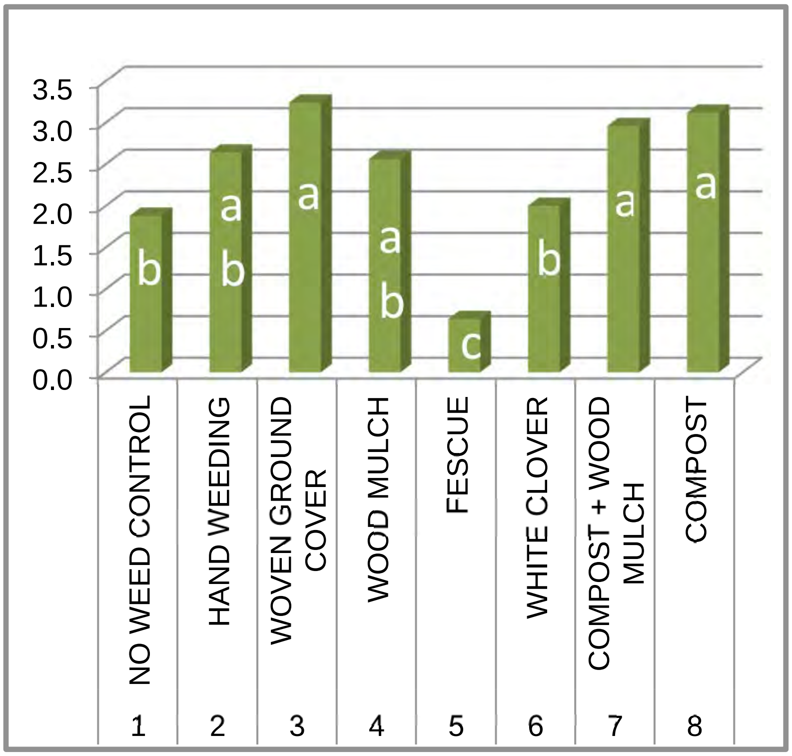

Figure 1. Seedling health ratings (0 = dead seedling, 4 = good growth and color). Means with the same letter are not significantly different (p=0.05), Tukey's Studentized Range (HSD) test.

The fact that the seedlings in the fescue plot exhibited moderate levels of growth (Figure 2) and the limited precipitation that occurred during July (0.5 inch) and August (0.4 inch) suggest that the poor seedling health may have been due to competition for moisture during the later part of the growing season.

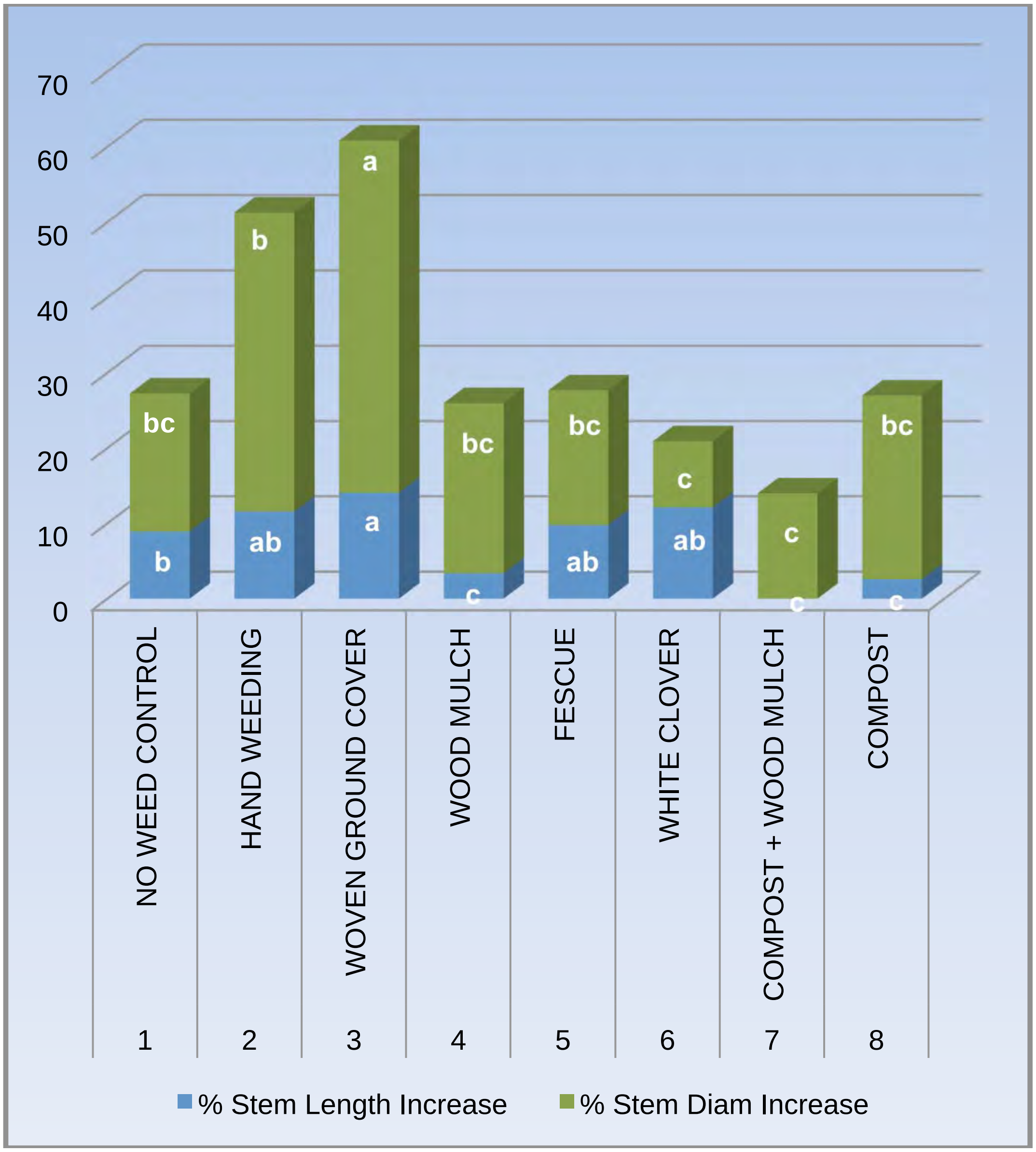

Figure 2. Increase in stem length and diameter in 2010 growing season (percentage). Means with the same letter are not significantly different (p=0.05), Tukey's Studentized Range (HSD) test.

Treatment cost is influenced by choice of material, application and maintenance labor and equipment cost, and the duration of effective weed control. Table 2 shows the approximate material cost of the treatments used in the trial. Within the 6-foot space between rows of trees, a 3-foot-wide strip of fescue was planted in all treatments, so the material cost estimates cover only the remaining half-acre not covered by fescue.

Table 2. Material cost of treatments used in trial.

	Treatment	Cost per acre
3	Woven ground cover	$1,500
4	2" aged wood mulch	$1,340
5	‘Aurora Gold’ hard fescue (80 lb/acre)	$173
6	White clover (32 lb/acre)	$76
7	2" compost + 2" aged wood mulch	$4,556
8	2" compost	$3,216

The aged wood mulch was used in place of bark mulch because of cost and availability. Although well proven to be highly effective in suppressing weeds and enhancing plant growth, bark mulch can be very expensive (as high as $20 to $30 per yard) because of demand from the landscaping market. The aged wood chips used in this study, a waste product of the local county composting facility, can be obtained at less than half the cost of bark mulch.

Summary

The woven ground cover treatment, though very expensive at an approximate material cost of $1.30 per tree, produced the healthiest seedlings, fewest weeds, and most height and caliper growth at the end of the first season. Additional data on seedling performance will be collected after the 2011 growing season.

References

Cregg, B., R. Goldy, and P. Nzokuo. 2009. Growth and physiology of newly planted Fraser fir (*Abies fraseri*) and Colorado blue spruce (*Picea pungens*) in response to mulch. HortScience 44(3):660–665.

Chastagner, G., A. Antonelli, K. Riley, J. Stark, and P. Kaufmann. 2003. Susceptibility of various true firs to insect pests in the Pacific Northwest. Program and abstract book, Sixth International Christmas Tree Research and Extension Conference, Hendersonville, NC, September 14–19, 2003.

Marshall, M.W., B.H. Zandstra, and R.J. Richardson. 2007. Comparison of integrated weed management strategies in Christmas tree plantations. Proceedings of the annual meeting—Eastern Weed Science Society 61:7.

Stark, J.D., A. Antonelli, and G. Chastagner. 2004. Arthropod pest management in Christmas trees in the Pacific Northwest. XXII International Congress of Entomology, Brisbane, Australia, August 15–21, 2004.

Newly registered grass herbicides for use in Christmas trees in Denmark

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Introduction

In Denmark, as well as in most other EU (European Union) countries, there is increased concern for the environmental effects caused by chemical weed control. All of the traditional soil herbicides—atrazine, cyanazine, diurone, hexazinone, simazine, and terbuthylazine—have been banned in all of the EU during the past 10 years.

During the past 10 years, therefore, several new herbicides have been tested in Denmark for use in Christmas trees. Most of the newly tested herbicides are sulfunylureas, and some of them have now been registered via an off-label registration for use in Nordmann fir (*Abies nordmanniana*). Most of the sulfunylureas have a short weed control period, so experiments have also been carried out with other soil herbicides such as diflufenican.

In recent years, there has also been a lot of work with graminicides (grass-controlling herbicides). Many have been tested, and a few have proven to be very successful. However, it was found that, after a change in formulation, the widely used herbicide fluazifop-P-butyl (Fusilade MAX) could give very severe discoloration. The change from Fusilade X-TRA to Fusilade MAX might produce lemon yellow trees (see Figure 1).

Figure 1. Nordmann fir sprayed with Fusilade MAX, July 1, 2010. During autumn 2010, some of the trees developed significant discoloration.

Cycloxidim (Focus Ultra)

Cycloxidim has demonstrated very good control, even on a variety of hard-to-kill grass species (Figures 2 and 3). This herbicide has proven very gentle to several tree species—both coniferous and broadleaf species. Until now, cycloxidim has had an off-label registration in Denmark for Nordmann and noble fir and also for beech and oak for forestry use.

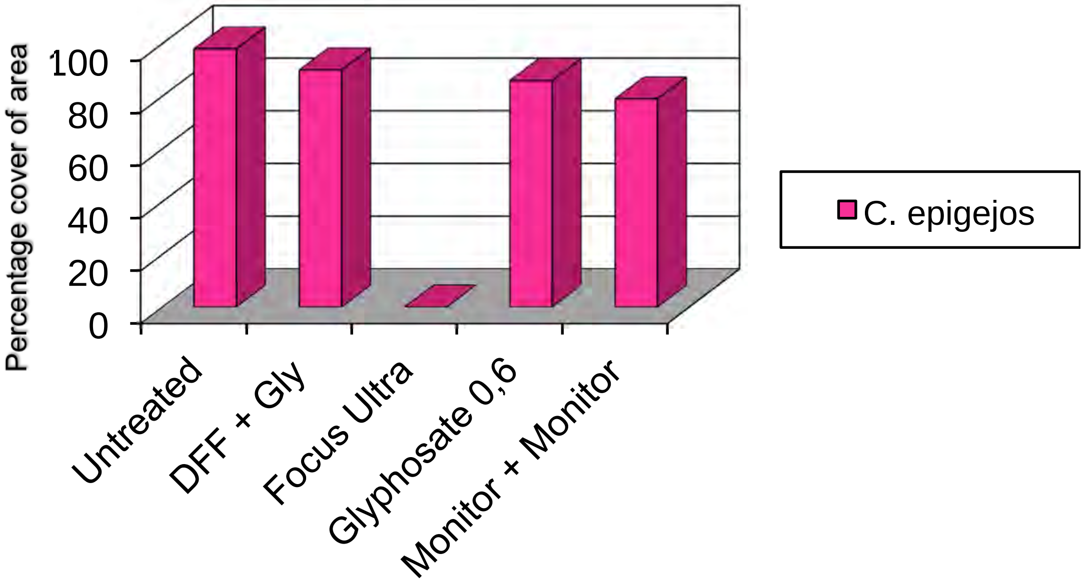

Figure 2. Vegetation control of *Calamagrostis epigejos*, 2010, comparing cycloxidim (Focus Ultra) and other herbicides.

Figure 3. Cockspur (*Echinochloa crus-galli*) totally controlled by cycloxidim applied July 7, 2010. Photo Sept. 1, 2010

During 2011, experimental work continued. It is expected that these trials will give further knowledge about the optimal dose and time of application for controlling individual grass species. It is also expected that other graminicides—for example propaquizafop (Agil)—will be registered for Christmas trees within the next year.

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Public relations for Christmas trees: Does professional PR make a difference?

Evaluation of the PR of the Christmas Tree Grower's Association from Lower Austria

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Introduction and research questions

Small and medium-size enterprises (SMEs) often lack the resources for continuous public relations (PR) activities. In their reality, PR messages are sent out on an irregular basis without any underlying strategic communication concept. Public relations agencies are addressing this situation by offering their professional services to relieve the "communication burden" from SME managers.

The public relations of the Association of Christmas Tree Growers from Lower Austria can be characterized by three periods, each with a differing level of PR intensity. Each period lasted 3 years. In the first 3 years (1994–1996), one press release (in the form of a press-kit) was sent out through an employee without any special knowledge in public relations. In the second period (2003–2005), the press kit was set up more professionally, and additional press releases were sent out during 1 year. In the third period (2006–2008), the public relations work was outsourced to a professional public relations agency. Due to this unique situation of three distinct periods of PR intensity, a study to evaluate the outcomes of the PR work was initiated.

The following research questions are guiding the evaluation:

- How did media coverage of Lower Austria Christmas Tree growers change over time?
- Quantitatively: How did the numbers of published articles change?
- Qualitatively: Did the message content of the articles change and, if so, how?

Theoretical background and methodology

Awareness, image improvement, increased sales—there are as many aims of communication as there are ways to communicate for companies, NGOs, or NPOs. The main communication tools for companies are advertising, direct marketing, public relations, sales promotions, and personal selling. As old as the need to communicate to customers is the need to know which promotion activities pay off.

Effectiveness of advertisement is often measured through the return on investment, looking at costs vs. sales, image effects (how much did the advertising campaign influence the image of a brand), or awareness and memory effects (e.g., recall or recognition values of brand names or specific advertising campaigns). There are several theoretical models available to evaluate public relation activities of a specific company (Lindenmann 1993; Cutlip, Center, and Broom, 2006; Macnamara, 2005; Watson and Noble, 2007). Common to all of them is the differentiation into different levels of PR input and output. Input factors include quality of message, as well as appropriateness of message content or selected media. Output measurements range from simple quantitative measures (e.g., number of messages in the media) to qualitative measures (e.g., type and content of messages). More sophisticated evaluation models encompass awareness and memory effects, changes in attitudes or motivations, or behavioral changes.

Figure 1 shows an example of the unified model of PR evaluation by Watson and Noble (2007).

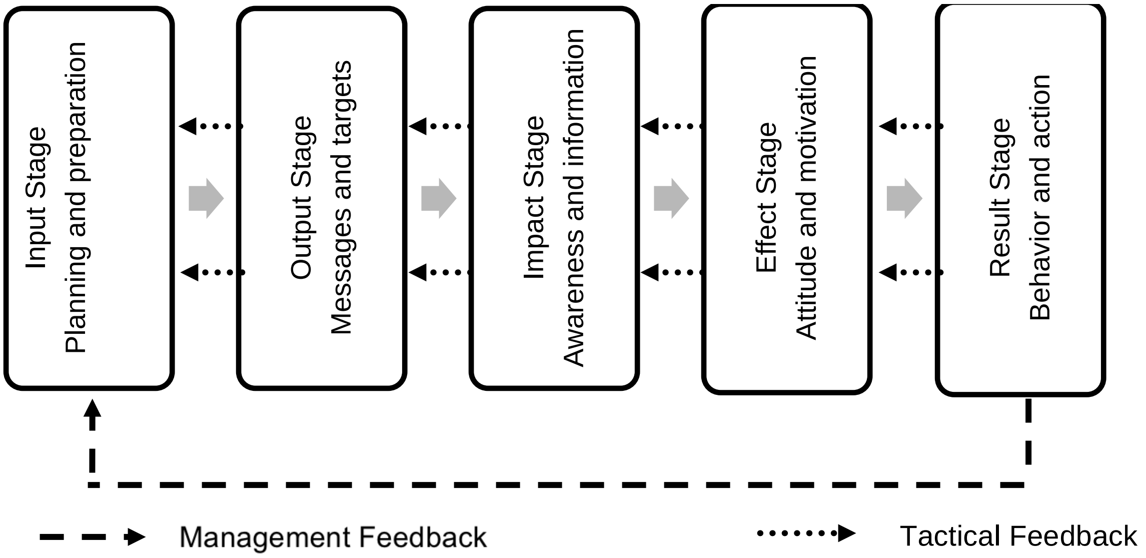

Figure 1. The Unified Model by Watson and Noble (2007).

In this study, we made a media response analysis, a form of input/output analysis, which encompasses the first two steps in the model by Watson and Noble (2007). We did not measure awareness or memory effects on the recipient side, nor did we measure changes in attitude or behavior. The input consists of the number of press releases sent to the media, and the output consists of the number of articles published and the content of the articles. Besides counting the number of press releases and published articles, a content analysis was applied to see whether and how the content of published articles has changed.

The Association of Christmas Tree Growers from Lower Austria provided reports of the number of press releases over the three periods (1994–1996, 2003–2005, 2006–2009). Five daily Austrian newspapers (*Kronen Zeitung, Kurier, Der Standard, Die Presse, Salzburger Nachrichten*) constituted the basic sample to search for articles about the Christmas Tree Association published during the above-mentioned periods. Figure 2 shows readership of the selected daily newspapers as a percentage of the Austrian population. Clippings from Observer, an Austrian media-observing service company, and desk research at the Austrian National Library provided the basis for the following content and media resonance analysis.

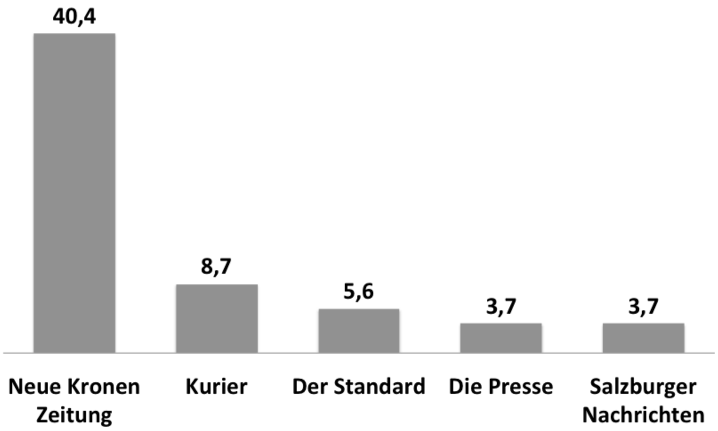

Figure 2. Readership (percentage of population) in Austria.

Initial search trials led to approximately 1,000 hits per year. The key words “Lower Austria,” “association,” and “label” were added to the main keyword “Christmas tree.” Furthermore, we excluded all articles with the keywords “burning Christmas tree” and “Disposal of Christmas tree.”

Results

The quantitative input-output analysis led to the following results (see Figure 3). The absolute numbers of published articles about the Christmas Tree Association increased from the first to the second period from 13 to 45 and from the second to the third period from 45 to 62. The ratio of published articles to press releases was 6.5 articles per press release in the first period, 4.5 in the second period, and 3.4 articles per release in the third period. A decreasing input-output ratio over the observed periods is a possible indicator that the efficiency of PR can be described as a function of diminishing returns.

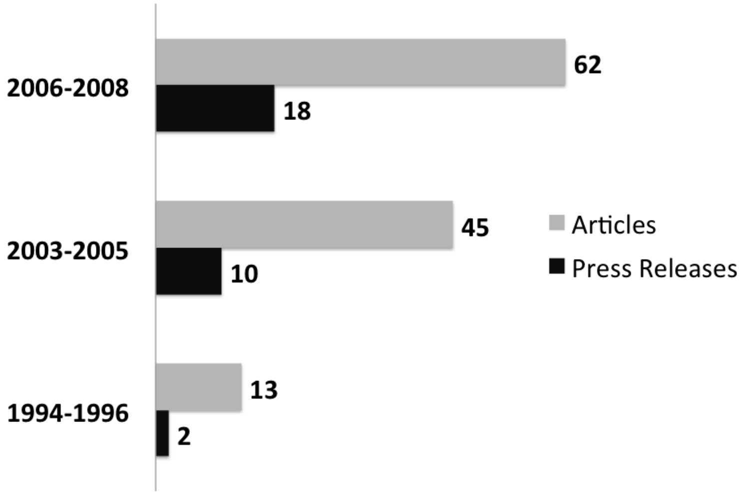

Figure 3. Numbers of press releases and published articles.

The authors also looked at the editorial departments in which the articles got published over the three periods. Figure 4 shows that the number of editorial departments increased from 4 to 7. This is another positive result of increased PR intensity. If articles are published in more editorial departments, it can be assumed that there is a higher probability of reaching more readers. The category “miscellaneous” encompasses editorial topics such as lifestyle, garden, foreign country, etc.

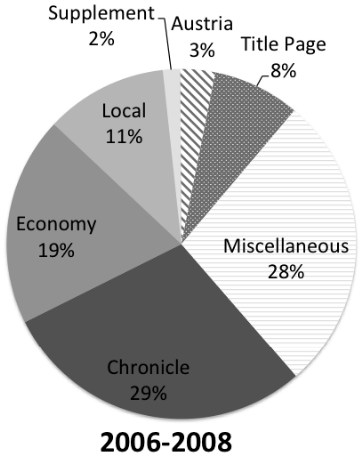

Figure 4. Editorial departments of published articles.

On average (over all three periods), an article consisted of 201 words and one adjoining photo. Approximately half of all articles contained one or more photos. The most photos were contained in the articles found in the supplements of daily newspapers. These articles had on average 578 words.

From reactive to active PR

The content analysis showed that, over all periods, journalists had a strong preference to use *data and facts* about the Austrian or European Christmas tree market. Specific market data about the volume of the Christmas tree market, market shares of national and international trees, or consumer shopping habits concerning Christmas trees have a high potential to be included in the articles. Prices, especially price increases, also have high news value. (In Table 1, the higher the news value is ranked, the more often it was reported in the articles.) *Positive* identified news values are:

- Christmas Tree Grower’s Association from Lower Austria
- Austrian Christmas tree label
- Freshness (including hints for maintenance)
- Quality label
- Home-grown
- Website
- Interview with the manager of the association
- Moon cut (some farmers are offering trees cut at specific moon phases)

News values identified as *neutral* are price, data, and facts. *Negative* coded news values are pesticides, imported trees, and price increases.

The news values also indirectly reflect the market situation. In period 2 and 3, a decline in the market shares of trees from Denmark was observed, followed by an increase in prices. Nevertheless, the higher ranking of the Christmas Tree Grower’s Association from Lower Austria is a sign of successful public relations, which succeeded in communicating a variety of news values about Christmas trees in Austria. The negative publicity about rising prices has been absorbed by information about the Christmas Tree Grower’s Association, the fact that the trees are home-grown (promoted by the Lower Austrian Christmas tree label), and the interview with the association's manager. The content of the interviews served to support an image of competence on the part of the grower's association, which produces high-quality trees in a local context. They also highlighted special attributes, such as trees cut in respect to moon phases.

Table 1. Results of content analysis.

News value (1994–1996)	News value (2003–2005)	News value (2006–2008)
Data & facts	Data & facts	Data & facts
Home-grown	Home-grown	Association
Price increase	Price	Home-grown
Import trees	Import trees	Price
Quality label	Association	Price increase
Moon cut	Moon cut	Website
Freshness	Freshness	Interview
Pesticides	Interview	Freshness
	Website	Import trees
	Price increase	Austrian Christmas Tree label
	Quality label	Moon cut
	Austrian Christmas Tree label	Pesticides
	Pesticides	Quality label

The following guidelines can be summarized based on the data:

- The best time for press releases is the end of November.
- Journalists are eager to use specific data and facts.
- Emotional and surprising news values (e.g., moon cut) are "door openers" for articles (in combination with naming the Association).
- A ready-made press map + regular press releases increase the number of published articles (memory effect).
- "Local" and "home-grown" news values are important.
- Press releases with 155–350 words are often taken "as they are."

The results show that it pays off to invest money and time in public relations. It is important to switch from a reactive to an active PR, i.e., not waiting until a PR scandal forces a reaction. A long-term public relations strategy, with a clear focus on the most important news values, is necessary to pursue active and successful public relations.

References

Cutlip, S., A. Center, and G. Broom. 2006. Effective public relations, 9th edition. New York: Pearson Education.

Lindenmann, W.K. 1993. An "effectiveness yardstick" to measure public relations success. Public Relations Quarterly 38:7–10.

MacNamara, J. 2005. Jim Macnamara's public relations handbook. Sydney: Archipelago Press.

Watson, T. and P. Noble. 2007. Evaluating public relations: A best practice guide to public relations. London und Philadelphia: Kogan Page.

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Christmas tree growing in Hungary

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An introduction to Hungary

The total area of the country is 9.3 million ha. There are roughly 10 million people. Hungary has been a European Union member state since 2004. The total agricultural area is 6 million ha. Forests cover a mere 20 percent (about 2 million ha) of the total land area, leaving Hungary with the lowest proportion of forested land in the central European region. The Christmas tree business is mostly out of traditional forestry.

Hungary is located halfway between the Nordic countries, where forests have a dominant wood production function, and southern European countries, which emphasize the protective function of forests. When the role of forests in economic development is considered, Hungary is also halfway between developing countries, which rely on natural resources to a large extent, and industrialized countries, which mostly focus on the protection and conservation of their forests.

In Hungary, there is no available official information about the area of Christmas trees. According to land registry regulations, each block has a land-use category (forest, plow land, grazing area, garden, etc.). Christmas tree stands should be indicated as gardens, but users do not change the land-use category, leaving the block registered as plow land, grazing area, etc. As Christmas tree stands have existed for less than 15 years, the state forest service—based on forest law—does not focus on Christmas tree producers at all.

Development of Christmas tree production

- Initial stage: Between World War II and 1989, Christmas tree management (planting, maintenance, harvesting, and sales) was carried out by state-owned forest companies.
- After 1989, in the process of transition to a market economy, the market shares of the state companies were taken over by small, dynamic Hungarian private companies and individuals—indicated as **small-scale producers.**
- Since the mid-1990s, professional investors have arrived from western Europe (Austria, Denmark)—indicated as **large-scale producers.**

As Table 1 shows—based on expert estimation—Hungarian Christmas tree production is currently dominated mostly by large-scale producers from western Europe. They have professional backgrounds and good international market access. This group mainly produces *Abies nordmanniana* and *Picea pungens*. The local Hungarian producers work on smaller land blocks and sell in the Hungarian market, focusing on cheaper trees such as *Picea abies* (Norway spruce).

Table 1. Production of Christmas trees in Hungary.

	Small-scale producers	**Large-scale producers**
Production area	about 500 ha	About 1,500–2,000 ha
Main species	Norway spruce	Nordmann, blue spruce

Hungarian market situation

As there are no official data available for the Christmas tree business in Hungary, the present market situation was estimated by expert calculations. Based on current trends, roughly 2.5 million trees are sold yearly at the end-consumer level in Hungary. Thus, more than 60 percent of households buy a tree at Christmastime. The turnover value of these 2.5 million trees is about € 37 million at the end-consumer level. According to expert estimations, yearly Hungarian production is 1.7 million trees.

There is a wide difference between the biggest and smallest producers in Hungary. Some rural families serve their neighbors and produce fewer than 50 trees per year, while the largest companies can harvest close to 250,000 Christmas trees yearly.

Reasons for choosing Hungary to produce Christmas trees

The most important reasons for choosing Hungary to produce Christmas trees are summarized in Table 2. The comparisons show that the price level in production (land price/land lease fees, etc.) is far less than in western European countries. In addition, the market prices of Christmas trees are better in eastern than in Western Europe. For instance, in Poland, citizens get loans in order to celebrate a full Christmas festival, including a tall Christmas tree. Furthermore, Hungary has a central position, close to large markets (Germany, 82 million; Romania, 23 million; Ukraine, 45 million; Poland, 38 million).

Hungary has a continental climate, but generally there is low risk of late frost damage in May.

Table 2. Advantages of Christmas tree production in Hungary.

• Lower price level in production
• Close to large markets
• Eastern Europe has better market prices than western Europe
• Good climate—low risk of late frost damage

Policy framework

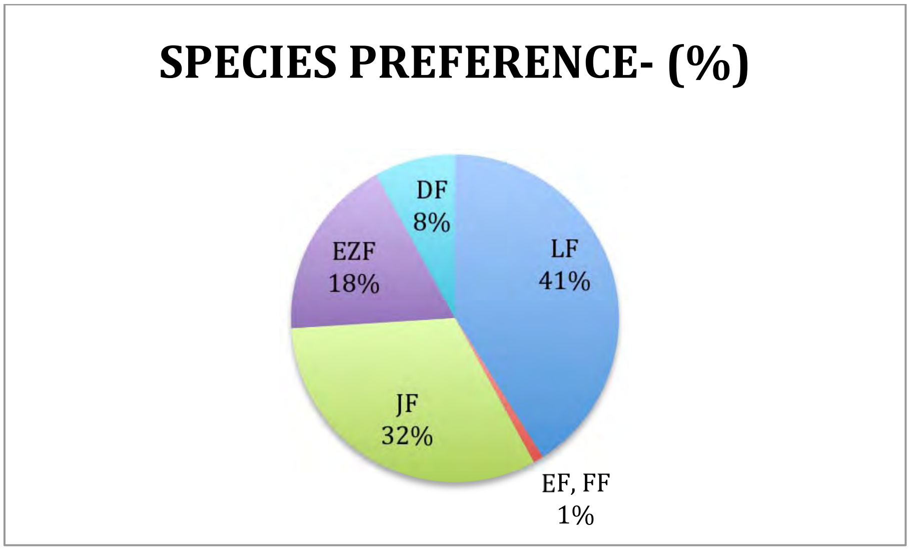
The legislative background of this sector is underdeveloped. There are no specific regulations on Christmas tree stands in Hungary. This is fortunate, as other traditional private forestry is overregulated. Also, there is no subsidy for Christmas tree production. In Hungary, if an agricultural/forestry sector is subsidized, it is usually overregulated with tons of paperwork. Christmas tree production is only a segment of the whole forestry/agriculture sector, and there is no national government or EU subsidy. Actually, this is the niche where the market economy more or less works.

However, the general agriculture rules (e.g., chemical regulations, plant health certificates in case of outside EU trade, etc.) directly influence the Christmas tree sector. In Hungary, Christmas tree producers act as independent market actors. There is no existing vertical/specialized industrial organization or other umbrella organization for small producers.

Market research

In 2004, an investigation (Figure 1) about the behavior of Hungarian Christmas tree end consumers showed that the most important species was *Picea abies* [LF], followed by *Abies nordmanniana* [JF]. One thousand persons were interviewed in the study. At the same time, almost one-third of the people preferred other species (*Picea pungens* [EZF], *Pseudotsuga menziesii* [DF], *Pinus nigra* [FF], and *Pinus sylvestris* [EF]).

The work also reported (Figure 2) that more than 50 percent of those interviewed purchased the Christmas tree between 21 and 23 December. Only 3 percent of consumers started to shop for a Christmas tree before 15 December.



DF = *Pseudotsuga menziesii*
LF = *Picea abies*
EZF = *Picea pungens*
JF = *Abies nordmanniana*
EF = *Pinus sylvestris*
FF = *Pinus nigra*

Figure 1. Which species do you prefer?

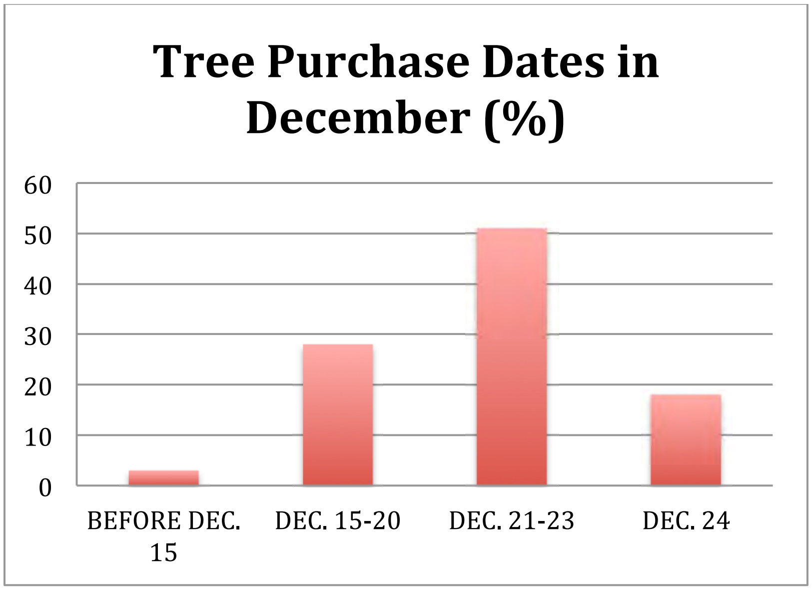


Figure 2. When do you buy your tree? Dates refer to December.

Main research questions

- Monitoring activity (survey with questionnaires) within Christmas tree producers
- Updating end consumer behavior analyses

Innovation areas

- Labeling/certification issues
- Improvement of logistics (reduce the share of trees remaining at the end of the season, development of e-trade, etc.)
- Taking full advantages of resources: e.g., local Christmas tree production can be added to tourism services.

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Where do the Christmas trees that Santa Claus/Father Christmas/Christkind brings come from?

Control of geographical origin by stable isotope analysis—a pilot study

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Abstract

Conifer trees sold as Christmas trees in Austria often have a designation of origin, as Christmas is a traditional holiday and religious celebration and is emotionally connected to one's home and region. Therefore, many people want to strengthen this link by buying a tree of local origin. As imported conifer trees are usually cheaper than locally grown trees, a measure to control the declaration of geographical origin is necessary. We analyzed spruce needle samples originating from Austria and other European countries for their stable isotope pattern of hydrogen (H), carbon (C), nitrogen (N), and sulfur (S). The main discriminating parameters are hydrogen and sulfur isotopes. These variations are caused by differences in the environmental conditions where trees are grown, such as climate and/or water sources, proximity to the sea, and the soil S isotope composition.

Introduction

Especially in western Europe, Christmas trees are very popular, and most homes have a tree for the Christmas celebration. Many consumers want to buy regional or local trees, as this is a tradition they know from their parents. They also assume that trees felled later will keep their needles longer, and they prefer to support regional farmers. Thus, many Christmas trees grown in Austria have a banderole naming the country and region of origin. However, there have been cases reported of foreign trees being incorrectly labeled with this banderole and sold as Austrian trees, thus deceiving consumers. For this reason, an independent method of labeling is needed that can control the product itself for its provenance.

Stable isotopes are already used on a routine base for the control of origin of European wine (e.g., Christoph et al., 2004), and in numerous studies have also been demonstrated to be a potent tool for the control of origin of other kinds of foodstuffs, e.g., meat (e.g., Heaton et al., 2008; Boner and Förstel, 2004; Camin et al., 2007; Guo et al., 2008; Horacek and Min, 2010), milk (e.g., Kornexl et al., 1997; Crittenden, 2006; Camin et al., 2008; Horacek and Papesch, 2008), vegetables (e.g., Schlicht et al., 2006; Kelly et al., 2009; Horacek et al., 2010), fruits (e.g., Camin et al., 2009,), and honey (e.g., Schellenberg et al., 2010; Kropf et al., 2010).

In Horacek et al. (2008 and 2009), it has been demonstrated that the origin of Siberian larch wood can be controlled by stable isotope investigations. Kagawa and Leavitt (2010) published the use of carbon isotopes to determine the provenance of pine trees from the southwestern U.S. Carbon and oxygen isotope measurements in wood have been performed by numerous researchers to investigate the potential of tree rings as climatic archives for paleoclimatic studies (e.g., Ballantyne et al., 2006 and references therein). Keppler et al. (2007) investigated the hydrogen isotope composition of lignin methoxy groups from wood. All of the studies dealt with wood samples, not with tree needles, as often no needle samples were available. In the present study, needles were analyzed instead of wood material, as they contain higher amounts of nitrogen and sulfur (for more details, see Horacek, 2012).

The isotopic composition of wood and tree needles is influenced by environmental conditions at growth sites. Carbon isotopes in photosynthetically produced organic matter are determined by the isotope ratio of the CO_2 incorporated by photosynthesis and the intercellular CO_2 concentration (Farquhar et al., 1982). Limited water availability results in closing of the plant stomata, leading to a decrease in intercellular CO_2 concentration, causing reduced ^{13}C discrimination and therefore enriched $\delta^{13}C$ ratios (Farquhar et al., 1989; Barbour et al., 2002). Oxygen and hydrogen isotopes in wood cellulose and tree needles are controlled by the isotope ratio of the soil water consumed and its enrichment due to leaf/needle transpiration (Roden et al., 2000; Yakir and Sternberg, 2000; Barbour et al., 2001). The isotope ratio of the soil water is directly linked to precipitation and evaporation processes in the soil, which are both influenced by geographic position and thus climatic conditions, such as temperature. Transpiration is controlled by opening and closing of the leaf /needle stomata, which depends on water availability.

The climate within Europe varies. Maritime climates (mild winters, moderate summers, and precipitation throughout the year) are found close to the coast, generally in western European regions. More continental climates (cold winters, hot summers, seasonal precipitation) are generally found in eastern and central Europe. These climate variations are also evidenced by differences in the isotope composition of western and eastern European precipitation, as the isotope ratio in precipitation is controlled by climate and geographic position (Bowen and Revenaugh, 2003). Water vapor evaporating from a water reservoir is isotopically depleted with respect to the water it emanates; it is fractionating isotopically (Dansgaard, 1964). The fractionation is temperature dependent, with strong fractionation at low temperatures and minor fractionation at elevated temperatures. Water vapor migrating in clouds from the Atlantic Ocean eastward across Europe becomes isotopically successively more and more depleted in ^{18}O and ^{2}H (latitude effect), as the heavy oxygen and hydrogen isotopes preferentially get into the liquid phase (rain and snow) and are removed from the clouds (Gat and Confiantini, 1981).

Materials and methods

Eight fir tree twig samples were taken from different locations: northern and southern Waldviertel (Austria), Hungary, eastern and western Denmark, northern Germany, and Ireland. The needles were removed from the twigs and oven dried at 45°C overnight. The needle samples were then homogenized and weighed into tin and silver capsules for C-, N-, S- and H-isotopes, respectively.

Measurements were performed with a Finnigan™ thermal combustion elemental analyzer (TC/EA) for H and a Vario™ elemental analyzer (EA) for C-, N- and S- isotopes. Both analyzers are connected via a Finnigan™ ConFlo™ to a Finnigan™ isotope ratio mass spectrometer (IRMS), where the isotope ratios are determined.

Results are reported in the conventional δ notation in per mil (‰) with respect to international standards: V-SMOW (Vienna Standard Mean Ocean Water), V-PDB (Vienna Peedee Belemnite), Nair and CDT (Canyon Diablo Troilite) for H, C, N, and S, respectively. Standard deviation is better than 1.5‰ for H, 0.2‰ for C and N, and 0.4‰ for S isotopes, respectively (1σ).

As the H isotopes partially exchange, they have to be corrected with a calibrated standard (casein); see Camin et al., 2007; Schellenberg et al., 2010; and Horacek and Min, 2010.

Results

The results are shown in Figures 1–3.

The Waldviertel samples have δ^{2}H values of -128 and -127‰, δ^{13}C values of -30.3 and -26.7‰, δ^{15}N values of -0.7 and 1.4‰, and δ^{34}S values of 5.4 and 5.6‰.

The Danish fir needles have δ^{2}H values of -122 and -113‰, δ^{13}C values of -31.8 and -31.2‰, δ^{15}N values of -1.9 and 2.2‰, and δ^{34}S values of 6.3 and 8.5‰.

The Irish trees have δ^{2}H values of -107 and -101‰, δ^{13}C values around -30.9‰, δ^{15}N values of 2.4 and 3.3‰, and δ^{34}S values of 8.2 and 8.7‰.

The isotopic pattern for the fir needle sample from northern Germany is a δ^{2}H value of -111‰, a δ^{13}C value of 31.7‰, a δ^{15}N value of 0.2‰, and a δ^{34}S value of 8.1‰.

The Hungarian samples have a δ^{2}H value of -123‰, a δ^{13}C value of -30.2‰, a δ^{15}N value of 2.6‰, and a δ^{34}S value of 6.4‰.

Figure 1. δ^{2}H versus δ^{34}S of the analyzed tree needle samples. There are two sample groups: one group represents the trees grown in a continental climate (low δ^{2}H values), and the second group represents the trees grown in a maritime climate close to the coast (elevated δ^{2}H values and elevated δ^{34}S values). It is interesting to note that the sample from eastern Denmark plots in the “continental” group.

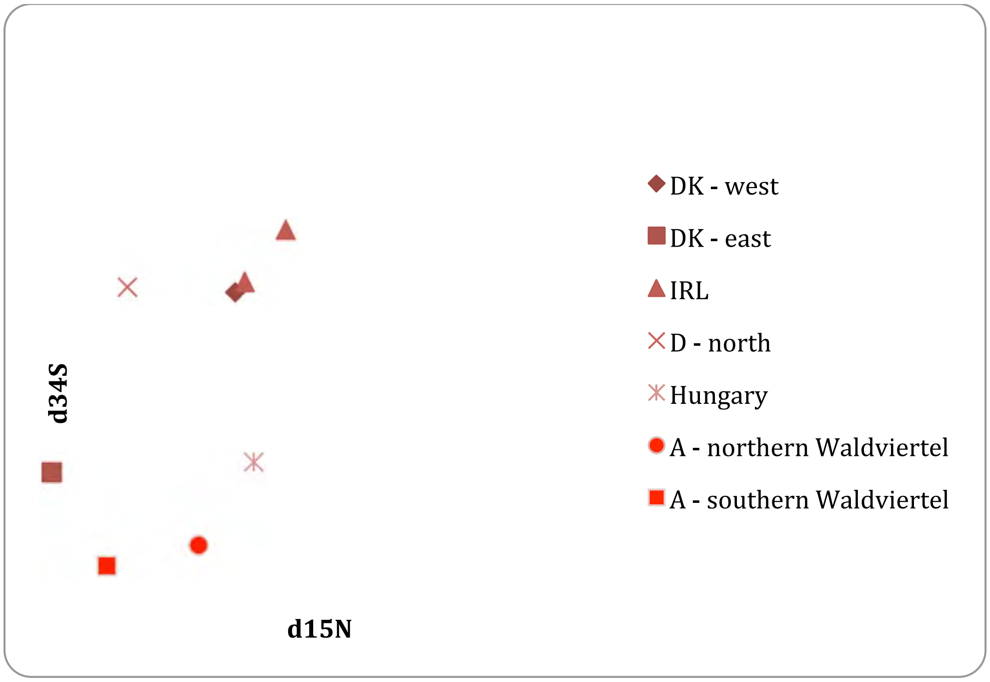

Figure 2. $\delta^{15}N$ versus $\delta^{34}S$. The $\delta^{15}N$ values show only a small variation, giving no distinctive geographic indication so far.

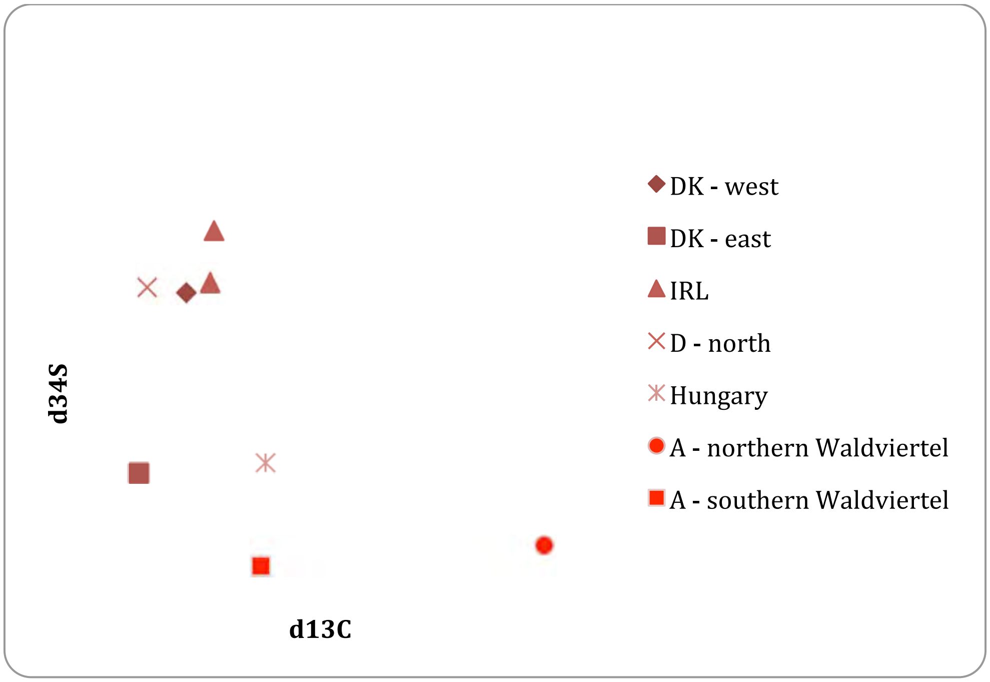

Figure 3. $\delta^{13}C$ versus $\delta^{34}S$. $\delta^{13}C$ isotopes give mainly homogeneous values around 31‰. One Austrian sample is significantly enriched in ^{13}C with respect to the other samples.

Discussion

The hydrogen isotope values of the investigated samples can be related to the δ^2H pattern of the ambient precipitation water the sampled trees probably had access to. Higher δ^2H values are found in coastal areas, and lower δ^2H signals in continental regions (Bowen and Revenaugh, 2003). It can be concluded that the hydrogen isotope ratio of the investigated samples is predominantly influenced by the isotope pattern of the precipitation in Europe, which in turn depends on factors such as proximity to the sea, temperature, and altitude. The hydrogen isotope values clearly distinguish two groups, with one represented by high δ^2H values of the samples grown in coastal regions (Ireland, northern Germany, and western Denmark). The second group is formed by the samples of more continental origin, having lower δ^2H values (Austria, Hungary, and eastern Denmark). The latter result is quite interesting, as such a variation across Denmark was not anticipated and thus needs to be confirmed with a larger number of samples.

The δ^{13}C values of the Austrian fir samples (and also of the other samples investigated in this study) are more negative to barely reaching the carbon isotope values measured for the larch wood samples (ranging from -26.1 to -23.5‰ δ^{13}C) in Horacek et al., 2009. This might be due to the fact that the investigated samples are “farmed” trees with conditions for optimal growth and constantly sufficient water supply, whereas the larch trees often come from less favorable sites, where they had to endure more water stress. Another possible explanation is the presence of significant amounts of lipids in the needles, which are isotopically depleted with respect to wood cellulose and lignin. Alternatively, this result also could be related to the different morphologies of the investigated tree species, with the larch being a deciduous tree and the fir a conifer. However, deciduous trees usually are more depleted in ^{13}C than are conifers (unpublished data). One Austrian sample, however, shows significantly enriched δ^{13}C values, arguably evidencing a less favorable growing locality.

Nitrogen isotope values of the analyzed samples are generally quite low, from slightly negative to slightly positive values. This can be explained by the application of synthetic fertilizer having a nitrogen isotope composition close to 0‰ (Bateman and Kelly, 2007), as these trees grown in tree nurseries are usually fertilized (Karl Schuster, oral communication, 2011).

The sulfur isotope composition of the investigated samples shows a pattern of “enriched” values (above about 8‰) at sites close to the sea (e.g., Ireland, northern Germany, and western Denmark). Values are significantly lower for sites farther from the sea. This can be explained by the influence of wind-transported sea spray bringing seawater sulfate from the sea onto nearby soil. The current sulfur isotope composition of the sea is around +23‰ (e.g., Kampschulte et al., 2004). This effect has been observed before, e.g., in lamb meat (Camin et al., 2007), beef (Horacek et al., 2010), and honey (Schellenberg et al., 2010).

Conclusions

Fir trees of different origin have been successfully differentiated by the stable isotope signatures of the fir needles, due to differing environmental conditions at the growth sites. Main discriminating parameters indicative for the investigated regions were the hydrogen isotope composition (related to precipitation) and the sulfur isotope ratio (related to proximity to the sea and the bedrock geology). This is a pilot study demonstrating the potential of stable isotope analysis for the determination of origin of Christmas trees. However, the investigation of a larger sample set will be necessary to verify these results and to show the spread of the isotopic signal within the investigated regions.

References

Ballantyne, A.P., N. Rybczynski, P.A. Baker, C.R. Harington, and D. White. 2006. Pliocene Arctic temperature constraints from the growth rings and isotopic composition of fossil larch. Palaeogeography, Palaeoclimatology, Palaeoecology 242:188–200.

Barbour, M.M., T.J. Andrews, and G.D. Farquhar. 2001. Correlations between oxygen isotope ratios of wood constituents of *Quercus* and *Pinus* samples from around the world. Australian Journal of Plant Physiology 28:335–348.

Barbour, M.M., A.S. Walcroft, and G.D. Farquhar. 2002. Seasonal variation in ^{13}C and ^{18}O of cellulose from growth rings of *Pinus radiata*. Plant Cell and Environment 25(11):1483–1499.

Bateman, A.S. and S.D. Kelly. 2007. Fertilizer nitrogen isotope signatures. Isotopes in Environmental and Health Studies 43(3):237–247.

Boner, M. and H. Förstel, H. 2004. Stable isotope variation as a tool to trace the authenticity of beef. Analytical and Bioanalytical Chemistry 378:301–310.

Bowen, G.J. and J. Revenaugh. 2003. Interpolating the isotopic composition of modern meteoric precipitation. Water Resources Research 39(10):1299–1312.

Camin, F., L. Bontempo, K. Heinrich, M. Horacek, S.D. Kelly, C. Schicht, F. Thomas, F.J. Monahan, J. Hoogewerff, and A. Rossmann. 2007, Multi-element (H,C,N,S) stable isotope characteristics of lamb meat from different European regions. Analytical and Bioanalytical Chemistry 389(1):309–320.

Camin, F., M. Perini, G. Colombari, L. Bontempo, and G. Versini. 2008. Influence of dietary composition on the carbon, nitrogen, oxygen and hydrogen stable isotope ratios of milk. Rapid Communications in Mass Spectrometry 22:1690–1696.

Camin, F., M. Perini, L. Bontempo, and L. Giongo. 2009, Multi-Element (H, C, N, O) stable isotope characterization of blueberries. Acta Horticulturae 810(2):697–703. IXth International Symposium on Vaccinium Symposium, Corvallis, Oregon, USA, 13–16 July 2008.

Christoph, N., G. Baratossy, V. Kubanovic, B. Kozina, A. Rossmann, C. Schlicht, and S. Voerkelius. 2004. Possibilities and limitations of wine authentication using stable isotope ratio analysis and traceability. Part 2: Wines from Hungary, Croatia, and other European countries. Mitteilungen Klosterneuburg 54:155–169.

Crittenden, R.G., A.S. Andrew, M. LeFournour, M.D. Young, H. Middleton, and R. Stockmann. 2006. Determining the geographic origin of milk in Australasia using multi-element stable isotope ratio analysis. International Dairy Journal 17:421–428.

Dansgaard W. 1964. Stable isotopes in precipitation. Tellus 16:436–468.

Degen, B. and M. Fladung, 2007. Use of DNA-markers for tracing illegal logging. Proceedings of the international workshop Fingerprinting Methods for the Identification of Timber Origins, October 8–9, 2007, Bonn/Germany. http://literatur.vti.bund.de/digbib_extern/dk040620.pdf (accessed September 5, 2011).

Deguilloux, M.F., M.H. Pemonge, and R.J. Petit. 2004. DNA-based control of oak wood geographic origin in the context of the cooperage industry. Ann. For. Sci. 61:97–104.

Farquhar, G.D., M.H. O'Leary, and J.A. Berry. 1982. On the relationship between carbon isotope discrimination and the intercellular carbon dioxide concentration in leaves. Aust. J. Plant Physiol. 9:121–137.

Farquhar, G.D., Ehleringer, Jr., and K.T. Hubick. 1989. Carbon isotope discrimination and photosynthesis. Annual Review in Plant Physiology and Plant Molecular Biology 40:503–537.

Gat, J.R. and R. Gonfiantini (eds.). 1981. Stable isotope hydrology: Deuterium and oxygen-18 in the water cycle, IAEA Tech. Rep., Ser. 210, pp. 103–142.

Guo, B.L., Y.M. Wei, J.R. Pan, and Y. Li. In press. Stable C and N isotope ratio analysis for regional geographical traceability of cattle in China. Food Chemistry 118:915–920. doi:10.1016/j.foodchem.2008.09.062

Heaton, K., S.D. Kelly, J. Hoogewerff, and M. Woolfe. 2008. Verifying the geographical origin of beef: The application of multi-element isotope and trace element analysis. Food Chemistry 107:506–515.

Hilasvuori, E., F. Berninger, E. Sonninen, H. Tuomenvirta, and H. Jungner. 2009. Stability of climate signal in carbon and oxygen isotope records and ring width from Scots pine (*Pinus sylvestris L.*) in Finland. Journal of Quaternary Science 24:469–480.

Horacek, M., A. Roßmann, S. Kelly, F. Thomas, K. Heinrich, F. Camin, L. Bontempo, C. Schlicht, A. Schellenberg, J. Hoogewerff, and B. Wimmer. 2009. Where does the meat come from? Discrimination of beef origin by stable isotope analysis. Final TRACE Meeting, Brussels, December 2–3, 2009.

Horacek, M. and J.S. Min. 2010. Discrimination of Korean beef from beef of other origin by stable isotope measurements. Food Chemistry 121: 517-520.

Horacek, M., M. Jakusch, and H. Krehan. 2008. Control of origin of larch wood: Development of a method to discriminate between European (Austrian) and Siberian origin, JESIUM 2008, Presqu` Ile de Giens, France.

Horacek, M., M. Jakusch, and H. Krehan. 2009. Control of origin of larch wood: Discrimination between European (Austrian) and Siberian origin by stable isotope analysis. Rapid Commun. Mass Spectrom. 23:3688–3692.

Horacek, M. and W. Papesch. 2008. Control of authenticity of Tyrolean milk. International Foodcongress, Ljubljana, 2008.

Horacek, M., J.S. Min, and G. Soja. 2010. Discrimination between ginseng from Korea and China by light stable isotope analysis. Analytica Chimica Acta 682(1–2):77–81.

Horacek, M. 2012. Where do the Christmas trees come from? Control of geographical origin by stable isotope analysis—a pilot study. Die Bodenkultur, *accepted*.

Kagawa, A. and S.W. Leavitt. 2010. Stable carbon isotopes of tree rings as a tool to pinpoint the geographic origin of timber. J Wood Sci, DOI: 10.1007/s10086-009-1085-6.

Kampschulte, A. and H. Strauss. 2004. The sulfur isotopic evolution of Phanerozoic seawater based on the analysis of structurally substituted sulfate in carbonates. Chemical Geology 204:255–286.

Kelly, S.D. and A.S. Bateman. 2009. Comparison of mineral concentrations in commercially grown organic and conventional crops—tomatoes (*Lycopersicon esculentum*) and lettuces (*Lactuca sativa*). Food Chemistry 119:738–745.

Keppler F, D.B. Harper, R.M. Kalin, W. Meier-Augenstein, N. Farmer, S. Davis, H.L. Schmidt, D.M. Brown, and J.T.G. Hamilton. 2007. Stable hydrogen isotope ratios of lignin methoxyl groups as a paleoclimate proxy and constraint of the geographical origin of wood. New Phytologist 176:600–609.

Kirdyanov, A.V., K. Treydte, A. Nikolaev, G. Helle, and G.H. Schleser. 2008. Climate signals in tree-ring width, density and δ13C from larches in eastern Siberia (Russia). Chem. Geology 252:31–41.

Kornexl, B.E., T. Werner, A. Roßmann, and H.L. Schmidt. 1997. Measurement of stable isotope abundances in milk and milk ingredients—a possible tool for origin assignment and quality control. Zeitschrift für Lebensmittel Untersuchung und Forschung A 205:19–24.

Kremenetski K.V., T. Boettger, G.M. MacDonald, T. Vaschalova, L. Sulerzhitsky, and A. Hiller. 2004. Mediaeval climate warming and aridity as indicated by multiproxy evidence from the Kola Peninsula, Russia. Palaeogeography, Palaeoclimatology, Palaeoecology 209:113–125.

Kropf, U., M. Korošec, J. Bertoncelj, N. Ogrinc, M. Nečemer, P. Kump, and T. Golob. 2010. Determination of the geographical origin of Slovenian black locust, lime and chestnut honey. Food Chemistry. doi: 10.1016/j.foodchem.2009.12.094

Roden J.S., G. Lin, and J.R. Ehleringer. 2000. A mechanistic model for interpretation of hydrogen and oxygen ratios in tree-ring of cellulose. Geochimica et Cosmochimica Acta. 64:21–35.

Saurer, M., F. Schweingruber, E.A. Vaganov, S.G. Shiyatov, and R. Siegwolf. 2002. Spatial and temporal oxygen isotope trends at the northern tree-line in Eurasia. Geophysical Research Letters 29:10. 1029/2001GL013739.

Schellenberg, A., S. Chmielus, C. Schlicht, F. Camin, M. Perini, L. Bontempo, K. Heinrich, S.D. Kelly, A. Rossmann, F. Thomas, E. Jamin, and M. Horacek. 2010. Multielement stable isotope ratios (H, C, N, S) of honey from different European regions. Food Chemistry 121: 770-777. doi:10.1016/j.foodchem.2009.12.082

Schlicht, C., A. Roßmann, and E. Brunner. 2006. Anwendung der Multielement-Multikomponenten Isotopenverhältnismassenspektrometrie (IRMS) zur Prüfung der geographischen Herkunft von Spargel. Journal für Verbraucherschutz und Lebensmittelsicherheit 1:97–105.

Sidorova, O.V., R.T.W. Siegwolf, M. Saurer, M. Naurzbaev, and E.A. Vaganov. 2008. Isotopic composition (d13C, d18O) in wood and cellulose of Siberian larch trees for early Medieval and recent periods. Journal of Geophysical Research Biogeosciences 113, G02019. DOI: 10.1029/2007JG00047.

Sidorova, O.V., R.T.W. Siegwolf, M. Saurer, M.M. Naurzbaev, A.V. Shashkin, and E.A. Vaganov. 2010. Spatial patterns of climatic changes in the Eurasian north reflected in Siberian larch tree-ring parameters and stable isotopes. Global Change Biology 16(3)1003–1018. doi: 10.1111/j.1365-2486.2009.02008.x
Van Stone, J.W.1958 The origin of driftwood on Nunavik Island, Alaska. Tree-ring Bulletin 22:12–15.
Yakir D. and L.D.L. Sternberg. 2000. The use of stable isotopes to study ecosystem gas exchange. Oecologia. 123:297.

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Christmas tree certification in the Pacific Northwest

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Introduction

A range of crops and products are grown under various certification programs. Some programs certify organic production, some a unique set of production standards and procedures, others a particular product type. The end goal for most of these programs is the opportunity to secure a market identity and ultimately a price advantage or niche relative to competing products.

There are likewise certification efforts that in part are “defensive” and are designed to protect a brand name and/or avoid public protests at storefronts or in the media.

In Christmas trees, the SERF (Socially and Environmentally Responsible Farm) program in the Pacific Northwest (PNW) is just beginning. In this paper we will provide an outline of the program and project history. We conclude with information on program status.

SERF background/history

Just prior to the economic downturn beginning in 2008, selected large wholesale buyers of PNW Christmas trees began to ask growers about “certification.” Other products were “certified” in a variety of programs, so “why not Christmas trees?” There was little in the way of specific direction to these inquiries or demands that the program be part of any existing program.

A few of the larger PNW growers quickly formed a certification/promotion program to meet buyer requests. The Coalition of Environmentally Conscious Growers program began in 2007 with four grower members as the first program designed for Christmas trees in the PNW.

After the “coalition” was established, a number of growers remained interested in developing a broadly vetted set of standards with inspection conducted by State Department of Agriculture officials. Such was the beginning of the SERF Certification Program.

In order to meet these broad goals and form a new certification program, Chal Landgren and Dr. Luisa Santamaria developed a grant and secured start-up grant funding to build the program. In outline, the grant process worked on the following programs and timelines.

1. 2009—Organized a certification working group to discuss conformance guidelines and indicators. This group was made up of growers; the PNW Christmas Tree Association; representatives of the University, environmental groups, and government agencies with interests in conservation and agriculture; and contractors.
2. 2009–2010—Developed and tested the conformance indicators and developed training materials for growers.
3. 2010–2011—Chal Landgren, Rick Fletcher, and Dr. Luisa Santamaria conducted 5 training modules to assist 18 interested and self-selected growers in preparing their plans. In addition, diagnostic IPM training materials were developed for growers/workers (English and Spanish).
4. 2011—Produced and distributed marketing materials for successfully SERF-certified farms. These include a website, SERF brochures, and tree hang tags.
5. 2011–2012—Evaluate the program's market success and with participating growers.

The current program

The result of these steps is a SERF program that is voluntary and requires the grower/farm manager to produce and follow a SERF Sustainability Plan. A certified farm supports a balanced economic, social, and environmentally sustainable Christmas tree operation. Each farm will develop a SERF Sustainability Plan detailing activities in the areas listed below. The farm must demonstrate via an inspection program that the plan is being used, updated, and followed in all phases of operations. Inspections will include all farm personnel (employees, family, and contractors) involved in operating the tree farm.

Biodiversity

- Maps/photos
- Protection of natural features, waterways, and habitat; promotion of biodiversity on the farm
- Evaluation of new production areas
- Worker understanding of biodiversity goals
- Familiarization with local wildlife (especially threatened and/or endangered species)

Protection of soil and water resources

- Soil maps and records of monitoring
- Soil erosion prevention
- Water resources identified and impacts assessed
- Protective measures developed

Integrated Pest Management (IPM)

- Personnel/contractors trained in IPM systems
- Farm maintains records of pesticides and fertilizers that include target pest, time, location, and other pertinent details
- Evidence of utilization of IPM in decisions
- Employees who handle or apply pesticides trained in accordance with farm IPM program
- Chemical products and fertilizers are stored and handled in compliance with applicable laws

Health and safety

- Person(s) are designated and trained to oversee farm health and safety
- Employees/contractors are adequately trained for activities performed
- Health and safety risks on the farm are identified, and training provided
- Any violations have been corrected
- First-aid/CPR certifications are present and up-to-date
- First aid equipment is readily available and appropriate for type of work

Community and consumer relations

- Farm is involved in community and industry organizations concerned with wise use/management of natural resources
- Farm promotes sustainability education
- Tree recycling information is provided to customers/community
- Measures are taken to promote benefits of farm-grown Christmas trees

After developing the “plan” and adjusting any on-the-ground practices that need changes, a grower submits the plan to, in our case, the Oregon State Department of Agriculture Commodity Inspection Division. Next, an inspector is assigned to review the plan and conduct an audit of the farm. The fee charged runs from $300 or higher, depending on farm size.

Observations and future plans

For the 2011 harvest season, there are five farms in Oregon that are SERF certified. Brochures and tree “hang tags” are being produced for use by these farms. Farm size ranges from 7 acres to 5,500 acres.

At the conclusion of this initial market year for SERF (December 2011), we hope to have at least an anecdotal evaluation of the program’s market impact.

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Christmas tree production in Croatia and the other Balkan states

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Production in the Balkan states

Over the past 20 years, there has been a large and well-developed production of Christmas trees. Most of these trees came from forests. Today, many Christmas trees still come from the forest, especially in Bosnia and Herzegovina and Serbia. In Croatia and Slowenia, this practice has mostly been abandoned. Species coming from the forest are Norway spruce (*Picea abies*) and European silver fir (*Abies alba*).

When discussing organized production, we can focus on the following states: Croatia, Slowenia, Serbia, and Bosnia and Herzegovina. In this paper, we will focus specifically on Croatia. Croatian Christmas tree production has traditionally come from forestry production and has improved over the past 6 to 7 years. At present, we have around 900 Christmas tree producers. Plots average 2.5 hectares.

Species in production are:

- Norway spruce: 63 percent
- Blue spruce: 21 percent
- Nordmann fir: 5 percent
- Other species: 1 percent

In the past few years, there has been an expansion in Nordmann fir production. There are currently about 1.2 million Nordmann fir planted. Within the Nordmann fir production, approximately 40 percent are Turkish fir (*Abies bornmuelleriana*), which has been tested and is very well adapted to our climate.

Overall, we can say that production in Balkan states is increasing and will surely be better in quality. More and more growers are shearing trees for shape. Shearing is started from 20 years, and currently we have a few growers who make fantastic quality with the technique of light shearing. We have also tested a lot of species in addition that we make a good market overview.

Markets in the Balkan states

The markets of Balkan states are as follows:

- Slowenia: 150,000 trees
- Serbia: 500,000 trees
- Bosnia and Herzegovina: 100,000 trees
- Croatia: 700,000 trees

Legal issues

In the past 4 years, we have made the following improvements in the law:

- All producers must be registered by the Ministry of Forestry, so that all plants must come from registered nurseries, with a known seed source.
- Trees that will be cut are inspected by forest rangers. Each tree that goes on the market is labeled with the species name and the producer’s unique production number.
- In this way we can plan our production in the future for our market and export

Christmas tree production in Austria (May 2010)

Karl Schuster
[1)]Chamber of Agriculture in Lower Austria and Association of Christmas Tree Growers of Lower Austria

Every year about 2.6 million Christmas trees are set up in Austrian households, a value of € 50 million (Table 1). Furthermore, thousands of tons of greenery are harvested by market gardens every year. This material comes partly from agricultural areas and partly, especially the greenery, from forests.

Table 1. Austrian Christmas tree facts.

3.5 million	Austrian households
2.48 million	Households with a natural tree (71%)
+ 0.07 million	Trees from households with more than one tree (2% with 2 and more)
+ 0.07 million	Trees in public institutions, churches, companies, etc. (+2%)
2.62 million	Sum of trees
- 0.32 million	Imported trees (a few thousand are also exported)
2.3 million	Inland production
- 0.2 million	Self production of farms
2.1 million	*Sold inland trees (about 2,000 per farm)*
1.7 million	*Trees from plantations (500 per hectare and year)—80%*
1.4 million	*Nordmann fir*
0.4 million	*Trees from forest—20%*

Market

The numbers and facts (GfK Group, 2003–2009):

- 59% of households had a Christmas tree
- 6% had a donated tree
- 6% had a tree from their own forest
- 6% had an artificial tree
- On average, customers kept their tree indoors for 15 days
- 75% bought their tree directly from the grower
- On average, customers spent nearly € 20 on a tree
- 75% preferred to buy a tree grown in Austria

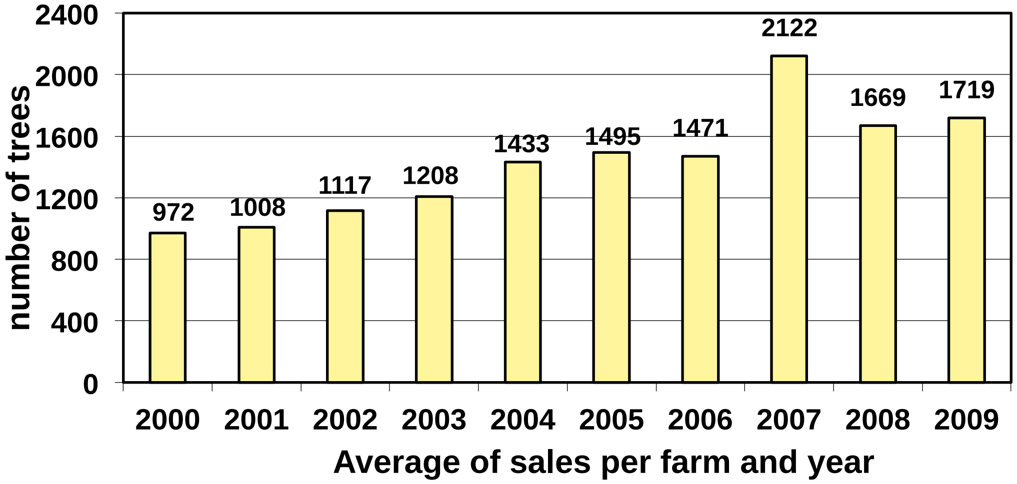

Figure 1. Austrian Christmas tree market data (GfK Group, 2003–2009).

From previous analyses, we know the following:

- Two-thirds of the trees were 1–2 meters in height
- 21% of the persons interviewed stated that they did not buy their own Christmas tree for the following reasons:
  - One-third spent Christmas with relatives
  - One-third never buys a Christmas tree
  - One-third had other reasons (too much dirt, alone at home, traveling, etc.)

Referring to the customers' statements, the most important criteria for buying a Christmas tree are the appearance and the price. Other criteria include freshness, recognizability of local origin, and personal relations to the producer. Special tree-cutting periods (related to the phases of the moon) and nearness of the shopping area also matter.

Many consumers in Austria do not like to just buy a Christmas tree; they also want to take home the mood of Christmas when buying their tree. Many growers adapt to this trend and arrange coach tours, build wonderlands for children, or offer their clients homemade pastries and mulled wine to make the purchase of the Christmas tree an experience.

Growers

About 90 percent of the Christmas trees come from Austria (80 percent cultivated, 20 percent from forests). Ten percent come from foreign countries, mostly Denmark and northern Germany, and these trees are almost exclusively Nordmann fir, *Abies nordmanniana*. The high percentage of local trees is due to our country's abundance of wood, since more than 47 percent of Austria's total area is covered with forests, with more than three-quarters being coniferous. The local tree trade is decreasing rapidly, however, because more and more people want a good quality tree such as Nordmann fir.

Figure 2. Much of Austria's Christmas tree production is based on a structure of small holdings.

In 2009, the inland production was about 2.4 million trees.

In Austria, there are about 1,000 growers, of which 600 are organized in one of the 7 federal associations. There is no national association in Austria. The average of each grower is 3–4 hectares, so there are more then 3,000 hectares of Christmas tree plantations in Austria.

Due to climatic conditions, there are traditional areas with a large number of Christmas tree plantations (e.g., South Waldviertel in Lower Austria), above all areas with a structure of small holdings (Figure 2). In Austria, the average plantation is 0.7–1 hectare, so you cannot speak of plantations in the original meaning. Many holdings have several production fields and grow Christmas trees to supplement their normal agricultural income.

Half of the Austrian production is in Lower Austria.

The Association in Austria, especially in Lower Austria

Christmas tree grower associations were founded in seven federal states during the years 1994–1997, principally for the following reasons:

- The opening of the eastern European countries
- The entrance of Austria into the EU and the increasing number of growers
- Import pressure from Denmark

A market study in 1996 was the first joint action of the associations. Other polls followed in 1999, 2001, 2003, 2005, 2007, 2008, and 2009.

Opening of the borders to the eastern European countries seems to be particularly significant in terms of competition to many Austrian growers. Some large-scale producers laid out extensive plantings (mostly with *Picea pungens*), for example in Hungary, that could flood the Austrian market. On the other hand, eastern Europe is a new market with an enormous sales prospect, since many people in these countries are Catholics and therefore celebrate Christmas with a tree. For example, most Austrian growers who have sold trees in Hungary have obtained higher prices there than in Austria. In the past 2 years, Austrian growers have also sold Nordmann fir trees to the eastern countries.

The associations have set the goal of advising and training their members more effectively by means of seminars and exhibitions. Especially regarding cultivation of alternative types and appropriate origins of *Abies nordmanniana,* there are several factors that can influence future success.

TV, radio stations, and newspapers are the most important partners for our advertising. Therefore, our slogan is: "Buy a natural tree—buy an Austrian tree—buy a tree from our members!" The website http://www.weihnachtsbaum.at is very important for customers and journalists.

Consumers value the quality and freshness of local trees, and the associations try to make it easier to search for Austrian goods by using labels of origin on Christmas trees and by labeling market stalls (Figure 3). One of our main problems is to protect this label, because some growers try to sell imported trees under the local label. Therefore, we have a project with the Seibersdorf Research Centre to find a method to identify the growing place of a tree by using isotopes of elements such as hydrogen (H), oxygen (O), or sulfur (S). For example, the isotopes of H found in trees from Denmark and Austria are different because the rain is “heavier” in Austria than in Denmark because of less tritium.

Figure 3. Christmas tree label.

All in all, it is not only the price that counts. The origin and high quality of trees are also important to the success of Christmas tree production.

Figure 4. Children are the customers of the future.

An important factor for our future is working with children, our customer of the future (Figure 4). In cooperation with the Forest Youth Games in Lower Austria, we have the chance to give information to more than 15,000 children of the 6th school class to tell them the importance of using a natural tree. We also have many social activities during Christmas time to get good “press.” For example, we give trees to SOS children homes and to soldiers on the Golan. We also bring a big tree to Brussels to the EU parliament each year.

Numbers and facts of the Association of Lower Austria

Tree species in plantations in 2009 and expected trend

Nordmann fir	80% ↑
Blue spruce	5% ↓
Grand fir	3% ↓
Red spruce	5% ↓
White fir	3% ↔
Noble fir	2% ↔
Silver fir	2% ↓
Others	1% ↔

Figure 5. The area of Nordmann fir is increasing rapidly.

During the past years, Christmas tree production has shifted more and more from forest to cultivation, which may be due to the changing preferences of customers—from the native *Abies alba* or *Picea abies* to larger needled, denser *Abies* species, mostly Nordmann fir (Figure 5). The better durability of the needles is another important reason for this change.

From 2000 to 2009, the members of the Association in Lower Austria increased the number of trees sold by nearly 75 percent (Figure 6). The number of Nordmann fir increased. During the same time, the average price fell from nearly € 20 to less than € 17 per tree until 2005, before increasing again to more than € 21 in 2009. The reason for the price decline was that the Association began to sell about 100,000 second-class trees to two large stores; thus, the numbers of sales per member rose, but the average price fell. At the same time, turnover increased, and the quality of plantations improved because the second-class trees were sold for a good price. This was very important because most Austrian growers sell their trees from their own stand or farm and therefore need high quality.

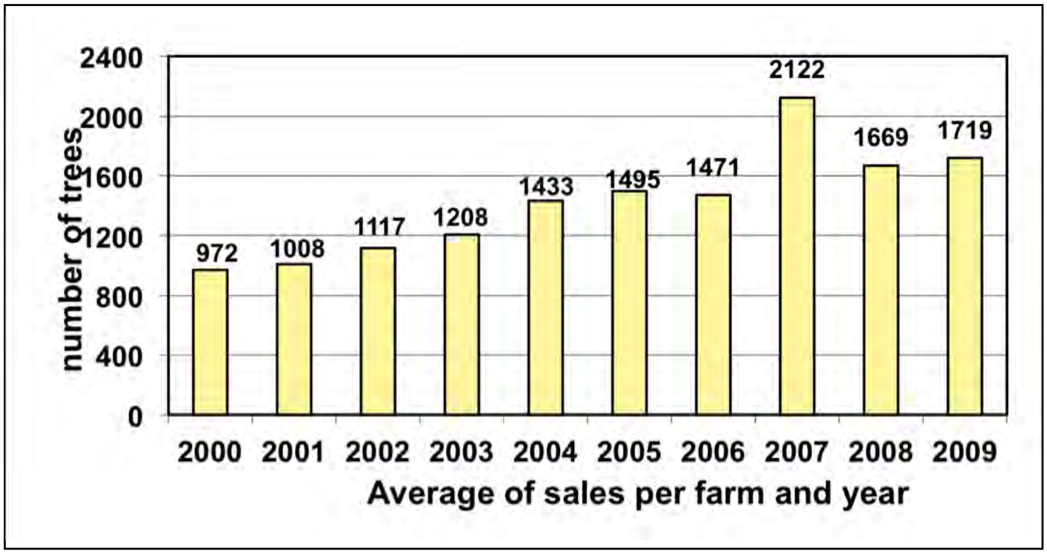

Figure 6. Sales by members of the Association in Lower Austria, 2000–2009.

The Association in Lower Austria tries to persuade their members to produce more A-trees and to use proper cutting methods and the Top-Stopp-Clipper. Various trials were made, often in cooperation with our research institutes. Examples include provenance trials, fertilizer and herbicide trials, and projects using cuttings of blue spruce. Courses to raise quality were offered, and a new branch regulator was found (Figure 7). Most of these things were communicated via the website http://www.christbaumtag.at.

Figure 7. Branch regulator to improve quality.

The provenance trial from 1996 showed that the Turkish provenances are not the best for the Austrian climate (Figure 8). A new trial beginning in 2006 compares 18 different Georgian and southern Russian Nordmann fir provenances.

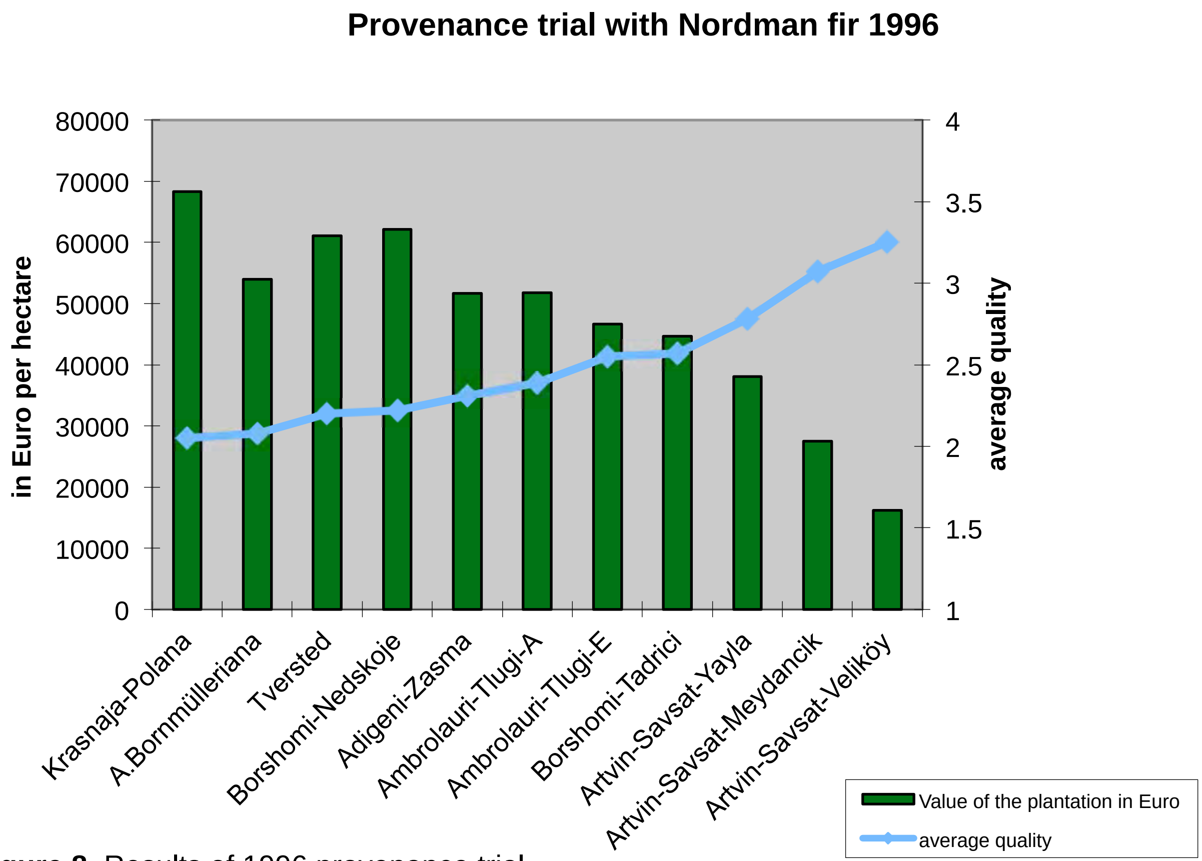

Figure 8. Results of 1996 provenance trial.

A new trial started in 2006 with 18 different Nordmann fir provenances. The first results showed the differing times of flashing of the leader bud (Figure 9).

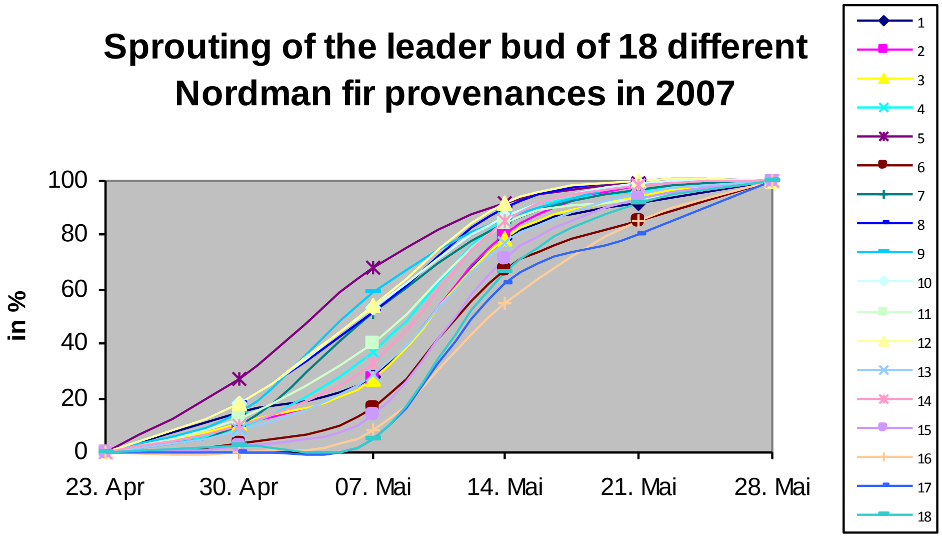

Figure 9. Dates of flashing of the leader bud for 18 Nordmann fir provenances, 2007.

Christmas tree fair in Lower Austria

One of the most important activities for the Association is the biennial Fair in Lower Austria (Figures 10 and 11). Between 500 and 1,000 growers come to see the new things in the business. The first fair was held in 1996 and was directed to growers who could not go to Langesø, the largest industry event. The fair offers an entire day with talks, machinery shows, exhibitions, field tours, field trial demonstrations, and evening talks. Also the "most beautiful Austrian tree" is chosen by visitors to the exhibition.

This fair is one of the three biggest in Europe beside Langesø and the German Fair.

Figure 10. Biennial Christmas tree fair in Lower Austria. Field tours are very popular with growers.

Figure 11. Biennial Christmas tree fair in Lower Austria, machine exhibition.

Seed orchard for Nordmann fir

Figure 12. Only very good quality branches were taken for the seed orchard.

Since 1996, when the Association of Christmas Tree Growers of Lower Austria was founded, members have complained of low-quality seed. Nordmann fir seed from nurseries had declined from previous years. Thus, we decided to establish a seed orchard for Nordmann fir in Lower Austria.

Some of our members had older trees of Nordmann fir in their plantations. The quality of these 20- to 30-year-old trees was the A quality of former times (Figure 12). The most important criteria were needle quality (color, length, and density) and growth form. Frost hardiness should also be good, because the trees clearly had no serious frost damage in the past 20 or 30 years, judging from the crown form.

Branches from these trees were grafted on 4-year-old Nordmann firs by staff from the Federal Research Centre of Forest (Figure 13). We founded 22 different clones on 5 stands that had the quality we wanted. We took material only from trees that had cones in the last years.

We looked for a field in an area with few silver firs in order to avoid crossings in the seed. We placed a poll-catcher in the field in 2005, 2006, and 2007 to see the influence of silver fir. The results are shown in Figure 14. The influence is very small, although there are some silver fir in this area and 2006 was a very good seed year for silver fir. We didn't want to establish the orchard in the northwestern part of Lower Austria, which is free from silver fir, because of the dryness of this area.

Figure 13. Potted trees after inoculation.

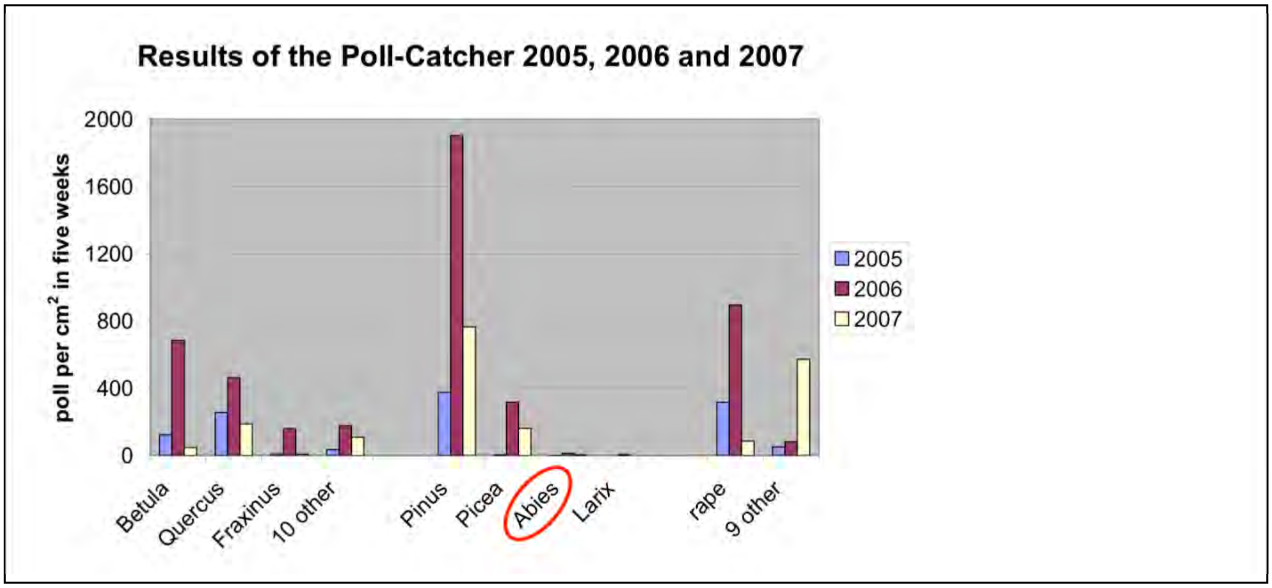

Figure 14. Results of poll-catcher, 2005–2007.

We will leave the poll catcher in the field. When the first cones grow, we will assess the influence of silver fir. If there is some influence, we can use artificial pollination.

As we wanted to know where the old trees are originally from, we sent some branches from each tree to ISOGEN in Germany to make iso-enzyme analyses. They compared the allele frequency of the three-gene locus GOT-B, PGI-A, and PGI-B with control samples. The genetic distance was very low to samples of Ambrolauri Lemaneori, and low to Ambrolauri Nikordcminda and to two samples from Bakuriani and Bordjomi. Thus, we know that the material is probably from the Ambrolauri area.

In autumn of 2007, the plants will be planted in the field we chose in the northern part of Lower Austria. The field is at the border of the natural range of silver fir. The plant spacing will be 4 to 5 meters in a kind of a triangular planting, so that the plants have enough space for growing and full sunlight for making cones. We have 2.5 hectares, so we need about 1,250 plants for the whole plantation or 60 plants from each clone. In a similar orchard of the Federal Research

Centre of Forest for silver fir, the first cones with seeding followed after about 7 years. The clone dispersal plan is made by specialists of the Federal Research Centre of Forest.

We are hopeful that in about 10 years we will have the first Austrian Nordmann fir seed and that it will be good quality. This is one further step in the right direction and a sign of the importance of working together. The next step should be more teamwork throughout Europe, with the European Association and the Christmas Tree Grower Council of Europe (CTGCE; see http://www.ctgce.com).

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IUFRO BUSINESS MEETING

24 August 2011

Minutes: IUFRO Christmas Tree Working Group, Hotel Steinberger, Eichgraben, Austria, 21:00 hours

Chal Landgren leading.

Old business: chair—Chal Landgren; deputies—Pascal Nzokou, Karl Schuster, and Ulrik Nielsen; newsletter—Bert Cregg; web page—Pascal Nzokou.

Nominations: Ulrik as chair; Bert Cregg and Gary Chastagner as deputies; Iben Thomsen, Forest and Landscape, University of Copenhagen, as secretary.

Reasoning behind nominations: Deputy moves up, Ulrik longest serving, moves up to chair. Leave one deputy position open for host of next meeting. Nominations agreed upon and move to accept (Jill O'Donnell). Second by all.

New business: Next meeting: Nova Scotia, with Pennsylvania and North Carolina as backup.

Shiyou Li will contact Nova Scotia personnel; he is concerned about having people on ground to line up field tours; organization of lectures is the easier part. Pascal—Raj Lade, researcher, works on Balsam fir in New Brunswick. Gary and Jill have contacts too. Rick Fletcher—large growers in southern Quebec.

Discussion: Preferred timing? Up to locals? Dovetail with NCTA national convention? Consider schools/university schedules for professors/spouses. Danes have Langesoe Fair, busy August. Don't have with NCTA—around Aug. 10–15. Check Canadian CTA schedule. 2015—Norway?

Newsletter: Bert asks for participation even if recycling articles from regional news. IUFRO likes newsletter. Karl will assemble the newsletter for Lower Austria Association. Abstracts to Chal October 1; will use the same editor.

Changes: Rick retiring, and Mike Bondi moving to Oregon State University administration. Claus Christensen replaced Kaj Østergaard with the Danish CTGA, and Lars Bo Pedersen replaced Claus. Welcome to new attendees—Hakan Şevīk and Burak Aricak from Kastamonu University, Turkey. Brian Davis, former IPM agent in North Carolina, now works with a private grower; IPM position filled. Jim Hamilton is back as director of Watauga Extension—some Christmas tree work. Terjer Hidle replaced Steiner Haugen of Norsk Pyntegront in Norway.

Collaborative opportunities: Species hybridization, marketing real trees, climate change and genetics work. Does it make sense to continue (through group) or more informally? Pascal—collaboration good, submitted joint proposal. John Frampton—did not necessarily follow groups, but collaborations started, especially among USA universities. Ulrik—just taking contacts to get info or host visitors ties up group/keeps together. Terjer—Norway topic of fertilizer/Mg problems; would like to work together. Chal—positive connections. Bert—bank of hybrid fir still in place, coning in Michigan. Can use. Ulrik—DK arboretum, old trees.

Other collaborative efforts: OSU—remote inventory with remote control “Hexicopter” carrying cameras (German technology). Finance problems facing all institutions—just being international contact helpful. Often don’t get $, but work to identify areas of concerns for all growers. Diverse skill sets needed, and we have within. Suggestion for a session at the next meeting—program manager from granting entity to give tips of what agencies look for. Use of Webinars. Expansion of production into eastern Europe—threat or opportunity? More $ for developing countries? European Christmas trees fall between forestry and agriculture. SCRI grants—national or regional? Cooperation viewed positively. Grant work—do homework between meetings; Skype after the new year? Talk of Washington, DC visit with program managers about Christmas tree projects—visit international agencies. Proposals need commitment for finance no matter who funds.

Meeting via Adobe Connect—better than Skype. US—talk with grower focus groups for current info; update within every region. January is usually the deadline for specialty crops grants. Feedback from specialty block grant administration—in justifying funding, multi-state impact proposals have more weight. Differences between states—North Carolina/Michigan don’t like competition for $. Danish update—only one full-time Christmas tree researcher. Tried for $—compete with Ag; political climate. Chal—positive note—entomology group success with TASC on international import/export issues; AHIPS entity; very receptive.

Adjourned 21:50

Prepared and submitted by:

AnneMargaret Braham

AnneMargaret Braham,
NCSU Christmas Tree Genetics Program

24 August 2011 IUFRO Christmas Tree Working Group Attendance:

AnneMargaret Braham
Chal Landgren
Paul Christensen
Kaj Oestergaard
Shiyou Li
John Ahrens
Ulrik B. Nielsen
John Frampton
Rick Fletcher
Hakan Şevīk
Burak Aricak
Jaroslav Kobliha
Pascal Nzokou
Inger S. Fløistad
Terjer Hidle
Claus J. Christensen
Lars Bo Pedersen
Gary Chastagner
Bert Cregg
Jill O'Donnell