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Job Satisfaction of Employees Horticultural Case Studies in Michigan

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Abstract

With growing farm sizes, retaining and motivating apt employees is becoming increasingly important. Limited management training of farmers and supervisors has led to concerns that labor retention and labor productivity are not sufficient, resulting in high turnover, depressed profits, and low farm wages. The paper analyses employees' job satisfaction as a factor in retention and motivation, based on in-depth interviews (n=30). A total of 14 Michigan businesses (four greenhouses, six nurseries, and four landscape contractors) participated in case studies focusing on their human resource management practices. Employees are much less likely to emphasize negative aspects of their work than positive ones. Supervisors and non-supervisory employees differ regarding their satisfaction with job components.

Introduction

With growing farm sizes, retaining, and motivating apt employees is becoming increasingly important. Limited management training of farmers and supervisors has led to concerns that labor retention and labor productivity are not sufficient, resulting in high turnover, depressed profits, and low farm wages. Job satisfaction of employees is considered to play a significant role in retention and motivation. Job satisfaction is believed to be closely associated with numerous work related behaviors, including performance, absenteeism, turnover, and organizational citizenship behavior (Fisher and Locke 1992; Locke 1976). Although job satisfaction is likely the most studied attitude in organizational behavior (Cranny et al. 1992), different theories coexist and the applicability of empirical results and the recommendations based on these results in agricultural contexts has not been determined. In addition, job satisfaction researchers discuss the use of unconventional methods to provide new perspectives on job satisfaction. As early as 1976, reviewing the state of job satisfaction research, Locke (p. 1343) concluded that research on job satisfaction has relied too much on rating scales and too little on interviews and has relied too heavily on correlational studies and could benefit from more case studies and in-depth interview studies. However, research methods have not much changed since then. This study is, therefore, taking a novel approach in both, research methods (case studies, in-depth interviews) and empirical field (horticultural employees).

Few studies of agricultural employees' job satisfaction have been published. Of those that have been published, very few appeared in peer reviewed journals, but rather in trade magazines or conference papers. Clegg (1963) studied county extension administrators as a replication of Herzberg et al. (1959). He interpreted the results as supporting the Herzberg model. Also, Bitsch (1996) studied horticultural apprentices in Germany and compared results to Herzberg et al.'s theory of job satisfaction. She found commonalities as well as differences to the Herzberg model for the studied population. Fogleman et al.

(1999) analyzed employees' job satisfaction on dairy farms based on Lawler (1973). Darboe (2003) studied job satisfaction among plant science graduates based on Vroom (1964). Billikopf (2001) interviewed agricultural supervisors, but did not contrast his findings with a theoretical model.

With respect to management practice, the Herzberg model has been the most influential of the above named approaches, as evidenced by a recent re-publication in the *Harvard Business Review* series "Ideas with Impact" (Herzberg 2003). Based on a literature review of job attitude research, Herzberg et al. (1959) developed a model of job satisfaction, which assumed that job satisfaction and dissatisfaction are not on opposite ends of a continuum, but are separate attitudes. They proposed that job satisfaction and dissatisfaction are caused by different underlying job factors and cannot substitute for each other for practical purposes. Their empirical study identified five factors as strong determinants of job satisfaction: achievement, recognition, work itself, responsibility, and advancement. These factors are called 'motivators.' Another group of factors caused or prevented dissatisfaction: company policy and administration, supervision-technical, salary, interpersonal relations-supervision, and working conditions. These factors are called 'hygiene factors.' Later replications of the seminal study found evidence for these and additional factors that the Herzberg model had postulated (Herzberg 1966). But job factors presented in research results vary widely, depending on the researched population.

This paper analyzes the job satisfaction of horticultural employees as an outcome variable, which employers seek to influence through their management practices. The Herzberg model is used to frame the reporting of the results and to compare non-supervisory employees and supervisors. In the process, the applicability of the Herzberg model is tested by applying it to an under-researched workforce (horticultural employees) and using a different research method. The original study employed the critical incident method, which is a semi-structured open-ended interview technique, focusing on exceptional experiences of the research participants (Herzberg et al. 1959). A more detailed discussion of the applicability of the Herzberg model to non-supervisory employees is provided in Bitsch and Hogberg (2005).

Material and Methods

This paper is based on a set of 14 case studies of human resource management practices in horticulture (four greenhouse operations, four landscape contractors, and six nurseries). All participating operations are located in Michigan and were visited between March and May 2003. The analysis is based on in-depth interviews with 15 non-supervisory interviewees and 15 supervisors (n=30). Interviewers used an interview schedule with open-ended questions on different aspects of human resource management practices. Respondents were encouraged to provide in-depth answers through probing. The order of questions was adapted to the interview flow. Themes brought up by the respondents were explored by the interviewers. In addition to questions directly related to job satisfaction, such as what respondents liked or disliked about their jobs, a number of questions on specific human resource management practices, such as training and employee evaluation, also yielded answers relevant to job satisfaction.

All interviews were tape-recorded and transcribed. Data analysis and coding were based on the transcripts, using the ATLAS.ti software package. The purpose of coding it to allow the comparative analysis of data by assigning data pertaining to the topic researched a specific label. The software serves as a data management tool to enable the inclusion of all occurrences of a specific work factor within each interview and their retrieval. Different from questionnaires, data pertaining to a specific factor could appear anywhere in an interview.

The coding scheme was modeled after the Herzberg model. In addition to satisfaction and dissatisfaction, ambivalence was included to allow for inner conflicts in job attitudes. Several of the job factors outlined by Herzberg et al. (1959) were collapsed to better adapt the coding scheme to the data, e.g., advancement, achievement, and possibility of growth were all coded as ‘achievement’ and responsibility was included in ‘work itself.’ Status was omitted from the coding scheme, because employees made no references to status.

The comparison and analysis of the job factors is based on the number of speech turns, not the number of respondents. Thus, when an interviewee talks about a specific factor at different times during the interview, each relevant speech turn is counted. Extended speech turns were broken into smaller units for comparability across factors and across respondents. This type of analysis assumes that a factor mentioned more often is more important to respondents.

Results

Results are presented in three sections each contrasting supervisors and non-supervisory employees: (1) aggregated findings on job attitudes, (2) specific results for individual motivators, (3) specific results for individual hygiene factors. Results are presented in percentages of total citations aggregated across each group of employees. Specific percentages cannot be generalized to the population of all horticultural employees, because the number of interviewees is relatively small. However, the percentages show trends regarding the job attitudes of the researched groups of employees.

Overall Satisfaction and Dissatisfaction - Supervisors and non-supervisory employees are similar in their overall attitudes towards their jobs (Table 1). Both groups of employees are more likely to talk about job satisfaction than to talk about dissatisfaction. Supervisors are slightly less likely to mention dissatisfying aspects of their jobs compared to non-supervisory employees; they are more likely to be ambivalent.

Table 1. Overall job attitudes of supervisors and non-supervisory employees.

	Job attitudes Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	59%	23%	18%
Non-supervisory employees (n=15)	63%	31%	6%

Motivators According to the Herzberg Model - Supervisors and non-supervisory employees are similar in their attitudes toward achievement at the workplace. This job factor, a motivator in the Herzberg model, shows the expected dominance of satisfied comments over dissatisfied comments (Table 2). Achievement can be considered a strong motivator for both groups of employees.

Table 2. Attitudes toward achievement of supervisors and non-supervisory employees.

	Satisfaction	Achievement Dissatisfaction	Ambivalence
Supervisors (n=15)	74%	14%	12%
Non-supervisory employees (n=15)	82%	18%	0%

Similar to achievement, recognition shows the expected prevalence of satisfied comments, indicating that it is a strong motivator. Supervisors’ satisfaction is slightly lower than non-supervisory employees’

satisfaction regarding recognition (Table 3). Potentially the supervisors are more conscious in providing recognition to their subordinates than their senior managers.

Table 3. Attitudes toward recognition of supervisors and non-supervisory employees.

	Recognition		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	59%	35%	6%
Non-supervisory employees (n=15)	70%	22%	7%

For the work itself satisfied comments also dominate dissatisfied comments, supporting its role as a motivator at the workplace. As seen with overall job attitudes non-supervisory employees are somewhat more likely to voice dissatisfaction than supervisors who are more likely to provide ambivalent comments (Table 4).

Table 4. Attitudes toward work itself of supervisors and non-supervisory employees.

	Work itself		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	58%	15%	28%
Non-supervisory employees (n=15)	58%	36%	7%

For all motivators (Table 2-4), the empirical findings support the Herzberg model for both groups of employees, which suggests a higher frequency of satisfied comments than dissatisfied comments for motivating job factors. Therefore, the Herzberg model is validated for motivators.

Hygiene Factors According to the Herzberg Model - The hygiene factors show a different picture than the motivators. The tendency suggested by the Herzberg model, a higher frequency of dissatisfied comments than satisfied comments, is the exception (Table 5-11). Therefore, the Herzberg model is not supported for the hygiene factors.

Both supervisors and non-supervisory employees show strongly positive attitudes toward job security (Table 5). Based on this result, job security should be interpreted as a motivator.

Table 5. Attitudes toward job security of supervisors and non-supervisory employees.

	Job security		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	100%	0%	0%
Non-supervisory employees (n=15)	85%	15%	0%

The interaction between personal life and work, which Herzberg et al. (1959) saw as a source of conflict and dissatisfaction, is seen very positive by non-supervisory employees. They have friends and family at work, and feel free to take time off when needed. Although supervisors are less satisfied and more ambivalent, they are still positive overall (Table 6). Supervisors often have to work longer hours and cannot be accommodated as easily, if they need to take care of personal issues during work hours.

Table 6. Attitudes toward personal life of supervisors and non-supervisory employees

	Personal life		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	56%	19%	26%
Non-supervisory employees (n=15)	90%	10%	0%

Employees have mostly positive comments regarding their supervision (Table 7). In general, they perceive their superiors as doing a good job in managing them. Therefore, supervision is more likely to act as a motivator than as a hygiene factor for horticultural employees.

Table 7. Attitudes toward supervision of supervisors and non-supervisory employees.

	Supervision		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	71%	20%	9%
Non-supervisory employees (n=15)	66%	30%	4%

Interpersonal relations at the workplace also are more likely to be mentioned in a positive context than to draw dissatisfied comments (Table 8). The somewhat higher frequency of dissatisfied comments for non-supervisory employees stems from two sources: relations with peers and relations with subordinates. Some interviewees, introduced as non-supervisory employees, have first-line supervisory responsibilities, but are not accepted by their peer as such.

Table 8. Attitudes toward interpersonal relations of supervisors and non-supervisory employees.

	Interpersonal relations		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	69%	19%	12%
Non-supervisory employees (n=15)	66%	31%	4%

Regarding the organization, its procedures and policies, employees have more positive than negative comments, with non-supervisory employees voicing slightly more dissatisfaction and supervisors being more ambivalent (Table 9). In general, employees accept policies and procedures as long as they leave enough room for individual cases. Dissatisfaction stems from policies and procedures not being enforced or a lack thereof.

Table 9. Attitudes toward organization of supervisors and non-supervisory employees.

	Organization		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	56%	24%	20%
Non-supervisory employees (n=15)	56%	38%	6%

While positive comments are still more frequent than negative comments regarding compensation, it is falling off compared to the previous job factors (Table 10). Wages are often seen as too low, particularly by non-supervisory employees; they also wished for more benefits. On the other hand, perquisites, such as lunches, end-of-season picnics, and work-related presents, are valued.

Table 10. Attitudes toward compensation of supervisors and non-supervisory employees.

	Compensation		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	52%	29%	18%
Non-supervisory employees (n=15)	49%	42%	9%

Non-supervisory employees are more positive regarding their working conditions than supervisors (Table 11). Typically supervisors are more stressed and show dissatisfaction with long hours. Only supervisors' attitude towards work conditions shows a higher frequency of dissatisfied comments than satisfied comments as suggested by the Herzberg model. Dissatisfaction with working conditions also relates to weather influences and low quality facilities.

Table 11. Attitudes toward working conditions of supervisors and non-supervisory employees.

	Working conditions		
	Satisfaction	Dissatisfaction	Ambivalence
Supervisors (n=15)	39%	45%	16%
Non-supervisory employees (n=15)	61%	33%	6%

Discussion and Conclusions

The Herzberg model of job satisfaction and dissatisfaction has provided a structured approach to analyzing employees' job satisfaction and classifying their job-related attitudes. This organizing function of the Herzberg model has proved useful for coding and data analysis, as well as for comparing supervisors and non-supervisory employees.

Regarding implications of the Herzberg model, namely motivators being more likely to cause job satisfaction and hygiene factors being more likely to cause dissatisfaction, the results of this study are not supportive. When accounting for employees' tendency to talk in a positive way about their job and its context, some factors that Herzberg et al. (1959) grouped as hygiene factors seem to function as motivators and some factors grouped as motivators are ambiguous.

Taking the overall attitudes of supervisors as a mean value and classifying factors with a frequency of satisfied comments notably above the mean as motivators, factors near the mean as ambiguous, and factors notably below the mean as hygiene factor, job factors fall into the following groups: (1) job security, achievement, supervision, and interpersonal relations are motivators; (2) work itself, recognition, organization, and personal life are ambiguous; (3) compensation and working conditions are hygiene factors.

For non-supervisory employees the frequency of satisfied comments indicates the following job factor

groups: (1) personal life, job security, achievement, recognition, supervision, and interpersonal relations are motivators; (2) work itself, organization, and working conditions are ambiguous; (3) compensation is a hygiene factor. Non-supervisory employees also voice more dissatisfied comments than supervisors regarding compensation, organization, work itself, interpersonal relations, and job security.

Supervisors and non-supervisory employees are similar in perceiving job security, achievement, supervision, and interpersonal relations as mostly satisfying, work itself and organization as ambiguous, and compensation as a hygiene factor, less so for supervisors than for non-supervisory employees. Non-supervisory employees perceive the interface between the job and their personal life more positive than supervisors and recognition also plays a more positive role for them. Working conditions play a more negative role for supervisors.

Summary

In this study, achievement and job security emerged as components of job satisfaction. The work itself plays an ambiguous role for non-supervisory employees, whereas supervisors see fewer negative aspects. Closely intertwined with the task itself are aspects of the working conditions, such as being outside, which is typically perceived as positive, and negative aspects, such as low quality facilities or weather conditions. Recognition is more satisfying to non-supervisory employees than to supervisors. The interpersonal relationships at the workplace also contribute to job satisfaction. The supervisory skills of their superiors is another important component of job satisfaction and responsible for employees' willingness to look for employment opportunities elsewhere. Business organization, policies, and procedures are additional components of job satisfaction or dissatisfaction. In general, procedures and policies are accepted as useful, particularly when leaving flexibility for individual cases. The compensation package is an important component of job dissatisfaction. Some non-supervisory employees are dissatisfied with their wages and the benefits available to them. Supervisors tend to be less dissatisfied with their compensation. Overall, employees are much less likely to emphasize negative aspects of their work than positive ones. Eliciting negative comments required intense probing, while interviewees liked to dwell on the positive. This corresponds with typical findings in job satisfaction studies of 70-90% satisfied employees, and does not necessarily indicate high satisfaction levels, but social expectations and response tendencies. The results of this analysis also correspond with findings by Bitsch (1996) on horticultural apprentices in Germany.

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Cone Stimulation of *Abies procera*

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Abstract

Noble fir (*Abies procera*), like many true firs, produces neither abundant nor frequent cone crops. In some periods, wild cone crops may be decades apart with precious little seed available for planting. Little information is available on *Abies* cone induction in general, with no literature specific to noble fir.

Noble fir has developed into the predominate Christmas tree species in the Pacific Northwest, replacing Douglas-fir. Currently, annual Christmas tree planting levels of noble fir in the Pacific Northwest exceed 7 million seedlings. Forest landowners in Oregon and Washington are increasing noble fir plantings above 1500 ft. elevation.

Noble fir seed orchards have been established at a number of sites in Oregon and Washington to help fill the seed needs for both Christmas trees and reforestation. These orchards contain clones selected by tree improvement programs. Yet, seed crop production has remained unpredictable, resulting in seed shortages and preventing capture of the full benefits from tree improvement.

This study investigated cone stimulation options that have operational relevance to seed orchard managers. Replicated trials were established at three orchard sites looking at 5 treatments. We used 3 rates of GA_{4/7}, applied the material at 2 different timing dates, and evaluated girdling. Results were mixed. One orchard showed no relationship to treatments for either cone or pollen production. Another orchard showed a treatment effect for cones but not pollen. At the third site, treatments influenced both pollen and cone production.

Materials and Methods

The experiment evaluated the effect of six stimulation treatments on cone and pollen production in noble fir seed orchards. The six treatments included three rates of GA_{4/7} applied at vegetative budbreak with girdling, one treatment at a medium GA_{4/7} rate applied 2 weeks following budbreak with girdling, one treatment of GA_{4/7} without girdling, and one control (Table 1). The number of cones present from the season before treatment (2003) and following treatment (2004) was counted for all trees. Pollen level following treatment was scored as high, medium and low.

Table 1. Treatment Overview.

Treatments	Girdling	mgGA _{4/7} / Inch DBH	Timing
1	None	0	NA
2	Double overlap	10	At vegetative budbreak
3(E)	Double overlap	20	At vegetative budbreak
3(L)	Double overlap	20	2 weeks after budbreak
4	Double overlap	40	At vegetative budbreak
5	None	20	At vegetative budbreak

Experimental treatments were replicated on three noble fir seed orchard sites. Trees selected for treatment were all >2" DBH and appeared not to have had heavy cone crops the previous year. Each treatment was applied to 24 selected candidate trees at each site. Where possible, all treatments were applied to ramets of the same clone. Treatments were randomly assigned to families at each orchard position while attempting to maintain a within-family distribution of treatments. The status of each orchard and treatment dates are summarized in Table 2.

For the double-overlapping girdling, a pruning saw was used to sever the cambium layer with overlapping half-circumferential cuts on opposite sides of the stem. The cuts were spaced 1.5 X stem diameter apart and overlapped 1" on both sides of the cut. The GA_{4/7} treatment used ProCone® containing 42 mg of GA_{4/7}/ml. The ProCone® was injected into holes drilled at a 30-degree angle 20 cm above the upper girdling cut and distributed evenly around the circumference. Hole depth was sufficient to hold the volume of ProCone® in the xylem.

Table 2. Summary of Orchard Site Information.

Owner, Location	AC.	Year Est.	Mean DBH (Inch)	# of Clones	Germplasm Origin	Treatment Dates
Bureau of Land Management, Colton, OR	3	1973	13.8	82	Oregon Cascade seed zones 451,452, and 462.	6/2/2003 & 6/18/2003
Weyerhaeuser Company, Sequim, WA	2	1974	11.4	53	53 clones selections from seed zones 041, 430 & 440. Cone production since 1999. Good pollen yields.	5/8/2003 5/22/2003
Dixie PNW Christmas Tree Association, North Plains, OR	2	1995	4.3	26	Coastal Oregon sources, No prior cone crops.	5/15/2003 & 5/29/2003

The operational methodology with respect to dose, volume and application of GA_{4/7} is summarized in Table 3. As an example, consider the 3(e) treatment applied to a tree 10 inches DBH (shaded). This tree received 250 mg. of GA_{4/7} at a rate of 20 mg. The GA_{4/7} was delivered as 4.8 ml of ProCone® distributed

in 4 drilled holes evenly spaced around the tree circumference above double overlapping girdles.

Table 3. Operational Summary of ProCone® dose, volume and hole numbers by DBH at various GA rates (10, 20, 40 a.i./ inch of DBH).

Mid Point	DBH	Dose of GA _{4/7} /tree (mg) for various DBH midpoints			Volume of ProCone/tree (ml) (42 mg a.i./ml)			Number of holes/tree- 1.2 ml of ProCone/hole (except where noted)		
		10	20	40	10	20	40	10	20	40 2.4 (mL per hole)
4	3-5	40	80	160	1.0	1.9	3.8	1 (0.6ml)*	2	2
6	5-7	60	120	240	1.4	2.9	5.7	1	2	2
8	7-9	80	160	320	1.9	3.8	7.6	2	3	3
10	9-11	100	200	400	2.4	4.8	9.5	2	4	4
12	11-13	120	240	480	2.9	5.7	11.4	2	5	5
14	13-15	140	280	560	3.3	6.7	13.3	3	6	6
16	15-17	160	320	640	3.8	7.6	15.2	3	6	6
18	17-19	180	360	720	4.3	8.6	17.1	4	7	7
20	19-21	200	400	800	4.8	9.5	19.0	4	8	8

The data were analyzed with ANOVA using SAS's GLM procedure (SAS Institute, Inc. 1988). Results are reported for a model that tested the effects of treatment and DBH on cone and pollen production in 2004 and for a model that included the effect of treatment and DBH on the increase in cone production in 2004 relative to 2003 levels.

Results

The results differed between seed orchard sites (Tables 4-6). There was no effect of stimulation method on either cone or pollen production in the BLM orchard. The experimental trees in this block were large, with mean dbh of 13.9", and larger trees produced more pollen and cones. By design, all experimental trees had few cones in 2003 (mean of 1.3 cones/trees). Most of the 144 experimental trees in this orchard, regardless of treatment produced cones in 2004, with 100 trees producing ten or more and 38 producing over 100.

In the Weyerhaeuser orchard, stimulation treatment had no effect on pollen production but, in models where cone production in 2003 was not factored in, the effect of stimulation method on 2004 cone production was significant. A series of orthogonal contrasts designed to detect differences among treatments revealed that stimulated trees produced significantly more cones than control ones ($F=8.50$, $p=0.0045$, d.f. =1). None of the differences among individual stimulation treatments, however, including girdled versus not-girdled, early versus late application of GA_{4/7}, and rate of GA_{4/7} proved to be statistically significant ($p \gg 0.05$ in all cases). As with the BLM orchard, the larger trees in this orchard produced more pollen and cones.

Trees in the Dixie seed orchard were much smaller (mean DBH of 4.3”) and not yet producing natural cone crops. Stimulation did have a statistically significant effect on cone and pollen production in 2004. Again, a series of orthogonal contrasts revealed that stimulated trees has significantly more cones than control trees ($F= 8.33$, $p=0.0045$, $df=1$), but no statistically significant differences among stimulation methods were evident ($p>>0.05$ in all cases).

Table 4. For each orchard site, mean DBH, # of cones in 2003 and # of cones in 2004 for each treatment and overall.

Orchard	Trait	Stimulation treatment						Average
		1	2	3E	3L	4	5	
BLM	DBH (inches)	13.9	13.3	14.5	13.3	14.2	14.3	13.9
	# cones in 2003	1.3	0.7	1.5	0.8	3.1	0.1	1.3
	# cones in 2004	52.0	49.0	61.8	46.0	79.1	70.7	59.8
Dixie	DBH (inches)	4.5	4.5	4.4	4.2	4.2	4.3	4.3
	# cones in 2003	0.4	0.0	0.4	0.3	0.6	0.0	0.3
	# cones in 2004	1.4	6.1	8.8	13.2	6.4	4.0	6.6
Weyerhaeuser	DBH (inches)	11.8	11.4	11.4	12.4	9.1	11.2	11.4
	# cones in 2003	22.3	8.9	8.3	6.4	19.6	10.8	12.0
	# cones in 2004	48.4	87.3	101.6	86.8	51.0	77.5	80.6

Table 5. The effect of stimulation treatment, dbh, and cone production in 2003 and cone and pollen production in 2004.

Orchard	Source of variation	Cone production in 2004				Pollen production in 2004			
		df	type III SS	F	P	Df	type III SS	F	P
BLM	Treatment	5	12424.9	0.45	0.8112	5	1.78	0.93	0.4608
BLM	DBH	1	58201	10.59	0.0014	1	4.96	12.98	0.0004
Dixie	Treatment	5	2115.3	3.78	0.0031	5	10.04	3.46	0.0057
Dixie	DBH	1	808.6	7.22	0.0081	1	1.05	1.81	0.1806
Weyerhaeuser	Treatment	5	7482.5	2.36	0.0467	5	3.46	1.14	0.3444
Weyerhaeuser	DBH	1	38876.7	12.26	0.0007	1	1.85	3.05	0.0841

Table 6. The effect of stimulation treatment and dbh on the increase in cone production in 2004 relative to 2003.

Orchard	Source of variation	df	type III SS	F	P
BLM	Treatment	5	11447.2	0.41	0.8387
BLM	DBH	1	52563	9.49	0.0025
Dixie	Treatment	5	2105.2	3.77	0.0032
Dixie	DBH	1	724.5	6.48	0.012
Weyerhaeuser Company	Treatment	5	60335.7	3.17	0.112
Weyerhaeuser Company	DBH	1	27769.7	7.3	0.0083

Discussion

The results showed that stimulation significantly increased cone and pollen production in one orchard, increased cone production but not pollen in a second and had no significant effect on pollen or cone production on trees in the more mature BLM orchard. We were unable to detect statistical differences among stimulation methods on any site. At all sites, large trees produced more cones.

One of the puzzles in the trial is why stimulation had no impact at the BLM orchard. One possible explanation might be the fact that there was a “natural crop” in 2004 in that area. This possibly masked any stimulation impact.

Future trails may investigate the use of calcium nitrate fertilization in addition to the 3E or 3L treatments used in this trial.

Environmental Control of Cone Production in Fraser Fir

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Abstract

Heavy cone production is a frequent problem in Fraser fir (*Abies fraseri*) Christmas tree plantations in Michigan. Cone production is controlled by a combination of endogenous and environmental factors, neither of which is completely understood. In order to better understand the influence of environmental conditions on cone production, I surveyed cone production in an operational Fraser fir Christmas tree plantation for three years; 2002, 2003, and 2004. Foliar carbon-13 isotope discrimination (an indicator of stomatal response to moisture stress) was determined for each year preceding the cone surveys. Foliar nitrogen concentration was determined on all trees in late summer 2004. Cone production was highest following the year with the greatest tree moisture stress and lowest following the least stressful year. Cone production increased with foliar N and tree size. The results suggest that growers may be able to reduce, though probably not eliminate, coning by irrigating during the early summer when next year's cone buds are formed.

Introduction

Fraser fir (*Abies fraseri*) is native to a relatively small geographic range in the southern Appalachian mountains of North Carolina and Virginia. In natural stands in its native region, Fraser fir does not reach reproductive maturity until age 15-30 years. Unlike other members of the Pinaceae, cones of true firs (genus *Abies*) do not persist entirely. Instead, the cone scales shed in the fall and only the cone stalks remain. The remnant cone stalks are unsightly and can reduce the value of Christmas trees or render them unsalable. The number of cones on a given tree can vary from a few to several hundred. Besides reducing the aesthetic value of a tree, the rapidly growing cone buds are a large sink for the tree's energy reserves. If cones are allowed to develop then current season needle growth may be significantly reduced (Powell 1974, Powell 1977). In Christmas tree plantations growers typically pick cones within a few weeks of cone bud-break. When the cone buds are less than 3 cm (1.25") long they can be easily pinched off. However, cone picking must be done by hand and can require significant amounts of labor.

Flower development in conifers is a complex process and year-to-year variability in cone production is common for most species (Bonnet-Masimbert and Webber, 1995; McDonald 1992). Flowering in *Abies* appears to be even more inconsistent than other conifers. While environmental and endogenous control of conifer flowering is not completely understood, there are several factors that are known to influence flowering. For the most part, our knowledge of these factors comes from studies directed at improving flowering of conifers in seed orchard production. Results of these studies indicate hormonal relations, endogenous patterns, temperature, water availability, nutrition, and tree size or age may influence conifer cone production. In Michigan, cone production in Christmas tree plantation varies annually and across

sites. Anecdotal evidence suggests that warm-dry weather in the previous summer results in high rates of coning.

The objectives of the current project were to characterize variation in cone production in an operational Fraser fir Christmas tree plantation and determine the relationship between coning and tree moisture stress.

For this study I used carbon-13 isotope discrimination as an indicator of tree moisture stress. The isotopic ratio of ^{13}C to ^{12}C in plant tissue is less than the isotopic ratio of ^{13}C to ^{12}C in the atmosphere, indicating that plants discriminate against ^{13}C during photosynthesis. Variation in discrimination against ^{13}C during photosynthesis is due to both stomatal limitations and enzymatic processes. Theoretical and empirical studies have demonstrated that carbon isotope discrimination is highly correlated with leaf stomatal conductance and plant water use efficiency. Ehleringer 1990, Farquhar *et al.* 1991. Stomatal closure during water stress results in decreased discrimination and carbon isotope discrimination of conifers is higher in wet years than dry years (Cregg *et al.* 2000) and higher under irrigation than under water stress (Olivas-Garcia *et al.* 2000).

Materials and Methods

In 2002, 2003, and 2004 I monitored cone formation, foliar nitrogen, and height on a large block of Fraser fir trees at a commercial Christmas tree farm (Tannenbaum farms, Mason, Michigan) near the Michigan State University campus. One block of 180 trees (6 rows x 30 trees) was surveyed each year. Mean tree height in 2004 was 2.21m (std. dev. = 39.5 cm) Trees were scored for number of female cones and pollen cones that developed each year.

I assessed tree moisture stress for 2001, 2002, and 2003 by carbon isotope discrimination analysis. Shoots were collected in 2004 from the upper half of each tree. The shoots were divided onto age-class samples for 2001, 2002, and 2003. The samples oven-dried, needles and stems were separated and the needles were ground to pass through a 40-mesh screen. The ratio of ^{13}C to ^{12}C of the foliage was determined at the Stable Isotope Unit, University of Waikato, New Zealand. Foliar N was determined on needles collected in the later summer of 2004.

Results and Discussion

The percent of trees producing cones varied ($P < 0.0001$) among years. Coning frequency was highest in 2003, with over 70% of trees producing cones (Fig. 1). Among the trees that produced cones, the average number of cones per tree was 53.3 in 2003 and 25.3 in 2004. All of the 44 trees that produced cones in 2002 produced cones in 2003 and 2004. There were 45 trees that coned in 2003 that did not produce cones in 2004. Seven trees (4% of total) produced pollen cones in 2003; no trees produced pollen cone in 2002 or 2004.

Coning frequency reflected tree moisture stress in the previous year as indicated by C13 discrimination. Carbon-13 discrimination was lower in 2002 than in 2001 or 2003, indicating reduced stomatal conductance due to increased moisture stress. Weather data from the Michigan State University Horticulture Teaching and Research Center (4 km from study site) indicate that mean daily high temperatures in June 2002 were higher than during the same period in 2001 or 2003. Rainfall was lower in June 2002 than in 2001 or 2003, especially in late June. Only 1.8 mm of rain fell during the last three weeks of June 2002. This period corresponds to the time when shoot growth Fraser fir in mid-Michigan is culminating. For many *Abies* species developing buds differentiate between vegetative and reproductive buds when the current year's shoot elongation is complete (Owens 1984, Owens and Molder 1977, Owens and Singh

1982).

Both temperature and water stress affect cone development (Owens and Blake 1985). However, it is often difficult to separate the two effects since warm years are frequently drier as well. Observations by Daoust et al. (1995) suggest that drought stress and elevated temperatures during the period of bud differentiation increased seed cone production in *Picea glauca*. Some of the strongest evidence for environmental control of coning in *Abies* is provided by Owens et al 2001. They significantly increased flower production in an *Abies amabilis* seed orchard in the Pacific Northwest by erecting small clear plastic tents over trees during the late-spring and summer. Air temperatures inside the tents increased up to 8°C above ambient. Placing tents over trees increased the average number of cones per tree from 3-8 to 22-24 compared to related treatments without tents. While it appears that high temperatures during the period of bud differential are the key environmental signal inducing cone formation, the data are not unequivocal since increased temperatures are often confounded with increased vapor pressure deficit resulting in increased transpiration and tree moisture stress

In addition to comparing moisture stress levels and coning, our data also enabled us to examine the effects of tree size and foliar nitrogen (N) on coning. Both frequency of coning and number of cones per tree increased with tree height (data note show) and foliar N (Fig. 2). This is consistent with a number of studies on cone production in conifers that suggest improved mineral nutrition increases cone production (Arnold et al. 1992, Ebell and McMullin 1970, Owens 1995).

Conclusion

The results of this study suggest that the effect of environmental conditions is superimposed over internal factors, such as tree age and biennial cone-bearing cycles (Powell 1977). From a practical standpoint, growers may be able to reduce cone formation by reducing tree moisture stress through irrigation, particularly early in the summer when the next year's buds are differentiating. The effectiveness of irrigation may be limited, however, during extremely warm weather. Cone production increased with foliar N but it appears nitrogen would have to be reduced to the point of deficiency in order to appreciably reduce cone production.

Acknowledgements

This research was supported by the Michigan Agriculture Experiment Station Project GREEN and the Michigan Christmas Tree Association. The cooperation of Tannenbaum Farms, Mason, Michigan is gratefully acknowledged. For growers that have the ability to irrigate this suggests that minimizing tree moisture stress can help to reduce coning. Growers can also improve moisture availability by maintaining good weed control.

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Table 1. Mean daily maximum temperature and cumulative weekly rainfall during June 2001, 2002, and 2003 at Michigan State University Horticulture Teaching and Research Center

Week beginning	Daily maximum temperature (deg. C)			Cumulative weekly rainfall (mm)		
	2001	2002	2003	2001	2002	2003
6/2	14.0	15.8	15.3	1.3	38.1	14.2
6/9	22.8	20.4	17.5	30.0	14.0	1.0
6/16	20.3	20.8	18.1	31.2	1.0	2.3
6/23	21.5	24.1	21.3	0.0	0.8	19.8
6/30	17.8	24.2	22.2	0.8	0.0	18.5
Total	19.4	21.2	19.0	63.2	53.9	55.9

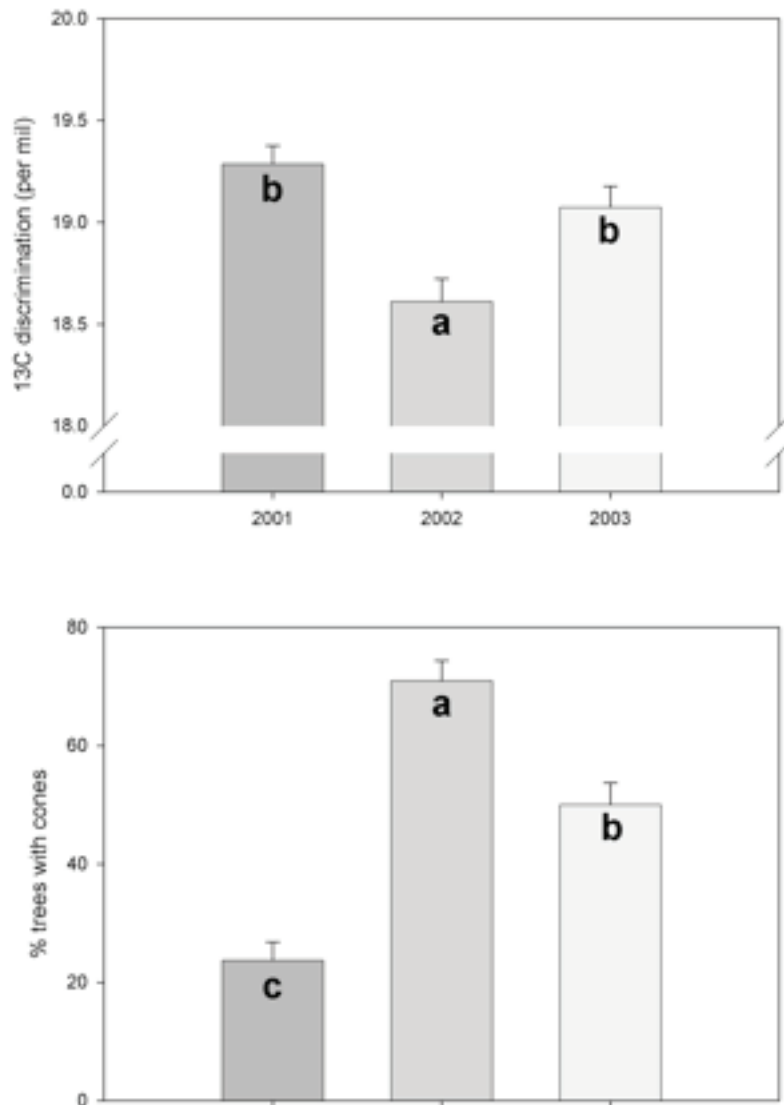


Figure 1. (top) Mean 13-C discrimination of needles formed in 2001, 2002, and 2003 in a Fraser fir Christmas tree plantation near Mason, MI (bottom) Coning frequency of Fraser fir trees in 2002, 2003, and 2004.

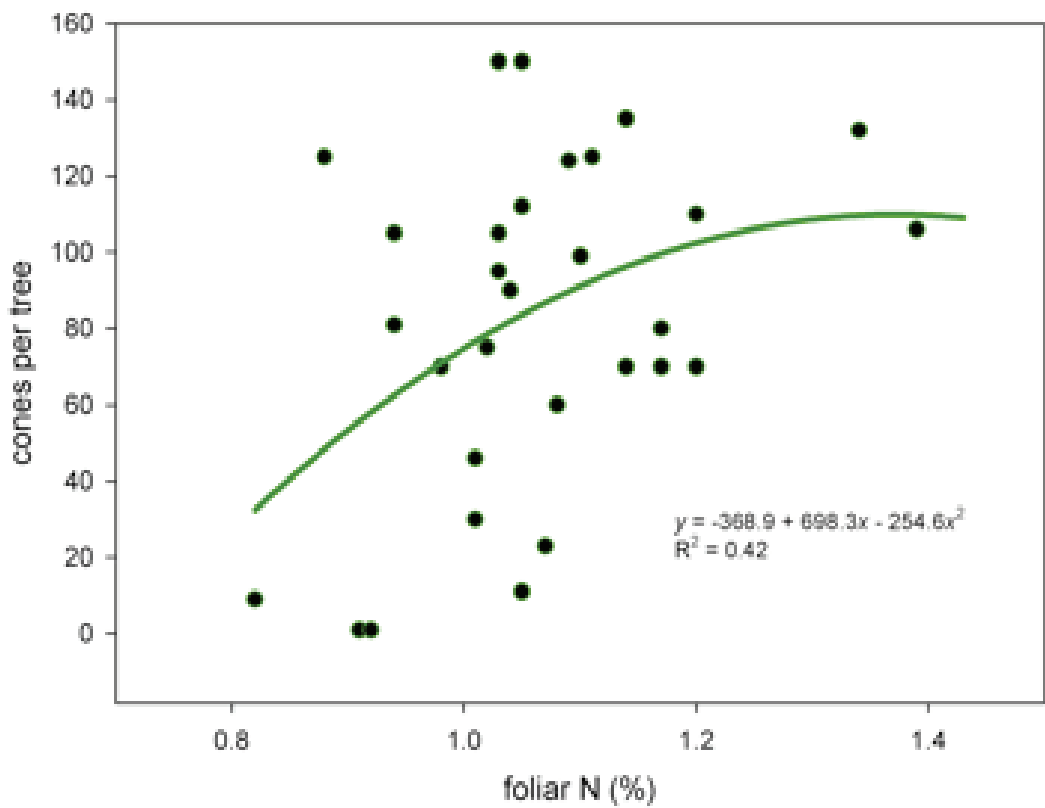


Figure 2. Relationship between cone density (cones per tree) and foliar nitrogen concentration of Fraser fir Christmas trees near Mason, MI, 2004.

Effectiveness of I-V Watering Devices in Maintaining Postharvest Freshness and Quality of Cut Christmas Trees

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Abstract

Experiments were carried out with cut Douglas-fir (*Pseudotsuga menziesii*) and Leyland cypress (*Cupressocyparis leylandii*) Christmas trees to evaluate postharvest water uptake, moisture status, needle loss, and tree quality when water was supplied to displayed trees either by an I-V device or a traditional method of placing the base in water. In both experiments, trees consumed about 4X as much water with the traditional method. Based on measurements of twig moisture content, xylem pressure potential (Ψ), needle loss, and total water consumption, tree freshness and quality was adequately maintained by the traditional method, but not by the I-V device.

Introduction

Displaying cut Christmas trees in water effectively minimizes drying and needle loss problems that reduce overall consumer satisfaction with real trees. Consumers have a large number of choices of water holding stands to display their trees in. Most of these stands consist of a water reservoir and a clamping device or center peg that holds the tree in a vertical position.

The effectiveness of stands depends on their water holding capacity and the need for consumers to maintain the water level in the stand so that it does not go dry. When stands go dry, air enters the xylem tracheids near the cut surface of the trunk. These air blockages greatly reduce water uptake even if the stand is refilled.

Another approach to supplying water to displayed trees is to use a device that operates on the principle of an intravenous feeding tube. A small hole is bored horizontally into the trunk, near the base, which is then connected to a water reservoir (i.e. milk jug) with a small plastic tube. The device acts as a siphon. When the tree loses moisture from the needles, it draws water from the reservoir through the plastic tube into the hole drilled into the trunk. Although these types of devices possibly make it easier to monitor water use by the tree, it is unclear how effective they are in maintaining the moisture status and quality of displayed trees.

Our objective was to compare the effectiveness of a commercially available I-V watering device to the traditional method of displaying the base of the tree in water.

Materials and Methods

Two experiments were conducted using Douglas-fir and Leyland cypress Christmas trees. Two versions of a I-V type watering device were tested. On Douglas-fir, the original TREE I-VEE (TREE I-VEE, Inc., P.O. Box 697, Missouri City -TX, USA) was used, while a newer version of this unit called the “Christmas Tree I-V Intravenous Water System” (Safechristmas.com, P.O. Box 697, Missouri City -TX, USA) was tested using Leyland cypress.

Douglas-fir test - Ten freshly cut sheared 6-7 ft tall Douglas-fir Christmas trees with trunk diameters of 6.3 cm were displayed in a large postharvest room maintained at $21 \pm 1^\circ \text{C}$ at Washington State University’s Research Center in Puyallup. The relative humidity was normally between 44% and 60%. Five trees were displayed with their freshly cut bases in a 19-liter bucket containing water, and the remaining five trees were fitted with TREE I-VEE’s. For trees attached to TREE I-VEE’s, three 1.3-cm diameter, intersecting holes were drilled into the stem of each tree about 20 cm above the base. The depth of each hole was about three-fourths of the trunk diameter. The TREE I-VEE system was then connected according to the manufacturer’s instructions to a clean, 3.8-liter plastic milk jug, which served as the water reservoir.

Trees were displayed for 4 weeks. Moisture status was determined periodically by measuring the xylem water potential using a pressure chamber. In addition, water consumption was measured daily by filling each bucket to a pre-determined mark. Needle loss was also assessed and overall tree quality was subjectively rated on a scale of 1 to 5, based on appearance: 1 (not acceptable), 2 (poor), 3 (fair), 4 (good), and 5 (very good).

Leyland cypress test - Four freshly cut 7-8 ft tall, dense Leyland cypress Christmas trees with trunk diameters a little less than 10 cm were displayed in a large room at North Carolina State University. Ambient temperature was $20 \pm 1.5^\circ \text{C}$; relative humidity 25% to 45%.

Two trees were fitted with Christmas Tree I-V’s by boring a 1.3-cm hole into the trunk about 20 cm above the base. The depth of the hole was about three-fourths of the trunk diameter. To avoid the risk of the reservoir running dry overnight, the tree was connected to a 19-liter bucket containing water that was set on a cinder block, giving about 0.6 m of hydraulic head. The freshly cut bases of the other two trees were then placed in buckets containing water.

The trees were display for 2 weeks. Changes in the percent moisture content (MC) were assessed periodically during this time, and water use was checked daily for 2 weeks.

Data from both experiments were analyzed with GLM procedures in SAS (SAS Institute Inc., 2000).

Results

Douglas-fir test - Trees fitted with I-V’s used only one-fourth as much water and dried significantly faster than trees displayed in water (Table 1). There were generally no significant differences in the loss of 1989 or 1990 needles on trees displayed in water or those attached to I-V’s. After 1 week of display, trees fitted with I-V’s had significantly lower moisture contents than trees displayed with their bases in water (Table 1). The longer the trees were displayed, the greater the difference in moisture levels became, which resulted in lower overall quality ratings (Table 1).

Leyland cypress test - Trees displayed with their bases in water used more than 12 liters of water in the first 2 days, compared to an average of 3 liters for the two trees fitted with I-Vs (Table 2). Water use decreased sharply after that, but total water consumption after 14 days was still about 4X greater for trees displayed in water. Initial MC averaged 142%. After 14 days, MC averaged 104% for trees displayed in water, compared to 35% for trees fitted with I-Vs. Trees in water had lost some quality as far as color and MC, but were still usable; in contrast, the trees with I-Vs were very dry.

Table 1. Water use, moisture levels, needle loss, and quality ratings for Douglas-fir Christmas trees fitted with a TREE I-VEE or displayed in water.

Trt ^a	Initial value	Display period (weeks)			
		1	2	3	4
Water use (liters)^b					
B	-	10.0 a	16.0 a	19.5 a	20.9 a
IV	-	3.7 b	4.0 b	4.2 b	4.2 b
Moisture level (-bars)					
B	9.2a	10.6 a	16.8 a	29.2 a	37.2 a
IV	9.2a	22.8 b	34.7 b	56.0 b	60.0 b
% Needle loss (1998 needles)					
B	8.4a	3.9 a	25.1 a	25.4 a	42.7 a
IV	7.5a	0.5 b	2.3 b	34.0 a	64.9 a
% Needle loss (1990 needles)					
B	5.2a	3.4 a	7.9 a	11.2 a	17.0 a
IV	3.2a	0.5 b	2.1 b	10.5 a	16.0 a
Tree quality ratings					
B	5.0a	4.8 a	4.2 a	3.6 a	3.0 a
IV	5.0a	4.6 a	3.2 a	2.4 b	1.8 b

^a B = displayed in water, IV=TREE I-VEE

^b Within each data set, numbers in each column followed by the same letter are not significantly different, P<0.05.

Table 2. Water use and twig moisture content for Leyland cypress Christmas trees displayed in water or fitted with a Christmas Tree I-V.

Trt ^a	Stem diam. (cm)	Water use (liters) ^b			Twig MC (%)	
		2 days	7 days	14 days	Initial	Final
B	83	12.5 a	15.8 a	22.2 a	145 a	104 a
IV	85	3.0 b	4.4 b	5.8 b	142 a	36 b

^a B = displayed in water, IV=Christmas Tree I-V

^b Within each column, numbers followed by the same letter are not significantly different, P<0.01.

Discussion

Although these experiments used a limited number of trees, results clearly showed that a properly maintained, traditional water holding stand would be superior to the I-V watering systems we tested in supplying water to Christmas trees to maintain their freshness and quality during display.

Numerous studies have documented total water consumption by Christmas trees, but none have described water movement in the stems of cut Christmas trees. Because Christmas trees are typically 5 to 15 years old from seed when they are harvested, virtually all the wood (xylem) is sapwood and likely contributes to water uptake. Since lateral (tangential and radial) movement of water in tree stems is slow compared to vertical movement up the tree, the ability of I-V types of devices to supply water should be primarily a function of the cross-sectional area of xylem that is exposed across the grain within the bored hole.

Based solely on a comparison of the xylem cross-sectional area that is exposed to water, the effective absorbing surface on the Leyland cypress trunk that were displayed in water would be about 5X greater than the absorbing surface area of trees attached to the I-Vs. In reality, there is probably some water uptake tangentially in the drilled hole, which would reduce the difference. In our experiments, both species used about 4X more water when displayed in water, which more or less confirmed expectations.

The major difference between the units we tested was the number of holes recommended to be drilled into the stem of the tree and the number of units that were to be attached to each tree. Instructions for the TREE I-VEE unit indicated that "Drilling one hole will enable your tree to drink, however for maximum efficiency drill 3 intersecting holes. The holes do not have to intersect exactly, any intersecting will allow water from the flow plug to pass into the other holes and finally into the main drinking areas of the tree". In the experiment with Douglas-fir, the use of multiple drill holes suggested a greater potential for water uptake, but actual water uptake was still only about one-fourth the amount for the traditional water holding stand.

Although displaying trees with their bases in water was clearly superior to using I-V water devices in our tests, consumers need to pay attention to the water holding capacity of the traditional types of stands they use to display their trees to minimize the chance the stand will go dry. Although a dry stand directly results from failure to adequately monitor and replenish the water, the overwhelming contributing factor to this problem is using a stand with a reservoir that is too small.

Water consumption varies by species, but as a general rule Christmas trees use about 1 quart of water per day for each 1 inch of trunk diameter. Thus a tree with a 4-inch diameter base, would need a stand that holds a minimum of 1 gallon of water. Even then, the stand would need to be checked daily by the consumer.

Acknowledgements

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Control of *Abies* Leader Growth in Oregon Christmas Trees via Chemical and Mechanical Manipulation

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Abstract

Annual leader growth of noble fir (*Abies procera*) and Nordmann fir (*Abies nordmanniana*) on Christmas tree farms in the Pacific Northwest during the last few years of the production cycle typically exceeds the 8-14" (20-35 cm) that is desired for proper spacing of whorls. Techniques of leader growth reduction utilizing physical scarring (Top Stop nipper) and application of Ethyl-l naphthaleneacetate (NAA), individually and in combination, were adapted from Danish techniques, and applied to Christmas trees in Oregon during 2004 and 2005. Results were somewhat variable by species, treatment and individual tree response, but overall revealed growth reduction possibilities in the 25-50% range, with the highest rates of hormone applications causing leader mortality, and the lower rates failing to reduce leader growth. A concurrent trial utilizing various surfactants with the growth hormones revealed possible differences depending upon surfactant applied. This range of responses provides significant opportunities to successfully use these techniques to reduce leader lengths operationally.

Introduction

Over the past decade, noble fir (*Abies procera*), has grown to 45% of Oregon's 8 million + annual Christmas tree production. Growing conditions in western Oregon can produce excellent quality trees in 7-8 years. One problem continuing to impact tree quality and profits has been too much leader growth during the last few years of the rotation. Noble fir trees typically start slow and may take 4 years to reach 1 meter in height. With succeeding growth years, some noble trees will begin to grow rapidly, producing annual leader growth of 20 inches (50cm) or more. The resulting unequal density of tree is not desired by growers, and can cause growers to cut leaders back to the desired 8-14 inches (20-35 cm) annual growth.

Cutting leaders creates several additional problems for growers. First, removing the terminal bud cluster disturbs the natural whorled shape of the tree and necessitates locating buds along the leader to serve as a surrogate terminal whorl. Another problem is finding a bud on the leader that can become a new terminal, and then making the cut accurately to favor the bud. Further, many times this bud has to transition from a branch bud to a leader bud, and turn up vertically during the next growing season. This is far from a guarantee, and sometimes growers need to straighten 50% or more of these leaders the following year utilizing a stick and ties. This tie up procedure can cost \$.50 or more per tree, per year, so the costs over a rotation can be significant.

OSU Extension agents worked with growers during the 1970's and 1980's to test a variety of leader control techniques. One method involved deep cuts at the base of the previous leader during early spring growth. The idea was to sever the conducting tissue nearly all the way around the stem, disrupting the flow of water and nutrients to the newly emerging leader, and reducing its growth. Although this technique was somewhat successful, giving a maximum reduction of about 25%, ultimately growers rejected it because it did not give enough growth reduction and tended to weaken leaders so that they sometimes broke off during harvest. Another technique utilized rubber bands to constrict growth of leaders, but this also was rejected by growers.

During the past decade, the Danish Christmas tree industry has been developing techniques for leader growth control in Nordmann fir (*Abies nordmanniana*). One strategy is a pair of pliers, called Top Stop Nippers, with thin metal blades that cut into the leader, severing the cambium and phloem most of the way around the leader. Another strategy utilizes the growth hormone, Ethyl-1 naphthaleneacetate (NAA), applied either with a sponge roller or sprayer to the newly emerging leaders in the spring. Extension agents Fletcher, Bondi and Landgren discovered these techniques in their travels to Denmark and began testing them in Oregon during 2004, with the help of Danish inventors Lars Geil (Top Stop Nipper), and Lars Madsen (Easy Roller).

Materials and Methods

2004 Plots - During May 2004, Fletcher and Landgren acquired Top Stop Nippers and with the help of Lars Geil installed plots on noble and Nordmann fir in the Willamette Valley of western Oregon. Each plot included 20 randomly assigned trees each for 4 treatments including controls, 2, 3 or 4 "nips" on the leader (1 nip = 4 incisions). In addition, one plot was established using NAA at 100 ml/L as Tip Off. Unfortunately, the plots were installed when new growth had already emerged too far on some plots, so the results were highly variable.

Results

2004 Plots - Although timing was a bit late for ideal evaluation of treatments during 2004, some of the plots did show a response. The Hupp plot showed a significant reduction between control and nipped trees, but not significant differences between nipped treatments. For the other three plots the average leader length actually increased as the number of nips was increased from 2 to 4 (Table 1). On the Holiday Tree Farm plot, all of the nipping treatments produced longer leaders than the control treatment. When a maximum length standard of 40 cm was applied the leader reduction impacts became a bit clearer, however, with 73% of the noble fir control trees needing cutting, compared with 50-60% of the treated trees. For Nordmann fir 54-60% of control trees needed cutting, while the nipped trees ranged from 20-50%. At least on the Eagles View plot the reduction in trees needing cutting was approximately 50% with top nipping. Although inconsistent, these results provided hope that greater results were possible.

Table 1. Plot Results from 2004 Top Nipper Plots.

Treatment	Leader Growth (cm)				Leaders > 40 cm (%)		
	Noble HTF Hupp		Nordmann HTF EVF		Noble	Nordmann HTF EVF	
Control	38	55	37	40	73	60	54
2 Nips	38	42	41	33	55	50	32
3 Nips	35	42	35	33	50	20	21
4 Nips	38	40	42	35	60	43	26

An additional site was established near Silverton Oregon with 100 trees per row treated with the same 4 treatments. At the end of the growing season the grower completed the yearly trimming and tallied how many from each treatment needed to be top cut. Results (Figure 1) revealed a steady and significant decline in % of trees needing top cutting. Although this was not a randomized study, so significance testing is out of the question, a reduction from 75% to 31% in trees needing top cutting certainly got the attention of the grower. Assuming Hupps are growing 1500 trees per acre, with 50% of cut leaders needing tying, and \$.50 per tree in tying costs, this amounts to a cost savings of \$165 per acre in just one year $((1500 \times .75 \times .50 \times \$0.50) - (1500 \times .31 \times .50 \times \$0.50) = \$165)$.

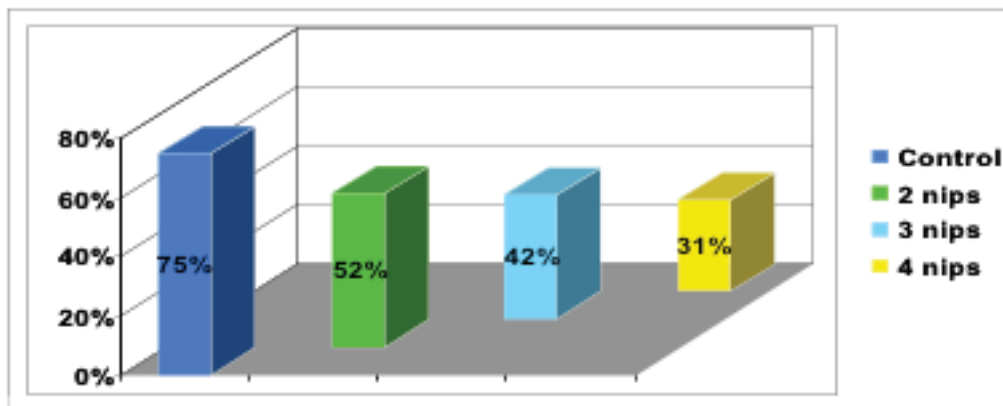


Figure 1. Hupp Nobles: % of trees with cut leaders 2004.

Application of NAA as Tip Off provided interesting, but inconsistent results (Figure 2). A single swipe on the tree on either June 3 or June 16 provided a significant leader reduction (19.9 average to 11.9 average). When the treatment was increased to two swipes, however, the effectiveness did not increase as might be expected. The only apparent reason for these inconsistent results appears to be that many of the leaders on certain treatments might have been too long when they were treated, and there were too few trees treated to overcome the non-responders. Still, many of the trees on the 2004 plot showed significant reduction.

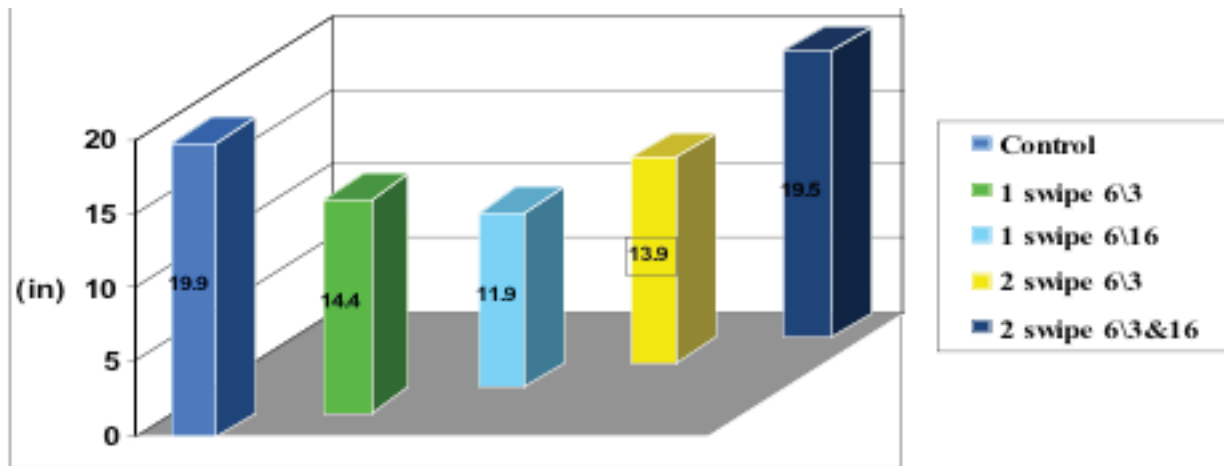


Figure 2. Schmidlin Noble Fir Response to NAA Treatment 2004

Encouraged by the preliminary results of 2004, the research team designed a new set of plots for 2005 to examine top nipping, chemical application and a combination of the two. Treatments included:

Randomized individual tree plots

- A. Top Stop Nipper; 4 nips (16 incisions)-
- B. Easy Roller; 1 treatment. Sucker-Stopper RTU (rate=40ml/L+ 2.5ml/liter of organosilicone surfactant, EXT 629-turpine resin) + Distilled Water.
- C. Treatment A + B
- D. No Treatment

In addition, the team was interested in exploring how the trees might respond to higher rates of NAA application, different methods of application, and different sources.

There are several sources of NAA commercially available in Europe and the USA. During 2004 the source procured was Tip Off, a material used in England. For 2005, the intent was to use sources commercially available in the United States and mimic rates of Pomoxone, the common source used in Denmark. Sources of NAA with corresponding concentrations are listed in Table 2 below.

Table 2. Comparative Use Rates of NAA for different commercial sources.

Product	NAA % a.i.	ml product/L water	NAA
Pomoxone	1.5	15	0.2
Pomoxone	1.5	30	0.5
Sucker-Stopper RTU	1.15	20	0.2
Sucker-Stopper RTU	1.15	40	0.5
Sucker-Stopper RTU	1.15	80	0.9
Sucker-Stopper RTU	1.15	120	1.4
Sucker-Stopper RTU	1.15	250	2.9

Tip Off	0.24	50	0.1
Tip Off	0.24	100	0.2

As the plots were installed, we noticed a lot of beading up of the chemical as it was applied, and began to question what surfactants might best carry the NAA into the leaders. In Denmark, the standard surfactant treatment includes a silicone spreader and a non-homogenized buttermilk sticker. TipOff, a chemical used in England uses an industrial cleaning solvent as the surfactant. We initially secured Ext 629, a common organosilicone surfactant, but also ended up testing several others.

Extra treatments using NAA at higher rates than used in Europe were of installed to test the efficacy and safety margin of the NAA treatment. They were not randomized, and were oriented in rows. These were applied on sites with discretion of grower/agent due to the risk of killing leaders and ruining trees. These extra treatments included:

- E. Easy Roller- Sucker-Stopper RTU -80 ml/L + surfactant + Distilled water
- F. Easy Roller- Sucker-Stopper RTU- 120 ml/L+ surfactant +Distilled water
- G. Easy Roller- Sucker Stopper RTU- 250 ml/L + surfactant + distilled water.
- H. Easy Roller- TreHold- 40 ml/L + surfactant + distilled water.
- I. Easy Roller- Tip Off- 100 ml/L + surfactant + distilled water.
- J. Easy Roller- Sucker-Stopper RTU- Out of bottle-No additional surfactant.

Other 2005 Plot Parameters:

Species of Interest - Noble fir, Nordmann fir, Turkish fir

Tree size at treatment - 3-5 feet tall

Treatment Trees - Trees that have grown more than 14 inches the previous year and otherwise appear healthy and/or were expected to exceed 16 inches of growth during the current growing season.

Experimental Design (randomized individual tree plots) - Each set of treatments was repeated 50 times for each plot, using a randomly assigned order each time (200 trees per plot). Treatment trees were flagged with colored flagging and number to identify treatment applied, according to colors listed above under treatments.

Timing of Treatments - Top stop nipper treatments were applied when leader buds on treatment trees were between ½ inch - 2" of new growth. Easy roller treatments began when new leader growth was 3-6 inches long.

Measurements - Measurements taken included total height and previous year's leader growth at time of treatment, length of new bud growth at treatment, and current year leader growth after treatment.

Plot Locations - Plots were located throughout the Willamette Valley in Oregon.

<u>Plot Location</u>	<u>Species</u>	<u>Grower</u>	<u>Plot Installer</u>
Beaver Creek	Noble	Holiday	Rick Fletcher
Peterson Road	Nordmann	Holiday	Rick Fletcher
N. Plains	Noble	Schmidlin	Chal Landgren
Stafford	Noble	Muhlenberg	Mike Bondi
Highland	Noble	Low	Mike Bondi

2005 Randomized 200 Tree Plots - Average leader length can be significantly reduced for noble fir and Nordmann fir using mechanical nippers, chemical hormone treatments, and a combination of these

methods (Figure 3). Current season leader length can be reduced about 3” to 6” when using the Top Stop Nipper or a 1.15% NAA growth hormone chemical application. Combining these treatments reduced average leader growth by about 7” on noble fir and up to 10” on Nordmann fir (Figure 1).

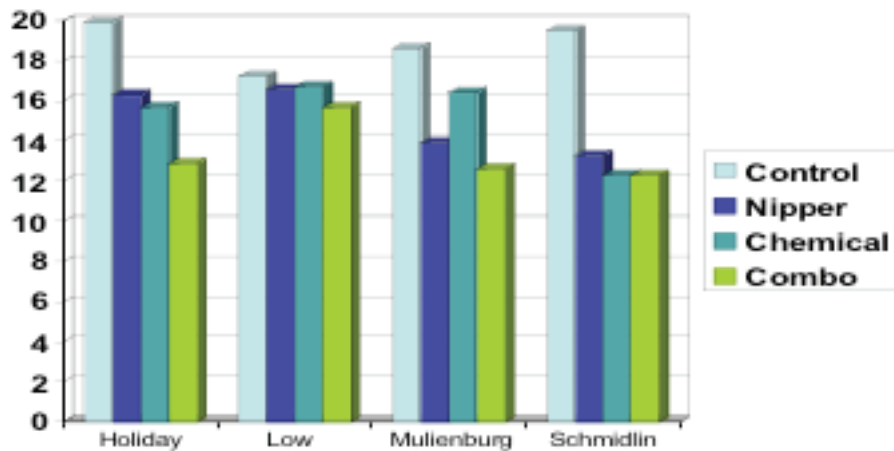


Figure 3. Average Noble Fir Leader Lengths following 2005 treatments.

An assessment of the proportion of noble fir and Nordmann fir tree leaders within a target growth range of 8-14” was determined as another method for measuring response. This estimate provides an indication of how many trees will require top working—a labor intensive and expensive field practice. This analysis used a generalized linear model to fit the data. The probability of a tree meeting the target growth was modeled as a function of the mechanical, chemical, and the interaction of these two treatments. The data were modeled as a binary with a logit link using PROC GENMOD in SAS v 91.

The proportion of noble fir trees estimated to achieve target growth with no treatment (i.e., control) ranged between 17 and 27%, depending on site. The mechanical (nipper) and chemical (hormone) treatments had similar effects on leader growth with the proportion of trees estimated to achieve target growth ranging between 40 and 52%. Applying both treatments together on the same tree (i.e., combination) further increased the target growth proportion to between 62 and 74%. See Figure 4.

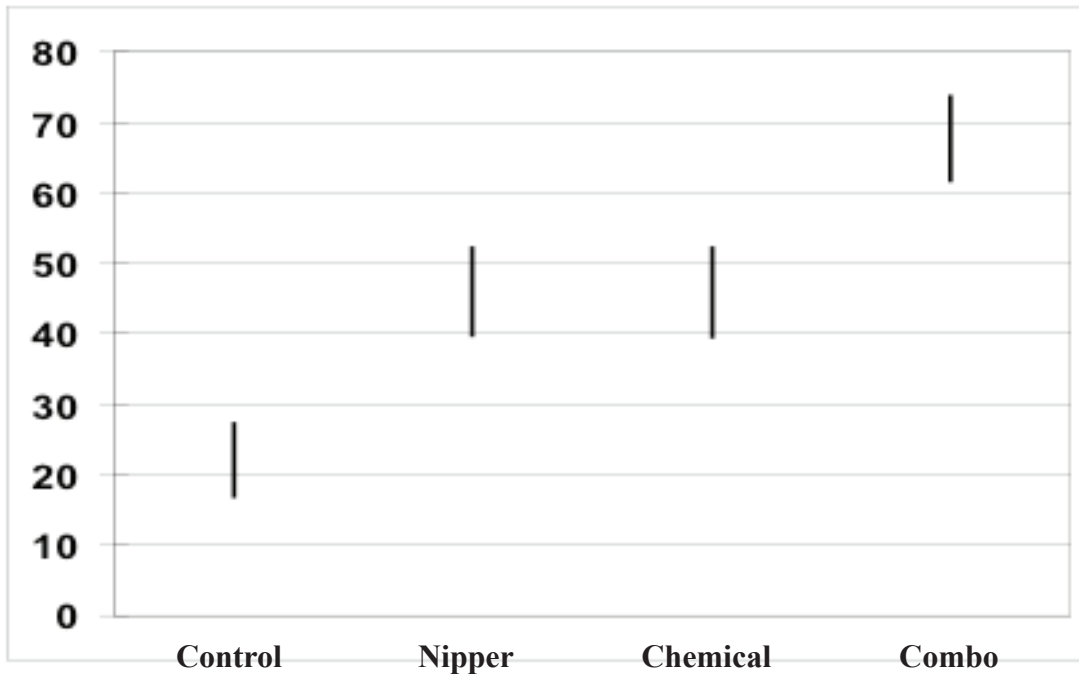


Figure 4. Proportion of noble fir trees achieving target growth in each treatment, all site locations combined. Confidence limits represent significant differences between the control and all other treatments ($p < 0.001$). The nipper and chemical treatments were not significantly different.

The individual noble fir site data are shown in Figures 3, 4, 5 and 6. Note that the strongest and most significant treatment effects were seen at the Holiday site. No treatment responses were observed at the Low site. Only a combination effect was measured at the Mulienburg site. And, treatment differences between the control and both the mechanical and chemical treatments were recorded at the Schmidlin site, but not between the combination treatment and the mechanical treatment.

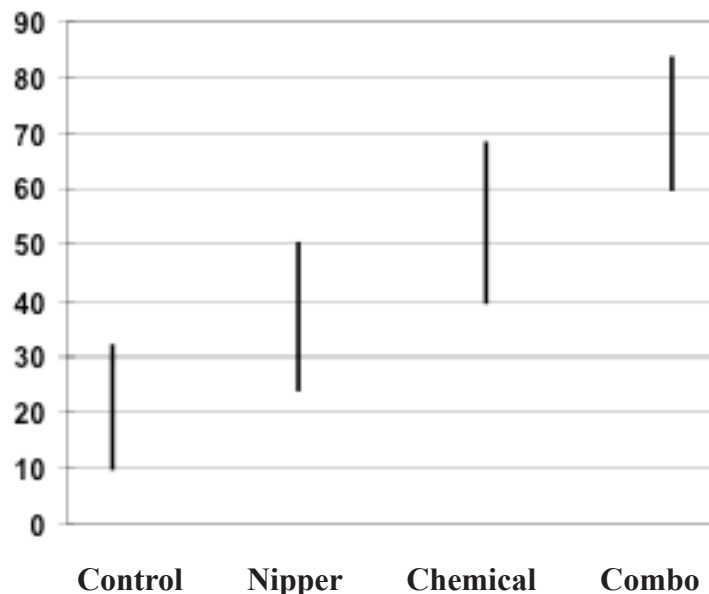


Figure 5. Proportion of noble fir trees achieving target growth at the Holiday Tree Farm site, Corvallis,

OR. Confidence limits represent significant differences between all treatments ($p < 0.001$).

Figure 6. Proportion of noble fir trees achieving target growth at the Low Tree Farm site, Beavercreek, OR. There is only a weak significant difference between the combination treatment and the nipper and chemical treatments ($p < 0.1$).

Figure 7. Proportion of noble fir trees achieving target growth at the Mulienburg Tree Farm site, Stafford, OR. There is only a significant difference between the combination treatment and other treatments ($p < 0.001$).

Figure 8. Proportion of noble fir trees achieving target growth at the Schmidlin Tree Farm site, North Plains, OR. There is significant difference between the control and all other treatments, but not between the mechanical or chemical treatments, nor between the mechanical and combination treatment ($p < 0.001$). The most dramatic treatment effects were observed on the Nordmann fir site (see Figure 7). However, only one Nordmann fir site was evaluated, so the data set is limited. Interestingly, no Nordmann fir control trees had leader lengths less than the upper target limit of 14"! 22% of the nipper treated leaders achieved the target growth range of 8-14". This is contrasted with 46% of the chemically treated leaders and 85% of the combination leaders.

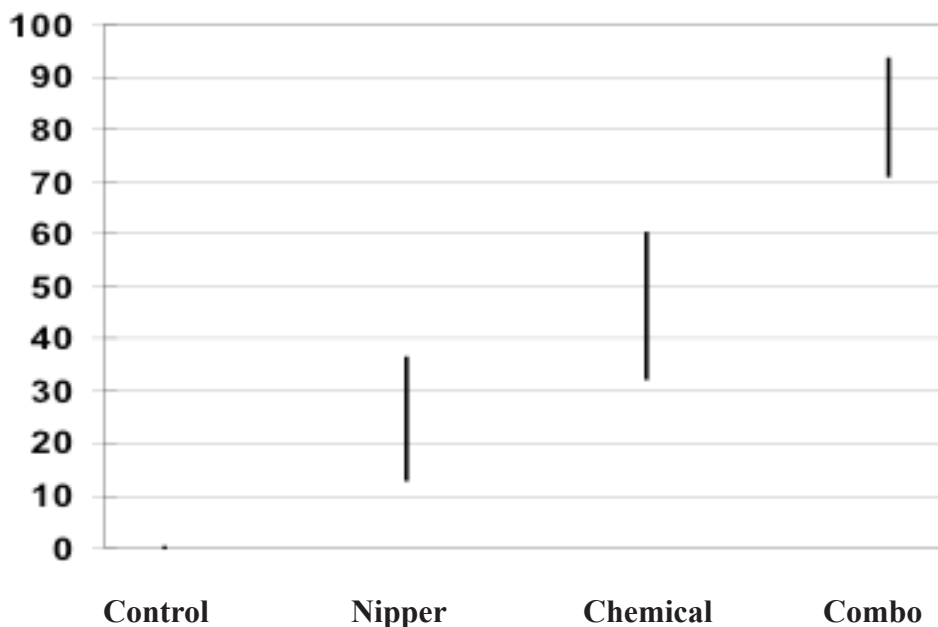


Figure 9. Proportion of Nordmann fir trees achieving target growth in each treatment for the only site location—Holiday Tree Farm, Corvallis, OR. All treatment differences are significantly ($p < 0.001$).

Extra NAA Rates and Sources - Extra treatments installed on the noble fir plots on Holiday (HTF) and Schmidlin (SCH) showed a much more consistent and greater response to NAA applications than the 40 ml rate used in the randomized plots (Table 3). On both plots, leader length reached a desired 12" average with 80 ml/L of NAA as Sucker Stopper. At the 120 and 250 ml rates, the average leader length was actually shorter than desired, potentially adding unwanted years to the rotation length. Buds per inch increased steadily as the rate of NAA increased. The one exception to the rate response curve was using

the TipOff source, which allowed more leader growth at 100 ml NAA concentration than 80 ml NAA applied as Sucker Stopper. The main explanation for this unexpected result was that the Tip Off was applied more than 1 week later than the Sucker Stopper, so the growth was more advanced. Although these were not replicated plots, the consistency of response argues for a relatively linear dose-response curve (Figure 10).

Table 3. Noble fir leader responses to different rates and sources of NAA. HTF= Holiday Tree Farms; SCH= Schmidlin Tree Farm.

Treatment	Leader Growth (in)		Buds per inch	
	HTF	SCH	HTF	SCH
Control	18.6	18.9	.63	1.1
40 ml\L	15.1	15.2	.82	1.3
40 ml\L TreHold	14.3		1.0	
80 ml\L	12.1	12.0	1.0	1.4
100 ml\L Tip Off	13.7	15.1	.90	1.3
120 ml\L	9.9		1.2	
250 ml\L		10.8		1.7

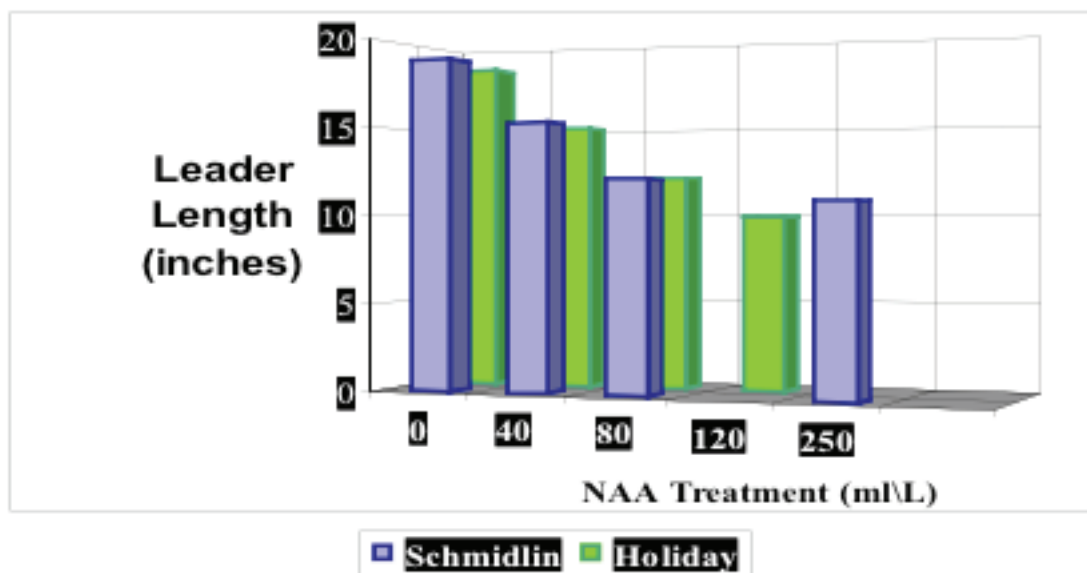


Figure 10. Noble fir leader lengths by rate of NAA applied.

Buds per inch also gives a very positive relationship as the NAA dose increases and leader lengths decrease, without any reduction in internode buds (Figure 11). This is a significant discovery, which should be related closely to trees quality as the retained buds become branches in the future.

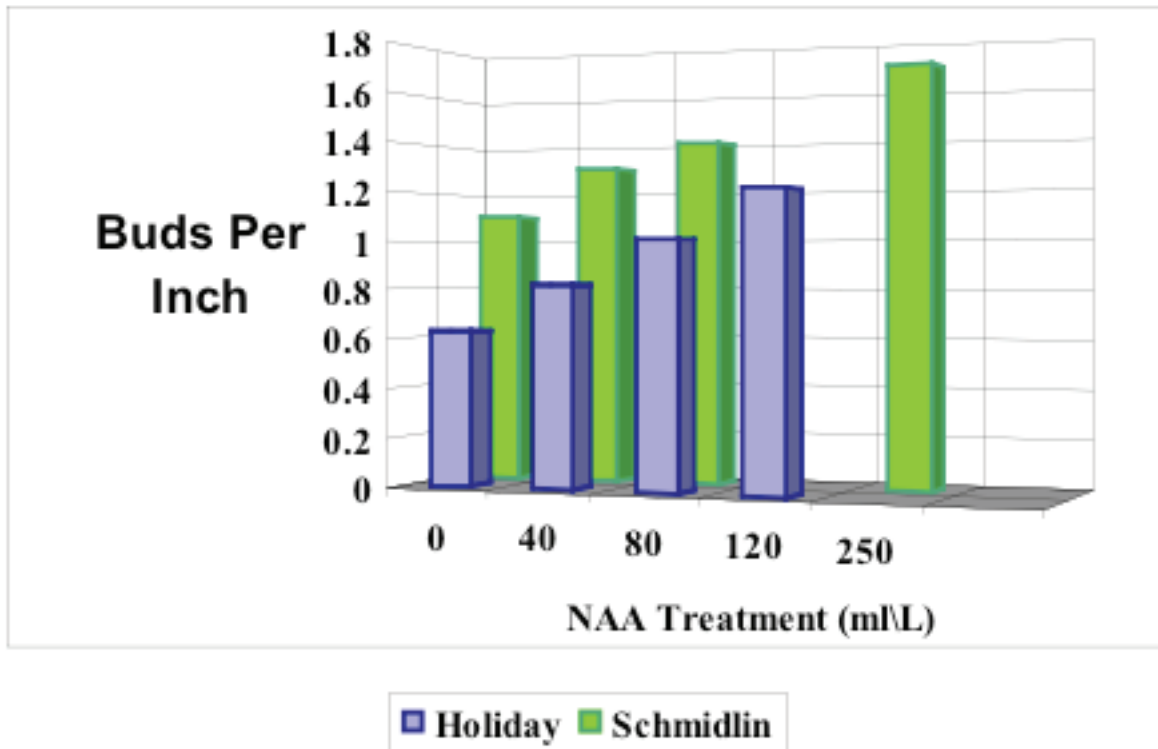


Figure 11. Noble fir internode buds per inch vs. NAA treatment.

Nordmann fir extra rates and sources showed a similar pattern to the noble fir results (Table 4). As with noble fir, the amount of NAA necessary to put trees into the desired 12-14” range was 80-120 mL/L, compared with the randomized plot rate of 40 mL/L, that left the leaders averaging more than 15”. In Denmark the recommended rate is 20 mL/L. Why such a difference? It may be due to the extremely vigorous growth experienced during 2005 in western Oregon (22” average growth on control trees). The take home message here, however, may be that much higher rates of NAA application will be needed to control leader growth in Oregon as compared to Denmark.

Can you apply too much NAA to the leaders? Although there were only 20 Nordmann fir trees treated at the full strength Sucker Stopper RTU rate (1.15%), in every case the leaders were so severely damaged that they had to be replaced with a new leader. This is fair warning against high rate applications of NAA, at least on Nordmann fir.

Table 4. Nordmann fir leader responses to various NAA rates and sources.

Treatment	Leader Growth (inches)	Leader Buds (ave.)	Buds\ Inch (ave.)
Control	22.1	18.9	.86
20 ml/L	15.7	17.1	1.1
40 ml/L	15.4	19.1	1.2
80 ml/L	13.9	18.7	1.3
120 ml/L	12.3	22	1.8
Full strength SS RTU (1.15%)	Dead or severely damaged leaders		

Role of Surfactants in Leader Length control of Noble fir - In Denmark, the common surfactant mix with Pomoxone (NAA) is Lissapol Bio (83% alkyl-ethoxylat applied at .5ml/L) combined with non-homogenized buttermilk. In the USA, Lissapol is not available and buttermilk is nearly all homogenized, so we begin this trial with a search for “new” surfactants.

Noble fir needles tend to be “waxy”, so absent a surfactant, the NAA + water mix beads up along the leader and drips. A “proper” surfactant aids in both the spreading and sticking of the NAA during application.

We evaluated 4 surfactants and used TipOff as a “standard” to compare efficacy. The surfactant screening in this trial used tree row “plots” rather than randomized individual applications. Similar trees were treated in each row, yet statistical differences between treatments would be difficult to ascertain.

The surfactants/products used in this screening were. (All surfactants were applied with Sucker Stopper at 40ml/L in distilled water) -

TipOff™-Is a proprietary formulation of NAA from the UK with Ethoxylated Nonyl Phenols as a surfactant included in the formulation. Evaluated at 100ml./L

Pierce Spreader Penetrant is a methylated Seed Oil silicon emulsifying surfactant listed at 100% a.i.. Evaluated at 12.5 ml./L

1st Choice Crop Oil Concentrate- Paraffin based petroleum oil, tall oil fatty acid+ alkyphenol ethoylate. Evaluated at 12.5 ml./L

WA-100+ Penetrating Surfactant Adjuvant. 100% active nonionic, non volatile and non-foaming. Includes penetrating surfactants, surface tension reducers and acidifiers. Tallow amine ethoxulates, fatty acids and Dimethylpolysiloxane. Evaluated at 10ml./L

Ext 629- Organosilicone+ turpine resin. Evaluated at both 2.5 and 12.5 ml/L.

Table 5. Noble fir leader lengths using various surfactants + Sucker Stopper at 40ml/L (treatments 1-5). Tip Off, Controls and surfactant only (treatments 6-8).

Surfactant or Treatment	Ave. Leader Length- in.
1. WA 100+	11.0
2. 1 st Choice Crop Oil	14.0
3. Ext 629 at 12.5 ml/l	14.4
4. Pierce Spreader Penetrant	14.7
5. Ext 629 at 2.5 ml/l	15.2
6. Tip Off	15.1
7. No Treatment (Control)	18.9
8. WA 100+ at 10ml/L (no Sucker Stopper)	18.8

A number of observations emerge from Table 5, they are:

- 1) It appears that all the surfactant combinations worked as well as the TipOff material. Likely, a number of surfactants, not included in this trial, could provide control.
- 2) Surfactant rate and type seem to influence length. Use caution however in inferring too much from Table 5, as each treatment was applied to only 50-75 trees. There likely are options to refine the surfactant amount and type with future trials.
- 3) The surfactant (at least WA 100+) did not damage (or shorten) the leaders when used alone.

Additional observations from treatment measurements:

- 1) The WA 100+ and the Pierce surfactants appeared to provide the best wetting at application. These also caused slight yellowing of the leader needles on some trees into August.
- 2) The Ext 629 surfactant appeared to “bead up” more than the other surfactants, yet control was similar.
- 3) The 10-12.5 ml/L surfactant rates are at the high end of use rates suggested on labels. Future trials will likely look into lower surfactant application rates.

Discussion

Results from 2004 & 2005 have shown great promise for these leader control techniques in noble and Nordmann fir Christmas trees in the PNW. Because of its ease of application, and low cost, use of NAA, possibly in combination with top stop nippers will be pursued aggressively in upcoming years. Plots will also be reexamined in 2006 during the growing season to determine fate of leader buds with the various treatments.

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Effect of Two Fire Retardants on the Postharvest Moisture Retention and Flammability of Fraser and Douglas-Fir Boughs

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Abstract

Two experiments were conducted to evaluate two recently developed flame retardant materials on Christmas trees. SafeTree Christmas Tree Fire Redardant was applied to freshly harvested Douglas-fir boughs, and RapidCool FRX Christmas Tree Retardant were applied to freshly cut Fraser fir boughs. The flame retardants were sprayed onto the foliage. SafeTree fire retardant accelerated the drying rate of Douglas-fir boughs, thus increasing branch flammability. RapidCool fire retardant treatments did not slow the drying rate of Fraser fir boughs, and had no effect on moisture content (MC) at ignition, flame time, total burn time, or total foliage consumed. For both species, initial ignition and propagation of flame occurred at MC between 60 and 70%. Fresh boughs did not ignite in burn tests, and therefore were not a fire hazard. Twig MC of Fraser fir increased 20% during display in water, further decreasing the possibility of ignition when exposed to a flame. Neither of the tested products appears to be suitable for use on boughs of Christmas trees.

Introduction

In recent years, concern about Christmas trees as a potential fire hazard has resulted in an increase in regulations concerning where and how they can be displayed. Although statistics show that only a tiny percentage of household fires originate in Christmas trees, these laws and regulations are causing difficulties for Christmas tree producers as well as consumers who might wish to display a real tree. Local and state ordinances and regulations often require the use of flame retardants in various situations even though limited research has been done to evaluate their effectiveness on real Christmas trees.

The objective of this study was to evaluate two commercially available flame retardants and a preservative to determine their effect on foliage quality, moisture retention and flammability.

Materials and Methods

SafeTree Fire Retardant Test - Freshly harvested 4-year-old Douglas-fir branches were utilized to determine if application of SafeTree Christmas Tree Fire Protectant (Summit Environmental Corp., Inc.) had any effect on the rate of moisture loss or flammability of displayed branches. Five branches were sprayed to drip with the fire retardant and 5 branches (checks) were sprayed with water. The branches were

allowed to dry outside for approximately 45 minutes. Next, pairs of treated and untreated branches were hung on wires in a postharvest display room at WSU Puyallup. Ambient temperature and relative humidity were ~ 20°C (68F) and 40 to 50%, respectively. The room was also continuously lit with fluorescent lights.

RapidCool Fire Retardant Tests - Branches for these tests were cut from the lower half of eight sheared Fraser fir Christmas trees. The branches from each tree were divided into six bundles of approximately equal size, with six or seven branches per bundle. Bundles were randomly assigned to one of four treatments. Where appropriate, the proximal end of each branch was trimmed of small twigs to make a “handle” for insertion into a bucket of water.

The experiment was a randomized complete block with 4 treatments and eight blocks. The treatments were: 1) control, displayed dry; 2) control, displayed in water; 3) flame retardant, displayed dry; and 4) flame retardant, displayed in water.

The RapidCool FRX Christmas Tree Retardant (Goodwin Group, Lynchburg, Va.) was mixed in water (1:8, v/v) and sprayed onto the upper side of the branches. After the foliage dried, branches were placed in buckets, with or without water. A fresh cut was made on the base of each branch that went into water. Branches were displayed in a large room maintained at 20°C for 4 weeks. The relative humidity was normally 25% to 45%, with an occasional spike above 60%.

Moisture Status of Branches - Changes in the moisture status of the displayed branches were measured by determining the percent moisture content of the branches at the start of the experiment and periodically during the display period.

Flammability Tests - Ignition tests consisted of holding 6-inch twigs vertically for 5 sec in a shielded, 1-inch flame from an alcohol lamp. After removal from the flame, a stopwatch was used to measure 1) the length of time the flame persisted (flame time), and 2) the total time until the last ember died (burn time). In addition, the proportion of the foliage consumed by the fire was subjectively rated.

Results

Application of the SafeTree Fire Retardant to Douglas-fir increased the rate of drying, which increased the flammability of the shoots (Fig. 1). After 6 days, the MC of treated branches averaged 39% versus 76% for checks.

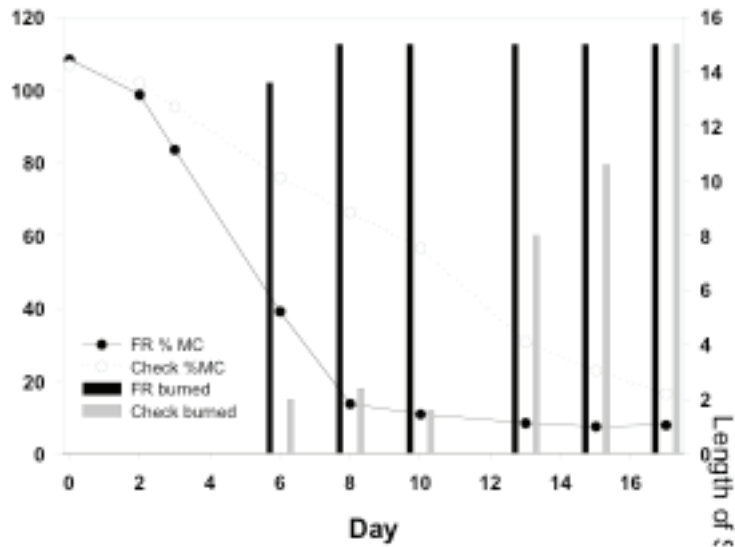


Figure 1. Effect of treating Douglas-fir branches with Safe Tree fire retardant on the rate of moisture loss and flammability of displayed shoots.

Applications of RapidCool FRX Christmas Tree Retardant had no effect on the rate of drying of Fraser fir branches that were displayed dry or in water (Fig. 2). The Initial MC was about 115%. When displayed dry, branches dried to about 20% MC. In water, branch MC gradually increased to 134% to 142% during the 30-day display period, indicating that branches contained up to 20% more water than when initially cut.

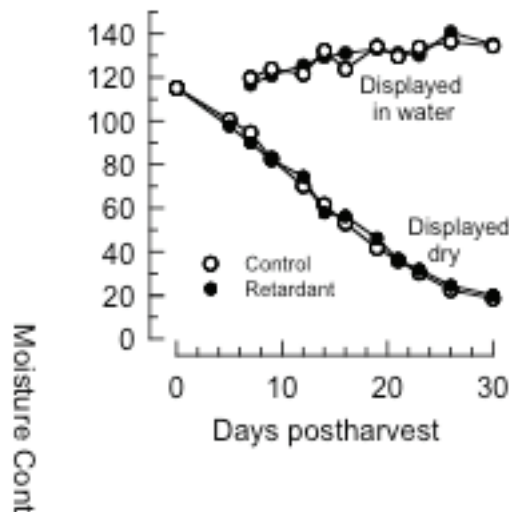


Figure 2. Effect of RapidCool FRX Christmas Tree Retardant on the moisture content of Fraser fir branches displayed in water or dry. In most cases, the number of observations in each mean was four.

Branches did not ignite and carry a flame when the MC was above 60%. As branches dried to a lower MC, they 1) ignited more readily, 2) burned more vigorously, and 3) progressively higher proportions of the foliage were consumed, with or without retardant (Fig. 3).

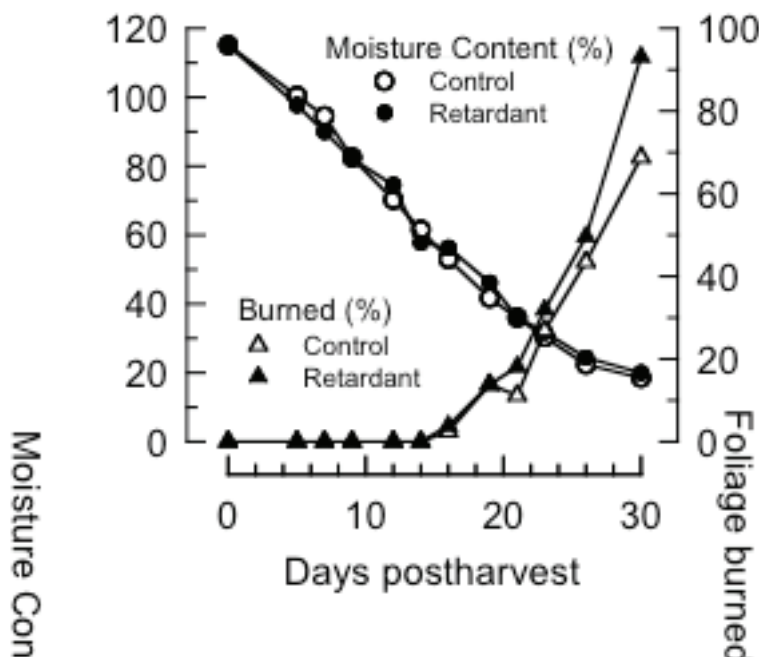


Figure 3. Effect of RapidCool FRX Christmas Tree Retardant on the moisture content and percentage of Fraser fir twigs consumed in a burn test when branches were displayed without water. In most cases, the number of observations in each mean was four.

At any given MC, the percent of foliage consumed on dry branches during the burn test was similar for controls and retardant, indicating that the chemical did not slow down ignition rates or burn time. In addition, burn time and flame time were not significantly different for controls (dry) or branches treated with retardant (dry). The RapidCool flame retardant increased needle loss in one of eight replications.

Discussion

Fire retardants have been relatively unsuccessful when tested on Christmas trees. They frequently discolor foliage, accelerate needle loss, or increase drying rate. In our experiment, applications of SafeTree Christmas Tree Fire Retardant increased the rate of drying, which increased the flammability of Douglas-fir branches. Although applications of RapidCool FRX Christmas Tree Fire Retardant did not adversely affect moisture retention, it was not effective in reducing the flammability of dry Fraser fir branches.

These studies confirm previous work that has shown that some fire retardants and preservatives (water additives) can adversely affect on tree quality and safety. They also confirm that the most effective way to minimize fire hazards associated with Christmas trees is to maintain high moisture contents by displaying them in water. In this study, flames self-extinguished when MC's were $\geq 60\%$. When displayed in water, the MC of the Fraser fir branches actually increased to levels well above initial values, indicating about 20% more water content than at the outset. Because fresh trees did not readily ignite and burn, the extra water gained during display would further reduce any chance of ignition from a small ignition source. These results again confirm that displaying a cut Christmas tree in water is the most reliable way to maintain its freshness.

Acknowledgements

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Sulfur Application and Role in Pacific Northwest Christmas Tree Production

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Abstract

Sulfur is an essential nutrient for growth and reproduction of plants. It is also used as fungicide, miticide, to acidify soil, and to reduce excess sodium in soil reclamation. As a fungicide, elemental S is applied to control surface diseases such as powdery mildew and rust. Recently, elemental S has been used in Douglas-fir forest plantations as treatment for Swiss needle cast, *Phaeocryptopus gaeumannii*. Advisors to Christmas tree growers extrapolated the use of elemental S from forest practices to Christmas tree plantations. In addition to Swiss needle cast control, the field representatives claimed that foliar elemental S application increased needle thickness, improved needle color, and increased branch thickness. To test the claims, combinations of micronized S rate and timing were applied to a 3 to 4 ft tall stand of Douglas-fir Christmas trees in Washington County, Oregon during May of 2001. The treatments were 0, 12, 24 and 36 lb S/a. A second application of S was applied to a portion of the trees two weeks later at the same rates as the previous treatment, resulting in total S application of 24, 48, and 72 lb/a. Needles were sampled in the fall of 2001 and 2004. Needle size, thickness, and nutrient concentration were measured. A single application of elemental S did not increase needle weight, thickness, total S, SO₄-S, or N concentration. The 48 and 72 lb S/a rate from the double application increased needle SO₄-S concentration. No additional measured parameters were influenced by the double S application. In addition, a visual examination did not provide evidence that elemental S reduced SNC.

Introduction

Sulfur is derived from the Latin, *sulphurium* meaning “burning stone” as it burns easily and is associated with volcanic eruptions. Most of the sulfur we use is produced as a by-product of oil refining or natural gas processing although some is mined from salt domes or layered sedimentary deposits. The majority of the sulfur produced in the United States is used to make sulfuric acid. Sulfur’s main use is in making chemicals for agriculture, mostly for fertilizers. Other uses of sulfur include refining petroleum, metal mining, and the production of organic and inorganic chemicals.

Sulfur serves multiple purposes for agriculture. The most familiar role, as an essential nutrient, is the focus of this paper. Sulfur’s multiple uses lead to confusion about its role, especially the cause-effect relationship of an application. A factor that adds to the confusion about sulfur’s role is application form, as it can be applied as either sulfate-S or elemental S.

Elemental S is used as fungicide, miticide, to acidify soil, reduce exchangeable sodium, and can be a nutritional source of S after oxidation to the sulfate form. Elemental S typically requires one to two months of warm moist summer weather for microbial oxidation to form sufficient sulfate-S to supply deficient

crops.

In contrast to the many uses of elemental S, sulfate-S is primarily supplied for plant nutrition and sometimes to reduce sodium in arid settings. It is a component of common fertilizers such as ammonium sulfate, potassium sulfate, magnesium sulfate, ferrous sulfate, ferrous ammonium sulfate, zinc sulfate and the soil amendment, gypsum. In addition, several multi-nutrient fertilizers containing S are available including potassium-magnesium sulfate or K-Mag, ammonium phosphate-ammonium sulfate (16-20-0-14), single super phosphate, and urea-sul. The latter is a physical blend of ammonium sulfate and urea, typically having 35 to 42% N and 6 to 12% S. Ammonium thiosulfate, $(\text{NH}_4)_2\text{S}_2\text{O}_3$, is available in some areas. It contains neither elemental S nor sulfate-S, for management purposes would be used in similar fashion to elemental S since the compound requires oxidation to the sulfate form.

Sulfur deficiency is uncommon in Oregon Christmas tree production. Without a history of S deficiency, we have not collected sufficient data to adequately characterize or describe situations in which S application is needed. Most of the soil at Oregon plantations used for Christmas tree research contained adequate S. Application of S on these sites was not expected to produce growth, color, or tissue concentration changes. Interpret data presented in this paper carefully. The goal of this paper is to use a project in which S was applied to present S nutrition principles in Christmas tree production.

S Application and Needle Concentration - Even though sulfate-S is the form of sulfur assimilated by roots, application of sulfate-S may not increase Christmas tree needle total S or sulfate-S concentration, needle color, or tree growth. For example, sulfate-S in ammonium sulfate and potassium-magnesium sulfate was applied annually to noble fir Christmas trees by Fletcher et al. (1998) at S rates from 5 to 165 lb/a. Needle S concentration decreased with time even when S was supplied (Figure 1).

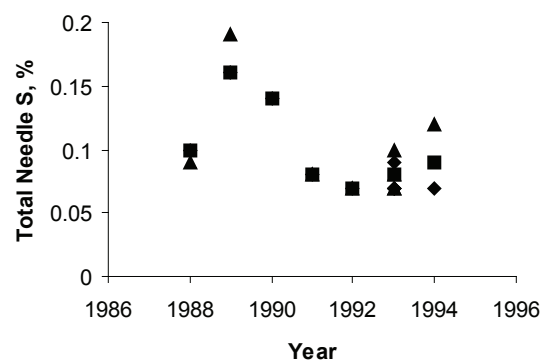


Figure 1. Noble fir Christmas tree needle S concentration following treatment. The treatment represented by diamonds (◆) received no nutrients. The treatment represented by squares (■), received 5 lb S/a for three years followed by 9 lb S/a for three years and a final application of 18 lb S/a. The treatment represented by triangles (▲), received 49 lb S/a for three years followed by 82 lb S/a for three years and a final application of 164 lb S/a.

In the same experiment, tree (needle) color was not related to needle S concentration (Figure 2) and sulfur fertilizer did not increase average tissue S concentration of trees at seven locations for the life of a stand. The average S concentration without S application was 0.10% and with S, 0.11%. This data illustrates the concept that situations having adequate S nutrition, additional S will not increase growth or tissue total S concentration.

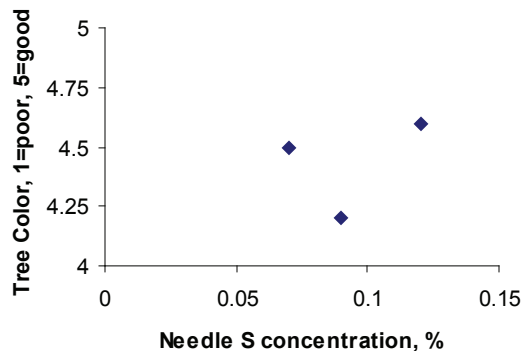


Figure 2. Average noble fir tree color at harvest measured on a scale of 1 to 5, with 5 representing best color.

Soil Testing for Available S - Soil sampling and testing to predict sufficiency or deficiency of sulfate-S is not recommended for Christmas tree production in western Oregon and Washington. Soil sampling and testing for S is complicated by seasonal fluctuations of sulfate, sometimes substantially different amounts of sulfate-S in surface and subsoil, and erratic growth response to S application.

Castellano (1990) measured seasonal fluctuation of $\text{SO}_4\text{-S}$ in the surface of a non-cropped Woodburn silt loam for two years. In December of the first year and March of the second year, $\text{SO}_4\text{-S}$ was highest, 15 ppm. By mid-June of both years $\text{SO}_4\text{-S}$ was lowest, approximately 5 ppm. A threefold seasonal fluctuation without cropping makes interpretation of $\text{SO}_4\text{-S}$ soil tests extremely difficult and of little value.

Sulfate-S is weakly adsorbed by clay. Subsurface clay accumulation is common in Western Oregon soil (Figure 3). Soil samples from the surface, a foot or less, commonly contain low soil test $\text{SO}_4\text{-S}$. Application of S fertilizer produces inconsistent results since the subsoil can contain a sufficient amount of S for crop production.

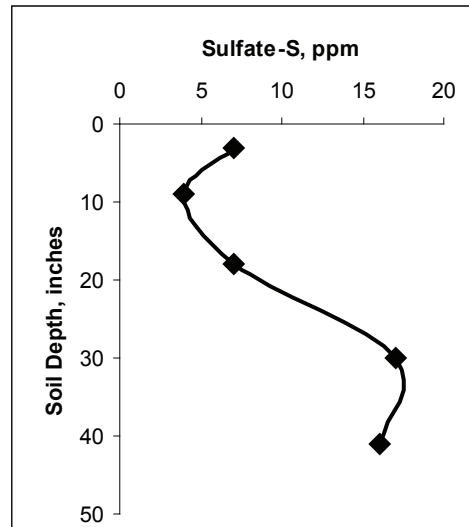


Figure 3. Soil SO₄-S with depth in a Woodburn silt loam receiving no S application for approximately 20 years before sampling.

Data in Table 1 illustrates that sulfate-S is sometimes but not always twice as high in the subsurface as the surface, making a surface soil test difficult to use for predictive purposes.

Table 1. Extractable Sulfate-S by soil depth from four western Oregon noble fir plantations.

Soil Depth	Site				
inches	1	2	3	5	
0 to 8	6	19	15	7	
9 to 16	10	33	29	12	

Blake et al. (1990) applied N and S to planted 12- to 30-year-old Douglas-fir forest stands in western Oregon and Washington. They concluded that levels of soil sulfate-S did not provide local or site-specific predictions of the magnitude of gain from applying N with S. Measured treatment effects were variable and difficult to interpret. Sulfur availability may be locally important, accurate identification of relevant soil or stand conditions is needed before prescribing S application. They state that Douglas-fir forest stand foliage S was not directly related to soil SO₄-S variables.

Soil textural class may be one reason that Blake et al. concluded soil test S did not provide site-specific predictions of S sufficiency. Many western Washington forest stands are located on sandy glacial outwash soil. Fall soil sampling and analysis can provide a high sulfate-S value. The measured sulfate may never be assimilated by the trees as winter rainfall can leach sulfate-S from soils with little clay in the surface or subsoil. This point is pertinent to Christmas tree production since Christmas trees are produced on sandy soil in several worldwide production areas.

Tissue or Needle S - Sulfur nutrition in Oregon and Washington Christmas tree production is managed using foliar analysis for total S from current season needles in the upper third of the tree obtained in late

summer or early autumn. The critical S concentration for Christmas trees grown in western Oregon and Washington is 0.06% (Hart et al., 2004). This concentration is low compared to other crops. It was chosen after examining total needle S, tree color, grade, and total value from approximately ten replicated noble fir and Douglas-fir Christmas tree experimental sites. The average total S concentration for all trees in the plots was low, 0.11%, compared to other crops. Mengel and Kirkby (1982) provide a range of 0.2 to 0.50% S as typical for crops. Oregon State University Central Laboratory personnel comment that forest conifer needle S concentration is less than other plants.

Total S concentration alone should not be used to evaluate Christmas tree S status. Two additional parameters can be employed, N:S and sulfate-S concentration.

The primary use of S in most plants is a synthesis of the amino acids, cystine, cysteine, and methionine. Approximately 90% of organic S is found in these three amino acids. Since a plant's need for S is in proportion to the production of the three amino acids and subsequent protein synthesis, the proportion of N and S provides a predictable ratio of the two nutrients. The stable relationship allows needle N:S ratio to be used as a diagnosis of S adequacy. When S demand is met, a ratio between 11 and 15:1 is used as an indication of S sufficiency in vegetative tissue for many species. The N:S of 15:1 is commonly used to distinguish between probable S deficiency and sufficiency. An N:S slightly above 15:1 does not always indicate S deficiency. A range of N:S and management implications are provided in Table 2. When S is deficient, the N:S ratio commonly is above 30:1.

Table 2. N:S ratio and interpretation of S sufficiency.

N:S ratio	Implication/comment
Less than 10	S high or N is insufficient, check N concentration
11 to 15	S adequate
16 to 20	S marginal
Above 20	S inadequate

The N:S ratio should not be used alone. Both N and S concentration need to be reviewed to determine that each is adequate.

Needle sulfate-S can be used to aid determination of S sufficiency. The concept is based on utilization of S in organic compounds until physiological need for S is satisfied. Beginning with deficient tissue S, supply of S increases total tissue S, but not SO₄-S. When sufficient S is present for protein production, tissue SO₄-S will increase while total S will change little, Mengel and Kirkby (1982).

Foliar S measurements would be helpful when S is applied as a fungicide to evaluate if a growth increase might be from S as a nutrient or fungicide. Unfortunately, few papers thoroughly address or consider S nutrition when the material is applied for disease control.

Sulfur for Swiss Needle Cast Control in Christmas Tree Production - As a fungicide, elemental S is applied to control diseases attacking the surface of plants such as powdery mildew and rust. Recently, elemental S has been used in Douglas-fir forest plantations as treatment for Swiss needle cast (SNC).

Swiss needle cast and the fungus that causes the disease, *Phaeocryptopus gaeumannii*, were first described in 1925 as devastating Douglas-fir plantations in Switzerland (Gäumann, 1930). Though the first description of the disease was by a Swiss scientist, researchers suspect the disease has always been present in the Pacific Northwest on Douglas-fir. In Christmas tree plantations, the disease causes premature yellowing, shedding of older needles, and reduces the time harvested trees remain fresh. Tree genetics vary susceptibility to the disease. Even with some resistance, the disease remains a potential problem nearly everywhere the species is grown in N. America and Europe.

In Christmas tree plantations, cultural operations that improve air movement around trees aid in disease control, but Chlorothalonil and other fungicides applications remain the best treatment options for prevention.

In Pacific Northwest forests, the disease, though widespread, tended to be a problem only in small areas. However, major disease outbreaks along the coasts of Oregon and Washington developed over the last 15 years. Since the coastal outbreaks, the disease has attracted more research attention and resulted in the formation of the Swiss Needle Cast Cooperative at Oregon State University. Researchers experimented with a variety of control measures, including S applications. Though fungicide treatments with Chlorothalonil are effective, the need for repeated application and stream buffer restrictions have limited fungicide use.

In 2002 and 2003, two aerial sprays of 60 lb/a of elemental S reduced the incidence of SNC infection in coastal Oregon and Washington forests. In Washington trials with a single application, S additions failed to reduce needle infection levels (Stone, 2004).

Even though Christmas tree treatment with fungicides remains the preferred SNC control, S application has been used. Advisors to Christmas tree growers extrapolated the use of elemental S from forest practices to Christmas tree plantations. Growers attempted many undocumented preventative measures for SNC because the value of Christmas trees is high and the devastation caused by SNC can be catastrophic.

In addition to SNC control, growers and their field advisors suggest that foliar elemental S applications may also improve needle color and thicken branches and needles.

Materials and Methods

Field Approach Evaluating Elemental S Application in Christmas Trees - To test the effect of a foliar elemental S rate and timing on needle size and thickness, and tissue S concentration, a plot was established in a plantation of 3- to 4-foot tall Douglas-fir Christmas trees in Washington County, Oregon during 2001.

On May 17, four replications received an application of S at 0, 12, 24 and 36 lb/a. Each treatment contained 63 trees. On May 25, one replication was split into smaller plots with three replications and a second application of S, at the same rates, was applied resulting in total S application of 24, 48, and 72 lb/a on this area. Each of these treatments was one row of 21 trees. The larger plots, those not receiving a second application were the same length, but three rows wide, containing 63 trees.

The undiluted sulfur product contained 6 lb S/gallon with particle size of 3-5 microns. The elemental S

product was diluted to achieve a 30-gallon/a application and delivered with a tractor-mounted air blast Solo sprayer. A silicon/latex surfactant was added at the rate of 1 qt/100 gallons.

On November 1, 2001, a composite lamas growth sample was collected from each treatment by combining needles from the three replications in a single sample. Since the samples were non-replicated, no statistical evaluation can be performed. In addition, the needle nutrient concentration cannot be compared to “conventional” analyses as lamas growth is not collected in “conventional” needle sampling. Lamas growth was sampled since it occurred after S application and a sample uncontaminated by S application was desired.

Needles were also collected on 11/8/2004 for measurement of thickness, needle weight, and nutrient analyses. Collection was made for each treatment in each replication so statistical analysis could be performed.

To determine needle thickness, ten randomly selected needles from each treatment were measured with a caliper. The average of the ten measurements was used for comparison. To determine needle weight, a sample of 500 needles was dried and weighed. After needles were removed for weight and thickness measurements, the remaining sample was dried and analyzed for sulfate-S and total S and N.

The data from the single application was statistically analyzed as a randomized complete block design with four treatments and three replications. The Statistix program was used to perform ANOVA and mean separation. Since the treatments receiving a double application were not allocated randomly, they were repeated measures rather than independent measurements and not statistically evaluated.

Results and Discussion

Total S concentration in lamas growth was probably adequate (Table 3). Since lamas growth is not normally sampled, speculation can only be offered that the S concentration in this tissue adequately represents S status in the tree. The total S concentration did not seem to vary by treatment and was higher than in normal samples taken in 2004. In a similar fashion to total S, the sulfate-S concentration did not apparently increase from S application.

Table 3. Lamas needle nutrient concentration the Fall 2001, the year elemental S was applied.

Treatment	Nutrient							
S	P	K	Ca	Mg	S	SO ₄ -S	B	Zn
lb/a	----- % -----				----- ppm -----			
0	0.23	0.94	0.45	0.23	0.15	291	51	20
12	0.19	0.91	0.49	0.22	0.14	269	54	23
72	0.12	0.83	0.57	0.25	0.15	267	60	28

When needles were sampled in 2004, a single foliar application of elemental S/a did not increase needle thickness, needle weight, needle SO₄-S, Total S or N concentration (Table 4). The N:S are high for grain and legume crops. We do not think they indicate any nutritional problem since the addition of S did not increase total S concentration. The total S concentration is above Oregon and Washington Christmas tree standards, N was sufficient for optimum color, and the trees did not show discoloration and grew

vigorously.

Table 4. The influence of a single elemental S application on Douglas-fir needle thickness, weight of 500 needles, N:S, total S, SO₄-S, and N concentration.

S Rate	Needle Thickness	Wt 500 Needles	Total S	SO ₄ -S	N	N:S Needle
lb/a	mm	g	%	mg/kg (ppm)	%	
0	0.41	3.19	0.13	80	2.01	15.5
12	0.44	3.62	0.12	52	2.08	16.9
24	0.42	3.29	0.12	55	1.96	15.9
36	0.43	3.21	0.12	57	2.05	16.7

A second application of elemental S apparently did not change needle thickness, weight of 500 needles, or total S concentration (Table 5). The N:S of 15:1 for the 72 lb S/a application rate is further evidence that a N:S ratio below 15 is not necessary for optimum Douglas-fir Christmas tree production.

Table 5. The influence of a two elemental S applications on Douglas-fir needle thickness, weight of 500 needles, SO₄-S, and S concentration.

S Rate	Needle Thickness	Weight 500 Needles	Total S	SO ₄ -S	N	N:S
lb/a	mm	g	%	mg/kg (ppm)	%	
0	0.41	3.11	0.13	45	1.96	14.3
24	0.44	3.16	0.13	51	2.03	15.6
48	0.42	3.31	0.14	86	2.01	14.7
72	0.43	3.13	0.13	74	1.97	15.2

Even though elemental S was applied to the foliage, S assimilation was through the roots. Sulfate in the form of S is used by plants. Conversion of elemental S to sulfate is a soil reaction. Much of the S application was received by the soil rather than needles. In addition, rain and needle drop added elemental S attached to needles to the soil.

The sulfate conundrum - Needle concentration of sulfate-S was not different for treatments receiving 0, 12, 24, or 36 lb S/a. Even though needle total S was adequate; sulfate-S did not increase with S application. The lack of sulfate-S increase with S application is not surprising since the application rates are relatively low and the material was applied three years ago.

In a similar fashion to total S, the sulfate-S concentration of the treatment receiving no S was higher, but not significantly different, than the concentration from any of the single application treatments. The higher average concentration results from a single value in replication 1, 145 ppm, as shown in Figure 4. Repeated analyses confirmed the concentration was higher in this sample compared to the other replications of the same treatment.

The elevated concentration creates questions about sampling the correct area, mismarked bags, and previous treatment of the area. Since we could not answer those questions, another solution was sought.

The concentration was adjusted to a value close to the other values for the treatment and the data set subjected to ANOVA. The conclusion remained the same, a single S application did not influence needle sulfate-S concentration.

For the plots receiving the double S application, needle $\text{SO}_4\text{-S}$ concentration seemingly increased when a total of 48 or 72 lb S/a was applied compared to any other S application (Tables 4 and 5). The increase in needle $\text{SO}_4\text{-S}$ concentration with the highest S application rates is a physiologically reasonable occurrence.

The 24 lb S/a application rate was common to both the single and double application. The resulting $\text{SO}_4\text{-S}$ concentrations were similar showing that time of application did not influence S utilization, and rate was the logical reason for the apparent sulfate-S differences.

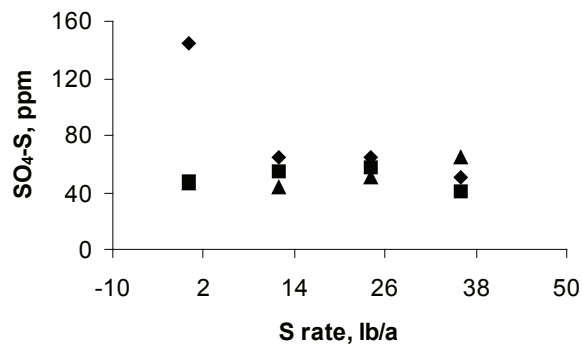


Figure 4. Needle sulfate-S concentration from all S application treatments. Diamonds (◆) represent replication 1, squares (■) replication 2, and triangles (▲) replication 3.

These observations are logical as the S was applied three years before needles were sampled and more than 24 lb S/a was necessary to increase sulfate-S three years after application.

Consistent or reproducible conifer sulfate concentration data is difficult to obtain. Analysis of $\text{SO}_4\text{-S}$ in pine and fir needles is a problem because resinous compounds unpredictably interfere with ion exchange column function (Austin, personal communication 2005). The coefficient of variation for $\text{SO}_4\text{-S}$ in Table 4 was 44.8%. High CV makes data difficult to interpret and little use diagnostically unless large differences measured.

Evaluation of S sufficiency or deficiency should be made carefully by combining several measurements, observation of tree growth, understanding of analytical procedures, and common sense. Total S and N: S are recommended as initial measurements. Combine them with tree color and vigor. A Christmas tree with a 16:1 N:S can produce excellent color and growth. Sulfate-S measurements are not recommended for routine nutritional assessment.

Conclusions

Few, if any differences from S application were expected, even though they were purported by field representatives. Benefits or changes from elemental S application were difficult to quantify. In addition to the data reported, field observations of color, SNC incidence, adelgid attack, and branch thickness, showed no observable differences between treatments. S efficacy reported for SNC control in forest situations was not found in this Christmas tree plantation. Growth characteristics purported by field representatives were not measured or observed. Careful evaluation of potential benefits from elemental S application should be considered by Christmas tree growers before applying the material.

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Clonal Testing and Selection of Eastern Redcedar

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Eastern redcedar (*Juniperus virginiana* L.) is an old-timey Christmas tree species used throughout the southern U.S., especially in rural areas. Choose and cut farms commonly plant this species in limited numbers as part of their species portfolio. Since many horticultural cultivars are available for planting, a clonal trial was undertaken to identify selections to provide growers with uniform and superior planting stock with Christmas tree characteristics. Growers participated in submitting candidate trees for inclusion in the clonal trial. Thirty-two trees assessed as outstanding as compared to surrounding check trees in the areas of 1) growth and form, 2) color, 3) foliage softness and 4) absence of *Phomopsis* blight were included in the trial. Cuttings of each selection were rooted in a propagation house at NCSU in 1997. The average rooting rate was 66% with individual clone rates ranging from 12 to 94%. The clones were grown in pots for 2 years with field trial establishment in 2000. Each trial site contained 230-250 rooted cuttings with an average of 6 cuttings per clone. Three sites, one each in the piedmont, upper coastal plain, and lower coastal plain, were cultured for 4 years by cooperating growers with annual measurements of growth and quality characteristics by NCSU. Clonal means for height ranged from 4.7 to 7.5 feet, with all cuttings averaging 6.0 feet in height. Clones showed considerable variation in straightness, softness, color, and quality also. After field verification with grower input, eight elite selections were made in early 2004. These selections reflected the varied color and foliage habit preferences by the growers. Dormant season cuttings were rooted in the NCSU greenhouses for initial archiving of material. The elite clones had a mean rooting percentage of 73.66, which was not significantly different from their original rooting mean of 70.33%. A clonal comparison of the rooting ability between stumped vs. non-sheared ramets was undertaken at NCSU. During the selection trip at the piedmont site, one ramet each of the eight clones was cut to approximately 2 feet in height and the side branches cut back to force new shoot development. Cuttings from both stumped and non-sheared ramets were collected in July 2004 and rooted at the NCSU greenhouses. Despite the non-optimal timing for rooting, the stumped ramets rooted significantly better (55.63%) than their non-sheared counterparts (11.79%). Further multiplication of these clones via rooted cuttings is underway to establish hedges for the production of planting stock for Christmas tree growers in the near future.

Evaluation of Chemical and Mechanical Methods to Reduce Leader Growth In Fraser Fir (*Abies fraseri*)

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Fraser firs are of economic importance to the Christmas tree industry of western North Carolina. Using chemical and mechanical methods to reduce leader growth allows for the production of a more European style, natural looking tree which may appeal to some consumers. A reduction in leader growth may also decrease shearing and minimize shipping and harvesting expenses by reducing the overall weight of the tree.

The mechanical study evaluated the effectiveness of the Danish made Top Stop Nipper. This tool has been shown to be effective in Europe in reducing leader length of Nordmann firs (*Abies nordmannian.*) The Top Stop Nipper wounds the tree by placing cambial incisions on the terminal leader which reduces nutrient flow to the apical bud.

The chemical study evaluated the effects of the potassium salt form of NAA (1-naphthalene acetic acid) on reducing leader growth. The concentrations were applied using a modified Easy Roller.

Two studies were established in Avery County, North Carolina in the spring of 2005. The Top Stop Nipper treatments were applied at three sites, each site containing 20 blocks, with 15 trees in each block (1 rep of each treatment) for a total of 900 trees. The sites were categorized as high elevation, mid elevation, and low elevation. The treatments consisted of five degrees of wounding (0-4 nips) applied at three stages of leader elongation (pre-bud break, 2-3 cm, and 6-9 cm.) For each treatment requiring more than one nip, the Top Stop Nipper was rotated 90 degrees before the next nip was applied. The NAA treatments were applied at three sites, each site containing 10 blocks with 24 trees in each block (1 rep of each treatment) for a total of 720 trees. Eight concentrations were applied (0,10,20,30,40,50,60, and 70 ppm) at three stages of leader elongation (6-9 cm, 12-18 cm, and 24-36 cm.) Weekly measurements were recorded at the mid elevation Top Stop Nipper site over a seven week time period and a final measurement was recorded for all trees at all six sites after nine weeks.

In conclusion, all Top Stop Nipper treatments applied significantly reduced leader growth. The number of nips which gave the approximate length many growers target (12"-14") varied at each site. Further research is needed to test annual sequential applications. Results for the chemical method showed no differences among concentrations of NAA or timing. Future tests should include using another form of NAA or higher concentrations of the same form.

7th International Christmas Tree Research & Extension Conference

Kettunen Center, Tustin, MI, USA
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Talk Abstracts

**6th International Christmas Tree
Research & Extension Conference
Kettner Center, Tustin, MI, USA
October 2 - 7, 2005**

Talk Abstracts

Alternative Herbicides to Methyl-Bromide for Weed Control in Conifer Seedlings.

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The methyl-bromide (MeBr) phaseout has reduced the ability of conifer seedling growers to adequately control weeds. In 2004 and 2005, field studies were conducted to evaluate herbicides as alternatives to MeBr in conifer seedling production. A standard control treatment of MeBr/chloropicrin (67:33) was applied at a rate of 392 kg/ha. The herbicides tested are flumioxazin (.28 kg ai/ha), granular oxadiazon (2.24 kg/ha), oxyfluorfen (1.12 kg/ha), oxyfluorfen plus dithiopyr (.28 kg/ha), oxyfluorfen plus metolachlor (1.68 kg/ha), mesotrione (.28 kg/ha), metolachlor plus mesotrione, metolachlor plus trifloxysulfuron (.007 kg/ha), metolachlor plus rimsulfuron (.035 kg/ha), granular pendimethlin plus oxadiazon (3.64 kg/ha) and an untreated control. Two-year old Fraser fir (FF) and Eastern white pine (EWP) were the used in the 2004 study and one-year old Douglas fir (DF), Colorado blue spruce (CBS), FF and EWP were used in the 2005 field study. Weeds present include large crabgrass, redroot pigweed, common ragweed, common lambsquarters and others. Crop injury and weed control were visually rated on a 0-100% scale, with 0% equal to no crop injury or no weed control and 100% equal to complete crop or weed death. Metolachlor plus trifloxysulfuron caused significant visible injury to FF both years, while metolachlor plus mesotrione was the only treatment to cause significant injury in EWP over both years. Most treatments provided weed control similar to that of MeBr with the combination of oxyfluorfen plus metolachlor giving the best and most consistent weed control. In 2005, a greenhouse study was conducted on seven conifer species using the same herbicides. The species include FF, EWP, CBS, DF, white spruce, Balsam fir, and Scotch pine. Ratings of visual injury and crop growth were observed. No significant growth reduction was observed. Slight crop injury was observed which varied among species and treatments.

Herbicide-Resistant Weeds in Michigan Christmas Tree Plantations

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Michigan is one of the largest producers of Christmas trees in the country, ranked in the top three in trees harvested and acres in production. Christmas tree growers use herbicides as part of an effective and economical weed management program. A few herbicides have been used extensively and exclusively for weed control in Michigan. Growers are concerned with the possibility of weed shifts and herbicide resistance.

In response, a survey has been initiated in Michigan Christmas tree plantations to (1) identify and document weeds species in the top five-producing counties, (2) collect mature seeds from these weeds, and (3) determine whether these species are resistant to several common Christmas tree herbicides.

To date, several independent greenhouse experiments have been conducted to evaluate herbicide resistance in common lambsquarters, common ragweed, hoary alyssum, horseweed, and velvetleaf. Herbicides used in these experiments include atrazine, chlorimuron, cloransulam-methyl, glyphosate, imazamox, oxyfluorfen, and simazine. Known susceptible control populations were included with each experiment.

Common ragweed plants survived foliar-applied cloransulam-methyl and imazamox at 88 and 220 g ai ha⁻¹, respectively. Horseweed plants survived soil-applied simazine at 4.4 and 13 kg ai ha⁻¹ and foliar-applied atrazine at 2.2 and 6.7 kg ai ha⁻¹. Additional horseweed plants survived foliar-applied atrazine at 6.7 kg ai ha⁻¹ and/or chlorimuron at 45 g ai ha⁻¹ and cloransulam-methyl at 88 g ai ha⁻¹. Velvetleaf plants survived foliar-applied atrazine at 2.2 and 6.7 kg ai ha⁻¹.

Results from experiments to date indicate acetolactate synthase (ALS) resistance in one common ragweed population, ALS resistance in seven horseweed populations, triazine resistance in four horseweed populations, and triazine resistance in three velvetleaf populations collected from Michigan Christmas tree plantations. At least one horseweed population demonstrated resistance to both triazine and ALS-inhibiting herbicides.

Assessing the risk of *Phytophthora ramorum* infection in Christmas tree plantations

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The identification of several conifers as hosts of *Phytophthora ramorum* has increased concerns about the potential spread of this regulated pathogen via shipment of Christmas trees, conifer nursery stock, and various forest specialty products. There are currently five conifers that have been identified as natural hosts of *P. ramorum*. These include Douglas-fir, grand fir, yew (English and Pacific), and coast redwood. In addition, some 20 species of conifers, including many types of true firs, have been shown to be susceptible to this pathogen under experimental conditions.

The risk of conifers being infected by *P. ramorum* in nature is poorly understood. In California, infected conifers commonly occur as understory plants beneath or adjacent to heavily infected hosts like California bay. In Oregon, infection on bays is limited and no infection of existing Douglas-fir trees has been observed, nor have seedlings planted next to infected tanoak stumps become infected. Laboratory studies indicate that infection of Douglas-fir seedlings is limited to a brief period of time right after bud break and is dependent on exposure to high inoculum levels.

In 2005, a plot was established in a 23-acre U-Cut Christmas tree farm west of Los Gatos, CA that is surrounded by a mixed forest containing a number of infected and highly susceptible hosts such as California bay laurel (*Umbellularia californica*), madrone (*Arbutus menziesii*), false Solomon seal (*Maiantheum racemosum*), toyon (*Heteromeles arbutifolia*), coast redwood (*Sequoia sempervirens*), and tanoak (*Lithocarpus densiflorus*) to examine the influence of various environmental conditions, inoculum levels and host phenology on disease development. Within the Christmas trees, infected Douglas-fir and grand fir trees can be found along the interface of the plantation with the infected mixed forest. Other conifers being grown at this site include giant sequoia, scotch pine, white fir (Kaibab seed source) and remnant small noble fir trees from an experimental planting. This site provides a unique opportunity to study the spread of *P. ramorum* along the interface of a mixed forest, containing highly susceptible hosts, into a Christmas tree plantation. Developing a better understanding of the relationship between inoculum levels and infection of conifers under field conditions will be very helpful in assessing the risk of infection and potential movement of *P. ramorum* on conifers.

Noble Fir Stump Removal – A Comparison Of Stump Grinding And Excavation

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Annosus root rot, caused by the fungus *Heterobasidion annosum*, has become a major problem in many noble and Fraser fir Christmas tree plantations in the Pacific Northwest, killing up to 40% of the trees prior to harvest. Stump removal before replanting is commonly recommended as one approach to minimize development of this disease.

During 2004, a replicated trial was established in a recently harvested noble fir field near Hillsboro, OR to compare the effectiveness of five different approaches to removing stumps and roots. Following completion of the treatments, trenches were dug around the edges of a 18' x 18' area that had contained 9 stumps within each plot and a backhoe was used to dig out all of the soil within the plot to a depth of 3'. All of the residual pieces of stumps and roots were collected and transported to Puyallup where they were dried to 10% moisture content.

All treatments decreased the weight of recovered material compared to the control “biomass” plots. The average weight of the material in the “biomass” plots was almost 30 kg (66 pounds). The total weight of residual material left after grinding was higher than either of the stump extraction treatments and all of the grinding plots tended to have a greater amount of root pieces than the extraction plots. The mass of residual stumps left in the field following the Evergreen “strip” grinding treatments was clearly higher

than the “broadcast” grinding treatment with this grinder or when the Fecon grinder was used. In part this resulted from stumps that might have been off center and were only partly partially ground by the grinder. In all of the grinder plots, only the tops of some of the stumps were ground off, leaving much of the stump and root system below the 8” grinding depth largely intact.

The use of an excavator to remove stumps, especially one equipped with a “brush rake” resulted in the least amount of residual stump material. This treatment was clearly the most effective in minimizing the amount of larger, residual stump pieces that remained in the field, which is where *Annosus* is more likely to survive for extended periods of time.

Predicting *Pucciniastrum epilobii* rust damage in Nordmann fir

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Nordmann fir (*Abies nordmanniana*) is the main Christmas tree species in Denmark. The host for the rust fungus *Pucciniastrum epilobii* is normally *Abies alba*, but some years infection occurs on *A. nordmanniana*. The alternate host is fireweed / rosebay willowherb (*Chamaenerion angustifolium*). The firs are infected during bud break, and the result is a premature defoliation on the current-year needles during summer. Damages on ready-to-sell trees makes them unsaleable, leading to financial loss for the producer.

Temperature and precipitation are considered the main factors determining whether infection occurs on Nordmann fir. Data from registered enquiries showed that infections of *P. epilobii* have occurred on either host in most years since 1970. But some years the disease has had very high impact in Nordmann fir. Based on climatic conditions in those years, predictions can be made concerning the risk of infection in Nordmann fir. Such predictions are valuable for the growers if they wish to prevent the damage with fungicides. Spraying can then be limited to the years and stands that are at risk, thus saving money and reducing environmental impact.

The main conclusions are:

- Spore dispersal of *P. epilobii* takes place in May after heavy rainfall (> 10 mm in 24 hours).
- If the first 2 weeks of May are wet, *A. nordmanniana* will not be infected (but *A. alba* may be).
- If the first half of May is dry, and it rains heavily after May 17th, *A. nordmanniana* will be severely affected by the disease.
- If heavy rainfall occurs both in early and late May, some *A. nordmanniana* stands may be infected.
- In most years with heavy damage in *A. nordmanniana*, high precipitation occurs at a heat-sum of 500° C (based on temperatures above +5 °C from March 1st).

In Denmark, monitoring the risk of infection by *P. epilobii* should be done in those years, where the first half of May is dry. At the first heavy rainfall after mid-May, Nordmann fir stands should be inspected. Only stands which have green buds or are in the first stages of shoot elongation after bud break, need to be sprayed immediately to prevent infection. Spraying with fungicides can cause damage to the new needles, so chemical, dosage and spraying method must be investigated. At present, no fungicides are approved for Christmas trees in Denmark. The accepted method to prevent infection is to control fireweed inside and within 500 meters of the stand.

Control of Abies Leader Growth in Oregon Christmas Trees via Chemical and Mechanical Manipulation

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Annual leader growth of noble fir (*Abies procera*) and Nordmann fir (*Abies nordmanniana*) on Christmas tree farms in the Pacific Northwest during the last few years of the production cycle typically exceeds the 25-40 centimeters that is desired for proper spacing of whorls. Growers usually cut leaders back to the correct length and then train up a new leader (usually by staking and tying) from a branch bud the next year, with great difficulty and significant cost. Over the past several decades researchers and growers have tried a variety of leader scarring and chemical treatments to reduce leader growth, but have been unable to operationalize any effective treatment.

Techniques of leader growth reduction utilizing physical scarring (Top Stop nipper) and application of Ethyl-1 naphthaleneacetate (NAA), individually and in combination, were adapted from Danish techniques, and applied to Christmas trees in Oregon during 2004 and 2005. Results were somewhat variable by species, treatment and individual tree response, but overall revealed growth reduction possibilities in the 25-50% range, with the highest rates leader nipping and hormone applications causing leader mortality, and the lower rates failing to reduce leader growth. A concurrent trial utilizing various surfactants with the growth hormones revealed significant differences depending upon surfactant applied. This range of responses provides significant opportunities to successfully use these techniques to reduce leader lengths operationally.

The 2003 and 2004 Fraser Fir Freshness Surveys

Jeff Owen¹, John Frampton², Dennis Hazel³

¹Area Extension Forestry Specialist, NCSU, ²Christmas Tree Geneticist, NCSU, ³Extension Forestry Specialist, NCSU

During the 2003 and 2004 Christmas tree harvest and sales seasons, we conducted a survey to evaluate handling and care of Fraser fir [*Abies fraseri* (Pursh) Poir] Christmas trees on the farm and in two diverse market places; the Raleigh, NC area and Florida (Ft. Lauderdale/Miami, FL in 2003 and Tampa/St. Petersburg, FL in 2004). The survey consisted of 1) collecting foliage samples from trees in North Carolina fields and storage yards to determine moisture content, 2) collecting foliage samples from Christmas tree vendors' stored and displayed trees for moisture content determination, and 3) appraising vendors' storage and display techniques. Stored trees on the farm were generally fresh, but in 2004 horizontally stacked trees were significantly dryer than those stored upright. On retail lots, tree species, the number of deliveries, frequency of irrigation, type of tree stand, type of shade, and vendor category influenced the moisture content and quality of trees. The greatest number of critically dry trees was observed at grocery stores although no vendor category was free of problem trees.

Handling Containerized Conifers

Bates R.M.¹

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The National Christmas Tree Association estimated that American consumers bought over 30 million live Christmas trees in 1999 and 23 million in 2003. During the same period, artificial trees displayed in homes rose from 44 million in 1999 to 62 million in 2003. This decreasing market share has caused concern among growers and has renewed interest in the development of niche markets and alternative Christmas tree products. Container-grown tabletop Christmas trees offer consumers an alternative to traditional cut trees and they have become one of the most popular winter holiday season pot crops over the past decade. Currently, *Chamaecyparis*, *Pinus* and *Picea* are the dominant genera used for container-grown Christmas trees. Some of the common species marketed in the Eastern U.S. are not reliably winter hardy in regions colder than USDA Zone 7 and stand a poor chance for survival if planted outdoors after the Christmas season. In addition, recommendations detailing how to handle these trees after indoor display is lacking or inconsistent. Few studies have addressed how to handle container-grown conifers during and after indoor display and the adaptability of the commonly grown species. The objective of this study was to determine the influence of display time and post-display handling method on the survival and growth of eight conifer species. This presentation will address methods of post-display handling, species susceptibility to winter injury and first-year survival and growth.

*Cone Stimulation of *Abies procera*- Evaluating Variable Rates of GA 4+7 Application Timing and Girdling*

Chal Landgren

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Noble fir (*Abies procera*), like many true firs, produces neither abundant nor frequent cone crops. In some periods, wild cone crops may be decades apart with precious little seed available for planting. Little information is available on *Abies* cone induction in general, with no literature specific to noble fir. Noble fir has developed into the predominate Christmas tree species in the Pacific Northwest, replacing Douglas-fir. Currently, annual Christmas tree planting levels of noble fir in the Pacific Northwest exceed 7 million seedlings. Forest landowners in Oregon and Washington are increasing noble fir plantings above 1500 ft. elevation.

Noble fir seed orchards have been established at a number of sites in Oregon and Washington to help fill the seed needs for both Christmas trees and reforestation. Many of these orchards contain genetically improved clones selected by tree improvement programs. Yet, seed crop production has remained unpredictable, resulting in seed shortages and preventing capture of the full benefits from tree improvement.

This study investigated cone stimulation options that have operational relevance to seed orchard managers. Replicated trials were established at three orchard sites looking at 5 treatments. We used 3 rates of GA_{4/7},

applied the material at 2 different timing dates, and evaluated girdling. Results were mixed. One orchard showed no relationship to treatments for either cone or pollen production. Another orchard showed a treatment effect for cones but not pollen. At the third site, treatments influenced both pollen and cone production.

A Growth Model For Nordmann fir: Biomass and Nutrient Consumption During One Rotation

Lars Bo Pedersen and Claus Jerram Christensen

Danish Centre for Forest, Landscape and Planning, The Royal Veterinary and Agricultural University, Hørsholm Kongevej 11, DK-2970 Hørsholm, Denmark.

Cultivation of high quality Nordmann fir (*Abies nordmanniana*) Christmas trees demands an adequate supply of nutrients. This study investigates the accumulated biomass and the amounts of nutrients (N, P, K, Mg, S, Ca) in three 9-year-old Christmas tree stands fertilized with 0, 150, 300 (normal practice in Denmark), 600 and 1200 NPK 23-3-7 ha⁻¹ yr⁻¹. The biomass characteristics and the amounts of nutrients identified are grouped in a model showing the progress in biomass and nutrient accumulation from planting to harvest. These results are compared with the results from a previous study on nutrient leaching and deposition in a nutrient cycling model for one rotation, at the same three sites.

The responses of the trees to the different fertilizer treatments indicate that logistic growth models can describe the biomass and nutrient accumulation. In general nutrient uptake reached a maximum between 300 and 600 kg NPK 23-3-7 ha⁻¹ yr⁻¹ (approx. 48 tons biomass ha⁻¹, 400 kg N ha⁻¹, 48 kg P ha⁻¹, 245 kg K ha⁻¹, 35 kg Mg ha⁻¹, 35 kg S ha⁻¹, 300 kg Ca ha⁻¹). However, 300 kg 23-3-7 ha⁻¹ yr⁻¹ constituted the limit where the accumulation in the biomass began to level out.

The ratio between nutrient in the biomass deviates considerably from the nutrient in the commonly used fertilizer NPK 23-3-7. A considerable lower N/K ratio as well as a higher N/S ratio and K/Mg ratio characterized the biomass.

The cycling of the different nutrients varies highly primarily due to 1) the different chemistry of the nutrients, 2) variation in input by deposition, and 3) variation in tree uptake. In general, leaching is highest in the middle-aged stands due to heavy fertilization in combination with a moderate uptake. In the last two years before harvest nitrogen and potassium uptake exceeded the input by approx. 150 kg ha⁻¹ and 110 kg ha⁻¹, respectively. Apart from S, similar deficits existed for all other investigated nutrients. Within the Danish quota on 75 kg N ha⁻¹ yr⁻¹, growers are recommended to transfer fertilizers from middle-age stands to stands ready for harvest within two years. Growers are also recommended to switch to fertilizers with other formulas.

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Interspecific Variation In Adaptive Traits Of True Firs (*Abies* spp.)

Grant Jones¹ and Bert Cregg²

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Recent efforts to increase conifer diversity for Christmas tree and landscape use have sparked increased interest in planting true firs and their hybrids. Expanded use of firs has been limited by their per-

ceived intolerance of many site conditions; however, recent research shows firs are more tolerant of environmental conditions than originally thought. In this project we studied adaptive traits of 17 species and interspecific hybrids of firs at four locations in the Lower Peninsula of Michigan. Project goals include characterizing species difference in: 1) budbreak and cold hardiness, 2) the influences of soil pH on foliar nutrition, physiological processes, and growth, and 3) the influence of needle morphology and shoot architecture on net photosynthesis and drought tolerance. Mean date of budbreak and growing degree days differed among species and location in both years. Fir species that broke bud early were more prone to late spring frost damage than species with late budbreak. Maximum mid-winter cold hardiness was negatively correlated with date of budbreak. Soil pH influenced nutrient availability of several important nutrients necessary for physiological processes. Net photosynthesis decreased with increased soil pH and response differed among species. Needle morphology differed among species and needle thickness was correlated with increased net photosynthesis. Needle carbon isotope discrimination was related to water use efficiency and varied among species. Continued improvement of stress tolerance of firs for the upper Midwest is possible through selection for late budbreak and tolerance to soil pH.

Clonal Testing And Selection Of Eastern Redcedar

AnneMargaret Braham¹ and John Frampton²

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Eastern redcedar (*Juniperus virginiana* L.) is an old-timey Christmas tree species used throughout the southern U.S., especially in rural areas. Choose and cut farms commonly plant this species in limited numbers as part of their species portfolio. Since many horticultural cultivars are available for planting, a clonal trial was undertaken to identify selections to provide growers with uniform and superior planting stock with Christmas tree characteristics. Growers participated in submitting candidate trees for inclusion in the clonal trial. Thirty-two trees assessed as outstanding as compared to surrounding check trees in the areas of 1) growth and form, 2) color, 3) foliage softness and 4) absence of Phomopsis blight were included in the trial. Cuttings of each were rooted at NCSU in 1997, grown in pots for 2 years with field trial establishment in 2000. Three sites, one each in the piedmont, upper coastal plain, and lower coastal plain, were cultured for 4 years with annual measurements of growth and quality characteristics. Based on the data and field verification with grower input, eight selections were made in early 2004. Dormant season cuttings were rooted in the NCSU greenhouses for initial archiving of material. A clonal comparison of the rooting ability between stumped vs. non-sheared ramets was undertaken at NCSU. Further multiplication of these clones via rooted cuttings is underway to establish hedges for the production of planting stock for Christmas tree growers in the near future.

Cone Stimulation of *Abies procera*- Evaluating Variable Rates of GA 4+7 Application Timing and Girdling

Chal Landgren

Extension Forester and Professor, OSU Extension Service, 18640 NW Walker Rd., Beaverton, OR 97006-8927; email: chal.landgren@oregonstate.edu.

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Noble fir seed orchards have been established at a number of sites in Oregon and Washington to help fill the seed needs for both Christmas trees and reforestation. Many of these orchards contain genetically improved clones selected by tree improvement programs. Yet, seed crop production has remained unpredictable, resulting in seed shortages and preventing capture of the full benefits from tree improvement. This study investigated cone stimulation options that have operational relevance to seed orchard managers. Replicated trials were established at three orchard sites looking at 5 treatments. We used 3 rates of GA4/7, applied the material at 2 different timing dates, and evaluated girdling. Results were mixed. One orchard showed no relationship to treatments for either cone or pollen production. Another orchard showed a treatment effect for cones but not pollen. At the third site, treatments influenced both pollen and cone production.

Review Of New Herbicides Examined In Denmark For Weed Control In Forestry And Christmas Trees

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In Denmark as well as most other EU-countries (European Union) there is increased concern for the environmental effect caused by chemical weed control. The traditional herbicides, atrazine, cyanazine and hexazinone were banned in 1995. Likewise, in 1997, a ban or severe restrictions were put on the use of phenoxyacids, dichlobenil and propyzamide. In 2005 a ban was put on simazine in all EU-countries, and it is expected that restrictions or even a ban for terbuthylazine and possibly diuron will be enforced because it is suspected that some of the decomposed products are leaching down into the ground water. Among the newly tested herbicides the following will be mentioned: Sulphonyl urea and florasulam. Among the sulphonyl urea herbicides that have been tested are: Amidosulfuron (Gratil), foramsulfuron (Equip), iodosulfuron (Hussar), foramsulfuron + iodosulfuron (MaisTer), mesosulfuron (Atlantis), met-sulfuron-methyl (Ally), rimsulfuron (Titus), sulfosulfuron (Monitor), tribenuron (Express) and triflurosulfuron-methyl (Safari). Doses of sulphonyl ureas are normally the size of few grams ha⁻¹. Therefore they are often called mini-herbicides. The various sulphonyl ureas have very different effects on the various weed species. Some control grasses, some control certain species of dicotyledonous plants and others control totally different species of dicotyledonous weeds.

In practice it is often necessary to mix two or more sulphonyl ureas to achieve sufficient effect on the naturally mixed weed vegetation on farmland plantations of forestation or Christmas trees. A good example of that is MaisTer that is a mixture of foramsulfuron and iodosulfuron. In forestland plantations the weed control is not sufficiently effective on most weed species within the doses that are approved.

Some of the herbicides give a risk of discoloration (yellowing) of the new needles on Nordmann's fir. The discoloration is acceptable on small fir plants, as they will have time to camouflage the damage long before they are to be sold. From an effectiveness and economical point of view, a range of sulphonyl ureas are expected to be the future method of chemical weed control on farmland plantations.

Flurasulam (Primus) provides more or less the same good effect on most species of dicotyledonous plants, as do the sulphonyl ureas. Flurasulam has other modes of action than sulphonyl ureas, and shifting between these groups of herbicides might prevent developing resistance on the weeds.

Alternative Herbicides To Methyl-Bromide for Weed Control In Conifer Seedlings

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The methyl-bromide (MeBr) phaseout has reduced the ability of conifer seedling growers to adequately control weeds.. In 2004 and 2005, field studies were conducted to evaluate herbicides as alternatives to MeBr in conifer seedling production. A standard control treatment of MeBr/chloropicrin (67:33) was applied at a rate of 392 kg/ha. The herbicides tested are flumioxazin (.28 kg ai/ha), granular oxadiazon (2.24 kg/ha), oxyfluorfen (1.12 kg/ha), oxyfluorfen plus dithiopyr (.28 kg/ha), oxyfluorfen plus metolachlor (1.68 kg/ha), mesotrione (.28 kg/ha), metolachlor plus mesotrione, metolachlor plus trifloxysulfuron (.007 kg/ha), metolachlor plus rimsulfuron (.035 kg/ha), granular pendimethlin plus oxadiazon (3.64 kg/ha) and an untreated control. Two-year old Fraser fir (FF) and Eastern white pine (EWP) were the used in the 2004 study and one-year old Douglas fir (DF), Colorado blue spruce (CBS), FF and EWP were used in the 2005 field study. Weeds present include large crabgrass, redroot pigweed, common ragweed, common lambsquarters and others. Crop injury and weed control were visually rated on a 0-100% scale, with 0% equal to no crop injury or no weed control and 100% equal to complete crop or weed death. Metolachlor plus trifloxysulfuron caused significant visible injury to FF both years, while metolachlor plus mesotrione was the only treatment to cause significant injury in EWP over both years. Most treatments provided weed control similar to that of MeBr with the combination of oxyfluorfen plus metolachlor giving the best and most consistent weed control. In 2005, a greenhouse study was conducted on seven conifer species using the same herbicides. The species include FF, EWP, CBS, DF, white spruce, Balsam fir, and Scotch pine. Ratings of visual injury and crop growth were observed. No significant growth reduction was observed. Slight crop injury was observed which varied among species and treatments.

Herbicide-Resistant Weeds In Michigan Christmas Tree Plantations

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Michigan is one of the largest producers of Christmas trees in the country, ranked in the top three in trees harvested and acres in production. Christmas tree growers use herbicides as part of an effective and economical weed management program. A few herbicides have been used extensively and exclusively for weed control in Michigan. Growers are concerned with the possibility of weed shifts and herbicide resistance. In response, a survey has been initiated in Michigan Christmas tree plantations to (1) identify and document weeds species in the top five-producing counties, (2) collect mature seeds from these weeds, and (3) determine whether these species are resistant to several common Christmas tree herbicides.

To date, several independent greenhouse experiments have been conducted to evaluate herbicide resistance in common lambsquarters, common ragweed, hoary alyssum, horseweed, and velvetleaf. Herbicides used in these experiments include atrazine, chlorimuron, cloransulam-methyl, glyphosate, imazamox, oxyfluorfen, and simazine. Known susceptible control populations were included with each experiment.

Common ragweed plants survived foliar-applied cloransulam-methyl and imazamox at 88 and 220 g ai ha⁻¹, respectively. Horseweed plants survived soil-applied simazine at 4.4 and 13 kg ai ha⁻¹ and foliar-applied atrazine at 2.2 and 6.7 kg ai ha⁻¹. Additional horseweed plants survived foliar-applied atrazine at 6.7 kg ai ha⁻¹ and/or chlorimuron at 45 g ai ha⁻¹ and cloransulam-methyl at 88 g ai ha⁻¹. Velvetleaf plants survived foliar-applied atrazine at 2.2 and 6.7 kg ai ha⁻¹. Results from experiments to date indicate acetolactate synthase (ALS) resistance in one common ragweed population, ALS resistance in seven horseweed populations, triazine resistance in four horseweed populations, and triazine resistance in three velvetleaf populations collected from Michigan Christmas tree plantations. At least one horseweed population demonstrated resistance to both triazine and ALS-inhibiting herbicides.

Douglas-Fir Needle Midge, *Contarinia pseudotsuga*, A New Pest For Pennsylvania Christmas Tree Growers

Sandra M. Gardosik

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Pennsylvania is one of the top Christmas tree producing states with Douglas fir as the state's No. 1 farm grown Christmas tree, since the 1980's, a ranking it still holds to this day. The Douglas-fir needle midge, *Contarinia pseudotsuga*, was found for the first time in Pennsylvania in the summer of 2002. Since then surveys have confirmed the midge is established in about one-third of the state, principally in the south-eastern counties. Samples and reports from several other eastern states confirm this pest is well-established in the east. Emergence traps have been utilized since 2002 in an effort to confirm seasonal history reported from the Pacific Northwest, where the midge is a serious pest. Control studies conducted by an affected grower in 2005 were disappointing.

Nordmann fir Phytohormone Studies: Potential Applications

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With the Danish near-natural Christmas tree style, architectural details such as the straightness of the stem and the position and density of branches are important price-regulating features. Branch-to-stem conversion is a major problem, as branches are basically plagitropic in contrast to the orthotropic stem. A rapid conversion is required when a branch is needed to replace a damaged leader shoot, and when branches are used as materials for vegetative propagation, whether by grafting or cuttings. The opposite problem arises, when branches spontaneously approach orthotropy to produce multiple stems in a tree.

We are mapping the distribution of major phytohormone groups – cytokinins, auxin and gibberellins – with high sensitivity analysis in 6 and 4 years old Nordmann fir (*Abies nordmanniana* Spach.). The repetitive and predictable branching pattern of this species enables us to easily identify and compare spatially homologous growth points over time. The distinctive seasonal and spatial patterns that emerge have provided new insight into the organization of the tree crown, the nature of branch plagiotropy, and the role of the root system in phytohormone supply. Knowing how endogenous phytohormone levels correlate with position and time in sections of the tree establishes a necessary background for manipulation of the architecture by exogenous hormone applications and for identifying the optimum scion or cutting material.

Control Of Abies Leader Growth In Oregon Christmas Trees Via Chemical and Mechanical Manipulation

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Annual leader growth of noble fir (*Abies procera*) and Nordmann fir (*Abies nordmanniana*) on Christmas tree farms in the Pacific Northwest during the last few years of the production cycle typically exceeds the 25-40 centimeters that is desired for proper spacing of whorls. Growers usually cut leaders back to the correct length and then train up a new leader (usually by staking and tying) from a branch bud the next year, with great difficulty and significant cost. Over the past several decades researchers and growers have tried a variety of leader scarring and chemical treatments to reduce leader growth, but have been unable to operationalize any effective treatment.

Techniques of leader growth reduction utilizing physical scarring (Top Stop nipper) and application of Ethyl-1 naphthaleneacetate (NAA), individually and in combination, were adapted from Danish techniques, and applied to Christmas trees in Oregon during 2004 and 2005. Results were somewhat variable by

species, treatment and individual tree response, but overall revealed growth reduction possibilities in the 25-50% range, with the highest rates leader nipping and hormone applications causing leader mortality, and the lower rates failing to reduce leader growth. A concurrent trial utilizing various surfactants with the growth hormones revealed significant differences depending upon surfactant applied. This range of responses provides significant opportunities to successfully use these techniques to reduce leader lengths operationally.

The 2003 and 2004 Fraser Fir Freshness Surveys

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During the 2003 and 2004 Christmas tree harvest and sales seasons, we conducted a survey to evaluate handling and care of Fraser fir [*Abies fraseri* (Pursh) Poir] Christmas trees on the farm and in two diverse market places; the Raleigh, NC area and Florida (Ft. Lauderdale/Miami, FL in 2003 and Tampa/St. Petersburg, FL in 2004). The survey consisted of 1) collecting foliage samples from trees in North Carolina fields and storage yards to determine moisture content, 2) collecting foliage samples from Christmas tree vendors' stored and displayed trees for moisture content determination, and 3) appraising vendors' storage and display techniques. Stored trees on the farm were generally fresh, but in 2004 horizontally stacked trees were significantly dryer than those stored upright. On retail lots, tree species, the number of deliveries, frequency of irrigation, type of tree stand, type of shade, and vendor category influenced the moisture content and quality of trees. The greatest number of critically dry trees was observed at grocery stores although no vendor category was free of problem trees.

Noble Fir Stump Removal – A Comparison Of Stump Grinding And Excavation

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Annosus root rot, caused by the fungus *Heterobasidion annosum*, has become a major problem in many noble and Fraser fir Christmas tree plantations in the Pacific Northwest, killing up to 40% of the trees prior to harvest. Stump removal before replanting is commonly recommended as one approach to minimize development of this disease. During 2004, a replicated trial was established in a recently harvested noble fir field near Hillsboro, OR to compare the effectiveness of five different approaches to removing stumps and roots. Following completion of the treatments, trenches were dug around the edges of a 18' x 18' area that had contained 9 stumps within each plot and a backhoe was used to dig out all of the soil within the plot to a depth of 3'. All of the residual pieces of stumps and roots were collected and transported to Puyallup where they were dried to 10% moisture content.

All treatments decreased the weight of recovered material compared to the control "biomass" plots. The average weight of the material in the "biomass" plots was almost 30 kg (66 pounds). The total weight of residual material left after grinding was higher than either of the stump extraction treatments and all of

the grinding plots tended to have a greater amount of root pieces than the extraction plots. The mass of residual stumps left in the field following the Evergreen “strip” grinding treatments was clearly higher than the “broadcast” grinding treatment with this grinder or when the Fecon grinder was used. In part this resulted from stumps that might have been off center and were only partly partially ground by the grinder. In all of the grinder plots, only the tops of some of the stumps were ground off, leaving much of the stump and root system below the 8” grinding depth largely intact. The use of an excavator to remove stumps, especially one equipped with a “brush rake” resulted in the least amount of residual stump material. This treatment was clearly the most effective in minimizing the amount of larger, residual stump pieces that remained in the field, which is where Annosus is more likely to survive for extended periods of time.

Handling Containerized Conifers

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The National Christmas Tree Association estimated that American consumers bought over 30 million live Christmas trees in 1999 and 23 million in 2003. During the same period, artificial trees displayed in homes rose from 44 million in 1999 to 62 million in 2003. This decreasing market share has caused concern among growers and has renewed interest in the development of niche markets and alternative Christmas tree products. Container-grown tabletop Christmas trees offer consumers an alternative to traditional cut trees and they have become one of the most popular winter holiday season pot crops over the past decade. Currently, Chamaecyparis, Pinus and Picea are the dominant genera used for container-grown Christmas trees. Some of the common species marketed in the Eastern U.S. are not reliably winter hardy in regions colder than USDA Zone 7 and stand a poor chance for survival if planted outdoors after the Christmas season. In addition, recommendations detailing how to handle these trees after indoor display is lacking or inconsistent. Few studies have addressed how to handle container-grown conifers during and after indoor display and the adaptability of the commonly grown species. The objective of this study was to determine the influence of display time and post-display handling method on the survival and growth of eight conifer species. This presentation will address methods of post-display handling, species susceptibility to winter injury and first-year survival and growth.

Sulfur Application and Role In PNW Christmas Tree Production

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Sulfur is an essential nutrient for growth and reproduction of plants, used as fungicide, miticide, to acidify soil, and to reclaim or reduce excess sodium. As a fungicide, elemental S is applied to control surface diseases such as powdery mildew and rust. Recently, elemental S has been used in Douglas-fir forest plan-

tations as treatment for Swiss needle cast, *Phaeocryptopus gaeumannii*. Advisors to Christmas Tree growers extrapolated the use of elemental S from forest practices to Christmas Tree plantations. In addition to Swiss needle cast control, the field representatives claimed that foliar elemental S application increased needle thickness, improved needle and increased color, branch thickness. To test the claims, combinations of micronized S rate and timing were applied to 3 to 4 ft tall stand of Douglas-fir Christmas Trees in Washington County, Oregon during May of 2001. On May 17, 2001, plots receiving S were treated with 12, 24 and 36 lb S/a. A second application of S was applied to a portion of the trees on 5/25/01 at the same rates as the previous treatment, resulting in total S application of 24, 48, and 72 lb/a on this block. Needles were sampled in the fall of 2004. Needle size, thickness, and nutrient concentration measured. Elemental S had no effect on needle weight, thickness, or SO₄-S, S, or N concentration. In addition, a visual examination did not provide evidence that elemental S reduced SNC.

Predicting *Pucciniastrum epilobii* Rust Damage In Nordmann Fir

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Nordmann fir (*Abies nordmanniana*) is the main Christmas tree species in Denmark. The host for the rust fungus *Pucciniastrum epilobii* is normally *Abies alba*, but some years infection occurs on *A. nordmanniana*. The alternate host is fireweed / rosebay willowherb (*Chamaenerion angustifolium*). The firs are infected during bud break, and the result is a premature defoliation on the current-year needles during summer. Damages on ready-to-sell trees make them unsaleable, leading to financial loss for the producer. Temperature and precipitation are considered the main factors determining whether infection occurs on Nordmann fir. Data from registered enquiries showed that infections of *P. epilobii* have occurred on either host in most years since 1970. But some years the disease has had very high impact in Nordmann fir. Based on climatic conditions in those years, predictions can be made concerning the risk of infection in Nordmann fir. Such predictions are valuable for the growers if they wish to prevent the damage with fungicides. Spraying can then be limited to the years and stands that are at risk, thus saving money and reducing environmental impact.

The main conclusions are 1) Spore dispersal of *P. epilobii* takes place in May after heavy rainfall (> 10 mm in 24 hours); 2) If the first 2 weeks of May are wet, *A. nordmanniana* will not be infected (but *A. alba* may be); 3) If the first half of May is dry, and it rains heavily after May 17th, *A. nordmanniana* will be severely affected by the disease; 4) If heavy rainfall occurs both in early and late May, some *A. nordmanniana* stands may be infected; 5) In most years with heavy damage in *A. nordmanniana*, high precipitation occurs at a heat-sum of 5000 C (based on temperatures above +5 oC from March 1st).

In Denmark, monitoring the risk of infection by *P. epilobii* should be done in those years, where the first half of May is dry. At the first heavy rainfall after mid-May, Nordmann fir stands should be inspected. Only stands which have green buds or are in the first stages of shoot elongation after bud break, need to be sprayed immediately to prevent infection. Spraying with fungicides can cause damage to the new needles, so chemical, dosage and spraying method must be investigated. At present, no fungicides are approved for Christmas trees in Denmark. The accepted method to prevent infection is to control fireweed inside and within 500 meters of the stand.

Assessing The Risk Of Phytophthora ramorum Infection In Christmas Tree Plantations

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The identification of several conifers as hosts of *Phytophthora ramorum* has increased concerns about the potential spread of this regulated pathogen via shipment of Christmas trees, conifer nursery stock, and various forest specialty products. There are currently five conifers that have been identified as natural hosts of *P. ramorum*. These include Douglas-fir, grand fir, yew (English and Pacific), and coast redwood. In addition, some 20 species of conifers, including many types of true firs, have been shown to be susceptible to this pathogen under experimental conditions.

The risk of conifers being infected by *P. ramorum* in nature is poorly understood. In California, infected conifers commonly occur as understory plants beneath or adjacent to heavily infected hosts like California bay. In Oregon, infection on bays is limited and no infection of existing Douglas-fir trees has been observed, nor have seedlings planted next to infected tanoak stumps become infected. Laboratory studies indicate that infection of Douglas-fir seedlings is limited to a brief period of time right after bud break and is dependent on exposure to high inoculum levels.

In 2005, a plot was established in a 23-acre U-Cut Christmas tree farm west of Los Gatos, CA that is surrounded by a mixed forest containing a number of infected and highly susceptible hosts such as California bay laurel (*Umbellularia californica*), madrone (*Arbutus menziesii*), false Solomon seal (*Maianthemum racemosum*), toyon (*Heteromeles arbutifolia*), coast redwood (*Sequoia sempervirens*), and tanoak (*Lithocarpus densiflorus*) to examine the influence of various environmental conditions, inoculum levels and host phenology on disease development. Within the Christmas trees, infected Douglas-fir and grand fir trees can be found along the interface of the plantation with the infected mixed forest. Other conifers being grown at this site include giant sequoia, scotch pine, white fir (Kaibab seed source) and remnant small noble fir trees from an experimental planting. This site provides a unique opportunity to study the spread of *P. ramorum* along the interface of a mixed forest, containing highly susceptible hosts, into a Christmas tree plantation. Developing a better understanding of the relationship between inoculum levels and infection of conifers under field conditions will be very helpful in assessing the risk of infection and potential movement of *P. ramorum* on conifers.

Training Spanish-Speaking Christmas Tree Farmworkers To Scout

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Many Spanish-speaking farmworkers in western North Carolina are not just seasonal workers that arrive only to harvest trees, but work throughout the growing season, returning to the same farm year after year. These workers have considerable experience with Fraser fir Christmas trees, but the language barrier has hampered in-depth communication and education regarding pest problems and their control. Workers may visit individual trees several times through the growing season to shear trees and apply fertilizers, herbi-

cides and other pesticides. Thus, they represent a grower's first line of defense in finding pest problems. From 2004-2006, a program was funded by the Pesticide Environmental Trust Fund administered by the North Carolina Department of Agriculture to help train these workers to recognize common pest problems such as balsam woolly adelgid, spruce spider mite, hemlock rust mite, rosette bud mite and Phytophthora root rot. Initially, experienced workers were interviewed to determine terms that Spanish-speaking workers were already using to describe pests and their symptoms. These terms were incorporated into a scouting manual that was written for workers and translated into Spanish. In 2005, 7 workshops were conducted in Spanish in western North Carolina by Jim Hamilton, a bilingual Extension Agent, which included powerpoint presentations describing the various pests. Symptomatic plant material was distributed at the workshops and all participants were given hand lenses to help them see and identify pests. In the afternoon, participants were taken into the field to practice scouting. Information was also presented on pesticide applications and pesticide safety to reduce risk of pesticide exposure. Follow-up work with participants was conducted by Bryan Davis who is continuing to meet with workers at the farms where they are employed to practice scouting skills and calibrate pesticide applications. Participants have already aided farmers in recognizing pest problems such as rust mites that were present in the field. Other participants either grow their own Christmas trees or are in charge of crews that apply pesticides and shear other growers' trees on contract. Due to overwhelmingly positive feedback, additional funding is being sought to continue these workshops into the future.

Environmental Control of Cone Production of Fraser Fir

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Fraser fir Christmas tree growers in Michigan frequently report that precocious cone production is a major problem in their plantations. In years of heavy cone production growers may spend more money for cone removal than for any other cultural activity. In 2002, 2004, and 2005 we conducted surveys of cone production in Christmas tree plantations in Michigan's lower peninsula. We also conducted a more intensive survey of cone production in a commercial plantation near East Lansing, Michigan. The objective of the surveys were to: 1) develop a baseline dataset on cone density (cones per tree) and coning frequency (percentage of tree of trees with cones). In addition to cone density and coning frequency we collected samples of current and previous year's needles for nutrient and stable carbon isotope analysis. Maximum cone density on an individual tree was 338 cones, however growers have counted up to 1,000 cones on large trees. Coning frequency ranged from 0 to 30%. Carbon isotope analysis suggests that water stress impacts cone production the following year. Coning density increased with tree size and needle nitrogen concentration. Although much variation in coning remains unexplained, growers may reduce coning by irrigating during the period of bud differentiation and reducing N additions until later in the growing season.

Phytophthora Species Found On Fraser Fir in Michigan

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Species of true firs (*Abies* spp.) and especially *Abies fraseri* (Fraser fir), are viewed as a premium Christmas tree by the Christmas industry in the United States. Species of fir are grown in nurseries, transplant beds, and plantations wherever Christmas trees are grown in North America. Root rot of Fraser fir caused by *Phytophthora* spp. can be a limiting factor in production if trees are planted in low areas with poor soil drainage capacity. *Phytophthora* root rot can be severe in nursery beds or in plantations. So far, more than eight species of *Phytophthora* including *P. cactorum*, *P. cambivora*, *P. cinnamomi*, *P. citricola*, *P. cryptogea*, *P. drechsleri*, *P. gonapodyides*, and *P. megasperma* have been associated with diseased roots and stems of Fraser fir in Pacific northwest, southern, and Great Lakes states. Generally, each region appears to have its own limited number of species that are problematic to fir production in that region. For example, in southern states, *P. cinnamomi* is recognized as the most common and severe species. In Michigan, *P. cinnamomi* has not been detected and losses from root and crown rot appear to be due to infection by other species of *Phytophthora*. When diagnosing root and crown rot, it is important to determine the species *Phytophthora* when diagnosing potential root rot as shipments of nursery material moving across the continent can potentially disseminate and introduce new species of *Phytophthora* to rural areas threatening native plants in natural landscapes.

7th International Christmas Tree Research & Extension Conference

Kettner Center, Tustin, MI, USA
October 2 - 7, 2005

Poster Abstracts

**6th International Christmas Tree
Research & Extension Conference
Kettner Center, Tustin, MI, USA
October 2 - 7, 2005**

Poster Abstracts

Pests

Envidor for Mite Control in Fir

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Envidor (spirodiclofen) is a new miticide produced by Bayer currently labeled for fruits and nuts. Envidor has a unique mode of action that disrupts the endocrine system, affecting energy production in mites and has proven very effective against citrus rust mites. Envidor was tested in Fraser fir in 2004 and 2005 over a range of rates for the control of two types of eriophyid mites: the hemlock rust mite (*Nalepella tsugifoliae*) and rosette bud mite (*Trisetacus fraseri*) as compared to dimethoate, the industry standard. Control of rust mites was comparable or better than dimethoate both years. Control of rosette bud mites will also be discussed.

Weed Control in Fraser Fir (*Abies fraseri*) Christmas Trees as Affected by Different Rates and Timings of Sulfometuron and Hexazinone.

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Michigan leads the nation in Christmas tree production with a net value of \$41.5 million in 2004. Long-term, consistent weed control remains difficult in this perennial crop system. Research studies were conducted in 2004-2005 to evaluate fall and/or spring herbicide treatment combinations on weed control in Fraser fir. In first study, treatments included premix of sulfometuron plus hexazinone (Westar) applied October 29, 2004 at 0.031 plus 0.625 lb ai/A, 0.047 plus 0.94 lb ai/A, 0.063 plus 1.25 lb ai/A, 0.031 plus 0.625 lb ai/A, 0.031 plus 0.625 followed by 0.031 plus 0.625 lb ai/A in the spring, 0.054 plus 0.57 lb ai/A, 0.065 plus 0.69 lb ai/A, 0.076 plus 0.8 lb ai/A, 0.065 plus 0.69 lb ai/A followed by 0.065 plus 0.69 lb ai/A in the spring, and flumioxazin (SureGuard) at 0.5 lb ai/A. Spring treatments were

applied April 15, 2005. A non-ionic surfactant at 0.25% v/v was included in each herbicide treatment.

Crop injury was minimal, except for the fall followed by spring sulfometuron plus hexazinone treatments 15 weeks after treatments (WAT). Fall followed by spring treatments of sulfometuron plus hexazinone provided 97% control of quackgrass, 100 % control of horseweed, and greater than 40% control of common milkweed 15 WAT. In addition, large crabgrass control was greater than 97% 15 WAT. In general, the fall only treatment of sulfometuron plus hexazinone provided marginal control of the above weed species.

In a separate study, the following spring only treatments were evaluated: sulfometuron plus hexazinone applied April 15, 2005 at 0.023 plus 0.469 lb ai/A, 0.035 plus 0.703 lb ai/A, 0.047 plus 0.938 lb ai/A, 0.032 plus 0.343 lb ai/A, 0.041 plus 0.429 lb ai/A, 0.049 plus 0.516 lb ai/A, 0.023 plus 0.352 lb ai/A, 0.035 plus 0.527 lb ai/A, plus 0.047 plus 0.703 lb ai/A, and flumioxazin at 0.255 lb ai/A. A non-ionic surfactant at 0.25% v/v was included in each herbicide treatment. All spring treatments except flumioxazin provided excellent control of quackgrass and horseweed; however, only the sulfometuron plus hexazinone treatment at the 0.03 plus 0.703 lb ai/A provided fair (33%) control of common milkweed at 15 WAT. Similar to the first study, fraser fir tree injury was 1% or less at 15 WAT.

Degree Day Accumulation Maps for Improved Timing of Insect Pest Management

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Insect pest management is an important aspect of Christmas tree production. Correctly timing activities, such as scouting or pesticide applications, can be challenging because of variation in weather among years and among locations. Many Christmas tree growers and farmers know that “degree days” can be a useful tool to help time pest survey and control activities. “Degree days” is a term that refers to the accumulation of heat units above a threshold temperature over time. If we intensively monitor a local population of an insect over time, and if weather data are available for that particular area, we can identify the degree day accumulation associated with significant events in the life cycle of the insect.

We compiled a list of economically important insect pests that affect forest trees, Christmas trees and ornamental trees, then acquired the degree day accumulations associated with significant events in the life cycle of each pest. We generated maps of average seasonal degree day accumulations for the region by acquiring daily weather records of maximum and minimum air temperature from 1971-2000 at 92 weather stations in Michigan and the surrounding North Central states of Wisconsin, Illinois, Indiana and Ohio (Midwestern Regional Climate Center, 2005). We calculated the average seasonal accumulation of growing degree day thermal units over the 30-year period for each location and exported the geographically-referenced Julian dates of degree day accumulations for each location to the ArcView 3.2 geographic information Separate GIS contour maps were generated for the average seasonal accumulations of 50 to 2000 degree days (base 50°F) throughout the region, at 50 degree day intervals.

In Table 1, we present a list of insect pests of Christmas trees and the respective degree day accumulations

associated with specific life cycle events for individual species. A version of this table and the degree day maps will soon be available as a link from the USDA Forest Service web site (<http://www.fs.fed.us/spfo/>). You will be able to select a pest of interest and it will bring up the appropriate degree day map. Simply find the location of your field or property and use the legend to determine when that degree day accumulation is likely to occur. You can successfully improve the timing of your pest scouting, pesticide applications and similar activities by using degree day accumulation rather than relying on calendar dates.

Diseases & Disorders

Population structure of *Heterobasidion annosum* infecting Christmas tree plantations in the US Pacific Northwest

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The population structure of *Heterobasidion annosum* was determined in Pacific Northwest (PNW) Christmas tree plantations using inter-sterility group (ISG) specific and sequence-tagged microsatellite markers. Seventy isolates from 5 different hosts in 4 PNW plantations were typed to strain using taxon specific competitive priming (TSCP) PCR assays. Additionally, isolates were sampled at 2 spatial scales and included 93 isolates sampled from single trees in 27 discrete disease foci and 104 isolates sampled from 12 root systems of noble and Fraser fir trees near Mossyrock, WA. These isolates were genotyped using 4 microsatellite markers and somatic compatibility tests to determine the spatial scale at which dispersal of single genotypes (clones) was occurring. All isolates from Washington and Oregon Christmas trees were found to be of the S ISG type using the TSCP PCR assay. DNA fingerprints and somatic compatibility tests indicated all isolates sampled from different trees in discrete disease pockets were distinct genotypes whereas the root systems of single trees were dominated by 1 or 2 genotypes. These results suggest that infection of PNW Christmas trees is the result of frequent primary infection events of adjacent stumps and localized secondary spread within root systems. The formation of disease pockets may be explained by variation in spore levels during selective harvesting of patches of mature trees over several years rather than the extensive growth of single clones from a single infected tree to adjacent trees.

Phytophthora root rot and stem canker in Norwegian fir plantations

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In 2004, damages by *Phytophthora* spp. were observed on three different fir species in Norway. In a nordmann fir (*Abies nordmanniana*) Christmas tree field on the west coast of Norway approximately 70% of the plants died within few months after planting. The massive infestation in a field previously used for grass production over decades, left no doubt that the disease had followed the imported transplants. Symptoms included poorly developed roots and discoloration under the bark from the stem basis downwards. The foliage had different stages of drought symptoms; pale green, yellow or brown. Except for the dominance of amphigynous antheridia over paragynous, a *Phytophthora* sp. with morphological features matching *P. megasperma* was identified as the disease-causing organism (homotallic, large oogonia - >50 µm, nonpapillate sporangia, internal proliferation, aplerotic oospores). In the same county, severe damage by *P. cryptogea* was observed in a 15 year old bough plantation of noble fir (*A. procera*).

A typical stem canker extending upwards from the roots resulted in dead basal branches (flagging). In the south-eastern part of the country, several seven-year-old Christmas trees from subalpine fir (*A. lasiocarpa*) were dying after attacks by *P. citricola*. In September 2005, ITS rDNA sequences of the isolates will be obtained to confirm the identification. *Phytophthora* spp. (*P. citricola* and *P. citrophthora*) are well known to cause problems on Lawson Falsecypress/ Port-Orford-cedar (*Chamaecyparis lawsoniana*) in Norway, but has never been reported in fir plantations. Therefore, a pathogenesis test to fulfil Koch's postulate is currently (by the deadline of this abstract) carried out on all the three fir species, each of them inoculated with the respective isolate. Typical *Phytophthora* symptoms have been observed on spruce (*Picea* spp.) in forest nurseries in Norway, but to our knowledge the fungus has never been isolated and reported. There are no published reports on *Phytophthora* on conifers in forest stands from Norway.

Susceptibility of Different Sources of Douglas-fir to Rhabdocline Needle Cast and the Effectiveness of Fungicides in Controlling This Disease

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Intermountain (IM) forms of Douglas-fir Christmas trees tend to have better postharvest moisture retention and are less likely to be injured by exposure to subfreezing temperatures than the coastal forms that are grown in the Pacific Northwest (PNW). Historically, PNW growers have avoided planting IM Douglas-fir because of their susceptibility to Rhabdocline needle cast. One possible way to improve the postharvest quality of PNW-grown Douglas-fir trees that are shipped into cold weather markets is to identify sources of needle cast resistant IM Douglas-fir that grow well in the PNW. In 1994, a plot was established to examine the variation in susceptibility of 21 different sources of Douglas-fir to Rhabdocline needle cast and determine the effectiveness of different fungicides in controlling this disease.

The susceptibility of the trees to needle cast was determined by rating disease severity each spring from 2000 through 2004. During 2003-04, a test was also conducted to compare the effectiveness of a single application of several fungicides in controlling needle cast on 9 highly susceptible trees in this plot. On May 8, 2003, randomly selected branches near the middle of each tree were tagged and the length of new growth on each branch was measured. A single rate of each fungicide was then applied to one tagged branch on each tree. On April 1, 2004, the effectiveness of the various fungicide treatments was assessed. Disease severity was rated on a scale of 0 (none) to 100 (>75% of the needles with severe symptoms).

There was tremendous variation in the susceptibility of the different sources of trees to needle cast. No disease occurred on two of the sources from the Shuswap region of B. C. and one source from the Clearwater N.F. Even among some of the highly susceptible sources, there were some trees that were totally resistant to needle cast.

Several of the fungicides included in our test provided effective control of needle cast. Although applications of Heritage and Kocide significantly reduced needle cast compared to the checks, these materials were not as effective as Insignia, Daconil WeatherStik, Thiolut, Fore and Compass.

Environment

Leader growth in Nordmann fir Christmas trees: Growth visualization and effects of fertilization, irrigation and drought.

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In Denmark, too long leaders cause the grower a lot of work in order to reduce the leader length and obtain a symmetrical tree. However, there is only limited knowledge on how to fertilization and climate influences the growth rhythm of Nordmann fir Christmas trees. A manipulation trial was therefore set up to analyze the effects different fertilization levels, as well as drought and irrigation during the growing season. The leader length growth was recorded by webcams taking pictures every 15 minutes during the day. Mean daily temperature and precipitation, obtained from nearby meteorological stations, and soil water content were measured every second hour.

Length of top shoots after termination of the growth period reflected increased input of water and fertilizer. Compared with the treatment receiving 75 kg N ha⁻¹yr⁻¹ fertilizer, the drought + 75 kg N ha⁻¹yr⁻¹ fertilizer treatment resulted in a leader length reduction of approx. 35 % whereas the irrigation + 75 kg N ha⁻¹yr⁻¹ fertilizer treatment caused an increased leader length of approx. 30 %. The highest mean and maximum daily leader growth during the growth season were 0.6 cm and 1.8 cm. Drought delayed the growth whereas irrigation resulted in a rather constant growth during the season.

Splicing the pictures together to a film visualized a huge daily movement of the leader. It is well known that the leader moves/bends slightly during the growing season, but as a side effect we discovered, that these movements could be very pronounced. However, the extent of moving/bending varied from tree to tree, and for some trees the recorded bending was approx. 150 degrees during one day.

Development of an *in vitro* screening method of Christmas trees for tolerance to water stress.

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The ability of Christmas trees to retain their needles and fresh appearance for a long period of time after harvest is a important trait for growers and consumers alike. Pre- and post-harvest needle retention in Christmas trees depend on many factors including water regulation, water availability and carbon source concentration and accumulation. During culture *in vitro*, bud expansion and growth depend

on some of the same factors. By conducting *in vitro* bud culture in a high osmotic environment it should be possible to select for clones with an improved tolerance to water stress conditions. We are testing such an *in vitro* system for selection under osmoticum-induced water stress as a surrogate for selection of improved needle retention in Christmas trees. Also it should be possible to know the tolerance level of a tree to water stress before harvest by using few buds and culturing them *in vitro* under water stress. This information could help growers, wholesalers and retailers optimize time of harvest for distant markets with less fear of losses in tree quality and value. Recently we optimized a protocol for Douglas-fir bud sterilization and establishment *in vitro* (Traore et al. 2005). To develop an *in vitro* method of selecting Douglas-fir, and other Christmas trees, for needle retention, we cultured Douglas-fir winter buds in various osmotic environments using PEG containing media. As expected, bud growth or survival was significantly reduced as PEG concentration increased. By 6 weeks over 85% of bud on high PEG concentration were dead. We found that at lower concentrations of PEG, bud expansion was suppressed without bud death. We are now testing these PEG concentrations on Douglas-fir spring buds, and some other Christmas tree species to see if differences in level of needle retention detected among them by whole tree post harvest experiments can also be detected using tissue culture.

Environmental Control of Cone Production of Fraser Fir

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Fraser fir Christmas tree growers in Michigan frequently report that precocious cone production is a major problem in their plantations. In years of heavy cone production growers may spend more money for cone removal than for any other cultural activity. In 2002, 2004, and 2005 we conducted surveys of cone production in Christmas tree plantations in Michigan's lower peninsula. We also conducted a more intensive survey of cone production in a commercial plantation near East Lansing, Michigan. The objective of the surveys were to: 1) develop a baseline data set on cone density (cones per tree) and coning frequency (percentage of tree of trees with cones). In addition to cone density and coning frequency we collected samples of current and previous year's needles for nutrient and stable carbon isotope analysis. Maximum cone density on an individual tree was 338 cones, however growers have counted up to 1,000 cones on large trees. Coning frequency ranged from 0 to 30%. Carbon isotope analysis suggests that water stress impacts cone production the following year. Coning density increased with tree size and needle nitrogen concentration. Although much variation in coning remains unexplained, growers may reduce coning by irrigating during the period of bud differentiation and reducing N additions until later in the growing season.

Nutrition

Nutrient deficiencies in nordmann fir for Christmas tree production in Norway

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Various needle discolorations, often due to lack of uptake of certain nutrients are frequently observed in nordmann fir (*Abies nordmanniana*) in Norwegian Christmas tree plantations. Most common are the yellow to necrotic needle tips on older needles caused by magnesium (Mg) deficiency (confirmed by chemical analysis of foliage). Even though chemical analysis of soil samples show that Mg is present in sufficient amount, various soil factors may cause Mg-deficiency; too high or too low pH, excess potassium (K) or too wet or too dry conditions. Antagonism, causing imbalance in nutrient uptake, can lead to negative effects. High pH may give Ca²⁺/Mg²⁺ antagonism, too low pH NH⁴⁺/Mg²⁺ antagonism, and abundant K K⁺/Mg²⁺ antagonism. During wet conditions K⁺ and other monovalent cations may leave the colloids to regain equilibrium between liquid and solid material. Then Mg²⁺ may easily bind to the free spaces on the colloids, and thereby becomes unavailable for the plants. If the soil is very dry there may not be enough liquid for the nutrients to be dissolved, and thus uptake inhibited. Nordmann fir is mainly grown in the southwestern coastal region of Norway since the climate there is fairly mild and suitable for this plant species. The yearly rainfall is high in that region, so a main cause for Mg-deficiency on nordmann fir is probably related to wet soil conditions. Uptake of Mg after foliage application has proved to be ineffective due to the wax layer on the fir needles. However application on young needles and shoots has been reported by the Norwegian extension service to be successful. K deficiency also results in discoloration of older needles, but symptoms can easily be distinguished from Mg deficiency. Both deficiencies results in yellowing of the needles, but different from K deficiency, the base remains green on needles suffering from Mg deficiency. Both Mg and K are very mobile nutrients in plants, and they are therefore easily translocated from older to younger needles. Samples with yellow discoloration of the youngest needles have been observed to be low in iron (Fe) and manganese (Mn), especially when the trees have grown in soil with high pH. Both nutrients are nearly immobile in plants after they have been transported to the cells, and they are therefore not available for the young shoots. Nitrogen (N) deficiency is seen as a uniform, pale green discoloration of both young and old needles.

Seasonal fluctuation in concentration and content of sucker, starch and nutrients in Nordmann fir (*Abies nordmanniana*) Christmas trees. Effects of fertilization

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Evaluation of nutrient analysis is a common practice to optimize the nutritional status of Nordmann fir (*Abies nordmanniana*) Christmas trees in Denmark. This study investigates the seasonal fluctuation in

carbohydrate reserves, needle weight and nutrients in current year needles that have been subjected to fertilization. Concentration and content of starch and sucker as well as N, P, K; Ca, Mg, and S were measured every second month. On the basis of a literature survey, a model for the seasonal fluctuation was developed.

Newly emerged needles contained considerable amounts of sucrose, starch, N, K, S and Mg, whereas the amount of Ca was very low. The sugar concentrations exhibited a general increase from June to October followed by a decrease lasting to February. The relative high amount of starch during the summer month was followed by a sharp decrease in September. In February starch again appeared in measurable amounts reaching the highest amount in May. In general, N, K, Mg, and S decreased from the highest amounts in the newly formed needles in May to the lowest amounts in the 1-year-old needles in May. The last five months showed relatively constant amounts of these nutrients. However, the progress was characterized by a local minimum in the late summer. In contrast to that, the amount of Ca increased rather fast during the first half year after which the amount was relatively constant. The needle weight exhibited a substantial increase during the summer and late autumn, a local minimum in January followed by an increase during the spring.

Translocation and retranslocation processes as well as fluctuations in amounts of sucker and starch could to a large extent explain the amounts of nutrient. The growth period characterized by labile amounts of nutrients is regarded, as a period unsuitable for needle analyses which has to be compared with standard values. On the other hand, the period from January to March is the most suitable for such analyses.

Postharvest

Effect Of Two Fire Retardants On The Postharvest Moisture Retention And Flammability Of Fraser And Douglas-Fir Boughs

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Two experiments were conducted to evaluate two recently developed flame retardant materials on Christmas trees. In one test, Safe Tree fire retardant was applied to freshly harvested Douglas-fir boughs, which were then displayed dry for 17 days. In the other test, foliar and pulse applications of Rapid-Cool FRX ChristmasTree Protectant were applied to freshly cut Fraser fir boughs. This flame retardant was either sprayed onto the foliage prior to displaying the branches dry or in water for 28 days, or applied as a pulse treatment by placing the freshly cut ends of branches in buckets containing the fire retardant and allowing them to take up the solution for 48 hours prior to displaying the branches dry or in water. Shoot samples were periodically collected to determine moisture content (MC). Flammability was tested by exposing shoots to a small flame for 5 seconds. Safe Tree fire retardant accelerated the drying rate of Douglas-fir boughs. After 6 days, the MC of treated branches averaged 39% versus 76% for non-treated controls. This fire retardant also increased branch flammability because of the increased rate of moisture loss. For Fraser fir boughs displayed dry, the pattern of drying was almost identical (linear) both for treated and non-treated branches. Fire retardant had no effect on MC at ignition, flame time, total burn time, or total foliage consumed, compared to controls. The pulse treatment caused massive needle abscission, probably from osmotic stress, whereas needle loss was minor with foliar applications. For both species, initial ignition and propagation of flame occurred at MC between 60 and 70%. Fresh boughs of Fraser fir and Douglas-fir did not ignite in burn tests and therefore were not a fire hazard. Twig MC of the Fraser fir boughs displayed in water increased 20% during display, further decreasing the possibility of ignition when exposed to a point source of flame. Neither the Safe Tree nor Rapid Cool fire retardant appears to be suitable for use on boughs or Christmas trees.

Effectiveness of I-V Watering Devices in Maintaining Postharvest Freshness and Quality of Cut Christmas Trees.

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Experiments were carried out with cut Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) and Leyland cypress [*x Cupressocyparis leylandii* (A. B. Jacks. & Dallim.)] Christmas trees to evaluate postharvest

water uptake, moisture status, needle loss, and tree quality when water was supplied to displayed trees either by an I-V device or a traditional method of placing the base in water. In both experiments, trees consumed about 4X as much water with the traditional method. Based on measurements of twig moisture content, xylem pressure potential (Ψ), needle loss, and total water consumption, tree freshness and quality was adequately maintained by the traditional method, but not the I-V device.

Genetics & Propagation

Somatic embryogenesis of Fraser fir (*Abies fraseri*)

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In conifers, the possibility of using cuttings for clonal propagation is limited due to the ageing effect resulting in insufficient rooting and poor shape of the trees. For some fir species that effect is already excluding the use of cuttings from an age of 5 yrs. Somatic embryogenesis is a promising alternative method for clonal propagation of conifers. The techniques has however not yet been optimized for many species. The potential for using somatic embryogenesis (SE) for clonal propagation of Christmas tree species has been investigated. The method for propagation of *Picea abies*, (Norway spruce) the most common Christmas tree in Europe, by SE is already well established. Protocols for propagation of subalpine fir (*Abies lasiocarpa*) have also been successfully developed. In the present study, we show the use of SE for another Christmas tree species, Fraser fir (*Abies fraseri*), which is important to the US Christmas tree market.

Somatic embryogenesis cultures were initiated from several seed sources. Different culture media were required for different developmental steps. Key components of the culture media were identified and further investigated. Embryogenic cultures from several genotypes have been established and progressed through maturation and germination. A small number of plants have been transferred to soil.

Christmas Tree Production in the California Sierra Foothills

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Christmas trees can be a lucrative specialty crop grown on California's Sierra foothill small farms. A large variety of true fir species, as well as Douglas fir, are grown on relatively small 'Choose n' Cut' farms in traditional fruit and winegrape agritourism locations. Many growers utilize stump culture for maximum production of trees. Specific pests, such as *Phytophthora* root rot, Balsam twig aphid (*Mindarus kinseyi*), and cribrate weevil (*Otiorhynchus cibricollis*), need to be managed for successful

production. Recently, an on farm study investigating the effect of certain Nordmann and Turkish seed sources for both *Phytophthora cinnamomi* resistance and for growth habit characteristics in California foothill microclimates has been initiated. A cost of production study, the first for Christmas trees grown in California, has also been initiated.