TREE IMPROVEMENT

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Seed and Seedling Extension Topics

David Trotter — Editor

Yes …we are still alive and kicking after a bit of a hiatus. The seedling count in BC continues on its 220 million plus effort with an ever expanding US market. It seems our American neighbours like our stock quality and efficiency coupled with our rapidly approaching 60 cent Canadian dollar. BC nurseries are positively embracing the idea of retractable roof houses in our constant drive to refine and re-tool. Forestry in BC continues with the ever-changing land use debate. It seems that certification is the next challenge to overcome in the drive to better define our forest practices to the rest of the world. Reforestation nurseries, seed orchards, seed handlers & processors will not be immune to this process so I encourage you to keep informed and get involved.

The 20th Annual Meeting of the Forest Nursery Association of BC is just around the corner. It will be in Prince George this year and Tom Helson and his organising committee have put together a stellar agenda. All the best Tom and see you in September.

As an added bonus, you will notice an attachment to the newsletter. It is an index of all the articles to date published in the newsletter and a special thanks to Eric van Steenis for compiling it. Also, Diane Gertzen will be taking over the reins of the newsletter for the next series of issues. In greater measure, all this would not be possible save for the untiring efforts of Diane in putting this jumble of information through the desktop publishing grinder. Thank you.

Well, I hope you are enjoying the new millennium and that the next 1000 years will present you with enough challenges and rewards.

Aloha!

Dave Trotter
Tree Improvement Branch
Ministry of Forests

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BRITISH COLUMBIA
Ministry of Forests

GROWER'S NOTES

Summary of Samples sent to the Canadian Forest Service's Forest Health Clinic April 1, 1999 to March 31, 2000

Overview:

The Canadian Forest Service's Forest Health Clinic (FHC) received 122 requests from various agencies relating to tree health and growth. Of these, 23 were from British Columbia Ministry of Forests (MOF). There were 13 requests from foresters dealing with plantations and other tree establishment problems. One request came from Agriculture Canada's Plant Health Division which was inspecting Douglas-fir imported as Christmas tree stock from the United States. Requests often contained more than one seedlot, container or type of seedling and a single sample often included a range of symptoms. Therefore, the number of assays performed was much higher. Container grown seedlings represented over 55% of the requests. Only 3% were for bareroot stock. Preventative assays represented 20% of the requests containing in excess of 100 samples composed mainly of seed or containers. Submissions of water and bareroot soil were also included in this category. These samples were assayed for potential pathogenic fungi and recommendations were made to nursery personnel on how to eliminate or minimize losses before they have a chance to occur. Over 8 % of the samples were from Christmas tree growers who had sent damaged plant tissues to the MOF Christmas tree specialist at Green Timbers Reforestation Center for recommendations. These samples were forwarded to the FHC for identification of fungal species present and to determine if their role was causal or secondary. Douglas-fir accounted for 39% of the samples by tree species with *Abies* and *Picea* species representing 23% and 17% respectively.

When age class was the criteria, 60% of the samples were 1+0 stock, 14% were over 3 years old and 9% were germinants. Seed represented 24% of the tissue type assayed for damage. Over 22% of the samples had unspecified damage to the whole plant, damage to the roots represented 20% of the samples, while foliage and shoot damage were both at 18%.

Fusarium disease, either seed infection, damping-off, shoot blight or root rot accounted for 40% of all samples sent. Grey mould (*Botrytis*) occurred on 12% and *Sirococcus* Blight on 6% of the samples. *Cylindrocarpon* was isolated in 20% of the samples while *Pythium* was found in 4%.

The FHC hosted 3 college groups one from Kwantlen, one from Malaspina and the other from Camosun demonstrating how the various laboratory assays done by the Clinic provide information required for Integrated Pest Management (IPM) in the forest industry.

An invitation was made by the Canadian Food Inspection Agency (CFIA) to participate in a workshop on the introduction of exotic pests to Canada. It was a joint exercise with the CFIA, the Canadian Forest Service, the B.C. Ministry of Agriculture and Foods and the Canada Customs and Inspection Branch. It provided valuable protocols to prevent the spread of introduced organisms by early detection and communication. Funding was supplied by the CFIA.

Contributions to Integrated Pest Management

1. Styroblock Assays

Sanitation of growing containers remains one of the most important steps in disease prevention for forest seedling production. Assay requests were submitted by clients prior to purchasing used containers, to determine if pathogens were at level that would require sanitation or to check on

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the efficacy of sterilization procedures. Styroblock samples were assayed for the presence of *Pythium* and *Phytophthora* using a water mould selective media. Positive results from this assay occurred only in unsanitized blocks. A second selective media, Komada's Medium, was used to assay for the presence of *Fusarium, Cylindrocarpon* and *Phoma*. Sodium metabisulphate treatment of styroblocks was the most effective cleaning procedure used by nurseries. Hot water and steam sterilization reduced pathogen levels up to 20 fold but on average only 50% of the material assayed was pathogen free. *Phoma* routinely was the last organism to be eliminated by the various heat treatments. Although not considered a primary pathogenic fungus, *Phoma* was isolated from plant tissues and soils in 20% of the samples sent to the Clinic. It appears to be able to take advantage of plant stress and cause some tissue decay. Used styroblocks appear to be a source for this fungus.

2. Seed Assays

Tree breeding in seed orchards has produced high quality seed with improved growing performance. However, the high cost of this improved seed makes even small losses due to disease unacceptable. Seed is a source of pathogens and the fungi can be seed-borne internally or present on the seed surface. Routine assays have shown that seed orchard seed is not free from disease causing fungi. Fungi often spread and colonize more seed during the stratification process. Mould found at nurseries during stratification stimulated requests for identification of the organisms present and their potential to cause damage to germinants when sown. *Fusarium* and *Cylindrocarpon* were isolated along with a number of other fungi that were saprophytic but grew on these seeds at low stratification temperatures. Assays identified several seedlots with the important seed-borne pathogens *Sirococcus* and *Geniculodendron*.

An increasing number of nurseries are growing seedlings for the export market. Forest companies in the United States are providing seed to Canadian nurseries which grow the crops and ship the seedlings back to the U.S. Samples of imported seed sent to the Clinic were examined and found to be contaminated with pathogenic species of fungi and infested with insects.

3. Water Assays

The use of green pears as bait to determine the presence of *Pythium* or *Phytophthora* in the water supply, confirmed water as a source of these organisms at one site. This explained the stunting of spruce seedlings the previous year and the chlorosis and poor growth starting to show on the current crop. The identifications helped the client eliminate, through water treatment, the source of these root rot pathogens in the spruce crop.

4. Germinant Assays

Disease development in new germinants produced numerous samples for the Forest Health Clinic. The most common fungi found causing damping-off were *Sirococcus, Fusarium and Phoma*. When *Sirococcus* and *Fusarium* were found, the seedlots were identified and clients notified so affected germinants could be culled to prevent spread of the disease. Phoma also colonized many germinants but typically only after drought or heat stress predisposed seedlings grown in old styroblocks that had not been sterilized.

5. Shoot Blights

Alder became a new host record for *Botrytis*. Approximately 50% of the alder crop was killed. *Botrytis* colonized up to 70% of the shoot on some plants. Shoot necrosis and sclerotia were observed on seedlings after they were removed from cold storage and *Botrytis* was identified in laboratory incubation tests. The crop had been grown in an open compound for the latter part of the season. An identical crop grown under cover for the entire season had no evidence of this pathogen. Samples of the affected crop were submitted to the PFC herbarium (DAVFP). In other samples, *Botrytis* girdled main stems and lower branches of western hemlock and lodgepole pine.

Phomopsis was isolated from 2 separate plantation samples of coastal Douglas-fir. Trees exhibited shoot dieback when seedling survival assessments were conducted. Seedling mortality at one site was assessed at 50%.

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6. Root diseases

Pre and Post Storage assays

Seedling assays performed at the time of lifting or after cold storage showed that late season root rot syndrome was present in a number of crops this year. Classic symptoms were small or empty buds, thick, often spongy lower stems and dark roots. *Cylindrocarpon* and *Fusarium* were isolated from many of the roots, even when there was no obvious root necrosis. This disease can be initiated and promoted by logistical problems rather than poor growing practices. If sites are not available for planting at the specified times (i.e. unexpected late springs or dry summers), seedlings held longer than planned become compromised. Crops grown for summer planting but held until late fall had the highest incidence of this problem.

Valuable rust resistant white pine seedlings destined for seed orchards were found to have *Pythium* and *Phytophthora* root rot. Recommendations were made on how to stop further root damage and prevent the occurrence in future crops.

7. Christmas Tree problems

Grosvesiella canker was reported on white fir Christmas trees (*Abies concolor)* for the first time in British Columbia. This tree species is not native to B. C. Growing trees outside their range might have encourage *Grosvesiella* canker disease. *Grosvesiella* was also found on *Abies grandis* from the same location.

Swiss needle cast (*Phaeocryptopus gaeumannii*) was the predominant fungal organism isolated from two Christmas tree samples in which the main symptoms were chlorosis and needle drop. Swiss needle cast has been a serious problem when interior seed sources were used to grow Douglas-fir on the Oregon coast. Compounded by warm and moist weather, the disease has created serious chlorosis and defoliation.

Milesina rust was found on grand fir being grown as Christmas trees. This was the first time this rust was found by the Clinic. The rust has sword-fern as its alternate host. *Rhizosphaera* needle blight was also found on the trees indicating the trees were probably stressed and had experienced humid weather.

8. Insect problems

Very few insect problems were diagnosed by the Forest Health Clinic. Most occurrences had insects as secondary invaders. Foliar damage by *Contarinia psuedotsugae* (Douglas-fir midge) was found in 2 samples during seedling survival assessments. There was a concern that the insects may have come from the nursery rather than the field site.

Fungus gnats continued to be insidious pests whenever excessive irrigation or fine particulate growing media was used. A sample of spruce roots confirmed this insect's ability to cause root necrosis without any assistance from root rot fungi. No pathogens were isolated from growing media or roots but fungus gnat larvae had stripped and eaten much of the root system.

A species of *Megastigma* emerged from a seedlot of *Abies* of foreign origin and is of significance since it demonstrates that seed has the potential to be a source of exotic insect introduction.

9. Other Important Occurrences

Septoria was isolated by the FHC from stem cankers on alder for the first time. In the past this organism has only been observed on foliage. Stem infections have a greater impact on seedling survival and quality. Therefore monitoring foliage for early signs of *Septoria* is recommended to prevent progression of the disease into the stem.

Phyllosticta abietus was identified and is considered rare in B.C. and was added to the PFC herbarium (DAVFP).

Chlorosypha seaveri and *Stemiopeltis* were found on plantation stock. They are both minor needle blights of western red cedar. The crop also had old infections of

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Keithia blight (*Didymascella thujina*) and a history of drought stress.

Several samples of growing media and seedlings were found to be colonized with actinomycetes, probably *Streptomyces*. There appeared to be no deleterious affects from having this organism in the soil and growers were assured that no corrective measures needed to be taken.

Tabular Summary of Forest Health Clinic Reports

For the period May 1, 1999 to March 31, 2000

Total requests	122 submissions
BCMF requests	23 samples

Number of samples by type:

Container	69
Bareroot	4
Plantation	8
Christmas tree	10
Seed orchard	1
Forest -	3

Preventative assays:

Bareroot soil	2
Styroblocks	72
Water	2
Seed	33

Number of samples by tree species:

Abies sp**.**	24
alder	2
black spruce	1
coastal Douglas-fir	30
interior Douglas-fir	11
jack pine	2
lodgepole pine	9
mountain hemlock	1
ponderosa pine	2
Sitka spruce	1
spruce (Sx)	16
western hemlock	4
western red cedar	6
western white pine	5
whitebark pine	1

Number of samples by age:

0.5+0.5	1	3	1
1+0	65	3+	14
1+1	6	germ	10
1p+1	2		
2+0	6		

Number of samples by damage

whole plant	30
foliage	24
roots	27
shoots	23
seed	33

(Continued)

Number of samples with the following diseases:

Botrytis	12	*Pythium*	6
Cyclaneusma	1	*Rhizosphaera*	2
Cytospera	1	*Sclerophoma*	2
Cylindrocarpon	33	*Septoria*	1
Fusarium	68	*Sirococcus*	6
Geniculdendron	2	*Streptomyces*	1
Grovesiella	2	*Verticillium*	1
Hormonema	1		
Keithia	1		
Milesina	1		
Pestalotiopsis	1		
Phaeocryptopus	4		
Phoma	25		
Phomopsis	2		

Insects:

aphids	1
fungus gnats	2
thrips	1
Contarinia psuedotsugae	2
Megastigma sp.	1

Samples sent in by Month:

April	23
May	7
June	18
July	0
August	5
September	15
October	5
November	19
December	8
January	6
February	5
March	11

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New Web-based Diagnostic System for Douglas-fir Cone and Seed Insects

This note announces the public release of the **DOUGLAS-FIR CONE AND SEED INSECT DIAGNOSTIC SYSTEM** – an electronic, interactive, knowledge base system accessible through the World Wide Web. This system was developed by Acquired Intelligence Inc. of Victoria, British Columbia with input from the BC Forest Service, Canadian Forest Service and Agriculture and Agri-Food Canada and the financial assistance of Forest Renewal BC. This site is located at on the BC Ministry of Forests, Tree Improvement Branch web page at:

http://www.for.gov.bc.ca/TIP/IID/

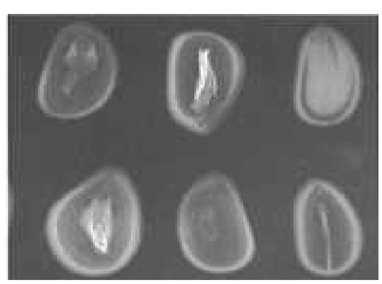
The "Douglas-fir Cone and Seed Insect Diagnostic System" was designed to enable researchers, orchard managers and technicians, seed dealers, and other field workers accurately to identify damaging insects associated with Douglas-fir cones and seeds. The system assumes the user has a basic understanding of Internet usage, conifer cones and seeds, and is in the process of evaluating a developing or matured cone crop. It works by prompting the user to choose answers to a series of questions starting from general (What stage is the crop at?) to increasingly specific (reasonably easy to observe characteristics of damage and/or insects in/on the cones). After the final question is answered a conclusion screen is reached which supplies an identification of the insect(s) you may be dealing with and more detail to help confirm the identification. Double clicking on photos in conclusion screens will enlarge them to full screen size. Conclusion screens will be linked sometime in 1999 to a BC Ministry of Forests general cone and seed insect information web site, currently being completed by Seed Pest Management. When finished, that site will provide up-to-date details on biology, current research, and management of most BC cone and seed insects.

Your comments on the "Douglas-fir Cone and Seed Insect Diagnostic System" knowledge base web site are welcomed.

Forward them to me at Robb.Bennett@gems6.gov.bc.ca

Robb Bennett
Tree Improvement Branch
Ministry of Forests

***Leptoglossus* eggs (and one hatching nymph)**



***Leptoglossus* or abiotic damage. No tunnelling or galling. Seed contents are missing or damaged.**

Germination Falldowns

The Quality Assurance (QA) program of the Tree Seed Centre (TSC) has been conducting germination tests on sowing requests since 1992. A total of 1972 sowing requests have been germination tested prior to shipping and 499 of these requests have had germination results forwarded from the nursery (Table 1). Sowing requests are selected for QA testing prior to seed withdrawal and grams added for germination and moisture content testing. Just prior to shipping a random sample is withdrawn for testing to determine germination capacity or moisture content at time of shipping. The falldowns indicated are relative to the latest germination capacity (GC), on SPAR[1]:

Shipping Falldown =
GC at Shipping – GC indicated on SPAR

Nursery Falldown =
GC at Nursery – GC indicated on SPAR

Table 1. Sample sizes, germination capacity (GC) and falldown {relative to the latest Lab germination} for sowing requests tested as part of Quality Assurance prior to shipping and at the nursery.

Sp.[2]	Tree Seed Centre at Shipping			Nursery Information		
	#	Mean GC	Falldown	#	Mean GC	Falldown
Ba	107	64	2	37	73	-2
Bg	34	76	0	12	71	-6
Bl	75	62	-11	37	69	-7
Cw	290	72	-8	88	73	-2
Fdc	117	91	0	32	91	-1
Fdi	129	89	1	35	88	-2
Hm	32	92	2	4	77	-14
Hw	109	90	-1	44	81	-8
Lw	143	79	-2	22	89	9
Plc	45	92	1	5	92	4
Pli	244	93	1	65	83	-9
Pw	119	61	-17	35	80	3
Py	89	85	-2	1	81	-4
SS	55	94	-1	1	82	-14
Sx	342	87	1	81	87	3
SxS	42	90	2	0		
	1972	82	-2	499	81	-3

[1] SPAR = **S**eed **P**lanning **A**nd **R**egistry system

[2] Ba=Amabilis fir; Bg=grand fir; Bl=subalpine fir; Cw=western redcedar; Fdc=coastal Douglas-fir; Fdi=interior Douglas-fir; Hm=mountain hemlock; Hw=western hemlock; Lw=western larch; Plc=coastal lodgepole pine; Pli=interior lodgepole pine; Pw=western white pine; Py= Ponderosa pine; SS=Sitka spruce; Sx=interior spruce and SxS=Sitka X interior spruce hybrid.

(Continued)

It is worth noting some differences present in the Quality Assurance testing program to fully appreciate these results.

1) The latest lab test GC, indicated on SPAR, is based on 400 seeds (4 replicates X 100 seeds). Lab tests for Cw are based on naked seeds (unpelleted)
2) The GC prior to shipping is based on 200 seeds (4 replicates of 50) except for Ba, Bg, Bl, pelleted Cw and Pw which are based on 400 seeds (4 X 100) starting in 1999.
3) The nursery germination is highly variable in terms of sample size and count initiation and duration (i.e. no standard method is used to determine germination capacity at the nursery), but these results are the best information we have on a provincial basis.
4) Nursery results indicating that upgrading was performed have not been included, but nursery results indicating other practices such as re-soaking in water prior to sowing, hydrogen peroxide treatments or priming have been included.

The overall mean falldown of all requests at the TSC was 2% below germination indicated on SPAR, but the majority of this difference can be attributed to subalpine fir and western white pine. Work is currently underway to explore alternative methods of pretreating Pw and work will be initiated to look at improvements that can be made in Bl. After yellow-cedar, which is 100% pretreated at nurseries, these species exhibit the deepest and most complex dormancy in BC conifers. Western redcedar also showed large falldowns, but a component of this can be attributed to the pelletting process which was previously estimated at slowing germination by four days.

The falldown at the nursery is, on average, surprisingly low at 3%. Both Sitka spruce and mountain hemlock showed falldowns of 14%, but this was based on a total sample of only five requests. It has been recommended that mountain hemlock blocks be covered in the nursery following sowing as light reduced the germination rate, but not the capacity (Edwards and El-Kassaby 1996). A falldown of 9% for interior lodgepole pine was surprising and is considered low for a species, which generally exhibits a very rapid and high germination capacity. A possible explanation is that due to the excellent germination characteristics in Pli it is sometimes sown outdoors under generally sub-optimal conditions. There were also quite a few nursery results of Pli that were excluded as the seed was upgraded to enable single seed sowing in Pli and this may have introduced a slight bias. In general we hear very few complaints about poor germination of Pli crops, but it is very important to be as efficient as possible with Pli due to significant shortages in available orchard seed for this species.

These falldown figures are intended as guidelines and provincial averages. They help establish priorities for the cone and seed improvement program at the TSC. The best estimates for your nursery are based on the values calculated as part of the quality assurance program at your nursery. I encourage all nurseries to perform at least some germination counts following sowing to determine what their actual falldowns are. Clients are becoming more frugal with seed and a proper quality assurance program will help you determine what you can and cannot do to meet the demands of your clients. Finally, I'd like to thank all the nurseries that have supplied germination data and I welcome your feedback on this program.

References

Edwards, D.G.W. and Y.A. El-Kassaby. 1996. The effect of stratification and artificial light on the germination of mountain hemlock seeds. Seed Sci. & Technol. 24:225-235.

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TECH TALK

Stratification Moisture Content

The moisture content of stratified seed has been determined on 1422 sowing requests, before shipping, between 1992 and 1999 as part of the Tree Seed Centre (TSC) Quality Assurance program. The overall average moisture content was 31.7 %, which varied by species from a low of 26.0% for Sitka spruce to 36.1% for subalpine fir (Table 1).

Table 1. Stratification moisture contents, confidence intervals, minimum and maximum values for sowing requests at time of shipping: 1992 to 1999.

Sp. [1]	Number of Requests	Mean MC%	95% Confidence Interval	Minimum Value	Maximum Value
Ba	81	32.9	0.8	26.0	46.6
Bg	31	33.6	1.2	27.0	42.0
Bl	72	36.1	1.0	30.4	52.3
Fdc	106	32.9	0.6	27.0	40.0
Fdi	128	35.1	0.5	29.0	41.0
Hm	20	33.2	1.2	29.5	40.1
Hw	86	27.1	0.8	18.5	36.0
Lw	123	35.0	0.9	21.9	45.0
Plc	33	30.7	0.6	26.0	34.0
Pli	208	30.4	0.3	22.4	36.0
Pw	75	34.0	0.7	26.0	42.2
Py	84	27.8	0.5	23.8	33.0
SS	46	26.0	1.3	18.0	35.0
Sx	291	30.1	0.4	21.1	41.0
SxS	38	30.2	1.0	25.0	37.0
	1422	**31.7**			

[1] Ba=Amabilis fir; Bg=grand fir; Bl=subalpine fir; Cw=western redcedar; Fdc=coastal Douglas-fir; Fdi=interior Douglas-fir; Hm=mountain hemlock; Hw=western hemlock; Lw=western larch; Plc=coastal lodgepole pine; Pli=interior lodgepole pine; Pw=western white pine; Py= Ponderosa pine; SS=Sitka spruce; Sx=interior spruce and SxS=Sitka X interior spruce hybrid.

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The general target of 30% moisture content corresponds well to the surface dry state in lodgepole pine and interior spruce which accounts for the majority of our requests (»75%). Several species are consistently under this 30% level when surface dry: Sitka spruce, western hemlock and Ponderosa pine. In 1998, a co-op student project looked at moisture uptake in Ponderosa pine and found that the 30% level was achieved after 24 hours, but moisture uptake continued beyond that point to approximately 32% after 48 hours. The situation will be further investigated to determine if a 24-hour running water soak is adequate. The goal of imbibition is to fully hydrate the internal components (megagametophyte and embryo). The other two species achieve higher germination at sub-30% moisture contents and are not as large of a concern.

In Table 1, confidence limits are given for each species indicated that 95% of the data fall within the range defined by the mean plus and minus the confidence interval (i.e. for Ba 95% of the requests are between 32.1 and 33.7% [32.9 ± 08]). In Figure 1 the species are arranged in order of increasing stratification moisture content with the confidence intervals represented by the attached bars. From this data I suggest that our species fall into three stratification moisture content groupings.

Low [<30%]	**SS, Hw and Py**
Medium [30 to 32%]	**Sx, Pli, Plc and Sxs**
High [>32%]	**Fdc, Ba, Hm, Pw, Bg, Fdi, Lw, Bl**

These values and groupings approximate the equilibrium moisture content of the internal seed components. Although both Pli (30.4%) and Sx (30.1%) approximate the general target of 30% there is much greater variability present in the equilibrium moisture content of interior spruce.

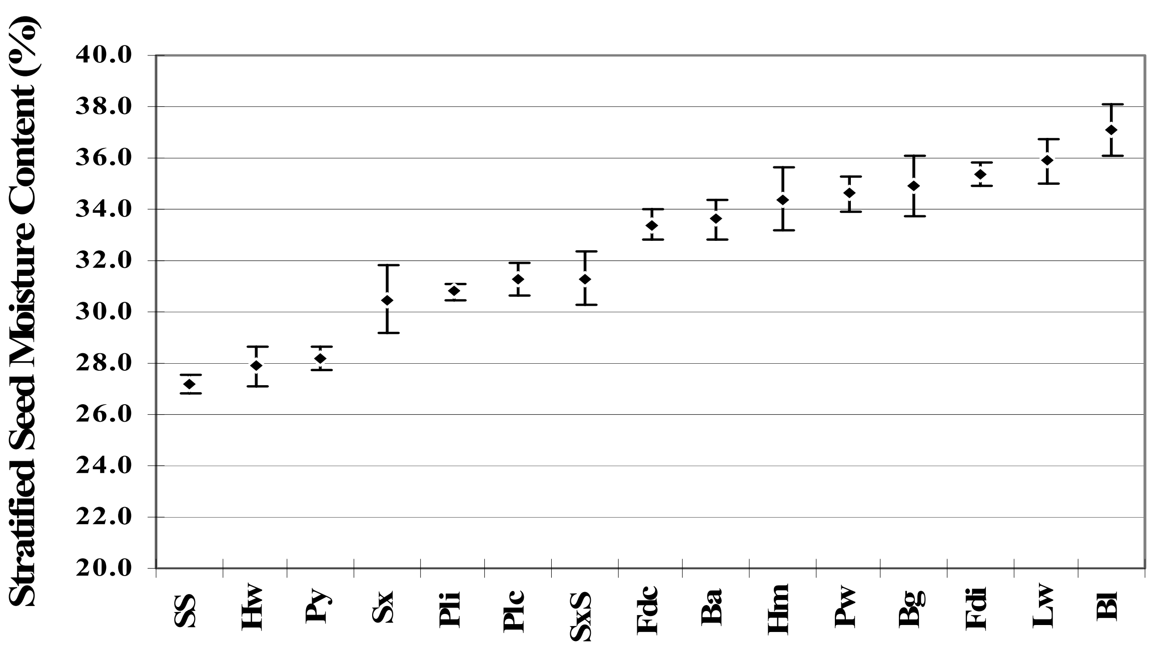

Figure 1. The means and 95% confidence intervals for stratified seed moisture content prior to shipping: 1992-1999.

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Another area that we have been involved with monitoring is the moisture content at the dryback stage for Amabilis and subalpine fir. These species are tested and pretreated for 28 days at approximately 45% moisture content and then dried back to between 30 and 35% for an additional 56 days. Moisture content at dryback was estimated by weighing the stratified seed and using target moisture content (knowing the initial request weight and storage moisture content). For example, if a sowing request is for 1351 grams at 7.9 % moisture content and it weighs 1840 grams after dryback we can estimate the moisture content as follows:

1) First determine the oven -dry weight of the request by using this form of the moisture content equation

ovendry weight = fresh weight * (1 – moisture content)

ovendry weight = 1351 * (1 – 0.079)
ovendry weight = 1244 g

2) Secondly, knowing the oven-dry weight we can calculate the moisture content at any weight using this form of the moisture content equation

$$\textbf{moisture content} = \frac{\textbf{fresh weight} - \textbf{ovendry weight}}{\textbf{fresh weight}}$$

moisture content = (1841 – 1244) / 1841
moisture content = 0.324 or **32.4%**

If unsure about the moisture status of a seedlot, or as part of a quality assurance program, this is a fairly simple method of determining moisture content non-destructively.

The results for the Abies species, which employ the dryback procedure, are given below in Table 2 indicating that our dryback procedures are providing seed at the desired range of 30 to 35% moisture content. The dryback, sample sizes used indicate the number of actual dryback events, which is equivalent to each bag of seed received in a sowing request. For Amabilis fir only seven requests were below 30% moisture content and only one with subalpine fir.

Table 2. The number of drybacks, average, minimum and maximum moisture contents for Abies sp. after dryback.

Sp.	Dryback #'s	Mean MC%	Minimum Value	Maximum Value
Ba	185	32.2	27.9	35.9
Bl	68	33.5	27.6	38.9
Bn	3	33.1	32.6	33.8

If you have comments or concerns regarding stratification moisture content, please contact me at the TSC (604) 541-1683 ext. 228.

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Seed-borne *Fusarium* on Seeds Collected from Seed Orchards and Natural Stands

Introduction

Fungi belonging to the genus *Fusarium* are responsible for both pre- and post-emergence damping-off and can be implicated with root rot and shoot blight of conifer seedlings. Spores that can be air-, water-, soil- or seed-borne are the primary propagules responsible for *Fusarium*'s spread. Seed-borne *Fusarium* is usually responsible for pre-emergence damping-off but can also lead to post-emergence damping-off as well as *Fusarium* root rot and shoot blight, in this order of importance. When and how conifer seeds are exposed to *Fusarium* remains uncertain, however this analysis indicates no difference in the frequency with which seed orchard (A-class) seed and seeds (B-class) collected from wild stands become contaminated by the fungus.

The potential for conifer seed to become contaminated with *Fusarium*, makes testing for its presence a viable first step toward integrated pest management (IPM) for this pathogen. Under contract to the Tree Seed Centre (TSC), Applied Forest Science Limited (AFS) has tested seed for *Fusarium* contamination. *Fusarium* assays on random, representative samples of specific seedlots, estimate the percentage of contamination for that entire seedlot. These results are then entered into the Seed Planning and Registry System (SPAR) where they can be viewed under a seedlot query within seedlot tests. As levels of contamination within a seedlot increase, growers can take steps to minimize any impact on seedling germination and growth.

Analysis:

By the end of 1998, a total of 4111 seedlots had been assayed for the TSC for the presence of fungal pathogens. These assays were made on 301, A- and 3810, B-class seedlots. Of the total number of seedlots assayed, 2622 were made for *Fusarium* spp., consisting of 205, A- and 2417, B-class seedlots. Some level of *Fusarium* contamination was observed on 113 or 55% of the 205, A-class seedlots and on 1098 or 45% of the 2417, B-class seedlots assayed for its presence (Table 1). Frequency distributions of percent contamination occurring on A- and B-class seedlots are shown in Figure 1.

	A-Class Seed	B-Class Seed	All Seed Sources
Number of assays for all pathogens	301	3810	4111
Number of assays for *Fusarium* spp.	205	2417	2622
Number of seedlots with some *Fusarium*	113	1098	1211
Frequency of <1% contamination in seedlots with some *Fusarium* *	72 (64%)	684 (62%)	
Frequency of 1 - 5% contamination in seedlots with some *Fusarium* *	34 (30%)	334 (61%)	
Frequency of 5 - 10% contamination in seedlots with some *Fusarium* *	7 (6%)	48 (4%)	
Frequency of > 10% contamination in seedlots with some *Fusarium* *	0 (0%)	32 (3%)	

Table 1. Numbers of fungal assays for all pathogens, for *Fusarium* spp. only and number of seedlots with some *Fusarium* contamination, on A- and B-class seeds as well as seeds from all sources and contamination frequency within seedlots assayed for *Fusarium* only.

* Number in brackets is percent frequency of seedlots with some *Fusarium*.

(Continued)

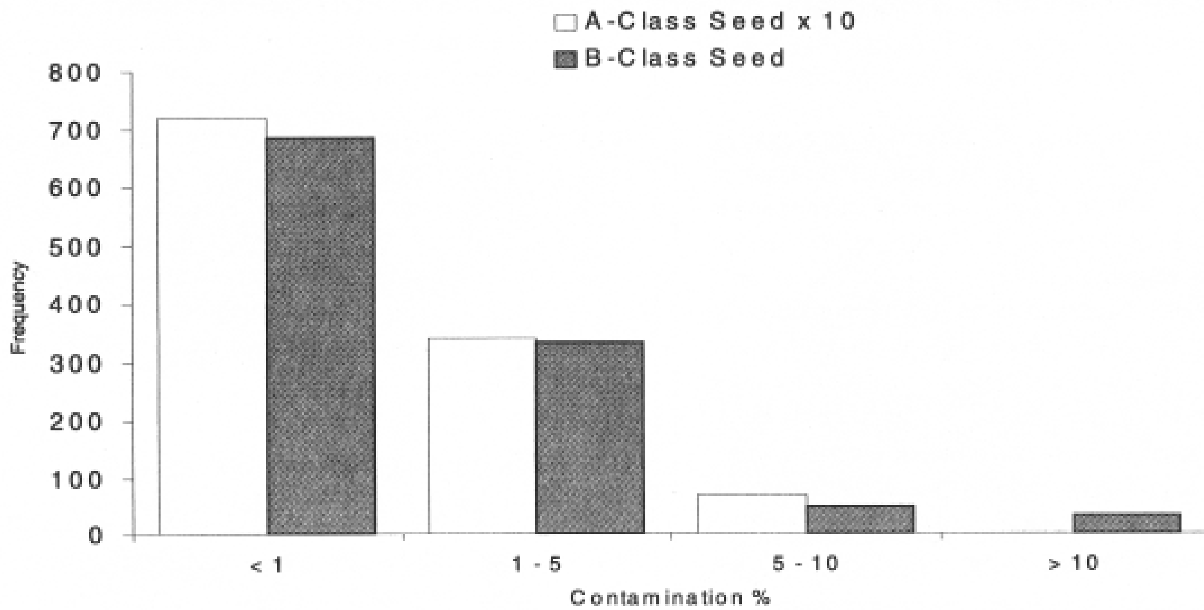

Figure 1. Frequency A-class (x10) and B-class seedlots where observed to be contaminated with less than 1, 1 - 5, 5 - 10 and greater than 10% *Fusarium*.

Fusarium levels on the 55% of assayed A-class seed, observed to be contaminated, occurred at levels of less than 1, 1-5, 5-10, and greater than 10% on 64, 30, 6, and 0% respectively (Table 1). Levels of Fusarium on the 45% of assayed B-class seed, was observed to occur with similar frequency, at levels of less than 1, 1-5, 5-10, and greater than 10% on 62, 31, 4 and 3% respectively (Table 1). The main difference between the frequency distributions of A- and B-class seed occurs at contamination levels of greater than 10%. No *Fusarium* occurred on A-class seed at levels above 10% while it was observed at levels above 10% on 3% of the B-class seed (Table 1, Figure 1). The levels of contamination on B-class seed above 10% ranged between 10.2 and 75.4%. While only 3% of this seed have levels above 10%, the high range, i.e. up to one seedlot with 75.4%, skews the average contamination level for B-class seed upward. The mean level of *Fusarium* contamination for 113 or 55% of the total number of A-class seedlots assayed was 1.5% while 1098 or 45% of the total number of assayed B-class seedlots were contaminated at levels of 1.9%.

Mean contamination is higher on B-class seed when all levels of contamination are examined as a result of skewing of the distribution caused by the 3% of contamination levels above 10%. However when the 3% of high contamination levels are removed and only contaminations of less than 10% are examined mean contamination is higher on A-class seed. In either analysis, there is no significant difference between *Fusarium* contamination on A- and B-class seed (paired t-test on arcsin transformed percents, $p=0.05$).

Discussion and Recomendations:

Fusaria are an ubiquitous group of fungi with spore inoculum being present in the environment throughout the year. Seed-borne contamination may occur through a variety of indirect routes such as via cone parts to the ovary and ovule tissues or through direct contact between seeds and contaminated soil, water or during some phase of the handling process including seed extraction. *Fusarium* spores freed from soil or grasses within and around seed orchards could be spread by irrigation sprinklers, espe-

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cially after mowing grass. This may be exacerbated by the use of sprinklers for delaying cone receptivity to control pollination in the spring. Indirect contamination through cone parts to the ovary and ovule tissues such as this might similarly occur in wild stands via rainfall. Seeds and cone parts harbouring *Fusarium* can contaminate processing facility equipment, which may then contribute to further contamination of otherwise clean seed. Regardless of the initial source, seed-borne *Fusarium* can finally spread throughout a contaminated seedlot during the period of imbibition prior to seed stratification. The level where the presence of seed-borne pathogens becomes significant is based on an understanding of the organism's lifecycle as well as past records of its frequency of occurrence. Nursery conditions and seed quality are also important. It must be remembered that thresholds used to indicate levels of significance are guides only and growers must use their judgement when interpreting assay results. Decisions regarding seed assay results must be tempered with other factors such as the economic value of specific seedlots. While unlikely, very low levels of seed-borne contamination or infection do have a theoretic potential to spread within a seedlot. However, potential risk to a seedlot increases as the threshold of significance is approached.

The ability for species of *Fusarium* to spread within a seedlot, combined with historical assay records indicate contamination levels of 5% within any seedlot to be significant. As the presence of seed-borne *Fusarium* approaches 5%, steps should be taken to minimize its impact. Strategies should be aimed at putting the pathogen at a disadvantage in its ability to spread within a seedlot.

Fusarium contamination can intensify within a seedlot during stratification following imbibition. Contamination denotes the occurrence of a pathogen on the surface of seeds - either spores or mycelium with spread of the fungus resulting from moisture associated with seed soaking combined with a prolonged damp, stratification. Current practice by the TSC as well as some nurseries in British Columbia is to use running water during imbibition of all seeds, regardless of their degree of contamination. This effectively washes *Fusarium* inoculum from seed surfaces and prevents any contamination from intensifying. For seedlots known to harbour *Fusarium* at levels approaching 5%, rapid germination is encouraged which will minimize pre- as well as post-emergence damping-off. Succulent shoots of newly emerged germinants can be injured where they traverse the layer of coarse grit covering the cavity surface. Any subsequent lesions here become infection courts and *Fusarium* inoculum originating from the seed coat could enter stem tissues and cause rotting. *Fusarium* root rot usually becomes symptomatic and leads to problems in seedlings that become heat stressed. As well as heat, drought also predisposes seedlings to *Fusarium* root rot and growers should be more diligent in avoiding either of these conditions for seedlots identified as being contaminated with seed-borne *Fusarium*.

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Management of Cone Beetles (*Conophthorus ponderosae*, Scolytidae) in Blister Rust Resistant Western White Pine Seed Orchards in British Columbia

In pines throughout most of North America and Mexico scolytid beetles of the genus *Conophthorus* are some of the most destructive cone and seed feeding insects known. Females of these cone beetles bore into and kill second year cones in spring, males mate with them there, and the resultant progeny feed on the dead and dying cone tissues. All attacked cones die and produce no seed. Damage is variable depending on locality, *Pinus/Conophthorus* species involved, and local conditions but up to 100% of natural stand or seed orchard crops may be ruined. The new generation of adult beetles emerges from destroyed cones in late summer or early in the following spring. In British Columbia (BC), *Conophthorus ponderosae* has been recorded from western white (Pw), lodgepole (Pl), and ponderosa (Py) pine cones but is common apparently only in Pw. In BC, there are no verified records yet of attacks in seed orchards but this cone beetle has caused severe damage in some Pw seed production areas in natural stands.

BC seed orchard managers have only recently become aware of the potential for problems with cone beetles because, in BC, *Conophthorus* beetles have never turned up in Pl orchards, there are no Py orchards, and Pw orchards are mostly quite young and just starting to enter production. However, in the United States and eastern Canada where susceptible pine seed orchards have long been established, *Conophthorus* infestations are dealt with on a regular basis. Likely it is just a matter of time before BC seed orchard managers will have to work with this insect.

Chemical controls have proven to be mostly ineffective and orchard managers, particularly in the United States, often rely upon cultural methods (collection and destruction of all infested cones before emergence of new adult beetles) to keep cone beetle populations in check. Current cone beetle research efforts are directed at the identification and use of naturally occurring behaviour modifying compounds (e.g. sex pheromones and host volatiles) for monitoring and control of beetle populations. Research programs are presently active in Ontario, BC, California, Idaho, the southeastern United States, and Michoacan Mexico.

In BC an isolated stand of Pw on Texada Island in the Strait of Georgia between the mainland and Vancouver Island exhibits strong natural resistance to white pine blister rust (*Cronartium ribicola*). For a number of years staff from the BC Ministry of Forests Sunshine Coast District office have managed this stand for local rust resistant Pw seed needs. Ongoing severe infestations of *Conophthorus ponderosae* have hobbled cone and seed production at the Texada Island site. The nature of the site (mature, second growth trees growing in thick underbrush) precludes cone beetle management through collection and destruction of infested cones. Current beetle management at this site relies upon the expensive climbing of all crop trees and securing of insect bags around cone bearing branches.

In 1997, in conjunction with a forest entomology consultant (Dr. Dan Miller), the Canadian Forest Service (Dr. Peter de Groot), and staff at Simon Fraser University (Dr. Harold Pierce and others), the BC Ministry of Forests Seed Pest Management group initiated a study of cone beetle sex pheromones and white pine volatile compounds at the Texada Island site and Simon Fraser University. The objectives of this study were to identify the sex pheromone of *Conophthorus ponderosae* and use this and/or host volatiles to develop an effective cone beetle trapping program for use in BC's young Pw seed orchards. This study continued into the 1999 field season and has been funded by the Operational Tree Improvement Program of Forest Renewal British Columbia.

Lab work at Simon Fraser University in the early spring of 1997 demonstrated that female *Conophthorus ponderosae* produce the sex pheromone "pityol." Subsequent field work that spring at Texada Island showed that pityol, in combination with the host volatile a-pinene, is a consistently effective lure for attracting male *C. ponderosae* beetles. In 1998 an operational beetle

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abatement trial using pityol/a-pinene baited traps was installed at the site. Between early May and late July over 2,500 adult beetles (primarily males) were captured. This trial was repeated in 1999 and, although trap catches have not yet been counted, it appears that beetle numbers are down substantially from 1998 levels. This could be due to success of the trial in limiting the reproductive success of females (and thereby lowering the resident beetle population) and/or a natural population fluctuation. With some luck and continued funding, additional trapping seasons and cone damage monitoring will indicate if the local cone beetle population is being reduced.

Also in 1999, pityol/a-pinene baited traps were placed in two BC Pw orchards (one coastal, one interior) to monitor for the presence of cone beetles. No beetles were captured at either location and these sites apparently are still free from cone beetle attack.

A manuscript describing the sex pheromone of *Conophthorus ponderosae* and the 1997 Texada Island trapping trials has been submitted to a scientific journal for review for publication. At this point, based on the results of previous work by other Canadian and American researchers and the initial findings of this study, some recommendations for monitoring and control of *Conophthorus ponderosae* in BC Pw orchards can be made. Protocols for estimating population size, predicting damage, or establishing economic thresholds have not been developed. The following monitoring methods can be used to determine if cone beetles are present.

MONITORING

Cultural method:

- Early season. Early season cone beetle attack usually will be indicated by the presence of small pitch tubes at or very near the base of young cones. As 2nd year cones begin elongating in early spring, watch for pitch tubes and/or aborted or aborting cones. In addition to pitch tubes, attacked cones will also have some amount of internal tunneling and associated fine frass along or near the cone axis basally. One or more adult beetles may be found in the tunnels. Adults are stubby, shiny, dark beetles ranging from 2-4 mm in length.
- Mid- to late-season Through the summer, attacked cones will become more obvious as healthy cones continue to lengthen and mature. Attacked cones will be dead or dying and may fall to the ground. Examine any suspect cones for pitch tubes as above and for internal evidence of beetle attack: Internal galleries packed with powdery frass; presence of C-shaped, white, legless grubs with small brown heads (mid season); presence of young adults (late season). By late summer, attacked cones will be almost completely riddled with galleries and filled with frass and most or all progeny will have matured to adulthood.

Trap method:

- Pityol and a-pinene lures are commercially available in British Columbia from Phero Tech Inc (Delta, BC). Reusable yellow plastic Japanese beetle traps can be ordered from Trécé (Salinas, California).
- Attach one 40 mg pityol bubblecap and one 15 mL a-pinene polyethylene bottle to the top vanes of a Japanese beetle trap. Ensure that the lures are inside the vanes and do not hang outside of the trap. Half fill a ½L plastic Mason jar with plumbing antifreeze (propylene glycol) and screw this onto the bottom of the trap. The antifreeze will kill and preserve any beetles or other insects attracted to the trap.
- Hang traps individually in the upper crown of crop trees, preferably adjacent to cones, as early in the spring as feasible (late March or early April). For monitoring purposes, likely a half dozen or so traps randomly placed throughout the orchard will be sufficient.
- Check traps on a weekly basis through to the end of July. Remove captured insects and replace antifreeze as necessary. Lures will be good for the season.
- IMPORTANT! Until you are familiar with what cone beetles look like, take any suspect beetles to BC Ministry of Forests seed pest management personnel (see addresses below) for positive identification. Some very similar looking (although usually smaller) bark beetles (as well as some weevils, rove beetles, and other beetles) may turn up in your traps. These are easily misidentified as cone beetles and may cause unneeded mental pain and anguish.

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CONTROL:

Cultural method:

- In mid- to late- summer collect and destroy all suspect cones. This will destroy the generation of beetles which will attack cones the following spring. Make sure you watch for attacked cones still pitifully clinging to branches as well as the more obvious ones lying on the ground.
- NOTE! Most cone beetles at the Texada Island trial site apparently do not overwinter in attacked cones (as do adults of most other species of *Conophthorus*) but leave the cones with the onset of wet fall weather. It may prove important in BC to ensure that attacked cones are collected and destroyed prior to the start of wet weather.
- Cone beetles in some pine orchards in the southeastern United States are managed successfully by controlled burning of ground cover and associated debris during the summer of the year before a required cone crop (or in the early spring of the crop year) before adult beetles emerge from old cones.

Trap method:

- Beetle trap-out using pityol/a-pinene baits has not yet been proven successful in controlling cone beetle populations but initial results from Texada Island trials are promising. The isolated nature of most BC Pw seed orchards should make them ideally suited for this sort of methodology. Work continues in this area . . .

Insecticides:

- Contact or systemic insecticides have largely proved ineffective in the control of cone beetle populations.

More information on cone beetles can be found in the publications listed below or by contacting Seed Pest Management at:

Robb Bennett
BC Ministry of Forests
Saanich Seed Orchards
7380 Puckle Road
Saanichton BC V8M 1W4
250 652-6593
Robb.Bennett@gems6.gov.bc.ca

Ward Strong
BC Ministry of Forests
Kalamalka Forestry Centre
3401 Reservoir Road Vernon BC V1B 2C7
250 549-5696
Ward.Strong@gems7.gov.bc.ca

References

Furniss, R. L. and V. M. Carolin. 1980. Western forest insects. USDA For. Serv. Misc. Publ. 1339. See pages 375-377. Out-of-date taxonomically but a good general account of cone beetle biology.

Hedlin, A. F. 1974. Cone and seed insects of British Columbia. Env. Can. publ. BC-X-90. See pages 34-35. Range map and general account of biology.

Hedlin, A. F., H. O. Yates III, D. C. Tovar, B. H. Ebel, T. W. Koerber, and E. P Merkel. 1981. Cone and seed insects of North American conifers. Can. For. Serv., USDA For. Serv., Secr. Agric. Recur. Hidraul. Mex. See pages 16-20. Best available illustrated general account of cone beetles.

Turgeon, Jean J. and Peter de Groot. 1992. Management of insect pests of cones in seed orchards in Eastern Canada. Queen's Printer. See pages 27-30. Good photographs and descriptive and other information.

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Management of Sesiid Pitch Moths in Seed Orchards in British Columbia

Stem attack by "pitch moth" caterpillars is a common problem in lodgepole pine (Pl), coastal spruce, and coastal Douglas-fir seed orchards and some plantations in British Columbia (BC). Since 1994 we have been researching the biology of these pitch moths at the Prince George Tree Improvement Station (PGTIS), in the Vernon area, and on southern Vancouver Island and developing a sex pheromone based management program for them. This work is partly supported by Forest Renewal BC.

BC conifers are attacked by a range of pitch moths from at least three different moth families: several species of *Dioryctria* (family Pyralidae) – the genus containing the well-known coneworms; at least two species of *Synanthedon* (family Sesiidae) – the sequoia (SPM) and Douglas-fir (DFPM) pitch moths; and several species of *Petrova* (family Tortricidae) – the pitch nodule moths. Of these, the species of *Synanthedon* and, to a somewhat lesser extent, *Dioryctria* are the most destructive (although *Petrova* can cause serious damage in young pine plantations).

Through our studies we have demonstrated that SPM, *Synanthedon sequoiae*, is found in the Vernon area Pl seed orchards while, in the Prince George area Pl orchards, DFPM, *S. novaroensis*, is the damaging agent. On the south coast, SPM is common in Sitka and Engelmann spruce seed orchards and in some Pl plantations. DFPM is also present on the south BC coast but is apparently uncommon and has not turned up in seed orchards there. Western pine moth, *Dioryctria cambiicola* (WPM), is also common at the PGTIS but is usually associated with cankers of stalactiform blister rust, *Cronartium coleosporioides*. This disease is prevalent in the Pl provenance trial at PGTIS but absent from the neighbouring Pl seed orchards (likely because the rust's alternate host Indian paint brush, *Castelleja* sp., is found in the provenances but not in the orchards). Therefore DFPM is the only pitch moth commonly found in the PGTIS orchards while WPM rules the roost in the provenances. DFPM shows some attraction to active rust cankers (especially those of western gall rust) but is much less dependent upon them than is western pine moth. DFPM adult females are strongly attracted to pitch actively flowing from tree wounds, especially "traumatic" secondary resin produced several days after wounding.

This work, particularly the sex pheromone-based management of DFPM, is ongoing but some results are worth reporting now.

- In Pl orchards, regular vegetation management will eliminate annual herbaceous secondary hosts of rust diseases and will help control insect species such as WPM that are strongly attracted to rust cankers.

- In Pl orchards, regular pruning of active western gall rust (which needs no alternate host in its life cycle) cankers from orchard tree branches will reduce attractiveness of trees to pitch moth attack.

- Pruning, topping, and other invasive orchard management practices should be done immediately after the flight period of DFPM and SPM to avoid attraction of them to wounds actively exuding pitch.

DFPM and SPM population levels and flight period can be monitored through the use of sex pheromone-baited traps (green Unitraps preferably, or sticky wing traps). Pheromone baits are commercially available, usually in 200 mg loads. DFPM responds to 200-800 mg (Z,Z)-3,13-octadecadienyl acetate lures. SPM responds to 200-1000 mg of a similar compound (Z,Z)-3,13-octadecadien-1-ol. For both moths, higher dosages capture more moths (dosages greater than 800 mg have not been tested yet for DFPM; 1000 mg captures dramatically more SPM than lower dosages and is considered to be at the upper limit of cost effectiveness).

- DFPM or SPM traps should be set by mid to late-May and monitored until early August to cover the potential flight period of either species. Lures should be replaced regularly (2-3 week intervals). As this is a monitoring measure and not a control measure, not many traps are needed – perhaps half a dozen randomly placed within a "standard" orchard. If you

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are confused, contact your local Seed Pest Management office (250 549-5696 in Interior BC, 250 652-7613 in Coastal BC) for guidance.

- It is most important that you take trapped moths to Seed Pest Management or other trained technical staff for proper identification. Both of the pheromones used in this program are "generic" and may trap other related species of pitch moths that are not damaging to conifer seed orchards or plantations. Fortunately, both SPM and DFPM are distinctively coloured, easy to distinguish from each other, and relatively easy to distinguish from other sesiid pitch moths (once you gain the power).

We are continuing to develop pitch moth management protocols under FRBC's Operational Tree Improvement Program. Based on the success of the DFPM and SPM trapping experiments conducted in our studies, mass trapping and/or mating disruption are excellent candidates for user friendly, environmentally safe, species specific, and (most importantly) effective control of these two moths. Currently (1998 and '99 field seasons), we are operationally testing mass trapping and mating disruption of DFPM in the PGTIS seed orchards.

Selection of seed orchard clones on the basis of pitch monoterpene composition shows promise for the development of pitch moth resistant lodgepole pine seed orchards and plantations.

Further information on pitch moths in lodgepole pine can be found at this web site:
http://otaku.unbc.ca/lindgren/research/pitch.html

Detailed technical information on pitch moths in lodgepole pine can be found in the following two scientific papers:

Rocchini, L. A., K. J. Lewis, B. S. Lindgren, and R. G. Bennett. *in press*. Association of pitch moths (Lepidoptera: Sesiidae and Pyralidae) with rust diseases in a lodgepole pine provenance trial. Canadian Journal of Forest Research.

Lindgren, B. S., L. A. Rocchini, and R. G. Bennett. *in press*. Effects of resin flow and monoterpene composition on susceptibility of lodgepole pine to attack by the Douglas-fir pitch moth, *Synanthedon novaroensis* (Lepidoptera: Sesiidae). Journal of Applied Entomology.

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Spittlebugs Reduce Seedset in Interior Lodgepole Pine

The spittlebug *Aphrophora canadensis* feeds on the shoots and cones of lodgepole pine, creating a frothy mass of spittle in which the immature stages of the insect hides. Spittlebugs are not true bugs, but are more closely related to aphids and cicadas. They overwinter as eggs, and spittle masses first appear in late May or June (Figure 1). The nymphs are soft-bodied, slow-moving insects up to 5 mm long; they moult 4-5 times before becoming adults in July. Adults, commonly called froghoppers, are hard-bodied, brown, wedge-shaped insects which jump with an audible snap and fly quickly. Their biology is described in Furniss and Carolin (1977) and Johnson and Lyon (1991).

Figure 1. Spittlebug masses on Lodgepole Pine Cones.

The only spittlebug of serious economic concern in conifers is the Saratoga spittlebug *Aphrophora saratogensis* (Wilson and Hobrla 1987). There have been reports of damage by *A. canadensis* (Furniss and Carlin 1977; Storer *et al.* 1998), but the effect of cone feeding is unknown. They have been observed with increasing frequency in lodgepole pine seed orchards in the southern Interior of BC, where the nymphs seem to prefer feeding on 2nd-year cones. At one seed orchard, 17% and 44% of shoots were infested in 1997 and 1998 respectively, while 62% and 95% of cones were infested in the same years. I conducted a study to determine whether *A. canadensis* affects seed count, weight, or extraction efficiency in lodgepole pine.

In late June of 1996, cones on 5 lodgepole pine trees were selected. Some cones were naturally infested with spittlebug; others had no observable spittle masses. Cones were flagged and some attempt was made to maintain the infestation level (infested or clean) until the spittlebugs matured to adulthood. We found that the clean cones frequently became spittlebug-infested, so we washed the insects off with a jet of water from a squirt bottle. We also found that the insects often deserted infested cones. We attempted to re-infest cones by moving spittlebugs back onto them, but these re-introductions never took. Cones which spent too much time with or without spittlebugs (according to the treatment) were dropped from the study. A total of 126 infested cones and 58 clean cones were used. They were harvested in August, seeds were extracted by the boil, bake and shake method (similar to the Surrey Seed Center), and then X-rayed to determine filled and empty seed counts. Untransformed data were statistically analyzed with a paired T-test.

We found that the spittle-bug infested cones had slightly lower seed counts but higher seed weights than the clean cones (Table 1). However, there was no statistical difference between seed counts or weights, meaning that there was so much variation in counts that the differences in the means are best explained by random chance. So I repeated the experiment in 1997, hoping to control the infestations better, thus reducing variation in the resulting data.

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Table 1. Seed data from spittlebug-infested or clean cones, 1996. No significant differences existed between treatments.

Treatment	Filled Seeds per Cone	Mean Seed Weight (mg)
Spittlebug-infested cones	2.78	4.171
Clean cones	3.26	4.071

In early June 1997, we flagged cones on 10 lodgepole pine trees. Up to 20 infested cones and 20 clean cones on each tree were flagged. Clean cones were chosen to be as far as possible from the nearest spittlebug infestation on either cones or shoots. No attempt was made to remove or replace spittlebugs from cones; if a clean cone became infested or an infested cones became clean, it was dropped from the trial. Ten cones which had remained clean, and 10 which had remained infested, were harvested from each experimental tree in August. Seeds were extracted as in 1996, except that after shaking, the cones were broken apart with pliers and all remaining seeds removed. This gave an indication of the extraction efficiency, i.e. the proportion of all seeds in a cone which are removed with normal extraction techniques. Seeds were X-rayed and data were analyzed with a paired T-test.

The 1997 data showed highly significant differences in filled seeds per cone between spittlebug infested and clean cones (Table 2). Filled seed counts in infested cones were only 54.5% of those in clean cones. The total seeds were not different, though, indicating that initial seedset was similar between the cones, but the spittlebugs subsequently caused some seeds to become empty. The extraction efficiency was not affected, so apparently the spittlebugs do not affect the structure of the cone, pitchiness, or other factors which may affect extraction efficiency.

Table 2. Seed data from spittlebug-infested or clean cones, 1997. Within a column, ** indicates a highly significant difference (a < 0.01).

Treatment	Filled Seeds Per Cone	Total Seeds Per Cone	Extraction Efficiency
Spittlebug-infested cones	7.39	39.13	88.4%
Clean cones	13.56**	34.50	93.2%

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Although these data appear at first to indicate that spittlebugs cause a reduction in seedset, there were some problems with the experiment which makes the results less unequivocal. For example, it's possible that spittlebugs choose to settle on cones which have fewer filled seeds to begin with. It's also possible that the Western Conifer Seedbug, *Leptoglossus occidentalis*, is attracted to spittlebug-infested cones. *Leptoglossus* is known to dramatically reduce seedset in Interior lodgepole pine seed orchards (Strong and Bennett 1998) by sucking seed contents while sitting on the cone. It would not be surprising if *Leptoglossus* avoided the spittle masses on spittlebug-infested cones.

To address these problems, I will be conducting a 3rd (and hopefully final!) experiment this year. Only spittlebug-infested cones will be selected; half the cones will be cleaned of spittlebug with safer's soap or other insecticide. All cones will then be bagged with insect bags to keep other potential cone feeders like *Leptoglossus* away. We'll then be able to welcome the new millenium with solid knowledge of the effects of *Aphrophora canadensis* on lodgepole pine seedset.

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Storer, A.J., D.L. Wood, K.R. Wikler, and T.R. Gordon. 1998. Association between a native spittlebug (Homoptera: Cercopidae) on monterey pine and an introduced tree pathogen which causes pitch canker disease. *Canadian Entomologist* 130(6), 783-792.

Wilson, L.F. and S.L. Hobrla. 1987. A procedure for sampling nymphs of Saratoga spittlebug, *Aphrophora saratogensis* (Homoptera: Cercopidae), using percentage of sample-units infested. *Great Lakes Entomol*. 20 (4) 187-192.

Strong, W.B., R.G. Bennett, and G. Hales. 1988. Leptoglossus and Low Seedset in Southern Pli Seed Orchards. *Seed and Seedling Extension Topics*, British Columbia Ministry of Forests 11 (1): 11-13.

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Germination and Seedling Vigour of Douglas-fir Grown from Seeds Damaged by the Western Conifer Seed Bug, *Leptoglossus occidentalis*

The western conifer seed bug, *Leptoglossus occidentalis*, attacks seeds of almost all conifer species (Koerber, 1963) and is a potentially serious pest of seed orchards throughout western North America. Adults and nymphs damage seeds by inserting their stylet-like mouthparts through the cone scales, penetrating developing seeds and depleting their contents. Seeds are often completely emptied by the bug, rendering them indistinguishable from naturally aborted seeds (Schowalter and Sexton, 1990). However, in field experiments, feeding by seed bug nymphs caged on Douglas-fir cones (6 nymphs per cage) for two-week periods resulted in ca. 10% of seeds sustaining partial feeding damage (Bates, unpublished data). Because partially damaged seeds may not be separated from sound seeds through the seed cleaning process, it is possible that they may be included in the final cleaned seed lot. Once sown, seed bug damaged seed could be responsible for a reduction in germination, or, if germination is successful, for a reduction in seedling performance (Blatt and Borden, 1998). Our objective was to determine the effects that partial feeding damage by *L. occidentalis* may have on the germination of Douglas-fir seeds and on subsequent seedling vigour of Douglas-fir seeds during normal nursery production. Our results indicate that, although germination rates were greatly reduced by partial seed bug feeding, seedling growth and vigour were unaffected.

Mature Douglas-fir seed was obtained from the B.C. Ministry of Forests Tree Seed Centre, Surrey, B.C. Seeds were x-rayed to ensure they were sound, and then exposed to feeding by *L. occidentalis* nymphs in a laboratory colony maintained at ca. 25°C and a 16L:8D photoperiod. After seven days, the exposed seed was x-rayed again. Seeds which showed signs of partial feeding damage were classed as either slightly damaged (over 67% of tissue remaining), moderately damaged (33-66% of tissue remaining), severely damaged (<33% of tissue remaining on the x-ray) or extremely damaged (seed empty) (Figure 1).

Seeds from the severe and extreme damage categories were excluded from the experiment since it was assumed they would not germinate (the embryo and megagametophyte of severely damaged seeds were damaged beyond recognition, while extremely damaged seeds were completely empty). The experiment comprised five treatments: 1) lightly damaged seed; 2) moderately damaged seed; 3) seeds exposed to seed bug feeding but showed no damage on the subsequent x-ray (full exposed); 4) seeds which were not exposed to seed bug feeding (full unexposed); and 5) seeds which were not x-rayed but assumed to be sound based on a weight of >8.0 mg (x-ray control). Approximately 50 seeds each from each treatment were stratified for 21 days at 4°C and then planted in styroblocks (type PSB412A) at Green Timbers Extension Services Nursery, Surrey. Nine to 14 seeds from each treatment were randomly distributed within each styroblock and a buffer of non-experimental seeds was planted in outside cavities surrounding the experimental seeds to eliminate edge effects. Percent germination, timing of emergence, height growth and shoot biomass at lift were recorded.

Both moderate and light feeding damage reduced seed germination by >80% compared to each of the controls (Figure 2). These results support the finding of Blatt (1997) who determined that 18% of partially-filled seed fed on by *L. occidentalis* successfully germinated. Surprisingly, the ca. 14% of damaged seeds in our experiment which did germinate appeared to suffer no adverse effects. Fed-on seeds germinated in the same length of time (Figure 2), and the ensuing seedlings had both a comparable shoot biomass after 39 weeks (Figure 2) and grew at the same rate as undamaged seedlings (Figure 3).

There was no difference between treatments with respect to the percentage of seedlings that met height and caliper specifications (18 cm and 3 cm, respectively) when the

(Continued)

seedlings were lifted. Although the reduction in the rate of germination can be considered severe, it appears that if the embryo is intact and if sufficient storage reserves remain in the seed, germination can occur, and the resulting seedlings are able to grow and successfully compete with undamaged seeds in a nutrient-rich environment. In field experiments on Douglas-fir, lightly and moderately damaged seeds fed on during their development weighed an average of 9.6 and 7.3 mg, respectively, at harvest; these weights were within the range of full seeds which had not been fed upon (6.5-17.5 mg) (Bates, unpublished data). Thus the weight loss sustained by partially damaged seeds may not be sufficient to ensure that they are blown off during seed cleaning, and seed bug feeding may account for some failure to germinate. However, it is unlikely that feeding damage by *L. occidentalis* is indirectly responsible for the significant number of Douglas-fir seedlings which are culled during normal nursery production.

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Figure 1. Categories of feeding damage to Douglas-fir seeds caused by *Leptoglossus occidentalis* as determined by radiography

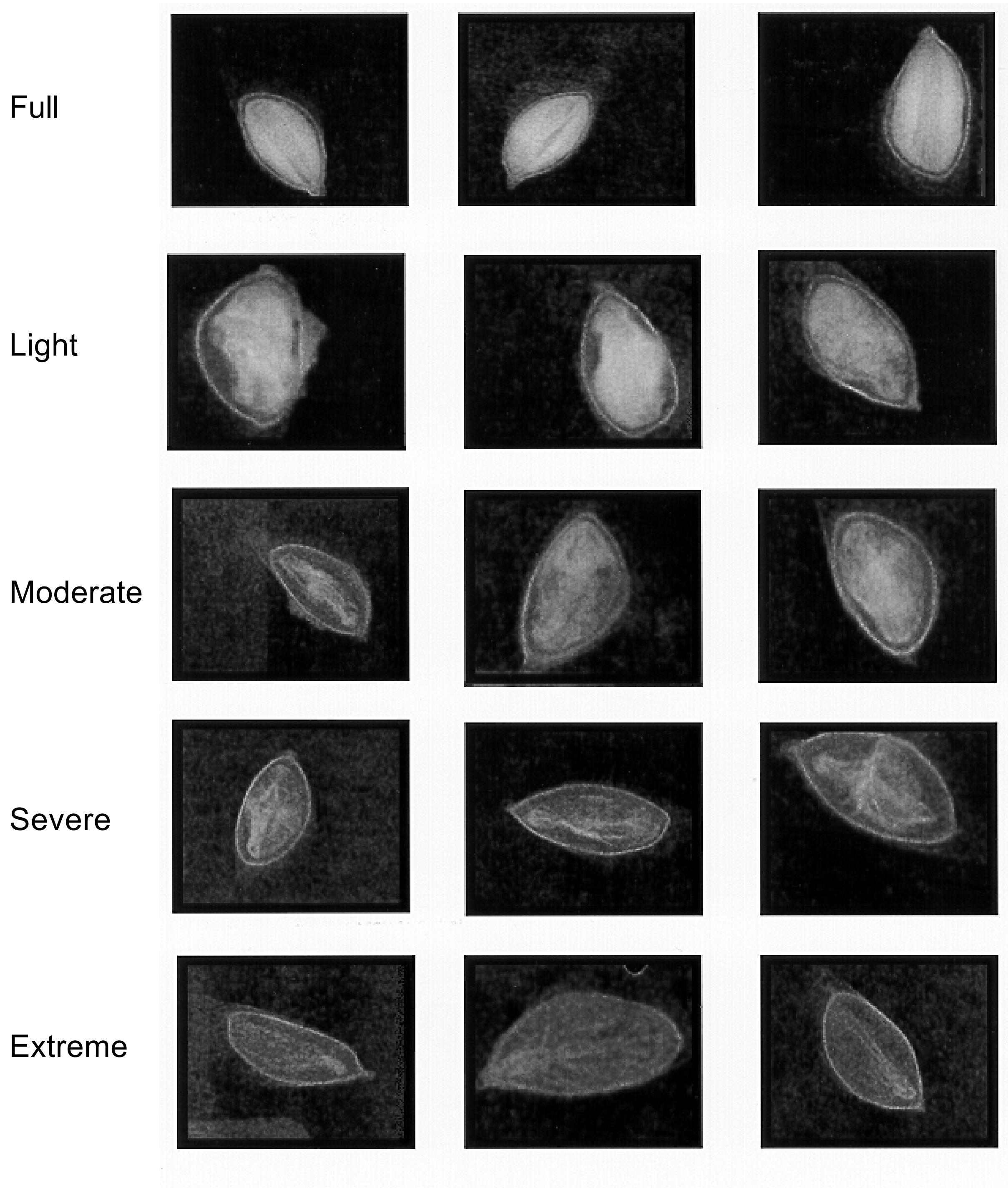

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Figure 2. Germination success of Douglas-fir seeds sustaining light and moderate damage from feeding by *Leptoglossus occidentalis* compared to full seeds x-rayed and then exposed or not exposed to seed bugs, and full seeds not x-rayed. Bars with different letters are significantly different, χ^2 test for multiple proportions (% germination) and Tukey Kramer HSD test (duration to emergence and shoot biomass), $P<0.05$.

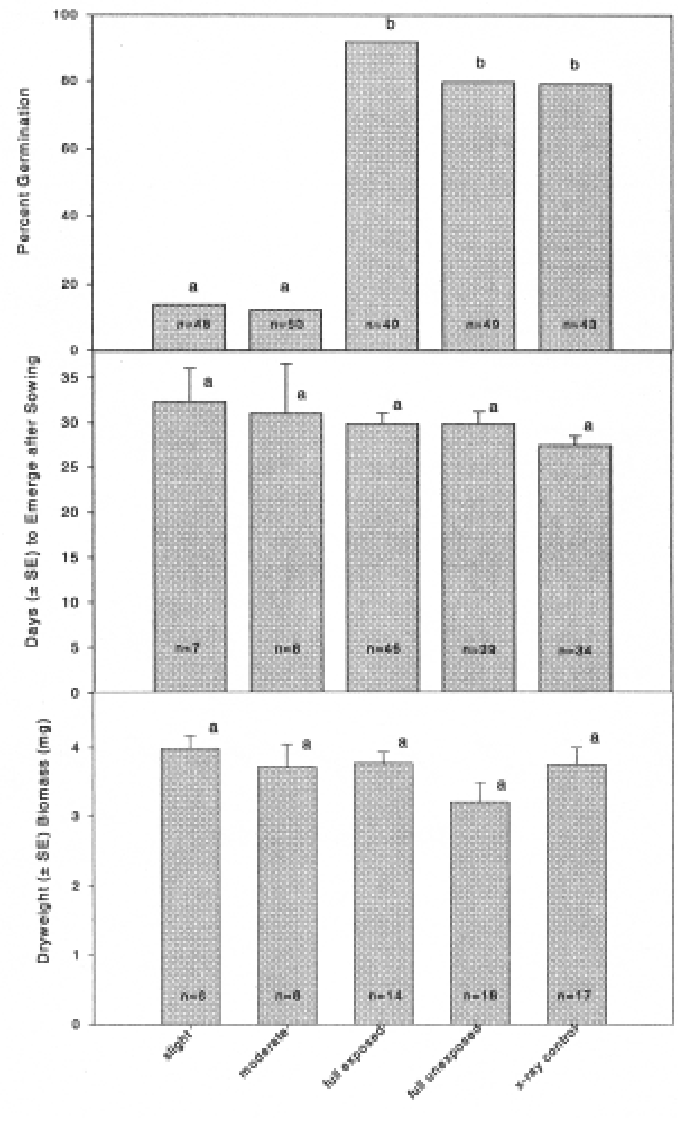

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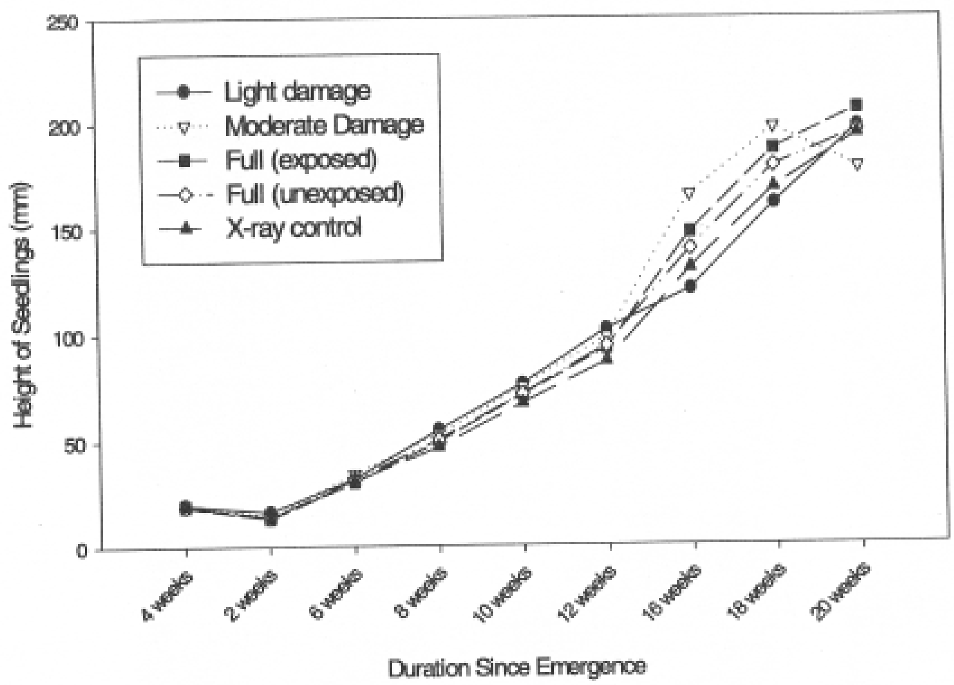
Figure 3. Growth of Douglas-fir seeds emerging from seeds sustaining light and moderate feeding damage by *Leptoglossus occidentalis*, compared to growth of seedlings from full seed in three control treatments.



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