TREE IMPROVEMENT
Volume 5, Number 2 January 1993

Seed and Seedling Extension Topics

Robb Bennett – Editor

New Facility Now Open at Saanich Seed Orchard

After being located in the Cowichan district for over 20 years, the administration office of Coastal Seed Orchards has moved to the Saanich Seed Orchard site. The existing building at Saanich has been expanded to accommodate the Coastal Seed Orchards staff as well as a new lab for the BC Seed Orchard Pest Management group (Pest Management head office remains at Bastion Square), the Island Nursery Administration office, and a conference room. An open house is planned for the near future (keep your ears open for further information).

Along with the move of the Coastal Seed Orchard office there have been some staffing changes. Judi Boyd, office manager for 14 years, has retired from the Forest Service to pursue a new career in private contracting. We wish her all the best in her future endeavours. The new office manager is Debbie Poldrugovac. Her assistant is Lee-Ann Swinton. Both look forward to meeting all those involved in the seed production business.

The new facility's address is:

BC Ministry of Forests
R.R. #3, 7380 Puckle Road
Saanichton, BC V0S 1M0
fax (604) 6524202

The following staff members may be contacted there:

Coastal Seed Orchards **(604) 652-5600**
David Reid, Seed Production Officer
Dan Rudolph, South Island Operations Supervisor
Brian Barber, Projects Officer
Debbie Poldrugovac, Office Manager

Saanich Seed Orchard **(604) 652-7616**
Carolyn Lohr, Orchard Supervisor

Seed Orchard Pest Management **(604) 652-7613**
Beverly McEntire, Biologist
Michelle Hall, Biologist

Island Nursery Administration Centre **(604) 652-8303**
Barb Wall, Technician

Brian Barber
Coastal Seed Orchards, Saanichton

Koksilah Seed Orchard Closes After 23 Years

The Forest Service's Koksilah Seed Orchard, located south of Duncan, was phased out at the end of September 1992, having reached the end of its productive life. Established in 1969, Koksilah has produced improved Douglas-fir tree seeds for the province's reforestation program since 1979. As one of the earlier orchards established by the Forest Service it:

- yielded over 400 kg of tree seed or enough to grow 18 million plantable trees and reforest 18,000 hectares,
- utilized overhead irrigation to delay orchard flowering and prevent outside pollen contamination from adjacent stands,
- helped develop new orchard management techniques now used province wide, and
- promoted public awareness of silvicultural practices through years of tours for school children and the public.

A new orchard, replacing Koksilah and providing a higher level of genetically improved seed, was established at Bowser, south of Courtenay, in 1991. The new material for this orchard was provided from the long-term breeding and testing program of the Ministry of Forests' Research branch. As the tree improvement program advances, new seed orchards are required to provide higher levels of seedling quality to maximize timber production on a limited land base. Because of this an orchard becomes out of date after 15-25 productive years.

Dan Rudolph
South Vancouver Island Seed Orchards, Saanichton

British Columbia
Ministry of Forests

British Columbia's Seed Orchards and their Production

There are now 82 seed orchards representing 12 species in the province of British Columbia. The Ministry of Forests and forest industry companies manage the orchards on 27 sites, totaling 200 hectares, throughout the province. Orchards are established to partially or wholly meet the seed needs of the provincial seed planning zones. Administration of the Ministry's seed orchard program is divided between the coast and the interior. Refer to the Seed Transfer Guidelines, Coast and Interior, for coverage of the seed orchards.

Since the first cone crop collections in 1967 the seed orchards of BC have produced a total of 3,967 kg of tree seed (equivalent to approximately 330 million seedlings). Based on our current inventory, approximately 163 million seedlings have been used for reforestation. The goal of the seed orchard program is to produce 85% of the seed needs on the Coast and 50% in the Interior by 2000. Of the 30 million seedlings sown on the coast in 1991 half were from seed orchard seed. The following tables outline the seed orchard production history and the existing seed orchards to date. Preparations for an updated Seed Orchard Directory/Handbook are underway.

For more information contact either:

Coastal Seed Orchards
Ministry of Forests
R.R.#3, 7380 Puckle Road
Saanichton, B.C. V0S 1M0
tel. (604) 652-5600
fax. (604) 652-4204

Interior Seed Orchards
Ministry of Forests
Kalamalka Forestry Centre
3401 Reservoir Rd
Vernon, B.C. V1B 2C7
tel. (604) 549-5577
fax. (604) 542-2230

Brian Barber
Coastal Seed Orchards, Saanichton

BRITISH COLUMBIA'S SEED ORCHARDS
(B.C. Forest Service and Industry) (as of November 1, 1992)

	BC Forest Service			Industry			Total		
Species	**#of Orch.**	**Size (ha)**	**# of trees**	**#of Orch.**	**Size (ha)**	**# of trees**	**#of Orch.**	**Size (ha)**	**# of trees**
Coastal									
Douglas-fir	5	23	5634	10	38	6112	15	61	11746
Western-Hemlock	1	4	1753	10	20	9878	11	24	11631
Sitka Spruce				5	4.5	3031	5	4.5	3031
Western Red Cedar				5	3	1719	5	3	1719
Yellow-Cedar				3	2	1404	3	2	1404
Pacific Silver Fir	1	3	270	3	10	4554	4	13	4824
Grand Fir				1	1	672	1	1	672
White Pine				2	n/a	n/a	2	0	0
Englemann Spruce				1	4	1440	1	4	1440
Sub-total	**8**	**34**	**9097**	**39**	**78.5**	**27370**	**47**	**112.5**	**36467**
Interior									
Spruce*	18	35	18936	3	14	8156	21	49	27092
Lodgepole Pine	9	29	9471	1	3	1200	10	32	10671
Western Larch	2	4	3800				2	4	3800
White Pine	2	2	1234				2	2	1234
Sub-total	**31**	**70**	**33441**	**4**	**17**	**9356**	**35**	**87**	**42797**
TOTAL	**39**	**104**	**42538**	**43**	**95.5**	**36726**	**82**	**199.5**	**79264**

BRITISH COLUMBIA'S SEED ORCHARDS (Ministry and Industry Combined)						
Seed Production Fact Sheet (1963–1991)						
Species	**Total Seed Production (kg)**	**Total Potential Seedlings (millions)**	**Current Inventory (kg)**	**Potential Seedlings Available* (millions)**	**Seed Used (kg)**	**Estimated Seedlings Planted (millions)**
Coastal						
Douglas-fir	3142	141.39	1517	68.27	1625	73.13
Western-Hemlock	117	27.85	67	15.95	50	11.90
Sitka Spruce	143	33.61	115	27.03	28	6.58
Western Red Cedar	131	40.35	44.50	13.71	87	26.80
Yellow-Cedar	3	0.13	1	0.04	2	0.08
Englemann Spruce	1	0.13	0.76	0.11	0.1	0.01
Sub-total	**3537**	**243.46**	**1745.26**	**125.10**	**1792.10**	**118.50**
Interior						
Spruce**	342	73.87	165	35.64	177	38.23
Lodgepole Pine	88	12.85	39	5.69	49	7.15
Sub-total	**430**	**86.72**	**204.00**	**41.33**	**226.00**	**45.39**
TOTAL	**3967**	**330.18**	**1949.26**	**166.43**	**2018.10**	**163.86**

* based on the species' average number of 313A PSB container seedling-s per gram as derived from the current sowing rules for Class A seed.
** Englemann, White, and Englemann x White Spruce

BC Seed Orchard Pest Update

The following is a listing of arthropod pests and diseases which BC Seed Orchard Pest Management staff are presently monitoring and/or conducting trials upon. Included is a taxonomic breakdown of the insect species listed as well as a brief bibliography of literature containing information relevant to the identification, management and biology of BC seed orchard pests.

INSECTS, MITES, AND DISEASES OF CURRENT (1992) CONCERN IN BC SEED ORCHARDS
(modified from a list compiled by D. W. Summers)

Douglas-fir

Cone pests

Leptoglossus occidentalis	western conifer seed bug
Dioryctria abietivorella and other species	fir and other coneworms
Barbara colfaxiana	Douglas-fir cone moth
Contarinia oregonensis	Douglas-fir cone gall midge
Megastigmus spertnatrophus	Douglas-fir seed chalcid

Tree pests

Adelges cooleyi	spruce gall aphid

(continued...)

Spruce	
Cone pests	
Leptoglossus occidentalis	western conifer seed bug
Dioryctria abietivorella and other species	fir and other coneworms
Choristoneura occidentalis	western budworm
Strobilomyia neanthracina	spruce cone maggot
Chrysomyxa pirolata	spruce cone rust
Tree pests	
Oligonychus ununguis	spruce spider mite
Elatobium abietinum	green spruce aphid
Mindarus spp.	twig aphids
Cinara spp.	giant conifer aphid
Adelges cooleyi	spruce gall aphid
Pineus similis	"
P. pinifoliae	"
Pissodes spp.	root and terminal weevils
Choristoneura occidentalis	western budworm
Hemlock	
Adelges tsugae	hemlock woolly aphid
Abies (true fir)	
Tree pests	
Mindarus spp.	twig aphids
Adelges piceae	balsam woolly aphid
Lodgepole pine	
Tree pests	
Trisetacus sp.	eriophyid mite
Pissodes spp.	root and terminal weevils
Synantheaon sequoias	pitch moth
Petrova albicapitana	pitch nodule moth
Dioryctria spp.	coneworms
Zellaria haimbachi	pine needle sheathminer
Endocronartium harknessii	western gall rust
Cronartium coleosporoides	stalactiform blister rust
White pine	
Cone pests	
Leptoglossus occidentalis	western conifer seed bug
Choristoneura occidentalis	western budworm
Tree pests	
Dioryctria spp.	coneworms
Pineus pinifoliae	woolly aphids
Cronartium ribicola	white pine blister rust
Western redcedar	
Cone pests	
Mayetiola thujae	western redcedar cone midge
Yellow cedar	
Pollen cone pests	
Trisetacus chamaecypari	eriophyid mite
Western larch	
Cone pests	
Adelges lariciatus	larch woolly aphid

(continued...)

Dioryctria spp.	cone worms
Tree pests	
Coleophora laricella	larch casebearer

CLASSIFICATION OF SEED ORCHARD MITE AND INSECT PESTS

Order	Family	Name
Acari (mites)	Tetranychidae (spider mites)	*Oligonychus ununguis*
	Eriophyidae (eriophyid gall mites)	*Trisetacus* sp.
Hemiptera (true bugs)	Coreidae (leaf-footed bugs)	*Leptoglossus occidentalis*
Homoptera (aphids *et al*)	Aphididae (aphids)	*Elatobium abietinum*
		Mindarus spp.
		Cinara spp.
	Adelgidae (woolly aphids)	*Adelges* sp.
		Pineus sp.
Coleoptera (beetles)	Curculionidae (weevils)	*Pissodes* sp.
Lepidoptera (moths, butterflies)	Coleophoridae (casebearers)	*Coleophora laricella*
	Sesiidae (clearwing moths)	*Synanthedon sequoiae*
	Yponomeutidae (ermine moths)	*Zellaria haimbachi*
	Tortricidae (leafrollers)	*Choristoneura occidentalis*
	Olethreutidae (olethreutids)	*Barbara colfaxiana*
		Petrova albicapitana
Diptera (flies)	Pyralidae (snout moths)	*Dioryctria* sp.
	Cecidomyiidae (gall midges)	*Contarinia oregonensis*
		Mayetiola thujae
Hymenoptera (wasps, ants, etc.)	Anthomyiidae (anthomyiids)	*Strobilomyia neanthracina*
	Torymidae (seed chalcids)	*Megastigmus spermatrophus*

Some Useful References For Seed Orchard Insects And Diseases

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9. Hedlin, A. F., H. 0. Yates, D. C. Touar, B. H. Ebel, T. W. Koerber, and E. P. Merckel. 1980. **Cone and seed insects of North American conifers.** Env. Can., Can. For. Serv.; USDA For. Serv.; Sec. Agric. Recur. Fbdraul., Mexico. 122 p.
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12. Martineau, R. 1984. **Insects harmful to forest trees.** Multiscience Publ. Ltd. 261 p.
13. Ruth, D. S. 1980. **A guide to insect pests of Douglas-fir seed orchards.** Env. Can.., Can. **For.** Serv. Publ. # BC-X-204.19 p.
14. Ruth, D. S., G. E. Miller, and J. R. Sutherland. 1982. **A guide to common insect pests and diseases in spruce seed orchards in British Columbia.** Env. Can., Can. For. Serv. Publ. # BC-X-231. 28 p.
15. Sutherland, J.R. and R.S. Hunt. 1990. Diseases in reforestation. in Regenerating British Columbia's forests. Lavender, D.P., R. Parish, C. Willis, and D. Winston, editors. Univ. BC Press. P266-278.
16. Sutherland, J.R., T. Miller, and R.S. Quinard. 1987. Cone and seed diseases of North American conifers. North American For. Comm., Publ. # 1. 177 p.

Robb Bennett
Seed Orchard Pest Management Officer, Victoria

Ambrosia Beetle Video "TINY BEETLES - EXPEN$IVE TA$TE$"

Ambrosia beetles (Coleoptera, Scolytidae) quickly damage and degrade the valuable clear sapwood of saw logs. The sawmill industry depends upon the premium grade sapwood lumber for profitable operation of their mills. The 1990-92 Ambrosia Beetle Task Force (Natural Sciences and Engineering Research Council, Science Council of BC, Phero Tech Inc., and UBC) showed that ambrosia beetle-caused losses on the non-cedar saw log inventory of MacMillan Bloedel Ltd. was in the order of $11 million during 1991. Surveys of 2250 log booms showed an average of 14% of logs had been attacked by ambrosia beetles. The estimate of the total losses to the coastal logging industry in BC is in the order of $120 million per year.

The new video "TINY BEETLES - EXPEN$IVE TA$TE$" presents the results of the surveys, as well as first ever videotape of live ambrosia beetles in their galleries. Viewers will gain an appreciation of ambrosia beetle biology as well as management strategies and the challenges faced by the coastal forest industry as it works to get logs to the mills faster.

For further information regarding this excellent video. contact either:

Dr. John McLean
Department of Forestry
The University of British Columbia
2357 Main Hall
Vancouver, BC V6T IZ4
tel. (604) 822-3360
fax. (604) 822-8645

or

Phero Tech Inc.
7572 Progress Way, R.R. #5
Delta, BC V4G 1E9
tel. (604) 940-9944
fax. (604) 940-9433

New Publication - "ONTARIO WEEDS" - Now Available

Local interest has been expressed in the new publication "Ontario Weeds" by Dr. Jack Alex (Department of Environmental Biology, University of Guelph). In 304 pages "Ontario Weeds" describes 315 weed species prevalent in Ontario (many have distributions beyond Ontario, weeds being renowned for ignoring political boundaries) including period of flowering, distribution records, identification keys for all species, line drawings (prepared by noted illustrator Gary Eden) of 282 species, and 169 full colour plates. "Ontario Weeds" (Publication 505 of the Ontario Ministry of Agriculture and Food) can be ordered from:

Publications Ontario
Ministry of Government Services
Main Floor, 880 Bay Street
Toronto, ON M7A 1N8
(416) 326-5320

Price is $15.00 plus GST and postage.

Other Publications Available

I have available for distribution about 50 copies each of **"Pine Shoot Insects Common in British Columbia"** and **"Cone and Seed Insects of British Columbia"** as well as a smaller number of **"Cone and Seed Diseases of North American Conifers."** These aren't exactly rare publications but if anyone would like copies please contact me and I will mail them out. Make your request to Robb Bennett, Editor, Seed and Seedling Extension Topics Newsletter.

Events

Forest Nursery Association of BC 1993 Annual Meeting
13-15 September 1993
Florence Filberg Centre
Courtenay, BC
More details to follow in next newsletter.

22nd Southern Forest Tree Improvement Conference
14-17 June 1993
Holiday Inn Buckhead
Atlanta, Georgia

For more information contact:
Mr. James L. McConnell
Chair, SFTIC Committee
1720 Peachtree Road NW, Suite 816N.
Atlanta, Georgia, USA 30367

Canadian Tree Improvement Association 1993 Meeting
17-19 August, 1993
Fredericton, NB
Theme: "The Future Forests - Options and Economics"

For more information contact:
Kathy Tosh, Chair, CTIA
Dept. Natural Resources and Energy
Provincial Forest Nursery
RR #6 Fredericton, NB, E3B 4X7
tel. (506) 453-9101
fax. (506) 453-1741

Integrated Vegetation Management Association of British Columbia 1993 Meeting
26-27 January , 1993
Richmond Inn
7551 Westminster Highway
Richmond, BC.
Theme: 'Vegetation Management: Policy, Promotion, and Practice."

For more information contact-
Larry W.Taylor
IVMABC
PO Box 48861 - Bentall
Vancouver, BC V7X 1AS
(604) 273-7878

Grower's Notes

More on Keithia Blight in Western Redcedar Seedlings

Early data from operational spray trials (conducted by Forestry Canada and BC Ministry of Forests) aimed at the control of Keithia blight on Western redcedar have been compiled and analyzed. Growers planning to carry over one year old crops or sow WRC in 1993 are advised to contact Gwen Shrimpton (Nursery Extension Services 604-582-6914) or John Dennis (Pacific Forestry Centre Pest Clinic 604-363-0600) for new recommendations on cultural practices and spraying regimes to aid in Keithia blight management.

An information sheet will be available early in 1993.

New Pest Alert: *Tomicus piniperda,* the Pine Shoot Beetle

Ed. note: the following new bark beetle alert is excerpted from an *article in Hortwest Magazine, Vol. 11 #5 which was itself based upon an Agriculture Canada preliminary pest risk assessment. I thank Ralph Huber for bringing it to my attention. Forewarned is forearmed (but not necessarily protected).*

Pine shoot beetle *(Tomicus piniperda)* is a major European and Asian forest pest. A significant infestation has been found in Ohio on Christmas trees. Twenty tree farms were found infested, eighteen detections being in Scots pine and two in eastern white pine. The principal host in Europe is Scots pine *(Pinus sylvestris).* In China, Yunnan pine *(Pinus yunnanensis)* is a major host. It also attacks other pines. Spruces, firs, and larches are less frequently attacked. *It is the most damaging bark beetle in Europe and Asia.* Overwintering adults and all immature stages can be present in logs with bark, including dunnage. Adults can fly up to one kilometre. Potential for infestations spreading naturally ... is high.

Computer-Assisted Diagnosis of Forest Seedling Nursery Problems

A computer program (HYPERNUR) for diagnosis of nursery problems using expert system-guided hypermedia has been developed by Dr. Alan J. Thomson (Pacific Forestry Centre, 506 Burnside Road, Victoria, BC V8Z IM5). A new version (1.1) is now available with improved diagnosis of *Scirococcus in* comparison to the original version. A copy of version 1.1 is available upon request.

Alan J. Thomson
Pacific Forestry Centre

Problems with Benlate DF

Ed. note: the following is abstracted from an article in the "Journal of Pesticide Reform" (Spring 1992, Vol. 12, 01, *p. 30-31). Dave Trotter (Nursery Extension Services, Surrey) notes that Benlate WP (not DF) is usually used in BC reforestation nurseries and problems have not been noted with this formulation. This issue should not be a major concern for nursery managers here but is worthwhile noting.*

Recently problems have surfaced with the DF formulation of the carbamate fungicide Benlate (benomyl, oral LD_{50} 9,600). Benlate DF is used on ornamentals and vegetables normally and has been causing problems resembling plant diseases or growth regulator problems in Puerto Rico, Costa Rica, and Florida. Symptoms reported are yellowing, stunting, and generally poor performance of plants and are positively correlated with increases in heat, light, and humidity. Effects may be residual for up to 10 or 11 months. The cause is presently unknown. Du Pont, the manufacturer, has researched and ruled out the possibility of herbicide or hormone contamination during production of the fungicide.

Sheep Grazing at the Saanich Seed Orchard

Sheep grazing has been used as an effective means of vegetation control at the Saanich Seed Orchard since 1982. Vegetation management has been a major concern in the 7.2 hectare Dewdney Orchard (approximately 1300 Douglas-fir trees) at this site where, to improve drainage, the trees were planted on mounds. Sheep were introduced into the orchard because standard mowing practices proved ineffective on the mounds.

In return for seasonal pasture, a local shepherd provides the sheep and their management. The sheep are brought into the orchard in early spring and remain as long as pasture is available. An additional 9 hectares of adjacent grassland is grazed when seed orchard management requires the sheep to be out of the orchard. Amongst other reasons sheep grazing has been successful at the Saanich Seed Orchard because: 1) a long growing season allows grazing for several months of the year and 2) the trees are mature and most of the branches are out of browsing reach. Furthermore this form of vegetation control reduces mowing expenses, is environmentally friendly, and encourages the local sheep industry.

Ed. note: for more on using sheep for vegetation management in BC see the November 1992 issue of "BC Pest Monitor' (Vol. 1, #2) or contact Dr. Helen Schwantje, Sheep Vegetation Management Committee, Ministry of Environment, Lands and Parks, 780 Blanshard Street, Victoria BC V8V 1X4.

Carolyn Lohr
Saanich Seed Orchard, Saanichton

Applying the IDS Method to Remove Seeds Infested with the Seed Chalcid, *Megastigmus spermotrophus,* in Douglas-fir, *Pseudotsuga menziesii*

Ed. note: *the following is reprinted from a detailed technical article published in 1991 in "New Forests", vol. 5, p 327-334.*

Application. The Incubation Drying Separation (IDS) method was used to remove most of the chalcid-infested seeds from Douglas-fir seedlots with no significant adverse effects on germination parameters. The IDS method should be useful for treating Douglas-fir seedlots that would otherwise require multiple sowing due to chalcid infestation.

Abstract. Douglas-fir seedlots were treated with the Incubation Drying Separation (IDS) method to test whether seeds infested with the seed chalcid, *Megastigmus spermotrophus,* could be separated from non-infested seeds. Seeds were soaked in distilled water for 24 hours, drained, placed in plastic bags, and incubated at 15°C for 3 days. The seeds were dried for either 0.5, 1, or 2 hours at 25°C, and then separated into floaters and sinkers in a water column. An average of 97% of the infested seed floated. The drying period did not affect the separation of infested seeds but significantly fewer sound seeds floated in the seedlots dried for 0.5 hours than those dried for 1 hour. Germination capacity of IDS-treated seeds did not differ from that of untreated seeds but the germination rate was significantly faster for IDS-treated seeds when all lots were stratified.

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Y. A. El-Kassaby
Canadian Pacific Forest Products, Saanichton
D. W. Taylor, D. G. W. Edwards, G. E. Miller
Forestry Canada, Victoria

Spider Toxin Incorporated into a New Viral Insecticide

Ed. note: *the following is abstracted from an article in "Harrowsmith" (#105, October 1992, p. 106).*

A new viral insecticide which incorporates a spider protein as the toxic agent has been recently developed. Researchers at NPS Pharmaceuticals in Salt Lake City, Utah have successfully cloned a spider protein and incorporated it into a nuclear polyhedrosis virus (NPV) capable of infecting larval Lepidoptera (caterpillars). The virus works in a manner similar to Bt: upon ingestion of the virus by a suitable host caterpillar, production of the spider toxin is stimulated and eventually paralyzes the insect. A marketable product may be available within three or four years.

Pesticide Disposal Tips

Writing this just after Halloween, it seems to be a good time to talk about cleaning out some skeletons in our closets – those old, tired, and expired chemicals lurking in pesticide storage sheds. With the reduction in the use of chemical solutions to our pest problems fewer pesticides are accumulating and being stockpiled. Disposal should be a one shot deal so just grin and bear the cost. The process is relatively painless. Following are some simple guidelines for cleaning up your backlog. Remember you are not alone!

Inventory. List the items for disposal including type of chemical (OP, Carbamate, etc.), P.C.P numbers, and total volume. Include pesticides which are older than 3 years, have been frozen, or are seeping though their containers. Be sure to include Safer's Insecticidal Soap as it has a high alcohol content (36%) and is quite flammable.

Contact and Arranging Pickup. Disposal companies are listed in the yellow pages under waste disposal. We chose one with an 800 number so phone bills wouldn't add to the cost. Fax in your list for an estimate. A good disposal company will come to your site, pack up the goods in barrels, haul them away, and dispose of them appropriately. The cost should be about $10 per liter of material. Large disposal companies probably are picking up other industrial chemicals in your area already and will include your facility on an established route.

Basically, all you have to do is an inventory, have a telephone discussion, pay the bill, and enjoy a feeling of satisfaction when this macabre job is behind you. Good luck.

Bev McEntire
Seed Orchard Pest Management, Saanichton

Elevation Splits in Kalamalka Seed Orchard

Each seed orchard seedlot is assigned an elevation against which seed transfer guidelines may be applied. For the many readers who may not be aware of how orchard seedlot elevation is derived, it is calculated in the following way. Every orchard tree has an elevation associated with it; in most cases this is the elevation of the selected wild parent tree from which the orchard tree was grafted. Orchard trees contribute to the seedlot in varying amounts through both pollen and seed production. Surveys are conducted each year to determine the amount contributed to the seedlot by each orchard tree. The seedlot elevation is then calculated as the weighted average of the elevations of the trees contributing to the seedlot, weighted by their proportional contributions.

Seedlot elevation can be controlled to some extent through orchard pollen management and selective cone collections. In response to a request from the Kamloops Region, at Kalamalka we have been manipulating seedlot elevation to better suit their planting requirements. Early seedlots from the Shuswap Adams Low elevation orchard had elevations that were too high for some of the lowest elevation planting in the region. Trees within the orchard are now identified according to their elevations and are categorized as either low-low or medium-low. Pollen is collected from low-low trees and applied only to low-low trees. At cone collection time, cones from low-low trees are kept apart and make up a separate seedlot. This seedlot has a significantly lower elevation than would a seedlot collected from the entire orchard. Other "custom" seedlots could be produced in this way.

Chris Walsh
Kalamalka Seed Orchards, Vemon

Evaluation of Ladybird Beetle Inundative Release at CPFP Nootka Seed Orchard

Between late March and late April of 1992 about 175,000 ladybird beetles of the species *Hippodamia convergens* (Coleoptera, Coccinellidae) were released at Canadian Pacific Forest Products' Nootka Seed Orchard (Saanichton, BC) in an attempt to manage green spruce aphid (GSA - *Elatobium abietinum)* on Sitka spruce *(Picea sitchensis)* (see SSET, vol. 5, #1 for background of this trial). Subsequent weekly surveys revealed coccinellid eggs, larvae, pupae, and adults (presumably *H. convergens)* appearing in a logical sequence and concentrated around the release points suggesting that short ten-n establishment was obtained. Long term establishment is less likely due to the inherent migratory behaviour of this beetle (Jim Matteoni, Westgro Sales, pers. *Comm.).*
The cost of this release was approximately $450.00. This includes cost of the beetles at $325.00 (2.5 gallons released over about 1.3 hectares) and $124.50 for a pre-release spot treatment of heavily infested trees ($24.50 for Safer's Soap and $100.00 for one day's application labour). Treating the entire orchard with 1% Safer's Soap would have cost about $625.00 ($425.00 for three applications of Safer's plus two days' labour – Cathy Cook, CPFP, pers. comm.). Early in May 1992 coccinellid larvae suddenly became numerous in branch beatings (up to 40 per beating) and the GSA population began to drop off dramatically (from greater than 50 aphids per beating to 10 or less). Neither a positive correlation between the build up of the beetle population and the reduction of the aphid population nor a quantification of the effect of the beetles on the aphids is possible because of the uncontrolled nature of this trial (beetles had access to all trees).
GSA populations have a tremendous capacity for rapid increase and they usually do this in mid to late winter on the coast. GSA control measures often need to be initiated in January or February when cold temperatures inhibit feeding activities of the beetles. It is unlikely that a release of coccinellid beetles alone will effectively control GSA because of this. An early insecticide treatment (using a registered product with low residual activity) coupled with a later beetle release (if necessary) when temperatures have increased sufficiently may be the answer to controlling GSA populations on Sitka spruce.

Michelle Hall
Seed Orchard Pest Management, Saanichton

On the Economics of Organic Weed Management Practices

Ed. note*: the following is abstracted from an article in "Harrowsmith" (#105, October 1992, p. 107).*
Peter Stonehouse, a researcher at the University of Guelph, has been studying and comparing conventional, low chemical input, and strict organic weed management practices in three different crops: corn, soybeans, and fall cereals. From his five year study involving farmers in southwestern Ontario he concluded that organic and low input systems gave superior weed control as well as higher and more consistent yields and net returns per hectare than did conventional systems. For example: with corn the growers' "gross margin" per hectare averaged $667.08 (organic), $443.92 (low-input), and $264.24 (conventional). Of course organic produce commands higher prices but if yields and prices are equal organic systems still come out on top because of decreased direct production costs. Stonehouse acknowledged the small sample size of his study but pointed out that conventional systems are well established, low-input systems are beginning to mature and, relatively speaking, organic systems are still in their infancy and have the "furthest to go in developing ... full potential."

Compatibility of Natural Enemies Against a Common Host/Prey

Ed. note*: the following is from a research paper presented at the AGM of the Entomological Society of British Columbia, 23 October 1992. It illustrates some of the complications that may be encountered in the establishment of a biological control program.*

The compatibility of natural enemies used to control pests in multiple species releases is the focus of my Ph.D. research. In a multiple species release, if characteristics of different predators and parasitoids complement each other, together they may have a greater impact on the pest population than if acting alone. However,

(continued...)

competitive and interference interactions among natural enemy species may negatively affect a multiple release biocontrol program unless the species are managed in such a way as to reduce these interactions.

In much of the world, the sweet potato whitefly, *Bemisia tabaci* is a serious pest. I have been studying the interactions of three likely candidates for the biological control of this pest: *Encarsia tabacivora and E. luteola* (two parasitoid aphelinid wasps) and *Delphastus pusillus* (a predatory coccinellid beetle). The potential for host/prey competition among these natural enemies is high. Adult females of both *Encarsia* species oviposit on late whitefly instars and both prefer to "host feed" on the tissues of smaller hosts. This competition 66com-es acute when host densities are low relative to parasitoids. *Encarsia tabacivora* tends to increase its rate of host feeding as host numbers increase. Thus, even when parasitism rates are low, the rate of overall host mortality can still be significant. This can be particularly important in inundative release situations where future reproduction of biocontrol agents is less important than immediate destruction of hosts.

One complicating factor is that *E. tabacivora* is an "adelphoparasitoid": whereas young female parasitoids develop normally within a whitefly host, larval males of this species must feed on developing female parasitoids inside the whitefly. Since a, female is sacrificed to produce each male, sex ratio shifts from generation to generation can be extreme, especially when unparasitized hosts are scarce. Part of my research investigates how availability of hosts can cause fluctuations in parasitoid numbers and influence their efficacy.

Addition of a second species of *Encarsia* complicates matters further. For example, *E. tabacivora* may prefer to use (hyperparasitize) the females of *E. luteola* to produce her males instead of females of her own species. The resulting destruction of *E. luteola* may imply incompatibility of these species in releases against the whitefly. However, using *E. luteola* as the host for E. *tabacivora* males may be beneficial in mass rearing of the latter. The influence of relative density of these two parasitoids on degree of hyperparasitism is under investigation.

Adults and immatures of *D. pusillus* compete directly with both *Encarsia* species by feeding on all immature stages of the sweet potato whitefly. *Delphastus pusillus* may also impact negatively on parasitoid populations through the destruction of parasitized whiteflies. Under experimental conditions it avoids feeding on whiteflies containing parasitoid pupae but will indiscriminately devour unparasitized whiteflies and those containing larval stages of *E. tabacivora.* In this case predator/parasitoid efficacy may be enhanced if predator release is made two weeks after parasitoid release.

To complement these behavioural studies we are conducting field studies in greenhouses to test the efficacy of each species separately and in varying combinations. I hope my studies of host use decisions will explain the patterns we see in field releases and also indicate how to use natural enemies of the sweet potato whitefly in the most efficacious manner.

Judy Nelson
Graduate Student, University of California, Davis

Signs for Greenhouses

The following is the proposed design for a system of greenhouse signs for BC Ministry of Forests Nursery Extension Services (at Green Timbers Reforestation Centre, Surrey, BC). The greenhouses are used for nursery culture and pest management trials and to improve the growth and viability of conifer seedlings. These signs have been designed with the visiting public in mind.

The signs need to:

1. offer clear and concise explanations of the trials in progress;
2. be able to withstand high humidity (60-100%), heat, natural and artificial light, and potential exposure to fertilizers and/or pesticides;
3. not cause shading of seedlings;
4. last anywhere from 3 months to 2 years (as trials continue, the signs will accompany seedlings to outplantings);
5. be easy for staff to make up themselves in as short a time as possible (the ideal turnaround time would be, of course, one day); and
6. look professional and adhere to a regular format as do other signs on the property.

A sign size of 11" x 17" allows lettering to be large and therefore inviting and easy to read. A laser printed "landscape" style 8 ½" x 11 " original can be easily enlarged by 154% with most photocopiers to 11" x 17".

A logo and header will be printed on the 11" x 17" stock and a template has been made for the changing text using Word for Windows. Black photocopy text will not fade with exposure to UV light.

(continued...)

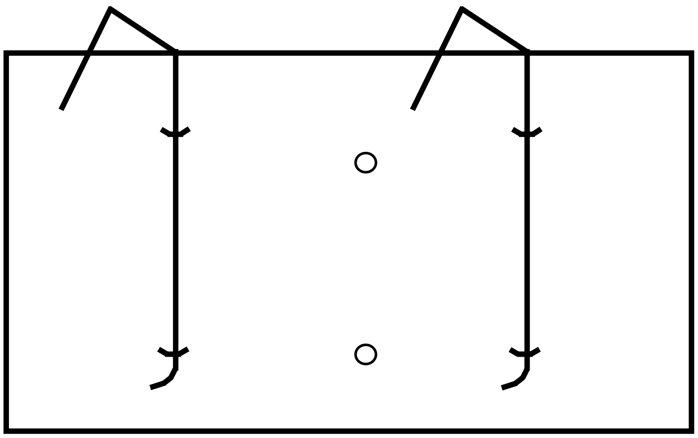

Figure 1. Back of sign holder showing screw holes and aluminum hangers for attachment to stake and styroblock respectively.

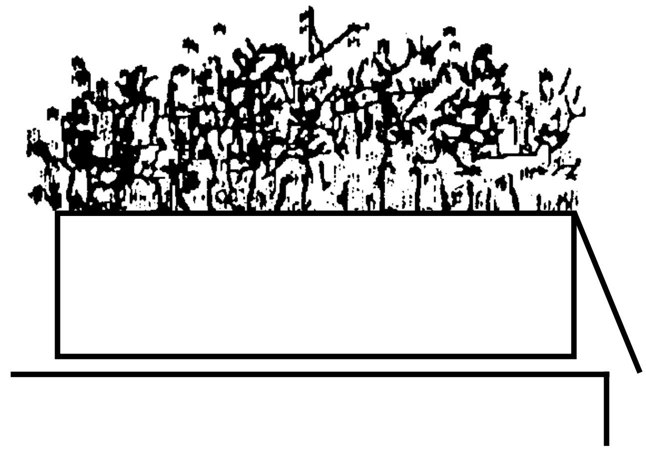

Figure 2. Styroblock and seedlings with sign holder attached.

Laminating the photocopies will protect them from conditions in the greenhouses and in the field. The polyester/polyethylene laminate film is inert, stable, and does not deteriorate noticeably with exposure to light, humidity, and/or heat. Commercial photocopying outlets offer 11" x 17" lamination services for an average cost of $5.50 but the lamination quality can vary greatly. Three mil laminate should be used with the finished product trimmed to ¼" all the way around. I recommend asking for "roll laminate" rather than laminating pockets as the pockets tend to bubble or the signs may come back uncentred. Such uncentred signs cannot be fixed by trimming.

Once laminated the sheets need to be mounted on a firm backing. Tests were made using sheets of 0.05" aluminum and 3/16" Coroplast® (distributed as Tenplast® in western Canada - a long-lasting, lightweight corrugated material made of polypropylene). Coroplast® was chosen because it does not easily break down, yellow, or become brittle with exposure to light, humidity, and/or heat. However, fluctuating temperatures caused expansion and contraction of the Coroplast® relative to the attached laminated sheets caused rippling of the sign surfaces. The aluminum sheets have proved to be satisfactory and also are easily reused and can be cut easily with a wallboard knife. The laminated photocopies are attached to the aluminum backing sheets around the edges and through the middle using 3M 9418 double sided tape. This tape is very thin, very sticky, and easy to apply. 3M is confident of its performance in humid conditions.

Each sign will slide into a 0.05" aluminum frame attached to the holes between the growing cavities in the end of an aisle styroblock by means of bent lengths of aluminum welding rod slotted into the back of the frame (see figures 1 and 2). The mounting wires can be adjusted to accommodate the hole spacing of most styroblocks and can be folded down against the back of the frame for storage. The wires will hold the signs at a 220 or 30' angle from the blocks for easy reading and flush with the top of the block so that seedlings are not shaded. When trials continue outside the greenhouses the wires can be removed and the frames can be screwed onto wooden stakes to be posted with the out planted seedlings.

This sign design is neat and professional in appearance, inexpensive (about $10.00 in materials for each sign, $3.00 for each frame), and easy to assemble. The signs are convenient for uses as short as three months or for up to two years. Prototypes of the signs and frames are being tested at Green Timbers Reforestation Centre with good results so far. This system is flexible and easy to use. It is even possible to put a sign in place within the ideal turn around time of one day. For more details contact the author at (604) 582-6904.

Shamina Senaratne
SFU Communications Co-op
Student Nursery Extension Services, Surrey

Tech Talk

Seed Orchard Seed and Seedlings: Genetic and Non-Genetic Implications and Operational Considerations

Ed. note: *this paper was presented at the AGM of the Forest Nursery Association of BC, 29 September - 1October 1992 and will be appearing in the Proceedings of that meeting.*

Abstract. By 2010 about one-half of BC's seed for the production of planting stock will come from managed seed orchards. Seed orchards are collections of selected offspring-tested trees from a particular geographically defined breeding or seed planning zone. From the nursery person's perspective there will likely be some differences in seed and seedling characteristics associated with different seed orchard seedlots in comparison to natural stand seedlots. These differences have genetic and/or environmental origins. Changes in seed handling practices and nursery growing regimes will likely be required for certain seedlots.

Introduction

The application of time proven agricultural plant breeding methods to forest tree species began in British Columbia in the 1950's with the selection and inter crossing of coastal Douglas-fir trees. Today we have breeding programs for 5 coastal and 5 interior species of commercial importance as well as seed source (provenance) testing work underway with a total of 13 species (table 1).

Table 1. BC's tree breeding and source testing programs.

	Breeding	Seed Source Testing
Coast	Fdc, Hw, Ss, Cy, Pw	Fdc, Hw, Ss, Cw, Cy, Plc, SxS, Bg, Bn, R. Alder
Interior	Si, Pli, Fdi, Lw, Pw, aspens, hy. cottonwoods	Si, Pli, Fdi (small effort)

Objectives of these activities include:

a) intelligent gene resource management via knowledge of species specific gene ecology, seed transfer, tolerance to environmental changes, and needs for gene conservation and preservation; and
b) increasing forest productivity via production and use of genetically superior planting stock for reforestation. Knowledge gained from our seed source testing and breeding research has resulted in the development of seed transfer guidelines for several species based on combined empirical evidence and biogeoclimatic rationale. These guidelines help field foresters make rational decisions about seed source selection for artificial reforestation work. To date most of these decisions have involved choosing among available natural stand collected seedlots. Only about 10% of the 250,000,000 seedlings produced and planted in BC in 1991 were grown from genetically improved seed orchard seed. By 2010, however, about one-half of the planting stock produced will come from seed orchard seed.

Orchard seed and seedlings grown from this seed may have physical and behavioural characteristics slightly different from those of seedlings originating from natural stand seeds including (but not limited to):

1) seed size and condition;
2) stratification treatment required, germination capacity and value;
3) seedling growth rates and rhythms;
4) variation of growth rates and rhythms within a seedlot; and
5) culling rates and recovery rates.

Differences in these characteristics may be the result of differences in gene frequencies between natural stand and orchard seedlots and/or differences in the physical and cultural treatment environments in which the two seed types are created. Following is a brief discussion of each of the above seed/seedling characteristics and possible differences between wild and seed orchard seedlots. Experiences of BC and neighboring American nursery persons, as well as those of the author, have contributed to these discussions.

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Discussion

Seed size and condition.

Cone and seed size can differ among trees of a species due to differences in both genetic makeup and physical/cultural growing environments. There is no evidence that our selected seed orchard parents produce inherently larger or smaller seeds than trees selected randomly from natural stands. However, environmental conditions in seed orchards are almost always more generous in terms of growing space, nutrients, moisture and often heat sums, than in natural stands. For this reason orchard seeds are frequently larger and heavier than those from natural stands (Table 2) On the other hand, flower stimulation treatments such as stem girdling, root pruning, hormonal applications, etc. can result in smaller seeds being produced due to temporarily reduced vegetative vigor of orchard trees. While there is no consensus among researchers about the effects of initial seed size on later seedling performance in the field (i.e., there are data to support various hypotheses!) most agree that nursery growth rates, particularly during the first weeks following germination, are affected by seed size. Generally larger seeds have larger embryos and more stored nutrient energy and are often more vigorous, at least early in the growing process.

**Table 2.
Seed size comparisons: natural stand vs. seed orchard**

	# Seeds/g (# seedlots)	# Natural / # Orchard x100
FDC S.O.	85 (63)	
Fdc Natural	97 (38)	114%
Pli S.O.	260 (13)	
Pli Natural	358 (10)	133%
Si S.O.	418 (4)	
Si Natural	504 (25)	121%

Stratification, germination capacity, and germination value

Stratification treatments required to break dormancy are largely dependent upon level of seed maturity at time of collection. Seed orchard cones are often collected just prior to seed drop (i.e., at a high level of physiological maturity). Natural stand cones are often brought in "green". Post-ripening treatments (cool, dry storage) may or may not increase seed maturity prior to seed extraction and cleaning. Therefore orchard seed is often more mature than natural stand seed and will likely require a longer stratification period for rapid and uniform nursery germination.

Germination capacity (completeness) is the fraction of seed that ultimately germinate under a given set of conditions. Germination value is a combined measure of germination capacity and germination speed. Table 3 shows BC experiences with orchard and natural stand seedlots for three species. Germination capacities for Fdc and Pli are the same for the two seed origins while orchard seed appears to be better for Si. Limited numbers of seed lots contributed to the Si germination capacity estimates so the mean difference observed may not be real. Germination values are approximately the same for these species. While stratification treatment times required for orchard seedlots may be longer than those for natural stand seedlots, germination behaviors do not appear to differ between the seed types.

**Table 3.
Seed germination capacity (GC) and germination value (GV) comparisons: natural stand vs. seed orchard (seedlot sample size in parantheses).**

	GC%	GV%
FDC S.O.	93 (43)	48 (37)
Fdc Natural	93 (24)	55 (22)
Pli S.O.	96 (15)	66 (8)
Pli Natural	92 (37)	59 (28)
Si S.O.	91 (4)	42 (3)
Si Natural	71 (11)	46 (5)

Seedling growth rates and rhythms

These characteristics will likely differ between orchard and natural stand seedlots. The reason for this is most likely entirely genetic and results from the way we choose among natural stand trees for inclusion in a seed orchard. Wind pollinated seedlings from selected natural parent trees are planted on a series of test sites ecologically representative of a particular seed planning zone. After a number of field seasons average height growth estimates of these seedling families are used as the principal criteria for determining which parent trees will be grafted into a seed orchard.

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These evaluation periods are relatively short compared with commercial rotation times (e.g. Pli - 5 years, Fdi - 6 years, and Si - 10-12 years). The practice of making seed orchard parent selections based on early field performance is common to most tree breeding programs around the world. Waiting longer to make orchard parent selections would provide slightly more genetic gain since fewer selection errors are made as tests approach rotation age but would significantly delay the transfer of genetic gains to operational planting programs. Thus we select earlier and make a few errors but get a reasonable level of genetic improvement into operational planting soon.

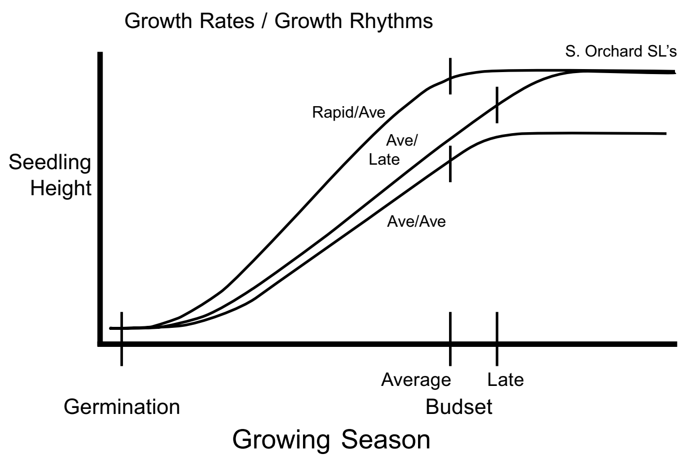

***Figure 1**. Hypothesized growth rate and growth rhythm comparisons: wild stand vs. seed orchard seedlots (curves not based on actual data).*

Selecting orchard parents this way may result in orchard seedlots that give rise to nursery seedling crops that; a) grow more rapidly per unit time, and/or b) grow later into the growing season (fig. 1.) Some orchard seedlots will be more vigorous during their free growth period and will require somewhat different management than natural stand seedlots, i.e., changes in the timing and/or severity of water and nutrient deprivations, use of blackout curtains, etc.

This season at the Skimikin Nursery, John Watson compared Si seedlings grown under identical conditions from natural stand and seed orchard seed. About 20% of the orchard seedlot seedlings were at least two weeks late in setting buds while the wild seedlot had about 8% late bud set. Presumably the late bud setters will require more time to achieve an acceptable level of cold hardiness and may create a problem at lift time or be more susceptible to frost damage in cold storage. Late budsetters from this and other Si orchard seedlots grown at Skimikin this year are being cold hardiness tested periodically up to lifting time to determine if sufficient hardiness is achieved by the time the entire seedlot (crop) is lifted in late October/early November (pers. comm. Dr. Chris Hawkins).

Variation in seedling growth rates and rhythms

Tree to tree variation in growth rates, growth timing (rhythm), and morphology is always large in conifer seedling crops regardless of origin. Our native conifers have evolved under environmental conditions as variable spatially and temporally as any on earth. Evolution of their genetic "coping" systems has resulted in very high levels of genetic heterogeneity among individual trees in a stand. Consequently, for genetic reasons alone, seedling variation in a nursery crop will be high. Add slight differences in germination timing among seeds, chance micro-environmental insults to certain germinants, and mid to late growing season competition effects, then the large observed variation for several characteristics should come as no surprise. To date only growth timing has been documented to show greater seedling to seedling variation within an orchard seed lot in comparison to a natural stand seedlot (1992 Skimikin Si crops).

Within crop variation in germination rates, growth rates, and growth timing are all potentially more manageable with orchard seedlots than with natural stand seedlots. These and many other seedling characters are all under some level of genetic control. If all seed parents of an orchard (usually 60 - 100 clones in an orchard) are progeny screened for a particular trait (e.g., growth timing) and the resulting parent ranking (e.g., early budsetters to late budsetters) divided into 2 or more fractions then cones could be collected and processed and seed be sown and grown by fractions. The different "fractional" orchard crops could be managed according to their individual natures resulting in reduced within crop variation. The extreme strategy would be for every seed parent to be collected and grown separately with resultant seedlings bulked at time of lifting.

With coastal Douglas-fir, germination values can be very different among individual orchard parent seedlots. Ultimately this can result in very unequal representation of orchard parents in final seedling crops (Yousry El Kassaby, pers. comm.). In BC we have an orchard seed crop certification requirement that any seedlot to be used for reforestation of Crown land should have an effective contributing parentage of around 20 parent clones. Even though a bulk collected orchard seedlot may initially meet this requirement, differential survival of seed parent offspring families from time of germination to the culling line may reduce the genetic diversity of the crop to an unacceptable level.

Therefore, in the future we may be growing several relatively small seedlots, a few moderately large ones, or a single bulked lot for each particular seed orchard.

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Culling rates and recovery rates

Will seedling culling rates be different for seed orchard seedlots? The answer is probably “yes” if the same absolute culling thresholds are applied to both natural stand and orchard seedlots (see fig. 2). The orchard seedlot distribution is displaced slightly to the right indicating a larger mean seedling size (height, stem caliper, etc.) for orchard derived seedlings. The total shaded area is the natural stand crop culled fraction. The smaller crosshatched area is the orchard crop culled fraction.

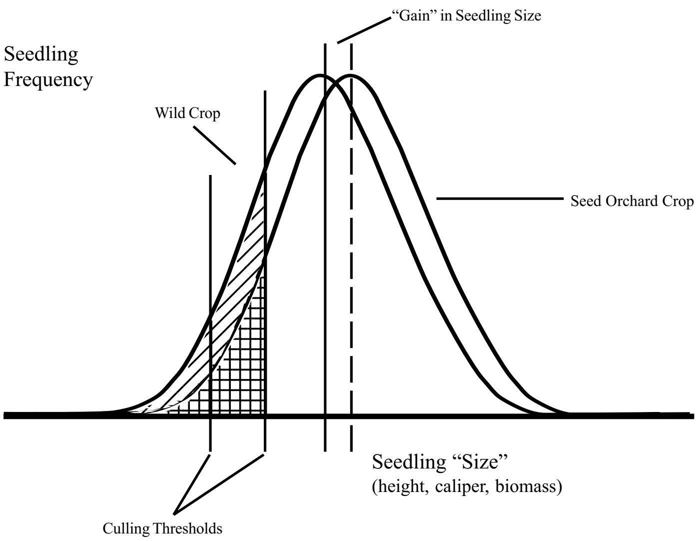

***Figure 2**. Seedling size distributions and cull fractions for natural stand and seed orchard seedlots.*

With the same absolute standard(s) applied to both crops a smaller cull fraction results with the orchard crop. If we choose to reduce the culling thresholds for orchard crops then the throwaway fraction would be even less. However, some workers suggest we should cull few, if any, orchard seedlings because they are “genetically superior.” This suggestion deserves further comment. The intermating of a large number of genetically diverse individuals (as in an orchard) produces a broad array of gene combinations. At least a small fraction of these do not have the potential to produce marketable trees and thus should be culled if identifiable at the nursery stage. Random environmental insults to seedlings at an early age coupled with subsequent competitive disadvantage will always result in some seedlings in a block being small for purely environmental reasons. Since we cannot distinguish at culling time seedlings with lesser genetic potential from those suffering environmental disadvantage we must cull all below a certain size limit. This is the way it has always been and will continue to be even though we speak of our orchard seedlots as “genetically improved.”

Finally, here is one last bit of local BC experience. Recent recovery rate data for Fdc seedlings produced from orchard and natural stand seed at Surrey Nursery are shown in Table 4. Recovery rates reflect cumulative losses from germination to the culling line. For Fdc, mean recovery rates over all years and stock types are essentially equal for the two seedlot types. However, for container-grown seedlings, seed orchard seedlots appear to have superior recovery rates with the reverse true for bareroot seedlings. The reasons for this are unknown to the author!

Table 4.
Seedling recoveries from seed orchard and natural stand seedlots — Fdc grown at Surrey Nursery 1985 - 1991

Mean Recoveries over all years and stock types:

S.O.	56% (n=38)
Natural	54% (n=92)

Mean Recoveries over all years and stock types:

	Container			Bareroot
	1+0	2+0	Average	
S.O.	57%	54%	55%	57%
Natural	57%	39%	48%	64%

Summary

There is evidence that some of our seed orchard seedlots will likely behave differently from natural stand seedlots for some of the characteristics discussed above. Explanations involve genetic and/or environmental factors depending upon the particular seed or seedling characteristic. The Forest Renewal Group of the Ministry of Forests Research Branch has recently begun work to identify and quantify these differences.

Dr. Chris Hawkins began applied seed orchard nursery crop research this spring at the Red Rock Research Station near Prince George. Over the next few growing seasons this research will attempt to answer the more important questions about if and how we should alter our procedures for collecting, processing and growing seed orchard seedlots. Orchardists’ and growers’ observations, concerns, and suggestions about growing future seed orchard seedling crops are welcomed. Contact Chris at (604) 963-9651.

Michael R. Carlson
Kalamalka Forestry Centre, Vernon

Evaluation of Peat versus Conifer Sawdust as a Water Holding Medium in Transplanted Spruce Grafts (SX: 88601G)

Abstract Ten three year old interior spruce clones were transplanted into either peat or conifer sawdust medium. Height increment and total height increment were significantly affected by treatment the second and fourth years respectively after transplanting. In both cases the height increase of trees planted in the peat exceeded that of those planted in the sawdust. No other significant nutritional effects were noticed in this trial.

Introduction

Because of its water-holding capability, commercial peat is commonly added to a planting hole when transplanting potted grafts. Conifer sawdust, a less expensive alternative, has never been tested for its suitability as a medium for growing transplants. This may be due in part to the tendency for sawdust to create soil nitrogen deficiencies. However, the proximity of several large conifer sawdust piles to the Prince George Tree Improvement Station made it worthwhile to investigate the comparative response of spruce grafts grown in peat versus sawdust.

Discussion

There was no significant difference in height increment between those grafted trees transplanted in peat or sawdust in the first year after planting. This may be due to the fact that the terminal buds of the grafts (which encloses the completely pre-formed and "telescoped" terminal shoot) had developed the season before at Skimikin Nursery under close to ideal cultural conditions. Treatment would therefore have less effect the first year after transplanting. Height increment in the second year after transplanting was significantly greater in those trees grown in peat than in sawdust.

Treatment did not have a significant effect in the third or fourth years after transplanting. However, total height increment was significantly affected by treatment. Trees in peat grew an average of 25% more than trees grown in sawdust. Although there was no significant clonal effect on total height increment, two clones (5608 and 5800) did grow considerably less in sawdust (respectively 80% and 47% less).

The reason for poorer height growth in the sawdust can only be speculated. Foliar analysis did not show any large difference between peat or sawdust grown trees. Surprisingly, those grown in sawdust had generally slightly higher foliar nitrogen levels that those grown in peat. A common concern about the use of sawdust is that it can create soil nitrogen deficiencies and will therefore require more fertilizer.

In conclusion, the use of sawdust as a transplant medium is not recommended. However, a similar study should be carried out, but on a greater number of grafts all of the same clone, to better show the effect of treatment.

Carole Lee
Prince George Tree Improvement Station

Use of Electronic Data Recorders in Forest Nurseries

Ed. Note*: Mention of trade name or products in this article does not constitute endorsement by the B.C. Ministry of Forests.*

Electronic data recorders are widely used throughout the B.C. forest industry for purposes such as log scaling, timber cruising, and data collection for seed orchards and forest nurseries. In the BC Ministry of Forests, Husky Hunter and Radio Shack data recorders were the first to be used. As with all computer technology, electronic data recorder technology has changed rapidly in the past ten years. Most manufacturers now make MS-DOS compatible devices with large memory capacities, which are capable of running various software programs.

In B.C. forest nurseries, the Polycorder 600 electronic notebook has proven to be a useful tool. It is a lightweight (less than 2 lb.), rugged, programmable data recorder which allows both hand-key and automated data entry from digital sensors. It was the first data recorder to have the capability to input data from digital calipers, an important factor in nursery use. The distributor for BC (Electronic Data Solutions in Idaho) also supplies various versions of a spreadsheet program, Dataplus, and can develop custom software for specific needs.

At Saanich Test Nursery (where operational trials are conducted by Nursery Extension Services, Silviculture Branch) a Polycorder 600 has been used for four years to collect trial data. It has eliminated time consuming manual data collection and error prone keypunching. Prior to using a Polycorder, one person would measure the seedlings while another person manually recorded the data. The figures would then have to be keyed into

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the PC. With a portable data recorder and digital calipers, one person can measure the seedlings with very few keystrokes and then download the data into a PC within minutes.

We primarily use the Polycorder (in conjunction with Dataplus and Mitutoyo digital calipers) to collect seedling height (to about 30 cm) and root collar diameter data. A Mitutoyo digital scale ruler is used for measuring heights from 30 cm up to 45 cm. Bar code wands and other digital sensors are available. An electronic balance with an RS-232 port can be used to automatically record dry weight data.

At Saanich Test Nursery, Lotus Symphony (a combined program with communications, spreadsheets, graphics, and word processing) is used on the PC to download the data through the RS-232 port onto spreadsheets, for data manipulation and production of graphs. All procedures are relatively simple and easy to learn. Once the initial Symphony spreadsheets have been set up, only a few keystrokes are needed to download the data each time it is collected. Other spreadsheet programs such as Lotus 123, Quattro or Excel and communications programs such as Procomm or Crosstalk are compatible with Polycorders.

The Polycorder 600 may have limitations for some users. The 600 series is not MS-DOS compatible. The LCD display is only 4 lines by 16 characters. The large keyboard is adequate when entering numerical data or using digital input devices, but letters must be entered by combining the shift key with the numerical keys. The screen size and keyboard layout could prove frustrating to the user wishing to view a large display area and enter comments, etc.

A variety of companies now produce MS-DOS compatible data recorders including:

Paravant RHC-44 - distributed by
R. White Woods Inc.,
Saanichton, B.C.

Polycorder 286LX series - distributed by
Electronic Data Solutions,
Jerome, Idaho.

CMT MC-V - distributed by
Tradetec Computer Systems Ltd.,
Nanaimo, B.C.

Husky Hunter 16 and Husky FS/2 - distributed by
Fortran Systems,
Richmond, B.C.

Dap Microflex - distributed by
Coast Forest Management,
Victoria, B.C.

Micro Palm PC3000 - distributed by
PDC Technology,
Victoria, B.C.

These are all relatively lightweight, portable, rugged and watertight devices with larger screens and more complete keyboards than the Polycorder 600. All units use rechargeable batteries and are available with different memory capacities. The specific features available and the level of MS-DOS compatibility vary between units. Naturally they are also more expensive than a Polycorder 600.

At the present time, the only MS-DOS compatible portable computer with a connection that enables input from digital calipers, making it suitable for nursery use, is the Paravant RHC-44. The distributor has developed a data collection program, EASYDC, for use with the Paravant, which can be set up for almost any application. The Paravant features a large screen (16 X 40 characters) with an optional backlit display, and a full keyboard with 60 keys which can also be backlit for low lighting conditions. The Paravant is slightly larger than some of the other available units but is still lightweight (2.7 lb.).

The specific portable data recorder needs of nursery, seed orchard, or field researchers should be discussed with suppliers and with other users. Good quality, consistently available hardware and software support is an important consideration when choosing an electronic data recorder. For some users, the availability of peripheral devices such as electronic calipers or barcode wands is essential.

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Sanitation Methods and Monitoring Progress Reduce Disease in British Columbia Container Nurseries

Ed. note: *this paper was presented to the Intermountain . Forest Association, Park City, Utah, 12-16 August 1991. Also see previous issue of SSET (Vol. 5 #2, p. 6-12) for related articles.*

Abstract. Conifer seedling nurseries in BC have reduced incidence of disease and application of pesticides. Sanitation methods and monitoring programs developed and implemented for nursery disease are discussed.

Introduction

In B.C. there has been a significant reduction in pesticide use at forest seedling nurseries. Over the last 3-5 years, use of chemical pesticides has decreased by 80%. Some nurseries in the province are producing stock entirely pesticide free, and at most facilities there is at least one stock type that is produced free of pesticides each year. There are no herbicides applied to container seedlings, which currently represent over 90% of the stock produced. A rough estimate has shown that approximately 30% of all stock currently produced in the province has not been treated with chemical pesticides. This of course will vary among nurseries, years, and crops.

There are several reasons for the reduction in the use of pesticides. Over the last ten years Integrated Pest Management programs have been developed. Many insects are hand removed and destroyed. Biological control agents are continuing to be tested. Improvements are being realized in nursery sanitation, crop nutrition, irrigation regimes, crop spacing, and growing media. Pest monitoring programs are being, and have been developed. Stock destined for the 1+0 summer shipping program is grown early in the year when many pest populations are inactive and, as a result, is usually pesticide free. Requests for this stock type are increasing each year.

Specifically there have been significant advances in nursery sanitation methods and disease monitoring programs. This paper discusses the sanitation methods that have been implemented, as well as the monitoring programs that have been developed for pathogens. Information is presented in a chronological order as it would be used through the growing season.

Discussion

Media testing

Before the seedlings are sown, samples of the growing media are analyzed for presence of pathogens by Forestry Canada's Pacific Forestry Centre plant disease clinic (operated by John Dennis). Recently, samples of grit used to cover container-sown seed were found to contain *Fusarium* and low levels of *Pythium*. To assay the grit, approximately 50 granules were sprinkled onto a petri dish with Komada's medium. The plates were incubated at room temperature under natural light and checked at 5 and 10 days. Plating dilution samples were ineffective, possibly because the *Fusarium* was bound tightly to the grit (John Dennis, pers. comm.). Assays showed that 80% of the grit pieces tested contained *Fusarium.* All *Fusarium* contaminated grit came from the same supplier. Washing the grit with a solution of bleach drastically reduced but did not eliminate this pathogen. The best solution appears to be choosing a supplier with Fusarium-free grit.

Samples of peat have also been tested for *Fusarium*, *Cylindrocarpon* and *Pythium*. To assay for *Pythium*, 1.25 gm of peat are added to 50 ml 0.1% water agar, plated at 1 ml per plate on a V8 juice medium, and incubated at room temperature in the dark. For *Cylindrocarpon* and *Fusarium,* 1.26 gm of peat are added to 200 ml 0.1% water agar, plated at 1 n-d per plate on Komada's medium, and incubated in the light at 20-200C for *Fusarium* and 15°C for *Cylindrocarpon* (John Dennis, pers. comm.).

A recent survey showed that 10% of peat samples tested contained Fusarium. Presence of the fungus varied drastically among bales of peat. For unknown reasons, there seems to be a trend toward higher levels *of Fusarium* in peat. Once growers find this pathogen they may choose to change their peat supply.

Seed testing

Prior to sowing, information about pathogens on the seed can be studied. The Ministry of Forests monitors seed held at the Tree Seed Centre to determine if *Sirococcus and* Fusarium are present. Presently, a list of seedlots contaminated with *Sirococcus* is available to all growers in the Province. For the *Sirococcus* survey, 500 seeds are collected from each seedlot, surface sterilized for 30 minutes in 30% H_2O_2, rinsed twice in distilled water, and air-dried on sterile towels in a laminar flow hood. They are then plated on 1.5% water agar at 25 seeds per plate. Plates are incubated at 20°C (day) and 16°C (night) with an 8 hour 900 lux photoperiod. They are checked after 8 days, then twice weekly for 2 weeks,and then weekly for another 3 weeks (John Dennis, pers. comm.).

(continued...)

Sirococcus is usually present inside seeds, rendering a control programme of surface sterilization ineffective. However, this information is helpful to nursery staff: when infested seedlots are sown, they are closely monitored and a fungicide applied as soon as symptoms appear. Diseased seedlings are rogued and burned when practical. The practice of sowing multiple seeds per cavity may allow the disease to spread between seeds in containers. This may explain the higher incidence of the disease in containers than in field culture.

Fusarium were initiated at the Tree Seed Centre in 1991. *Fusarium* inoculum is usually present both inside and on the surface of the seed. Surface cleaning methods have been effective at reducing levels of this seed-borne pathogen. In some Douglas-fir seedlots in storage up to 23% of the seed can be infested with *Fusarium*. However, this is not common. For *Fusarium* surveys, 500 seeds are collected from each seedlot, plated onto medium -(25 seeds per plate), and incubated at room temperature (25-28°C) with either normal or constant light. Plates are checked for *Fusarium* after 7 and 14 days (John Dennis, pers. comm.).

In 1990 a trial was conducted using five Douglas-fir seedlots to determine if cleaning or disinfecting treatments would reduce the levels of *Fusarium.* A 24-hour running water soak instead of standing water prior to stratification reduced the incidence of *Fusarium* on the seed. A four-hour soak in 3% hydrogen peroxide or a 10-minute soak in 2.1% sodium hypochlorite followed by a 48 hour running water rinse after stratification reduced the *Fusarium* levels further, but results were inconsistent. A three-minute soak in 70% ethanol reduced germination by 50% in tab and field assessments. The simple running water treatment appears to be an effective way to reduce seed-borne pathogens.

Styroblock sanitation

Ensuring that peat, grit and seeds are pathogen free is a wasted effort if contaminated styroblocks are used. Algae and pathogenic fungi are often maintained from year to year through poor block sanitation. Blocks are used for up to 6 years and significant levels of inoculum can be found especially in the lower third of the seedling cavity. Pathogens such as *Pythium, Fusarium, Phoma, Cylindrocarpon,* many species of algae and liver-wort spores can all be isolated from used containers.

In 1990, over 100 different sanitation treatments were investigated for control of pathogen inoculum on used styroblocks. The most effective methods for reducing fungal and algal propagules were: steam (95°C for I minute); heated soaps (Safer's De-moss or Ivory soap, 10-second dip in 5% solution at 80°C); bleach (10-second dip in a 0.5% solution buffered to pH 7.0); hydrogen peroxide (10-second dip in 10% solution); sodium metabisulphite (10-second dip in 5% solution); and sulphur dioxide fumigation (Peterson, 1990). Most nurseries in BC are using heated water, bleach, or sodium metabisulphite. Sodium metabisulphite provides the best control of fungi, algae, and weeds but is difficult to use and requires full protective clothing.

Pallet sanitation

After sowing, blocks are moved to either greenhouses or open compounds where they used to be placed on wooden pallets. Poor drainage often resulted due to blockage of cavities by the wooden pallet slats. This frequently encouraged disease. To eliminate this problem, angled runners were designed for the blocks to rest on, allowing free drainage.

Recently a *Rhizoctonia* problem on lodgepole pine was traced to pallets previously contaminated with this fungus by a poinsettia crop. The greenhouse had been bleached but not the wooden pallets. In cases where seedling roots are known to be infected with *Pythium* or *Fusarium,* these pathogens can also be isolated from samples of wood taken directly beneath the styroblocks. We do not know if the disease came from the styroblocks first or whether the pallets could be transmitting the fungi to the stock. Some nurseries have a program of washing the pallets with bleach between crops.

Greenhouse sanitation

Greenhouse floors, walls, roofs and benches can also be a source of disease fungi and should be cleaned. The facility may first be washed with a high-pressure hose followed by an application of household bleach (6%) at 1 part bleach/ 10 parts water. Some nurseries leave the bleach solution in the house and turn up the heat to obtain a fumigant effect. Algae and some weeds can be controlled on greenhouse floors using a slurry of copper sulphate (20 lb. in 100 gal. H_2O). Care should be taken to keep the solution away from metal because it can be corrosive.

The advent of large outdoor compounds for production of container stock has caused an increase in weed problems, particularly liverworts. It is important to keep the ground free of weeds in these areas. Asphalt or cement are obvious choices, but often the expense is prohibitive. Ground covers such as black propex have been effective. Herbicides such as glyphosate, simazine and gramoxone are applied on compound floors, and in and around greenhouses to control weeds.

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Disease monitoring
To reduce disease spread during the growing season, all crops are monitored closely. Diseased seedlings are rogued and the affected area noted. Roguing is particularly effective at reducing *Sirococcus* and *Fusarium* foliar blights. A fungicide tolerance test is used to determine resistance by *Botrytis, Rosellinia Cylindrocarpon,* and *Fusarium.* Aerial conidia or sporodochia are inoculated onto 5 marked areas on PDA medium amended with 50 ppm of the fungicide to be tested. When observed under a compound microscope, fungicide-sensitive strains will either not germinate or produce abnormal germ tubes and hyphae. Resistant strains will grow normally although somewhat slower (John Dennis, pers. comm.).

Water testing
At most nurseries, supplies of water used to grow the stock are monitored. Nurseries obtain their water for irrigation from a variety of sources such as rivers, lakes, wells or municipal water systems. Water can be a source of pathogenic moulds and it is important to check any water source before it is used. This can be accomplished through baiting with an unripe pear. The pear is placed in a mesh bag and submerged in an area where water is flowing such as near the surface of an inlet or outlet. This allows a large volume of water to be sampled. The length of time the pear is left in the water Depends on the temperature of the water:

40-50°F	7 Days
50-60°F	5 Days
60-70°F	4 Days
80-90°F	2 Days

Swimming zoospores of Pythium and Phytophthora infect the pear tissue and produce a brown dry, corky-type rot. The pear is then sent to the lab where the brown spots are cultures from the decay margin onto PDA and CMPV (cornmeal agar containing Vancomycin 20ppm and Pimaricin 20ppm) agar (see Dennis, 1992).

If pathogens are discovered the nursery can investigate alternate water supplies or install a chlorination system on site. The use of injected chlorine gas in irrigation water can reduce disease spread. A level of free chlorine of 2 ppm for a minimum of one-minute will kill spores of Phytophthora cinnamomi. The recommended residual level of chlorine in irrigation is 0.5-1.0 ppm (Barnett, 1990).

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New Storage Mould Damages Spruce Seedlings

In the spring of 1992, 400,000 two year old spruce were destroyed at primary storage facilities and more were thrown out near planting sites (J Sweeten, pers. comm.) due to the fungus *Septonema. Septonema* (formerly *Ramularia)* was first identified on container grown spruce seedlings in BC in 1986. At that time it was found on the lower needles of spruce just before lifting, during the frequent storage checks, and when seedlings were thawed for planting. It did not appear to be doing any serious damage. Research done in Norway in 1983 indicated that *Septonema* was pathogenic on spruce needles and reported some growth and taxonomic characteristics of the fungus.

The disease is recognized by whitish-gray to yellowish mould growth on water soaked, darkened spruce needles. Needles near the bottom of the plant appear to be infected first but the fungus moves up the seedling by prolifically producing spores. *Dasyscypha, a* very small white cup fungus, may be the perfect (or sexual) stage of *Septonema. Dasyscypha* is also observed on stems, branches, and needles of stored spruce. When *Dasyscypha* is seen, it is probably an indication that *Septonema* is present as well. *Septonema* does not appear to damage woody stems but may defoliate plants sufficiently to reduce their photosynthetic potential. It is not known if this fungus affects outplanting success.

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In the fall of 1991, a policy of not using a pre storage spray for stock that was frozen stored and not infected with *Botrytis* may have allowed *Septonema* to spread during the seedling thawing phase. Seedlings were tested at Forestry Canada's Pacific Forestry Centre (PFC) in the fall for presence of *Botrytis* before a pre storage spray decision was made. This test consisted of incubating a representative sample of spruce trees in the laboratory at room temperature (approximately 24°C). Tests conducted on spruce known to have *Septonema* since the spring 1992 losses indicate that it prefers a lower temperature and does not show up in incubations done at room temperature. Septonema did show on-incubations done at 15°C.

Additional tests were done at PFC to determine the sensitivity or resistance to fungicides currently used to control storage moulds. *In vitro* laboratory tests done with growing media amended with fungicides have shown that the *Septonema* isolates tested were sensitive to captan, ipridione, and benomyl but some showed resistance to chlorothalonil. The protective effect of pre storage fungicide sprays on *Septonema* infested seedlings are not known. For spray recommendations, the Ministry of Forest Nursery Extension Services at the Green Timbers Reforestation Centre in Surrey should be consulted.

Future pre storage testing of spruce at PFC will include a low temperature (15°C) incubation in an attempt to identify stock with potential for *Septonema* induced damage. To prevent spruce seedling losses, recommendations are that trees with *Septonema* be stored at freezing temperatures and thawed in as short a period as feasible before planting.

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Resistance and Susceptibility of Sitka Spruce to the White Pine Weevil

Ed. note*: the following is from a research paper presenter at the AGM of the Entomological Society of BC, 23 October 1992.*

The white pine weevil, *Pissodes strobi,* is the primary factor preventing reforestation with Sitka spruce, *Picea sitchensis,* in coastal British Columbia (1). The rapid growth rate of this tree makes it desirable for planting in wet, coastal areas, but repeated damage to the terminal leader by *P. strobi* results in stunted, deformed, and out competed trees which eventually die (2). Various control techniques such as shading, leader clipping, insecticides, and biological control agents have been ineffective or impractical (3). Some Sitka spruce provenances appear to resist attack by the white pine weevil, although the immediately surrounding trees may be repeatedly attacked (3). If the mechanisms by which these trees resist or tolerate attack were known, it might be possible to develop a multicomponent resistance index which would allow young trees to be screened for use in breeding weevil-resistant trees. Trees could be screened for factors that may be involved in host selection such as host volatiles, feeding and oviposition stimulants and deterrents, and morphological and chemical characteristics of the leader, and the ability of the host to resist attack through resinosis.

Our objectives are to (i) determine mechanisms of resistance and susceptibility of Sitka spruce to the white pine weevil and (ii) to develop a multicomponent Resistance index for use in selection of trees for a breeding program.

Preliminary work has examined several aspects of leader morphology. We sampled resistant and susceptible provenances from four provenance trials (Sayward, Head Bay, Nass River and Kitimat) and one clonal outplanting (Fair Harbour). We measured DBH, height, number of times weevilled, leader length, leader thickness, needle density, and the angle between needles and stern. To avoid leader damage, measurements were made on an upper branch cut with pole pruners (such branches reflect the characteristics of the leader). We also removed a sample of cortical tissue from each tree to examine the anatomy of the resin/canal system. The number of outside and inside resin ducts/cm, the depth and diameter of the outside and inside resin ducts, and the distances between resin ducts were measured on hand-cut sections under a dissecting microscope using an ocular micrometer.

Compared to susceptible trees, needles on resistant trees were pressed more closely against the stems at Fair Harbour (ANOVA, P) and at Nass River (ANOVA, P). If this is a resistance mechanism, it may be that needles pressed more closely to the stem interfere with feeding and oviposition.

Of the resin duct measurements, the number of outside ducts/cm was significantly higher in resistant provenances (ANOVA, P) than in susceptible provenances. This was true for all sites except for Head Bay where the average leader diameter was smaller.

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These trees were perhaps not able to express the same range of variation as trees at other sites. Another exception was the Green Timbers provenance. This historically resistant provenance had the same number of outer resin ducts/cm as the susceptible provenances suggesting that it is resistant through some other mechanism.

We plan to investigate the phenomenon of resistance more closely by measuring the physical and biochemical properties of resin from resistant and susceptible trees. We will also investigate other resistance mechanisms such as feeding and oviposition stimulants and deterrents, and the occurrence of attractive or repulsive host volatiles.

It is hoped that several different resistance mechanisms will be discovered in order to promote polygenic resistance that would allow effective, long-term management of Sitka spruce plantations.

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Development of Botanical Insecticides

Ed. note*: the following is from a research paper presented at the AGA4 of the Entomological Society of British Columbia, 23 October 1992.*

Because of the threat of conventional insecticides to the environment and to public health, the exploration for alternatives to chemical insecticides is highly desirable. One potential source of novel insecticides is higher plants. At present, two botanical insecticides, pyrethrum and rotenone, are registered for use and widely available in Canada. In the United States, ryania and sabadilla have also been registered. The recent registration of insect control products derived from the neem tree *(Azadirachta indica;* Meliaceae) has opened the door for additional botanical insecticides. However, the extreme structural complexity of azadirachtin, the active ingredient in neem, precludes its synthesis on a commercial scale. Therefore, neem-based commercial products will depend on the ongoing availability of neem seed. There is an urgent need to identify new sources of botanical insecticides. Efforts made towards the discovery of simpler active ingredients, which could be synthesized, for insect control is clearly warranted.

Our project aims to identify new botanical sources with bioactivity against insects. We have found that in addition to *Azadirachta* (neem), at least two other genera, *Aglaia* and *Trichilia,* have significant bioactivity. Both genera consist of roughly 100 species of shrubs and medium-sized trees. *Aglaia* species occur throughout Southeast Asia. *Trichilia* is a pan tropical genus but is best represented in tropical America. Studies on *Trichilia* species revealed that crude extracts of T. *connaroides* (exocarp, seed, wood, and bark), T. *glabra* (wood), and T. *hirta* (wood) significantly reduced larval growth and deterred larval feeding of the variegated cutworm, *Peridroma saucia,* a model species to screen natural insecticides. The overall activity of these materials against phytophagous insects is likely a result of both deterrence and toxicity. In T. *connaroides* there were significant differences between the various tissues with respect to bioactivity, suggesting they have different phytochemical profiles. Identification of the active components present in the crude extracts is underway.

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Root Pruning of Bareroot White Spruce Planting Stock does not Affect Growth or Survival after Six Years

Ed. note*: the following is excerpted from an article with the same title previously published in "Tree Planters' Notes."*

Introduction

Many bareroot nurseries endeavour to produce planting stock with compact, readily plantable root systems using nursery bed root-culturing treatments such as undercutting, root wrenching, and lateral root cutting (Daniels and Simpson 1990). Even with root culturing, however, long lateral roots often grow within the drill rows. Seedlings with long roots are more difficult to plant and may be more prone to root deformation.

It is therefore common practice after lifting to prune the roots of bareroot seedlings. Root pruning may remove many root tips, thus reducing root fibrosity; in some cases it can result in reduced root growth potential (Simpson unpublished data). As well, pruning decreases seedling root-to-shoot factors.

These factors are usually associated with decreased stock quality and field performance.

This experiment was undertaken to determine if root pruning bareroot white spruce planting stock would affect survival and growth after outplanting.

Discussion

Root pruning plug-transplant or 2 + 0 bareroot white spruce planting stock even to what seems an extreme degree (10 cm below the root collar) has a very minor effect on field performance (table 1). The small, albeit statistically significant, reduction in first field season shoot growth due to root pruning is unlikely to be of practical significance. It is clear that, at least under the field conditions experienced in this experiment, the pruned root systems of plug-transplant or bareroot white spruce were able to provide sufficient moisture during the early growing seasons so that mortality did not occur and growth was only slightly impaired. In a similar study with Douglas-fir (Hermann and Lavender 1976), root pruning of 2+0 and 2+1 bareroot stock to as short as 12.5 cm did not affect survival on "favourable sites"; however, on "moderate" and "severe" sites, root pruning the smaller 2+0 stock reduced survival. It is unclear what the results of the present experiment might have shown had the outplanting environment been more stressful. Planted spruce seedlings are known to regenerate adventitious roots (Coutts *et al.* 1990), which might replace lost nursery roots and thus minimize the potentially adverse effect of root pruning. Blake (1983) found that pruning to reduce root area by as much as 75% had no effect on measured root area after 6 weeks of growth. Thus in his experiment, root pruning prior to planting substantially stimulated new growth such that no effects on water relations or drought resistance were evident.

Table 1
Effects of root pruning on growth and survival of white spruce

Depth of Root Pruning (cm)	FY GRO (CM)	YR6 GRO (cm)	YR5 HT (cm)	YR6 HT (cm)	RS GRO (%)	YR6 Survival (%)
Plug Transplant						
Control	6.4 a	10.2	73.6	83.8	14.4	99
25	6.5 a	8.5	74.4	82.9	11.8	98
20	6.1 a	9.5	73.3	82.7	13.3	98
15	5.6 b	9.8	72.5	82.3	13.6	96
10	5.1 c	9.2	69.6	78.8	13.5	96
Bareroot						
Control	3.7 a	10.0	68.4	78.4	14.8	96
25	3.4 ab	8.8	65.5	74.3	13.8	98
20	3.2 b	8.2	66.5	74.8	13.4	93
15	3.2 b	8.4	66.0	74.4	13.6	97
10	3.1 b	8.1	65.3	73.4	13.5	92

Means followed by the same letter(s) are not significantly different (P).05). FY GRO = first year's growth, YR6 GRO = terminal shoot growth in year 6, YR5 HT & YR6 HT = total height after 5and 6 years, RS GRO = relative shoot growth in year 6.

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Nutrition PPM vs. Millimoles

Ed. note: the following is reprinted (mostly unchanged) from "21st Century Gardener" vol. 6(5), p 32-35, September/October 1992.

PPM

Current convention in fertilizer application that is familiar to most of us is PPM or parts per million". PPM is a calculation based on the weight of one substance, in relation to another with which it is mixed or associated. An example of one (1) PPM would be 1 gram/1000 kilograms (1 gram/1,000,000 grams). Thus, a PPM of anything is equal to one part of it (by weight) to one million parts (by weight) of something else. In our case it is usually grams of a particular nutrient relative to grams of water. Water is particularly useful in this case because it weighs I gram/milliliter or I kilogram per liter. Hence I gram of a nutrient per 1000 liters of water equals 1 PPM (1g/1000L x 1000g/L 1g/1,000,000g).

From the grower's perspective this convention works fine because it relates directly to the fertilizer mixing process, which requires weighing out specific fertilizer amounts and adding them to water. Hence, thinking of feeding nutrients in PPM sized portions keeps things in perspective. Moving onward, one would assume that 1 PPM of Calcium and 1 PPM of Magnesium mixed together equals a 1:1 Ca:Mg feeding regime. This is true on a weight basis but lets look at it from the plant's perspective.

Millimoles

Plants take up nutrients on an individual ion, atom, or molecule basis, i.e. one Ca or Mg atom at a time. To understand the implications of this one must revisit the periodic table of elements. Here one finds that Ca and Mg have atomic weights of 40 and 24 grams, respectively. This means that 1 mole (a mole is a standardized quantity of 6.02×10^{23} items) of Ca atoms weighs 40 grams and I mole of Mg atoms weighs 24 grams. Ca atoms are 1.65 times as heavy as Mg atoms (40 24)! So when a grower is feeding equal proportions of Ca and Mg on a PPM (weight) basis he/she is actually feeding 1.65 times as many Mg atoms as Ca atoms.

This may have serious implications when attempting to sort out competition effects, ionic balance, or just set up nutrient feeding ratios. A way to address this is to look at nutrient feeding rates on a concentration instead of a weight basis, i.e. using relative molar ratios of nutrients. Concentration is normally expressed on a per liter basis, hence a solution containing 40 grams of Ca/liter is a 1 molar solution. Similarly, a solution containing 24 grams of Mg/liter is also a 1 molar solution. Both solutions have the same nutrient concentration, although containing different weights of the respective nutrients.

Compound Molecules

Another difficulty with PPM can arise when the nutrient is taken up as part of a larger molecule or ion. Lets take for example Silicon (Si), taken up by the plant in the form of SiO_2.

(continued...)

Table 1:
Silicon feed rate comparisons

form	grams/ mole	feeding rate	actual Silicon fed/litre H_20
Si	28	100 ppm	0.100 grams (3.57 mmoles)
SiO_2	60	100 ppm	0.047 grams (1.67 mmoles)
Si	28	4 mmoles	0.112 grams
SiO_2	60	4 mmoles	0.112 grams

(mmole = millimole = 1/1000th of a mole)
* from periodic table

Table 2:
Conversion of PPM to millimoles

To convert PPM to millimoles use the following formula:

$$\frac{\text{PPM Nutrient feed}}{\text{Atomic or Molecular Weight}} = \text{Millimoles of Nutrient/litre } H_2O$$

e.g. $$\frac{\text{PPM Ca feed}}{40} = \text{Millimoles of Ca/litre } H_2O$$

If the nutrient is supplied as part of a molecule, multiply by the number of nutrient atoms in the molecule.

e.g. $$\frac{\text{PPM } P_2O_5 \text{ feed}}{\text{MW of } P_2O_5} \times 2 = \text{Millimoles of Ca/litre } H_2O$$

(MW of P_2O_5 = 142)

In table 1, part of the weight contained in the "PPM" feed of SiO_2 is the pair of Oxygen atoms. Consequently, it takes a lower number of SiO_2 molecules to make up a 100 ppm feed. When feeding on a concentration basis (4 mmoles), the number of Si atoms supplied is the same in both regimes (Si and SiO_2). Hence, to prevent confusion and/or improper feeding rates, it is important to specify the exact form that the feeding rate refers to. Similar misunderstandings can come about when considering P_2O_5 vs. P, or K_2O vs. K feeding rates.

Table 3 shows the difference between the two conventions. The ratio columns are multiplied by 100 to reduce confusion with decimal places and to see the relationships more clearly. An easy way to work with the PPM ratio column is to say that for every 100 grams of N supplied the solution is supplying 23 grams of P, 145 grams of K, etc. The mmole ratio column can be looked at in a different way. For every 100 N atoms supplied the nutrient solution supplies 11 P atoms, 52 K atoms, etc.

Table 4 compares concentrations of nutrients at a constant 100 PPM feeding rate. It shows how the atomic weights of the various elements, as well as the form in which they are supplied or taken up, affect the actual amounts available.

The choice of convention is up to the grower. To make calculations easier and less prone to error a simple spreadsheet can be made up using any conventional software.

Table 3:
Sample conversion of PPM to millimoles (using the BC Dept. of Agriculture tomato feeding formula for sawdust culture. Table from "21st Century Gardener," vol. 6(3), p17.

Element	Symbol	PPM	*ppm ratio (x100)	Mmoles (per litre)	*mmole Ratio (x 100)
Nitrogen	N	196	100	13.99	100
Phosphorous	P	46	23	1.48	11
Potassium	K	285	145	7.29	52
Calcium	Ca	144	73	3.59	26
Magnesium	Mg	32	16	1.32	9
Sulphur	S	42	21	1.31	9.4
Iron	Fe	1.5	0.76	0.0269	0.19
Zinc	Zn	0.1	0.05	0.0015	0.01
Copper	Cu	0.05	0.03	0.0008	0.01
Manganese	Mn	0.5	0.26	0.0091	0.07
Boron	B	0.5	0.26	0.0463	0.33
Molybdenum	Mo	0.05	0.03	0.0005	0.004

*Ratio of the amount of a particular nutrient to the amount of N, ie. ppm P / ppm N =46/196= 0.23
(multiplied by 100 = 23) or mmoles P / mmoles N 1.48/13.99= 11

(continued...)

Table 4:
Conversion of 100 PPM to millimoles for some plant nutrient elements and compounds

Element	Compound	Atomic or Molecular Weight	Symbol and Charge	Mmoles @ 100 ppm	Mmoles of Elements	PPM of Elements
Nitrogen		14.0	N	7.14	7.14	100.0
	Nitrate	62.0	NO_3 -	1.61	1.61	22.5
Phosphorus	Ammonium	18.0	NH_4 +	5.56	5.56	77.9
		31.0	P	3.22	3.22	100.0
	Phosphate	97.0	H_2PO_4 -	1.03	1.03	32.0
	Phosphate	96.0	HPO_4 2-	1.04	1.04	32.3
	fert. equiv.	142.0	P_2O_5	0.70	1.41	43.8
Potassium		39.1	K +	2.56	2.56	100.0
	fert. equiv.	94.2	K_2O	1.06	2.12	82.8
Calcium		40.1	Ca 2+	2.49	2.49	100.0
Magnesium		24.3	Mg 2+	4.12	4.12	100.0
Sulphur		32.1	S	3.12	3.12	100.0
	Sulphate	96.0	SO_4 2-	1.04	1.04	33.3
Sodium		23.0	Na +	4.35	4.35	100.0
Chlorine		35.4	Cl -	2.82	2.82	100.0
Iron		55.8	Fe 2+	1.79	1.79	100.0
		55.8	Fe 3+	1.79	1.79	100.0
	Chelates	343.5	Fe EDT	0.29	0.29	16.2
		387.7	Fe DTPA	0.26	0.26	14.5
		614.0	Fe EDDH	0.16	0.16	8.9
Zinc		65.4	Zn 2+	1.53	1.53	100.0
	Zinc Hydroxide	82.4	ZnOH +	1.21	1.21	79.1
	Zinc Chloride	100.8	ZnCl +	0.99	0.99	64.7
	Chelates	353.5	Zn EDTA	0.28	0.28	18.3
Copper		63.5	Cu 2+	1.57	1.57	100.0
	Copper Hydroxide	80.5	CuOH +	1.24	1.24	79.0
	Chelates	349.5	Cu EDTA	0.29	0.29	18.5
Molybdenum		95.9	Mo	1.04	1.04	100.0
	Molybdate	159.9	MoO_4 2-	0.63	0.63	60.6
Manganese		54.9	Mn 2+	1.82	1.82	100.0
	Chelates	342.3	Mn EDTA	0.29	0.29	15.9
Boron		10.8	B	9.26	9.26	100.0
	Borate	61.8	H_3BO_3	1.62	1.62	17.5

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Deadline for Contributions to Next Issue

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Spiders are your friends!

Spiders are very important predators of insects and other arthropods in all terrestrial ecosystems. Wherever spiders are found, they contribute greatly to the natural control of many insect populations.

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