

PROCEEDINGS OF THE 39th ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

**Silver Star Mountain Resort, British Columbia
August 5-9, 1991**



Proceedings of the 39th Annual Western International Forest Disease Work Conference

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**Compiled by:
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Protection Branch
Victoria, British Columbia**

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Edited by John A. Muir
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Agenda

August 5th (Monday) to 9th

Monday	1900-2100	Arrival, Registration, Wine and Cheese
Tuesday	0730	Root disease committee breakfast—Opera Room
	0800	Registration
	0900	Chairman's Welcome—A McCain
	0915	Introductions, new staff, new projects
	1015	Break
	1030	Continue
	1105	G. Wellbum — forester for Fletcher Challenge — An introduction to the forests of the Okanagan
	1130	B. Eav — Dwarf mistletoe incorporation into and F. Hawksworth PROGNOSIS growth model for the west
	1145	R. Bennetts and — Indirect effects of Ponderosa pine dwarf mistletoe F. Hawksworth on wildlife
	1215	Dwarf mistletoe luncheon—J. Muir
	1330	Introduction to disease problems within the different Physiographic regions of British Columbia—BCFS pathologists
	1500	Break
	1520	Think Tank Sessions J. Beale — Intro on B.C. way of doing things (20 Minutes) Break audience into roundtable groups, each to discuss one of the following questions. Moderators may run their sessions as they choose and are solely responsible for their own reputations. (70 minutes or until bored)
		1. How much root disease is too much? (H. Merler)
		2. How do we integrate resource management concerns into forest health? (D Norris)
		3. Addressing forest health problems in partial cut systems. (D. Doidge)
		4. How do we best quantify pest damage at the forest planning level? (J. Beale)
		5. Relative pest nastiness—dealing with multiple pests/Dividing up the bucks—how do we set research priorities? (S. Zeglen)
		6. How do we best sell the concept of forest health? (J. Fournier)
	1650	Adjourn
	1830	D. Norris — Pushover-logging—the movie
	1900	D. Norris — A repeat—controlling root disease by push-over logging
	1930	K. Reynolds — System for spruce beetle management
Wednesday	0730	Disease Control Breakfast—R. James
	0900	Business meeting
	1000	Break
	1030	White pine blister rust genetics F. Williams — The view from the Ribes host

		B. Kinloch	— The view from the pine host
		E. White	— The view from the pathogen — DNA variation
1130		B. Vander Kamp	— Genetics of disease resistance —multiplicative model explained
1215		Rust comm luncheon—R. Hunt	
1330		Each moderator will present the results of Tuesday's think tank session and throw the conclusions out for the audience's examination. We would like to encourage reactionary and inflammatory discussion at this time. Time limited to approximately 15 minutes per issue.	
1500		Break	
1520		M. McWilliams and E. E. Nelson	— Results of grafting Port Offord cedar
1530		K. Lewis	— Synopsis of research on <i>Inonotus tomentosus</i>
1555		D. Rush	— Looking for ds RNA virus in <i>Phellinus weirii</i>
1605		B. Lockman	— Population structure interfertility groups of <i>Heterobasidion annosum</i> in mixed conifers stands on the Nezperce National For., Idaho -Preliminary results
1615		Forest Health Monitoring	
		1) The Canadian Way—B. Callan	
		2) The American-West Way—T. Shaw	
1700		Adjourn	
1900		Poster Session	
		R. Wall	— Biocontrol general staff
		W. Litke	— Weyerhaeuser Forest Pest Management
		R. Hunt	— Blister rust resistance in B.C.
		R. Prasad	— Biological control of forest weeds with natural herbicides —pathotoxins
Thursday	0800	Field trip	
	1900	Banquet	
	2100+(?)	Return to hotel	
Friday	0800	D.W. Ross—Integrating Forest Protection with Silvicultural Planning and Practice	
	0840	P. Comeau—Forest Vegetation Management in British Columbia	
	0920	C. Sutherland and T. Newsome	— Sheep Grazing—A Biological Tool for Controlling Competing Vegetation in Spruce Plantations
	1000	Coughee	
	1030	R.E. Wall	— Some Examples of Field Experimentation in Forest Weed Biocontrol
	1055	S. Shamoun—Isozyme Analysis of Candidate Plant Pathogens used as Mycoherbicides	
	1110	A. Ekramoddoulla	— Biochemical Characterization of a Potential Mycoherbicide <i>Chondrostereum purpureum</i>
	1125	P.C. Quimby—Integrating Plant Pathogens into Weed Management Systems	

Business Meeting Minutes

J. Muir
Conference Secretary

Chairman Art McCain convened the WIFDWC business meeting August 7th, 9 to 10 a.m. A minute of silence was held in memory of Mrs. Kimmey.

Seven new honorary life members were recognized: Ed Wicker, Frank Hawksworth, Dick Parmeter, Bob Scharpt, Otis Maloy, Stuart Whitney, and Dick Smith (Victoria, B.C.)

K. Russell presented an interim Treasurer's report, and the final version is included in these proceedings. H. Offord's letter and donation were gratefully acknowledged, and the secretary was directed to send Harold a copy of the proceedings, with thanks from the conference.

The 1990 business meeting minutes by Jim Hoffman were read by J. Muir, and adopted as read. The minutes will be included in the proceedings of the 1990 conference being prepared (we hope) by J. Hoffman.

Terry Shaw read Bill Jacobi's report on the National Council for Forest Health issues. The chairman is Bill MacDonald, vice-chair Evan Nebeker, Mississippi State, and secretary Fred Hayne. Based on suggestions at the North American Insect Conference March 1991 at Denver, Colorado, the constitution and by-laws are being re-drafted for council members in the next few months. The council also sent a letter to the Secretary of Agriculture expressing their concern about the import of logs from Russia to the Pacific Northwest (attached). Where to go and how to survive are the major issues that the council will work on this year. For further information please call Bill MacDonald, Dave Wood or Bill Jacobi.

Frank Hawksworth volunteered to update the index to the WIFDWC proceedings, and his offer was unanimously accepted.

Meeting locations selected or confirmed by the conference were:

- Durango 1992 (third or fourth week of July—Pete Angwin)
- Boise Idaho, September 1993—Jim Hoffman

The conference decided to postpone a decision on meeting with the Western Insect Work Conference in March 1994 or 1995 until the 1992 WIFDWC meeting. Terry Shaw recommended that John Laut determine information on the 1994 joint meeting proposal from the entomologists, and report to the 1992 WIFDWC meeting. This suggestion was supported by the conference. Two proposals were made for the 1994 meeting:

- Hood River area, Washington—by Ken Russell
- Kalispell, Montana—by Jane Taylor

These will be considered at the 1992 WIFDWC meeting.

The issue of importing Russian logs was discussed, and the secretary was instructed to write to G. Beatty requesting a copy of a recent report of the task group be sent to the new WIFDWC secretary, S. Frankel.

New officers were nominated by C.G. (Gardner) Shaw and seconded by R. Hunt:

- Chair: D. Morrison
- Secretary: S. Frankel
- Program Chair: C.G. (Terry) Shaw

Pete Angwin gave a report on local arrangements for the 1992 WIFDWC meeting at Durango. Accommodation will be at the Fort Lewis College, with very reasonable rates. Terry Shaw announced that a contest for the best T-shirt will be held, and requested that anyone with WIFDWC trivial pursuit questions send them to him for the next edition.

Conference thanks were extended to Hadrian Merler for great local arrangements, banquet and field trip. Hadrian recommended that the conference request participation

from more B.C. Forest Service regional forest pathologists at future meetings.

The business meeting was adjourned at 10 a.m.

Report on National Council for Forest Health Issues

W. Jacobi

Please report to WIFDWC at the business meeting the status of the organization. I am sorry I cannot make the meeting and report in person.

- The Chairman is Bill MacDonald
- The Vice Chair is Evan Nebeker (Mississippi State)
- The Secretary is Fred Hayne

The Constitution and Bylaws of the organization are being redrafted and will be submitted to the council members in the next few months.

Council activities this year were to meet at the North American Insect Conference in March of 1991 at Denver, CO. The bylaws were discussed and it was decided to revise them slightly. The issue of Siberian log importation into the U.S. was discussed and a letter from the Conference was sent to the Secretary of Agriculture in Washington. I have attached it so you can read it if you want.

Where we are going and how we are to survive are the main issues for the Council's board to work on this year. Any other questions? Please call me, Bill MacDonald, or Dave Wood in California.

Resolution

Whereas the first North American Forest Insect Work Conference (representing a joint meeting of the Western Forest Insect Work Conference, the North Central Forest Insect and Disease Work Conference, the Northeastern Forest Insect Work Conference, and the Southern Forest Insect Work Conference) notes that the timber industry of the U.S. Pacific Coast plans to import raw, whole logs of Siberian conifers to be milled in the United States, and

Whereas the published record and personal observations of many scientists indicate that there are numerous pest

organisms infesting Siberian conifers that occupy similar habitats as North American pests, suggesting that they could survive and cause great damage if introduced into North American forests, including those of Canada, the U.S.A. and Mexico, and

Whereas there is a long history of accidental introduction of foreign forest pests into North America, in many instances resulting in enormous economic losses and ecological disruption, and the establishment and spread of new forest pest organisms in North America on logs imported from the U.S.S.R. is very likely, and

Whereas previous experience indicates that it is impossible to evaluate the risk of each and every species becoming established on new and often unanticipated host species, and because rare, innocuous and largely unknown organisms can reach epidemic proportions once introduced into a new region, and

Whereas no current, operational method of mitigating pest organisms on and within raw logs has been demonstrated to be completely effective in killing all pest organisms,

Be it resolved that

1. The North American Forest Insect Work Conference recommends that no importations of raw logs from the U.S.S.R. into the U.S.A. be allowed until an acceptable method of killing all organisms on and within raw logs has been scientifically proven to be efficacious, and has been operationally validated, and
2. The members of the North American Forest Insect Work Conference offer their assistance as a resource on scientific issues relating to the proposed importations, and
3. The North American Forest Insect Work Conference requests that there be timely notification of deliberations and events relating to this issue, that such notification will be conveyed to the Chairperson of the National Council on Forest Health Issues, and that this organization be given the opportunity to comment and assist as appropriate before issues are resolved.

Treasurer's Report, 39th WIFDWC

Balance recorded at close of thirty-seventh meeting in Redding	\$3,783.26
Note: proceedings estimate (\$1300) in Redding proceedings was not subtracted from balance	(1,300.00)
Corrected balance on hand of close of Redding meeting	2,483.26
Adjustment for 1990 (38th) proceedings cost (Original estimate was \$1300.00; actual cost was \$883.14)	416.86
Interest paid July 1, 1990 through June 30, 1991	217.80
Miscellaneous proceedings sales (4) from 1/1/91 to 12/31/91	40.00
Special contribution from Harold Offord	25.00
SUB-TOTAL	3,182.92
 Thirty-ninth WIFDWC transactions from Vernon meeting	
Net Receipts:	2,483.49
Regular participants 68	
Students 10 prox	
Spouses 8 prox	
Amount shown does not represent the total taken in. Explanation below.	
 Expenses:	(1,485.66)
Note: Amount shown does not reflect all of Vernon meeting bills. Some were paid directly in cash at the meeting by local arrangements in order to simplify the bookkeeping. Amount shown here covers only expenses paid by check through the credit union account.	
Proceedings printing estimate for 160 copies	(1,400.00)
 BALANCE AT CLOSE OF THIRTY-NINTH MEETING	2,780.75

Funds held in account 936258-3, Washington State Employee's Credit Union. PO Box WSECU, Olympia, WA 98507. Phone (206) 943-7911. Official signatures for withdrawing funds are Walt Thies, Ken Russell and Fields Cobb.

Ken Russell, Treasurer, March 4, 1992.

The Indirect Effects of Dwarf Mistletoe on Bird Communities in Colorado Ponderosa Pine Forests

Robert E. Bennetts and Frank G. Hawksworth¹

Abstract: Dwarf mistletoes (*Arceuthobium* spp.) may dramatically change the structure and function of coniferous forest communities. We studied the indirect effects of southwestern pine dwarf mistletoe (*A. vaginatum* subsp. *crptopodum*) on the abundance and diversity of bird communities in ponderosa pine in central Colorado. Four stands each were selected at two locations, which ranged in level of mistletoe infestation from none to heavy. These stands were surveyed approximately weekly during the breeding seasons of 1989 and 1990 using spot mapping. The number of birds detected showed a positive correlation with the level of dwarf mistletoe and this pattern was consistent among eight foraging guilds. The number of species observed also was positively correlated with dwarf mistletoe levels. Dwarf mistletoe has been traditionally viewed as a forest pest because of it causes reduction in timber volume. However, we suggest that an alternative viewpoint may be warranted in some areas because of the positive effects of dwarf mistletoe on wildlife.

Introduction

Although the dramatic effects of dwarf mistletoes on forest structure and composition are well known, there have been no previous studies as to how these changes affect wildlife habitats. Previous dwarf mistletoe-animal studies have dealt primarily with seed transport (Hudler *et al.*, 1979, Nicholls *et al.*, 1984).

Dwarf mistletoes have been traditionally viewed as forest pests, although there has been some recent attention given to them as natural components of forest ecosystems (Hawksworth 1975, Parneter 1978, Tinnin *et al.* 1984).

In this study we examine the indirect effects of southwestern ponderosa pine dwarf mistletoe (*A. vaginatum* subsp. *crptopodum*) on abundance and diversity of birds in ponderosa pine forests of the Front Range in central Colorado.

Study Areas

We studied the influence of ponderosa pine dwarf mistletoe on bird communities during 1989 and 1990 at two Colorado locations: (1) Cheesman Reservoir located 60 km southwest of Denver at approximately 2200 m elevation, and (2) Florissant Fossil Beds National Monument located 80 km west of Colorado Springs at approximately 2500 m elevation. Both locations occur on Pikes Peak granite soils, and consist primarily of gently rolling slopes. Cheesman Reservoir is a municipal water supply for Denver and consequently is closed to public access except for limited shoreline fishing. Florissant Fossil Beds National Monument has considerable public access that is concentrated primarily on a system of trails through areas of fossil deposits and forest settings. Although some historic cutting has occurred, primarily at the turn of the century, both sites have been protected from timber harvest for at least the past 20 years. Thus, potential confounding effects from timber harvest were minimized. The two localities were located about 35 km apart.

At each location, we selected four study areas of 10.2 ha (ca. 25 acres) each that varied in level of mistletoe from zero to heavily infected, but were similar with respect to stand age, slope, aspect, elevation, and soil type. These areas were representative of available ponderosa pine

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stands within the protected areas, but are not typical of adjacent timber harvested stands. In addition to the criteria noted above of similar physical characteristics among stands, we selected stands that were essentially pure ponderosa pine and were large enough to allow a 100-m buffer adjacent to the sampled area before encountering another habitat type. Each 10.2-ha study area was gridded at 20-m intervals for a total of 256 cells. The corners of each cell were marked by small surveyors' flags.

Each tree was assigned a dwarf mistletoe rating using the 6-Class system (Hawksworth, 1977). The average stand dwarf mistletoe rating (DMR) based on all trees in the 256 cells for each stand was then computed. The diameter of all live tree and dead standing tree on each cell was recorded.

Wildlife Studies

We surveyed each 10 ha study area approximately weekly from 15 May to 4 July 1989 and from 12 May to 4 July 1990. Observers walked every third grid line and recorded location and species of each bird observed using spot mapping protocol (Verner, 1985). We used the number of detections during each survey as a measure of bird abundance.

To supplement the bird surveys, we also conducted nest searches. Each time a stand was surveyed we spent the following 1 hour following birds observed carrying food or nest material. Equal effort was spent on each stand for these searches.

We assigned each bird species to one of eight foraging guilds: aerial insectivores, bark insectivores, flycatchers, canopy omnivores, foliage insectivores, ground insectivores, or nectivores.

Results

Average DMR for each study area ranged from 0 to 4.5 (Table 1). The overall infestation levels at Florissant were higher than at Cheesman. The most heavily infested stand at Cheesman was only slightly more infested than the moderate levels at Florissant.

We detected a total of 3,036 birds of 47 species during the two summers observed. Average stand dwarf mistletoe rating was by far the most significant factor affecting the both the number of bird species and the total number of bird observations (Table 1).

The number of nests found was also positively correlated with average stand dwarf mistletoe rating. Of 163 nests found during this study 47 were cup nests in live trees

and had the potential of being placed in witches' brooms. Twelve of the 47 (26%) were in witches' brooms. Only 24 of the 47 nests in live trees were in trees infected with mistletoe. Thus, 50% (12 of 24) of the cup nests in infected trees were placed in witches' brooms. The species found nesting in witches' brooms were western tanagers (5 nests), chipping sparrows (3 nests), American robins (2 nests), hermit thrush (1 nest), and Cassin's finch (1 nest). Other birds that have been found nesting in ponderosa pine witches' brooms, but not in our study areas, are mourning dove, house wren, red crossbill, and great horned owl.

Six of the eight foraging guilds showed a significant stand dwarf mistletoe effect: aerial insectivores, bark insectivores, canopy omnivores, foliage omnivores, ground granivores, and ground omnivores. Only two guilds (flycatchers and nectivores) were not correlated with stand dwarf mistletoe rating.

Discussion

Dwarf mistletoe is the most damaging disease agent of ponderosa pine in the southwestern United States and southern Rocky Mountains (Hawksworth, 1961, Johnson *et al.*, 1984). Because it causes such widespread damage, dwarf mistletoe has been traditionally regarded as a forest pest by organizations and agencies concerned primarily with timber production. However, in light of an emerging emphasis on biodiversity in forest ecosystems (Thomas and Salwasser, 1989), and the growing realization that dwarf mistletoes are integral parts of the forest ecosystems (Hawksworth, 1975), an alternative perspective of dwarf mistletoe may be warranted in some stands where values other than timber production are of primary concern.

Dwarf mistletoes can be viewed not only as individual species, but also as a disturbance process that changes the structure and function of ponderosa pine and other host communities (Tinnin, 1984; Tinnin *et al.*, 1982).

In addition to considering dwarf mistletoe as a member of the native flora and as a disturbance process, there is considerable evidence regarding many additional biotic interactions associated with dwarf mistletoes (Nicholls *et al.*, 1984; Hawksworth & Wiens, 1972). Our results suggest that dwarf mistletoe has a positive influence on both the abundance and diversity of birds. The witches' brooms caused by dwarf mistletoes are an important nesting substrate for many species of birds and squirrels (Bull & Henjum, 1990; Bull *et al.*, 1989; Forsman *et al.*, 1984). Witches' brooms also provide important roosting habitat for some birds (Martinka, 1972), and the dwarf

Table 1. Number of bird species observed in each of the eight study areas in relation to average stand dwarf mistletoe rating.

Location	Study Area	Stand Dwarf Mistletoe Rating	Number of Bird Species	Number of bird Observations
Cheesman	1	0.0	25	289
Cheesman	2	0.6	26	307
Cheesman	3	2.1	29	393
Cheesman	4	2.6	32	611
Florissant	5	0.0	28	246
Florissant	6	2.4	31	307
Florissant	7	2.4	33	419
Florissant	8	4.5	33	464

mistletoe plants are a known food source for some birds (notably Douglas-fir dwarf mistletoe for blue grouse – Severson, 1986), mule deer (Urness, 1969; Currie *et al.*, 1977), elk (Craighead *et al.*, 1973), Abert's squirrels (Farentinos, 1972; Hall, 1981), chipmunks (Broadbooks, 1958), and porcupines (Taylor, 1935). Thus, where a priori management goals emphasize timber production or protection of trees in recreation areas or homesites, dwarf mistletoe reduction programs may be warranted. In areas where management goals are not fo-

cused on timber production, however, control of dwarf mistletoe may not be justified, or even desirable. Wicker (1984) reminds us that "dwarf mistletoe is a slow, insidious pest that fights a war of attrition. It wears down our interest, the visibility of our efforts, and thus the financial support of our control programs." We suggest that when it is consistent with management objectives, an alternative to fighting a "war" with dwarf mistletoe is to let it exist where it has coexisted as part of ponderosa pine ecosystems for eons.

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Panel: Aspects of Forest Health Operational Programs in British Columbia

(no text report submitted by J. Beale)

Introduction to the Ecological Associations and Pathogen Management Issues Of Coastal British Columbia

Jeff Fournier
Forest Pathologist
Ministry of Forests
Vancouver Forest Region

Jeff Beale has already introduced British Columbia's ecosystem classification system so I will now provide an overview of the major ecological situations in the coastal area. Subsequent to that, I will touch upon some of the challenges that face integrated disease management in these areas and some of the new techniques that we are looking at to help resolve these problems. The following is a Readers Digest version of the status quo.

Biogeoclimatic Situation on the Coast

Without getting into the particular details of individual subzones involved, the coast has basically three broad biogeoclimatic groupings. The most extensive category is the hypermaritime zone that extends from the southwest tip of Vancouver Island to the Queen Charlotte Islands and the southern tip of Alaska. This area represents the wetter variants of the coastal western hemlock zone and is typified by moist cool summers, wet cool winters, and an average annual precipitation of 4.5 meters. The predominant tree species are western hemlock, western red cedar, amabilis fir (north and mid-coast) and Sitka spruce (north Vancouver Island and the Queen Charlottes). The area is also known for its rugged terrain, poor access, and large inventory of virgin timber.

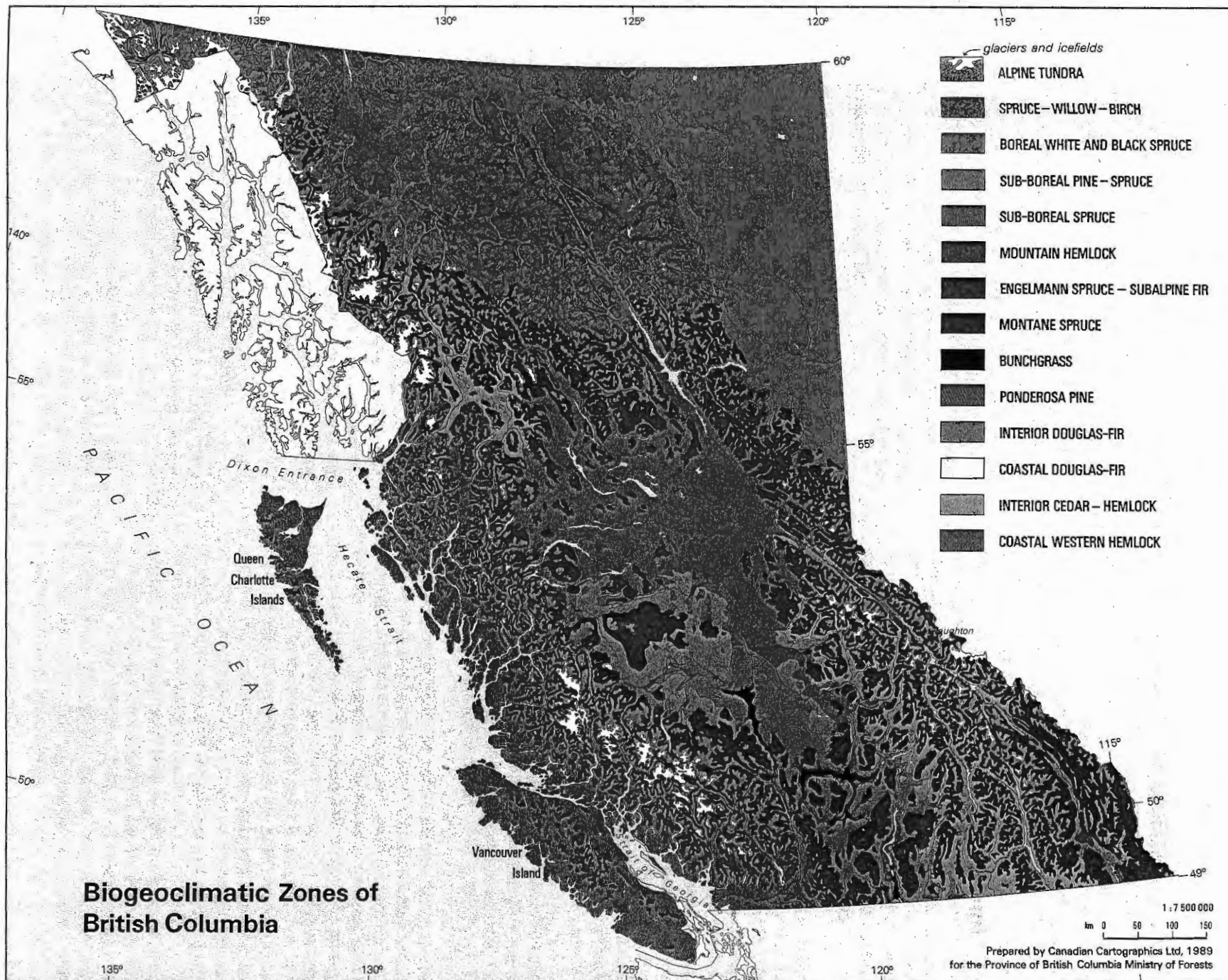
The second important association is the coastal rain shadow area that extends along the western section of Vancouver Island and across to the lower southwest portion of the mainland. This grouping contains the coastal Douglas-fir zone and the drier variants of the coastal western hemlock zone. Warm dry summers, moist mild winters, and an average annual precipitation of

1.5 meters are all characteristic of this area. Predominantly second growth timber, these forests contain coastal Douglas-fir, western hemlock and western red cedar. The terrain here is generally gentle to broken in nature.

The final broad category that needs consideration is the coastal interior transition zone. This narrow interface area has moist mild winters, hot dry summers, annual precipitation of 1.0 meters and experiences rapid and extreme shifts in temperature and humidity. This rugged area is covered by forests of coastal and interior Douglas-fir, western hemlock and western red cedar.

Pathology Program Challenges

So much for the biogeoclimatic situation we are faced with; here are some of the major forest pathology issues that we need to tackle in the coastal forests. The first and foremost hurdle that our forest pathology program faces is a shortage of trained manpower. Currently the entomologist and I are the only full time staff for a forest health program that looks after five million hectares of productive forest land. With the exception of one dedicated individual, assistance at the district level is only part-time and is often provided by personnel with limited forest pathology training or experience. So what is new right? Well compound this problem with the fact that a good proportion of coastal region has extremely poor access and you can easily visualize that our ability to detect disease problems and to make site specific prescriptions is inadequate.



Biogeoclimatic Zones of British Columbia

Another major challenge facing integrated disease management are the juvenile stands that we have inherited from harvesting during the pre-disease management era. Disease levels in these stands are for the most part unquantified however, in the coastal rain shadow and coastal/interior transition zones losses from *Phellinus weirii* alone are estimated to be in excess 300,000 cubic metres annually. Recent forest renewal initiatives are injecting hundreds of thousands of dollars worth of improvements into these young stands. Presently there is not enough qualified manpower to identify or assess disease problems prior to treatment. Even if disease infestations are caught at this stage, there is insufficient economic information on the costs and benefits of disease control vs no control scenarios to determine what the best site prescription would be.

The full impact of *Armillaria ostoyae* in the coastal/interior transition zone remains an enigma. In certain locations, the disease behaves like it does in the classic coastal situation and stands are able to outgrow *Armillaria*-related mortality by age 25. In other locations its activity parallels that of the interior situation and *Armillaria*-related mortality occurs throughout the life of a stand. Without the ability to predict the ultimate impact of the disease on a given site we are unable to determine whether or not stand disturbances or investments should be undertaken and what their consequences will be.

In the north reaches of the coast, large scale harvesting and subsequent reforestation have created expanses of prime habitat for porcupines and eliminated habitat of their predators. As a result of this, populations of the prickly devils have exploded to unprecedented levels and have expanded into new ranges. Concurrently, porcupine feeding damage has risen dramatically in amabilis fir western hemlock, Sitka spruce and lodgepole pine. Cumulative top kills in the 30%-60% range are common with the greatest damage occurring in dominant and co-dominant trees between 15cm-35cm D.B.H.. Stand enhancement activities such as spacing and fertilization have accentuated feeding damage problems.

Potential Solutions to Challenges

So much for the gloom and doom end of things, let's look at some of the techniques that should help resolve some of our program problems.

The pre-harvest survey prescription phase is the most critical step in the detection, evaluation and ultimate control of laminated root disease. It is at this stage that post harvest disease treatments are prescribed and

scheduled. Undetected disease infections allow inoculum carry over that often intensify in the ensuing regeneration. Presently, and unfortunately, the majority of laminated root disease infestations are not detected during the PHSP field inspections. In certain instances presence of the disease is intentionally ignored for financial liability reasons. Usually auditing field staff have neither the resources or background to catch such omissions.

To help ensure that all significant *Phellinus* pockets are detected and properly recorded in the PHSP's we are developing a timber supply area hazard rating scheme. The resultant information will provide a "flag" that will alert field staff that they need to be looking out for the disease during their field inspections, will illuminate where licensee audits should be performed, and help prioritize area for more intensive incidence and impact assessments.

The data used to generate the hazard rating is drawn from ground based information collected over the last 10 years. Based on this information, we can roughly correlate *Phellinus* incidence levels to stand age, species mix, site productivity, and biogeoclimatic variant. Tying this information into data from our inventory data base will provide basic stand to stand predictions on where disease problems are likely to occur and what their magnitude is likely to be. The electronically generated hazard values are colour theme mapped to allow a quick visual and spatial account of potential problem areas.

Note: Unfortunately the *Phellinus* is the only pathogen whose incidence is documented well enough to allow this type of analysis and at that the supporting information is limited to the lower coast.

A research stage item that shows promise is the use of the chemical glyphosate to accelerate the decomposition of laminated root rot infected stumps and reduce the persistence of the inoculum. (Glyphosate, marketed under such trade names as Round-up and Vision, is a readily available and widely used forest herbicide.) Glyphosate, applied to fresh stump surfaces or injected into live trees, is rapidly transported to the root systems of the host tree and within a few weeks kills root cambium tissues. This abrupt mortality of the root tissues is expected to cease further spread of the disease and to encourage immediate invasion by antagonistic fungi. Both factors are anticipated to affect *Phellinus*' ability to establish its territorial defenses. Investigations into these theories are currently being conducted by a graduate student at Simon Fraser University. Future investigations may look at the combining glyphosate applications with antagonistic fungi inoculations.

Northern Interior

R. Reich
Prince George, B.C.

The focus of the presentation on the Northern Interior of B.C. was the problems associated with the sub boreal spruce (SBS) and the boreal black and white spruce (BWBS) ecological zones.

The four main problems are tomentosus root rot, pine stem rusts, lodgepole pine dwarf mistletoe and climatic injury. All of the above occur throughout these two zones except for mistletoe which is at its northern portion of its range. Tomentosus root rot affects spruces primarily and is present in most stands. Surveys in our oldest spruce plantations (20-25 years) indicate that the incidence is low (around 1-3%) in the SBS and very low, <1% in the Interior Cedar Hemlock (ICH) zone where spruce is a minor component in the mature stands. The focus at present in plantations is on establishing large stem mapped plots to monitor rate of mortality and spread.

In mature stands, the focus is on developing suitable survey methodology based on several projects in the Prince George and Prince Rupert Forest Regions. A five year remeasurement of a spaced 80 year old spruce stand is scheduled for this year. Two root removal trials

exist in the Prince Rupert Region, and the first destumping trial in the Prince George Region is scheduled for this fall in the BWBS zone.

Work on Pine stem rusts includes surveys in 4 of 8 districts in the Prince George Region. In the future we are working towards having pest information collected during pre-stand tending silviculture surveys as a means of getting extensive coverage at low costs. The major effort for rusts is at the training level. All districts have had training sessions and spacing crews and survey crews are trained at request.

Rehabilitation of NSR stands caused by rusts is an ongoing challenge.

Mistletoe is less of a problem at the northern end of its range since spread from cutblock boundaries is slow and blocks are generally large. A five year remeasurement of a spacing trial is underway.

Climatic injury is a periodic occurrence which is becoming much better understood.

Addressing Forest Health Problems in Partial Cut Systems

D. Doidge
Williams Lake

Good afternoon, my name is Don Doidge, Regional Pathologist for the Cariboo Forest Region headquarters in Williams Lake, British Columbia.

Today I am supposed to enlighten you on quote "putting research into practice". I may mention some incidences where we are actually attempting to apply some aspect of forest disease research.

However, that will be only accidental, as the practice of "Forest Pathology" in the Cariboo Forest Region has been very slow to **catch on**.

Pathology isn't totally ignored; diseases such as **rusts, cankers, and dwarf mistletoe** of lodgepole pine are usually considered when spacing.

What I am going to discuss is a major disease problem of the Cariboo and some attempts at quantifying the damage. On a much wider scope this disease occurs throughout the "Interior Douglas-fir Biogeoclimatic Zone" of B.C.

Armillaria Root Disease

What I wish to discuss are three manifestations of the root disease that we as forest pathologists know will occur, given the particular set of circumstances.

1. *Armillaria* caused mortality in Douglas-fir stands diameter limit logged in the 1960's. One of the main reasons for diameter limit logging is that in the Interior of B.C. Douglas-fir is shade tolerant species, requiring an understory in order to survive. This particular area, Young Lake, which is East of 70 Mile House, was diameter logged in the 1960's with the intention of a second pass before the requirement of treatment of the understory. The residual stand is now non-commercial because of *Armillaria*

root disease. Also besides the mortality to the mature trees the understory is dying—**NEW FORESTRY**.

2. *Armillaria* caused mortality in Douglas-fir stands logged in the 1960's and spaced in the 1980's. Actual data from such an area indicated infection by *Armillaria* to be 30%, and crop trees are still dying.
3. The third manifestation of the vast disease is the consequence of an action committed in ignorance: "not detecting the disease before spacing". This action occurred in a lodgepole pine stand west of Quesnel; 31 hectares were spaced in September 1987. Tree mortality was noticed by October 1988. Surveys of the area indicated that 43% of the crop trees died the first year after spacing and mortality is continuing at a rate of 3% per year. The causal agent being "Gallopings *Armillaria*". This rate of mortality will slow as the openings increase in size.

Discussion

The Forest Manager is a beleaguered species; he is required by his company to make a profit, which in turn provides revenue to the Province via taxes and stumpage. He is besieged on all sides by different factors that demand different uses for his land base, e.g. Urban Expansion, Parks, New Wilderness areas and Old Growth Forest.

The Forest Pathologist, who is normally a doom and gloom kind of guy, spreading tales of death, destruction, and devastation, can actually provide a small ray of sunlight for the unfortunate person. High standards of detection, adherence to the Pre-Harvest Silviculture Prescription requirements and proper root disease management decisions can return previously unproductive land to his forest land base.

How Do We Best Quantify Pest Damage at the Forest Planning Level?

Group Facilitator: J. Beale

Objectives:

- (1) To provide statements on the forest health conditions.
- (2) To assist in planning forest management opportunities, for example, silvicultural treatments or strategic land uses.

Determination of forest health conditions (pest damage quantification) at the forest level, is best sampled as part of the forest inventory, silviculture surveys or perhaps special forest health inventories. Without pest quantification at the inventory level, forest health will continue to be reactive, and not proactive in forest land management planning and silvicultural treatment programs.

Some problems associated with pest quantification as part of the forest inventory are: (a) determining acceptable pest damage measurement standards that are compatible with forest inventory and growth & yield measurement units, (b) maintaining measurement quality assurance (due to complexity of identification and assessment procedures), and (c) high turnover and often junior skills/experience levels of inventory staff. These problems

may be resolved through tougher contract specifications, quality assurance (monitoring) standards, greater financial remuneration for the work, and greater commitment to the importance of collecting top quality data to support the complex multiple resource management decision-making that spins out of the resulting data.

An alternative is to conduct special pest inventories with dedicated highly skilled professionals or contractual staff, for example, the US Forest Inventory & Assessment crews, or the Kamloops Forest Region/District Pest Incidence Survey crews. Pest inventories can be conducted and or monitored with the aid of local pest specialists, thus ensuring the highest quality assurance. The question of cost efficiencies of forest health inventories was raised but considered unresolvable at this time, although the qualitative advantage of being able to factor into decision-making what are considered to be the greatest damaging agents of forests and conversely the greatest opportunity for treatment gains is clearly the way to go in a resource-scarce world.

Dividing Up the Bucks—How Do We Set Research Priorities?

Group Facilitator: S. Zeglen

Participants in this session were from a variety of agencies and this provided a diversity of opinion which everyone felt free to express. Discussion centered around how agencies deal with the process of selecting and funding research topics. Strategies were discussed and suggestions were made for agencies whose planning process might be less developed than others.

The process used for selecting research problems is consistent between all the agencies polled. The first step is to gather together topics, whether they be submitted by clients or of some personal interest to the researcher. Next, cull out inappropriate research items by asking whether it is possible to research them given constraints the agency may operate under. Finally, assign each elected research topic a priority based on the immediate need for an answer.

The timeframe a research project may be put into might vary depending on which agency is examining the problem. Private industry puts most of its research emphasis into the short-term where the time between the posing of

a problem and its solution may be only a year or two. Conversely, most government agencies schedule longer term projects which may involve numerous interrelated problems or the in-depth examination of a single subject.

Almost all agencies develop management plans that deal with both aspects of their research programs. Short-term plans are developed annually to lay out exactly what work will be conducted over the course of the year. Long-term (5 to 10 year) plans are concocted in order to provide goals and direction to the program. These plans may be revised on an annual or biennial basis but their focus is always into the middle or far horizon.

The consensus key to any research planning is vision. Without this vital element any research conducted is just so many individual experiments. Vision stems from having a concise idea of what is desired. In the case of forestry, this is often closely tied to the land use objectives for an area. In cases where no clearly defined land use policy exists, vision is difficult to maintain and, as a result, any program which is dependent upon it suffers.

Working Group Session on How Do We Best Sell the Concept of Forest Health?

J. Fournier

The following is the working group's step-by-step approach to the getting the "work" out.

1. Get an in-house commitment to selling the program from within the group.

Requires:

- dedicated staff time and funding
- well defined goals
- a long term commitment that build from a small effort to a concerted effort as program benefits become apparent.

2. Target who needs to get the message.

- Primary target is the general public with secondary emphasis on the media, community leaders, politicians and extremists.
- Secondary targets are the other in-house departments and affiliated organizations.

3. Educate the target (ie: public) on why the need to deal with the subject in the first place. Make information easy to digest.

Facilitate through:

- Open dialogue—open houses/informal presentations
- Literature—publications/displays

4. Proceed with more detailed education. Provide information (balanced view point) not propaganda.

- Educate the educators in the school systems.
 - Requires specialized skills and tools to get message across ie: high tech videos that are interactive
 - Help educate the next generation of decision makers; students. Consider employing teachers or their association to create suitable material. Video games ideal—fun to work with.

5. Commence the in-house and inter-disciplinary sell of program benefits.

- Tie into whatever land use strategies exist*. ie: in certain areas enhancing disease activity may help meet the objectives of the land. On the other hand, in other areas pest activity may be inconsequential.
- Target departments separately—highlight the benefits specific to their concerns.

* A non-partisan multi-disciplinary task force may be required to help determine when and where forest health management is required. Individual subcommittees would look at specific issues, socio-economic constraints and costs and benefits.

SBexpert: A Knowledge Base System for Spruce Beetle Management

Keith M. Reynolds¹

Introduction

The term "knowledge base" is relatively new, so a few comments on the genesis of the term are probably in order. Knowledge base systems are basically an extension of expert system technology in which a program adaptively responds in a dialogue with the user to provide advice on a specific topic. Knowledge of the relationships between facts and expert observations pertinent to a particular topic are built into a knowledge structure that the expert system uses to solve the problem. In a sense, the process of building a knowledge structure about a topic is an engineering problem, so the process is commonly referred to as knowledge engineering. The process of constructing a knowledge base on a topic is virtually identical. However, the goal in a knowledge base system is not necessarily limited to providing advice; knowledge base systems are designed to provide information that may include advice. In addition, from an engineering perspective, there are clear analogies between organizing data into a database and organizing knowledge into a knowledge structure, hence the "base" in the term, knowledge base.

General Features of SBexpert

SBexpert is an object-oriented knowledge base system designed to provide advice on spruce beetle management and, more generally, information about the biology, ecology, and management of spruce beetles. The prototype version of the system is being developed jointly by the PNW Research Station and Forest Health and Protection, USDA Forest Service Alaska Region. SBexpert is actually a collection of four applications developed in the KnowledgePro Windows (Knowledge Garden, Inc., Nassau, NY) environment. Each application runs independently in the Microsoft Windows

(Microsoft Corporation, Redmond, WA) environment for IBM PCs and compatible computers. Any two, three, or four of the SBexpert applications can be run simultaneously because of Windows' multitasking capability. Moreover, other Windows applications may also be running at the same time, giving users great flexibility in program control and information usage. Features common to all four SBexpert applications include:

1. use of a highly intuitive, graphical user interface that is standardized across all SBexpert applications,
2. use of hypertext and hypergraphics to package information for optimum system use over a broad range of spruce beetle expertise,
3. easy access to an extensive help system for both Windows systemlevel help and application-specific help to accommodate a wide range of computer skill level, and
4. full access to Windows' task switching capabilities so that more experienced users can take full advantage of Windows' multitasking features.

The Applications

The help subsystems

The help system in SBexpert consists of four subsystems. SBinfo is an independent knowledge base application that describes the basic features of the other SBexpert applications and explains the operation of each in a general way.

Each SBexpert application has a menu bar at the top of its main window. From the menu bar, the user can obtain general help both on working in the Windows environ-

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ment and help that is specific to the application they are currently using.

Finally, by pressing the F2 function key, the user can view an annotated copy of the SBexpert window in which they are currently working. The annotated copy identifies each object that appears on the screen and explains the use of that object to control program operation.

SBtext Application

The SBtext application is, in effect, an on-line textbook to which the user can refer for background information on the biology, ecology, and management of spruce beetles. Subject matter is displayed by selecting a chapter and section to view. Within the displayed material, expanded discussions on selected topics, literature references, and illustrations are accessed by selecting hypertext (which appears on the screen as text highlighted in red). For example, during a general discussion of control measures, SBtext shows the word "pheromones" highlighted in red. If this text is selected by the user, a hypertext window is generated in which an expanded discussion of pheromones is presented. Deeper layers of information are therefore readily available to users who need more details, but users experienced in a particular subject area can pass over such detailed explanations. By organizing information into a general text discussion and associated hypertext topics, information retrieval is optimized for most users. Thus, SBtext could more accurately be described as short, concise textbook with numerous small appendices that are extensively cross-referenced.

SBsearch Application

Literature searching is performed by the SBsearch application. The user can select up to three authors, a range of years, and up to three keywords as search criteria. If multiple authors or keywords are selected, the user can specify the logical relation(s) among, for example, authors. Once matching records have been retrieved, references can either be displayed on screen, or directed to a printer or file. The present database of spruce beetle literature contains approximately 500 references and is current through 1990. In its present form, SBsearch performs a sequential search through all database records. However, we plan to acquire KnowledgePro Windows' database utility package which will substantially improve the search process through indexed searching and database filtering. With the database utility, users will also be able to update the literature database that is shipped with SBexpert whenever they wish.

SBrisk Application

SBrisk is a spruce beetle expert system that evaluates expected stand damage (hazard), probability of an outbreak (risk), and effects on resource values (impact), and provides management recommendations based on these evaluations.

HAZARD. Stand hazard is classified with a logistic regression model developed for the Kenai Peninsula, Alaska (Reynolds and Holsten, *unpublished*). Low (0-10%), medium (11-30%), and high (>30%) basal area mortality are predicted on the basis of percentage stand basal area in spruce, percentage of spruce basal area in trees with a diameter of at least 25 cm, and average 10-yr radial growth increment (mm) of dominant and codominant spruce. In the stepwise logistic regression analysis, neither total stand basal area nor site characteristics were significant predictors after accounting for the other variables.

In SBrisk, the user can either enter actual stand values obtained from a stand inventory, or, in the event values of one or more predictors is (are) unknown, low and high estimates. Two hazard outcomes are predicted for each stand variable entered as a range of values, corresponding to the low and high estimates. SBexpert would present the user with 8 possible outcomes in the event that low and high estimates were entered for all three predictors. Hazard outcomes, together with the corresponding stand conditions are displayed in a table format. With hazard outcomes presented in this manner, the user can perform a crude sensitivity analysis by comparing hazard outcomes for low and high estimates of a stand variable. For example, if the stand basal area data were known from an inventory, but 10-year growth data were not available, the user could enter low and high estimates of 10-yr growth that they felt confident would bracket the true value. SBexpert would produce 2 outcomes for the stand, corresponding to the low and high growth rate estimates, given the fixed basal area conditions. If the hazard rating changed with growth rate, the user would know that the value of this variable is necessary to improve the accuracy of the hazard prediction, given the known basal area conditions. Conversely, if the hazard classification did not change with the low and high estimates of growth rate, and assuming the low and high growth rate estimates did indeed bracket the true value for average growth rate, then the user would know that the growth rate data were not critical to an accurate estimate of hazard.

SBrisk also allows for less-determinant hazard classifications. In a typical logistic regression application, predictions of hazard class are based on singular

cutpoints defined by the values of the logistic functions. However, in SBrisk we have defined regions in the two-dimensional space defined by the logistic functions within which we say that the predictive ability is "fuzzy" (i.e., we don't have a high degree of confidence in a prediction of, say, low hazard). In such cases, hazard is classified as low-medium.

RISK. After the hazard classification is performed in SBrisk, the user can ask for a risk analysis, which will provide an estimate of the likelihood of an outbreak for each of the hazard outcomes. In contrast to the case for the hazard analysis, we don't have adequate data in Alaska to derive a statistically based risk model. Instead, we are relying on the advice of local spruce beetle experts to develop the initial structure for a risk model.

Our approach entails obtaining a risk score for a stand that is computed as the product of its median hazard score for the predicted hazard class and weighting factors for spruce beetle population size and trend in neighboring stands, and predisposing factors such as presence of windthrown trees in or near the stand. We are still in the process of prescribing a set of weights that reproduce the experts' expectations. The risk score that will be obtained will be converted into a final probability by transformation with a Weibull function.

EFFECT OF WEATHER ON RISK. Risk, as described above, is initially computed assuming "normal" weather that is defined for the user. If weather applicable to their stand during the past year differs from the defined norm, then they need to supply weather data. Weather effects will also be represented as multiplicative weights that modify the risk score described above.

Further development. Topics to be handled by SBrisk that we have not yet begun work on include:

1. analysis of resource impacts associated with predicted hazard,
2. management recommendations to reduce hazard, risk, and resource impacts given expected hazard and the relative values of resources described by the user,
3. "what if" scenarios that will demonstrate the relative values of possible management tactics and strategies through game-playing,
4. presentation of simulated stand images that are structurally similar to the user's case and that illustrate expected damage, and
5. a report generator.

Topics 1-4 are each associated with a button on the screen that, when selected, performs the procedures associated with the topic for the currently selected hazard outcome. The report generator will create a log of the user's SBrisk session for later reference and documentation.

Conclusion

Although we have been developing a knowledge base system specifically for spruce beetles, much of the system architecture is readily transferable to other insect pests and diseases. Indeed, modifications to SBtext and SBsearch for other pests would be trivial compared to the initial engineering effort involved in development of SBexpert. Although expert system applications for different pests may require higher levels of customization on a case-by-case basis, there is still much of the basic structure of SBrisk that also would be readily transferable. Consequently, SBexpert could serve as a generic prototype knowledge base system for forest pest management. Considerable economies could be achieved in the development of new systems by standardizing system design to some extent.

Selection of Blister Rust Resistant White Pines for Coastal British Columbia Seed Orchards.

R.S. Hunt & M.D. Meagher
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The British Columbia Forest Service and Forestry Canada joined forces in 1985 to produce a white pine (*Pinus monticola* D. Don) seed orchard with resistance to blister rust (*Cronartium ribicola* J.C. Fisch.). Over 300 very carefully selected parent trees were located and seed has been collected from many of these. Replicate family rows of two-year-old seedlings in styroblocks are inoculated each fall. Needle-infection intensity is determined each spring by tallying all spots on each seedling. Mean intensity per family varies, with those above about 20 spots becoming nearly 100% cankered; while those with less than about 10 spots vary from 30 to 100% cankered. Highspotted families are culled from

the resistance program. Some individuals within the low-spotting families seem resistant to initial infection, and are selected for seed orchards. Trees with normal cankers either die quickly or produce long cankers and die later. A few individuals appear to be able to slow the growth of *C. ribicola*, sometimes into recognizable "slow-canker-growth" (SCG) reaction types. Some of the SCG infections girdle the stems slowly, or not at all. Since most blister rust cankers in the field need to grow down the branch to the stem, it is believed that "slow canker growth" reaction types may fail to do this or fail to girdle the stem. SCG individuals from low-spot families are selected for seed orchards.

Genetic Variation in *Cronartium ribicola*: What Is the Evidence?

B.Kinloch

The question of genetic variation in *Cronartium ribicola* underlies all of our anxieties about being able to control blister rust by breeding for resistance, but the magnitude of this variability is uncertain. The purpose of this talk is to briefly review and evaluate the kinds of evidence available, with the caveat that such evaluation necessarily reflects my own biases.

Our main concern, of course, is with variation in virulence on white pines. This requires direct evidence through controlled inoculations or field tests; but the potential for such variability often can be estimated from indirect evidence on the genetic structure of rust populations, using marker genes, or from knowledge of the sexual or epidemiological behaviour of the rust.

Variation in Virulence

On Pines

Evidence is strong for two races that attack resistant pines. One of these is specific to major gene resistance (MGR) in sugar pine, but it does not overcome other known resistance mechanisms in this species or in western white pine. The other (the "Champion Mine" strain) overcomes certain resistant western white pine selections, but does not affect sugar pines with MGR. Neither race has spread measurably from the localized sites where they were originally discovered. Other reports or suggestions of racial variation, based on morphological markers (e.g., needle spot colours), or higher-than expected infection rates on resistant selects, have not been adequately substantiated.

On Ribes

The published evidence here is overwhelmingly negative (but see Williams, these proceedings). Species, varieties, and individual plants of *ribes* vary greatly in susceptibility to blister rust, but extensive inoculations in Europe, Canada and the U.S. during the 30's and 40's, failed to demonstrate variability in rust populations capable of

overcoming the different resistant mechanisms presented. The few positive reports of differential interactions between rust and *ribes* are difficult to evaluate because they are fragmentary, not repeated, or unconvincing.

Genetic Markers

Quantitative variation has been observed in *C. ribicola* for several growth and epidemiological traits, but the problem of separating true genetic variance from phenotypic variance has not been adequately resolved. Molecular markers (see White, these proceedings) offer promise, because they are unconfounded by environmental variance. Unpublished data from our lab showed that California populations of rust were homogeneous for 15 isozyme systems.

Sexual Behaviour

Knowledge of sexuality in *C. ribicola* is important because it will define whether genetic recombination among virulence loci can occur, and how variation is distributed. The issues are whether or not pycniospores are functional in exchanging genetic information and required for aeciospore production, and if so, whether the fungus is heterothallic or homothallic. Controlled matings are awkward to make and have only been attempted twice. Neither test unequivocally showed that pycnial transfer was necessary for aeciospore production, and although the data were interpreted differently in the two studies, Hirt inclined toward either homothallism or functionless pycniospores, while Hunt considered that both Hirt's and his own data suggested heterothallism. Another claim for heterothallism was made from a study of morphological markers (needle spot types), but the genetic basis of these markers was not established.

Epidemiological Behaviour

The epidemiological unity of the current epidemic—from its point of origin in Latvia in the middle of the last century, rapid spread over northern Europe, and subsequent export

on infected pines to both coasts of North America—implies a corresponding genetic unity. It is unlikely that gene frequencies will vary much within and among these areas. This contrasts drastically with variability expected and expressed in gene centres of origin in Asia. Here, several *forma speciales*, including an autoecious species (*Peridermium yamabense*), exist in a complex with different alternative host affinities and different relative virulence on both native and exotic white pines selected for resistance, compared with Europe and North America.

Conclusions

The view of genetic variation in *C. ribicola* presented here is relatively conservative, not necessarily because such variation does not exist, but because it has not been convincingly demonstrated, or because the evidence is ambiguous. Nevertheless, there is no room for complacency. The two races virulent to resistant pines are sufficient to indicate that others could arise against as many resistant genes as are discovered. Reintroduction of any sources of the Asiatic complex represents a constant threat with potentially very serious consequences.

The Distribution of Resistance to Western Gall Rust in Natural Populations of Lodgepole Pine

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Ever since I started work on *Peridermium pini* in Scotland at the beginning of my career as forest pathologist I have been uneasy about the measurement of resistance to diseases like stem rusts. Clearly, there is considerable variation in resistance in natural pine populations. But how large is that variation and what is its distribution? For instance, what is the difference in susceptibility between the least and most resistant 10% of a pine population? Intuitively I believe that one should be able to draw a graph of tree frequency over relative susceptibility, such as in Figure 1A, and that it should be possible to make definite statements such as that the most susceptible 10% of the host population is 25 times more susceptible (ie under the same conditions will have 25 times as many galls per tree) than the least susceptible 10%.

A related problem is the measure used to express disease severity. Should it be number of infections per unit of host tissue or percent of such units of host tissue infected? And how are these two related? One would like to believe that at infection levels well below saturation, a true doubling of the amount of inoculum would result in a

doubling of the number of infections per tree. However, the percent infected will certainly not double under those circumstances. Why does the relationship between number of infections per tree (or unit of host tissue) and percent infected take the peculiar form it does? There are many reports of the distribution of disease severity in pine stands, but these don't answer the question. The shape of the distribution changes with increasing disease severity (Fig. 2 and 3), and to my mind that shouldn't be. The *expression* of resistance may depend on hazard, but resistance itself is a genetically determined character of an individual, and shouldn't change. In this paper, then, I deal with two kinds of distributions. The first is the underlying distribution of relative susceptibility, such as shown in Fig. 1A. The second kind is the distribution of disease severity, which describes the amount of disease (in my case the number of galls) on trees as observed in stands and experimental plots.

Let's look at that in some more detail. Fig. 4 is an example of theoretical work to try to determine the consequences of various types of resistance and pathogenicity, and of

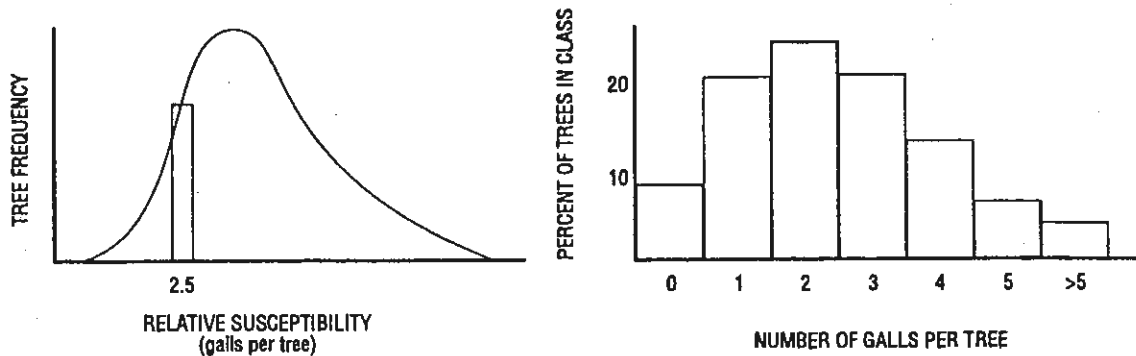


Figure 1. (A) A hypothetical distribution of susceptibility; and (B) the expected distribution of disease severity among trees in the susceptibility class shown in (A).

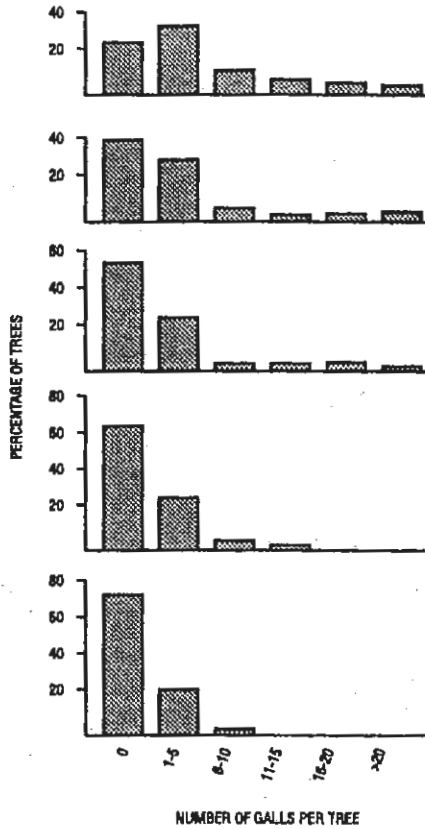


Figure 2. Gall rust disease severity distributions in five blocks of trees all derived from the same lodgepole pine population.

the interaction between host and parasite. In theory, these studies should serve to eliminate certain possibilities because the distributions they predict differ from those observed. In practice, it doesn't work. Which of the various distributions of disease severity such as shown in Figs. 2 and 3, should be used to test these models? All of them are descriptions of the same pine populations.

These are troubling questions. I very much fear that in the absence of an answer, we are groping in the dark in some of our programs for selection and breeding for resistance, because we can't measure or estimate the characteristic we are interested in directly, and because we don't know the distribution of resistance in the population from which we are selecting.

I've struggled with questions of this sort for the last ten years, and in the end achieved what I hope is some resolution. The paper describing the essential work appeared in *Phytopathology* (80:1269-1277) last winter. Before I go on I want to recognize the help and advice I got from

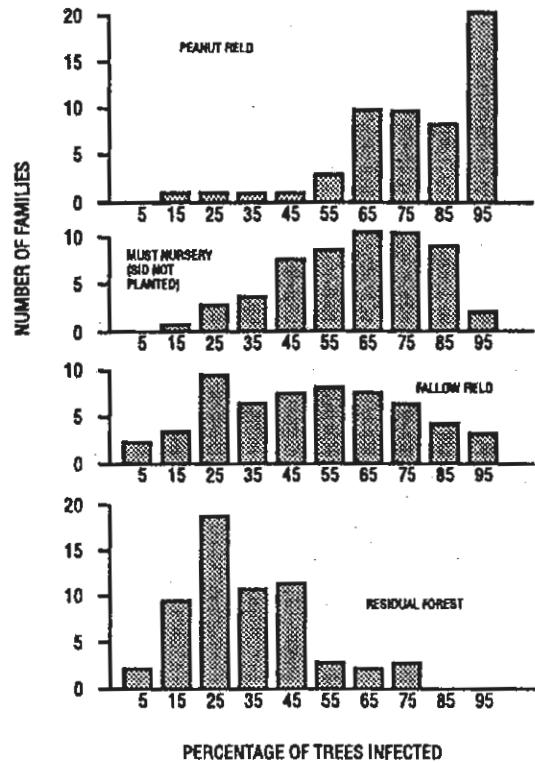


Figure 3. Fusiform rust severity distributions for a set of loblolly pine families planted at four different locations. (Kinloch and Stonecypher, 1969 *Phytopath.* 59:1246-1255)

Dave Tait, a mathematician in our Faculty. He was the only one who understood my first convoluted solutions, and without his encouragement I would probably have abandoned the whole project in frustration. Needless to say, the paper, which in my view is easily the most, and perhaps the only significant thing I ever published, came still born from the press. I've received only a few comments and requests. So I'm gratified that Rich Hunt asked me to speak today. Perhaps I can get you to share my view of how resistance to gall rust (and to other diseases in which there are typically only a few infections per tree) is manifested.

Methods

I want to start this discussion with a thought experiment. Let's imagine that out of a population of pine we could select a set of trees of equal resistance, and furthermore that we were able to expose these trees to a uniform inoculum in such a way that the average number of

infections per tree was 2.5 (Fig. 1A). (It doesn't matter here whether you think of a single inoculation leading to that disease level or whether you imagine a slow increase of disease over time, with an observation at the point in time at which that particular disease severity was reached.) What would we actually expect to see? You can't have 2.5 infections on a tree; it has to be at least either two or three. The solution to the problem goes as follows. Each tree has a large number of infection courts, probably many 1000's at least. (Under optimum conditions in the lab we can easily get 150 galls per m of internode, and the total length of branches on a 15-year-old, 6 m tall pine can exceed 100 m). In our imaginary experiment, each tree receives an identical number of viable spores, and these spores are randomly deposited on each tree.

Let's assume that each tree has 1000 infection courts. At 2.5 galls per tree, the probability that a particular court becomes infected is then 0.0025. Hence the probability that such a tree escapes infection is $(1-0.0025)^{1000}$ or 0.082. Clearly some trees will escape infection. Similarly we could calculate the probability of having any specific number of galls per tree. However, we don't know the number of infection courts, nor does it seem likely that

all such courts will have the same probability of infection. All we know is that the total number of courts per tree is very large relative to the number of infections, and hence that the probability that any specific court becomes infected is very small. Under these conditions, the Poisson distribution estimates the probability of having 0, 1, 2, 3, etc. galls per tree, and these probabilities will also represent the proportion of trees in our imaginary set of trees of equal resistance that will have 0, 1, 2, 3, etc. galls. Thus the distribution of disease severity that we would expect to see on the trees in our thought experiment is shown in Fig. 1B.

If we want to predict the distribution of disease for the population in Fig. 1, all we need to do is to divide the population into a number of classes of (for all practical purposes) equal resistance, calculate the proportion of trees in each class, and then, by a process similar to the one just described, calculate the expected number of trees with 0, 1, 2, etc. infections per tree for each class, and add all these together.

However, we don't know what the distribution is, and so we are stuck at square one. The process doesn't work backwards. If we observe a tree with 3 infections, we

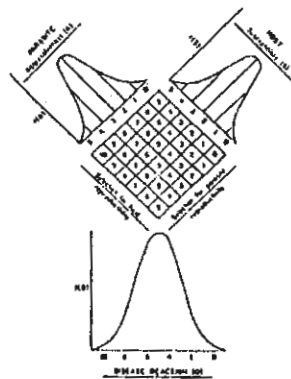


Figure 1. Additive model. Here (1) is the frequency with which individuals with amount n of the trait under consideration occur in the population of concern. Because of their polygenic determination we suppose normal frequency distributions in parents; aggressiveness, A , and host susceptibility, S . Assuming the amount of disease is $D = A + S$, the points record the severity of disease for the various indicated classes of host-parasite interaction. The resulting probability density function for D , $f(D)$, is normally distributed. (This figure was used with permission by Rosal Robinson, 1978.)

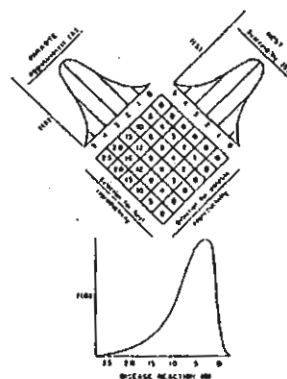


Figure 2. Multiplicative model. This figure is directly comparable to Figure 1. Here disease reaction is given by $D = A \times S$. The shape of the resulting probability density function for disease reaction, $f(D)$, depends on the parameters of the distribution for aggressiveness and susceptibility (see text). Usually $f(D)$ is approximately lognormally distributed.

Figure 4. An example of the kind of theoretical work that requires a distribution of relative susceptibility to determine which models reflect reality. This from Fleming and Person, 1982 *Can. J. Plant Path.* 4:89-96.

cannot calculate the probability that the true infection rate for that tree under the observed conditions lies between some range of values (for instance between 1 and 2 or 7 and 8 infections per tree).

The solution to the problem is to try various distributions, and to determine whether the best gives a reasonable fit. The right distribution of relative susceptibility should be able to predict the distribution of disease severity in a standard population of trees under a variety of infection severity conditions.

Now to the data for a moment. The study I'm reporting here is based on a planting density trial near Prince George established in 1967 and measured in 1980. That trial consists of 20 blocks of 100 or more trees each, all derived from a single large seed collection, and therefore all representing the same population. The average number of galls per tree in blocks varied from 0.58 to 6.07 at age 15. The trial was replicated at three separate locations, with 6-8 blocks at each location. For each block we prepared a stem map showing the location of each tree and the number of galls on that tree.

I'm going to argue that trees within blocks were exposed to a uniform inoculum load. You can read up on the various tests that support that assertion in the Phytopathology paper; I'll mention one here. Let's imagine a non-uniform inoculum distribution. That might well arise from random early infections leading to local increased spore concentrations and a clumped distribution of infections. It might also result from variation in environmental conditions within blocks (the largest blocks were 0.22 ha). To test whether such a non-uniform distribution did in fact occur, we divided the trees in each block into three classes. The first class consisted of the ten most heavily infected trees or all trees with more than 10 galls, whichever was least. Then we divided the remaining trees into two groups, those immediately adjacent to the heavily infected trees and the remaining trees. Fig. 5 presents a map for one of the blocks. The test consisted of comparing the average number of infections in the last two groups. A non-uniform distribution of inoculum should result in a higher level of infection in the 'adjacent' than in the 'other' group. In fact, the level of infection in the two groups was identical. So, we had the data set necessary to test hypothetical distributions of resistance to gall rust within a lodgepole pine population. The proper distribution of susceptibility should be able to predict the observed distributions of disease severity (Fig. 2) for all 20 blocks.

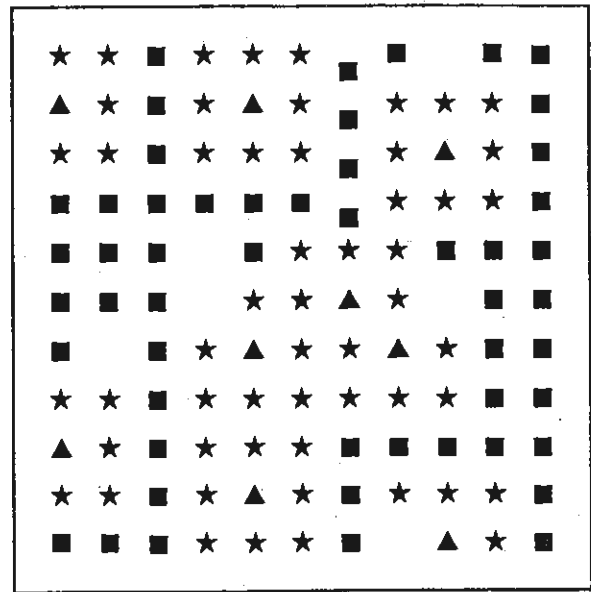


Figure 5. A test of uniformity of inoculum levels within a block of trees. Triangles represent heavily infected trees. Stars are trees adjacent to these, while squares are trees some distance from heavily infected trees. The average number of galls per tree for 'stars' and 'squares' was the same.

Now back to the method. Before proceeding to the test, we had another problem to resolve. That problem was: how do we model the interaction of separate resistance mechanisms. Two basic approaches were tried, these are illustrated in Fig. 6. The first (Fig. 6A) visualizes the outer surface of the tree as a barrier to infection, with holes representing infection pathways. Different holes can be 'closed' or 'reduced in size' by different resistance mechanisms, and the amount of infection, under standard conditions, will be proportional to the number and size of 'open' holes per tree. The population of trees will have an average number of 'open' holes, and, with a freely outcrossing breeding system, one would expect a normal or near-normal distribution of number of 'open' holes per tree. This generates what we refer to as the almost universally assumed in theoretical studies of the distribution of resistance in natural plant populations. Fig. 7A gives an example of the sort of distribution of infection rates that would result.

The second model visualizes the infection pathway as a tunnel that may be partially blocked at any of several locations, each location representing a particular resis-

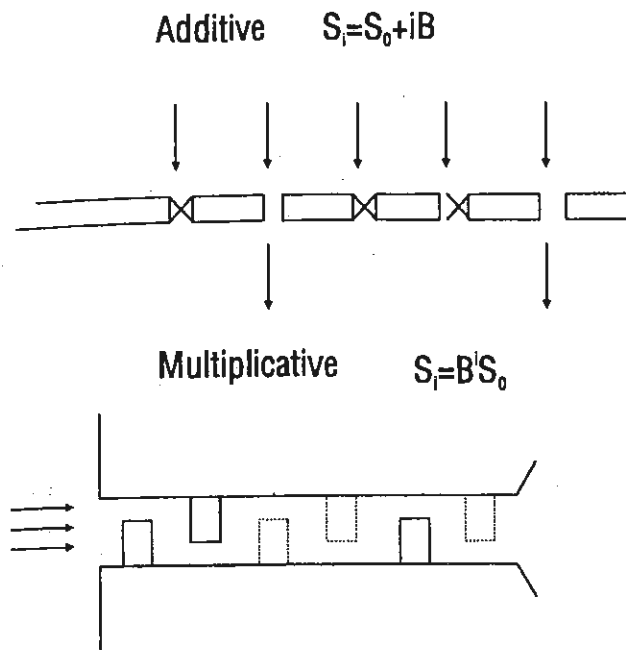


Figure 6. Two models of the arrangement of separate resistance mechanisms:
 (A) additive;
 (B) multiplicative

tance mechanism (Fig. 6B). Each resistance mechanism, if present, reduces the number of penetrations that make it past that point in the tunnel by a characteristic percentage. For instance, you could imagine two resistance mechanisms, one depending on cuticle structure, the other on the nature of the epidermis. The cuticle mechanism, if present, might reduce the number of penetrations that make it through the cuticle by 60%, and the epidermal mechanism by 40%. If, when neither mechanism is present, the number of penetrations is 100, then, with the cuticle mechanism only, we would expect 40 penetrations, with the epidermal mechanism only 60 penetrations, and with both mechanisms present 60% of 40% or 24 penetrations. Notice that the mechanisms interact in a multiplicative fashion. Hence we called this the multiplicative model. All the resistance mechanisms are assumed to be partial or rate reducing. If there were mechanisms that blocked the 'tunnel' completely, then we would have immune trees. I don't believe there are such trees. If the inoculum load is high enough, and conditions suitable, all trees become infected. Peter Blenis has published some results that show this nicely.

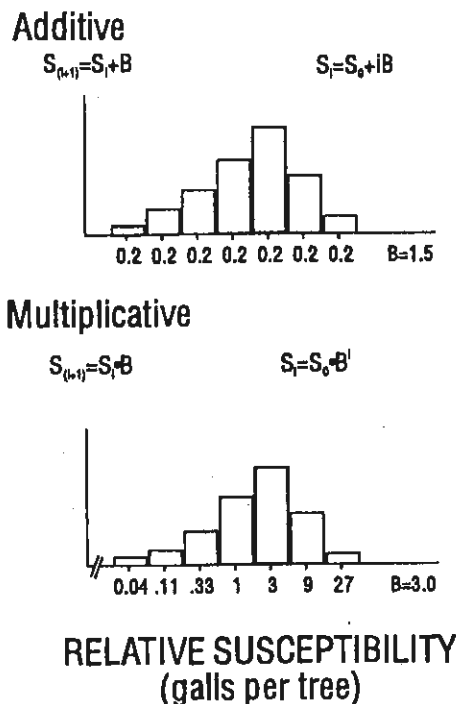


Figure 7. The two distributions of relative susceptibility that follow from the models in Fig. 6. Notice the difference in the relationship between adjacent susceptibility classes in these two models.

The multiplicative model leads to a different kind of distribution of resistance in the population than the additive model. Fig. 7B shows what results. We still have a near-normal distribution of the frequency of resistance mechanisms, but the difference between adjacent classes is no longer a certain number of infections. Rather, the difference between classes is a particular factor (in the example shown = 3.0). (In Figure 6 and 7, S_i is the susceptibility of the i th class, and S_0 is the susceptibility of the most resistant class.)

Now we are ready for the test. We assumed that we could divide the trees in the pine population into 21 classes with, for all practical purpose, uniform resistance within classes. We started by testing binomial distributions (defined in terms of N and p , and in which p controls the skewness of the distribution). We tested hundreds of such distributions using different values for p and B (the difference between adjacent classes), keeping N constant at 20, and testing both the additive and the multiplicative model, all the while searching for a

distribution that would give an adequate prediction of the distribution of disease in each of the 20 experimental blocks. From each theoretical distribution we calculated a predicted number of trees with 0, 1, 2, 3, 4-5, 6-7, 8-10, and 10 infections per tree, and then we compared these to the observed number of trees in each block using a Chi-square test. The best distribution was found by searching for the minimum overall Chi-square. Furthermore, an adequate description of the distribution of resistance should yield a Chi-square less than the critical Chi-square value.

Finally, some bookkeeping. The Chi-square tests compared the predicted and observed number of trees in each infection severity class for each block. Predicted values for a particular block were based on the parameters p and B (N being fixed at 20), and the total number of trees and galls in the block under consideration. First the number of trees in each of the 21 classes of the theoretical distribution was calculated by multiplying the class probability by the total number of trees in the block. Then the expected infection rate for each class was calculated for the case in which the average number of infections per tree in the block was one. Finally, these class infection rates were then multiplied by the observed average number of galls per tree in the block.

Results

The results appear in Table 1, and the best theoretical distribution in Fig. 8. The first, somewhat surprising result was that the additive model was no good. On the other hand, the multiplicative model with the proper values for p and B gave very good predictions. So, of the two models of the arrangement of resistance reactions in Fig 6, the second one yields predictions that are supported by observation, while the first one doesn't. That's rather surprising, when you realize that the literature assumes the additive model in all cases I have seen. I searched for years (literally) with various versions of the additive model, and never got anywhere. Then I half-accidentally tried the multiplicative model, and immediately things fell into place. I didn't sleep for three nights after that!

Let's look for a while at Figure 8. The X-axis gives relative susceptibility. By that I mean the average number of galls per tree for each class of trees when the population mean infection rate is one gall per tree. For different disease severity levels, one would simply multiply the numbers along the X-axis by the average number of galls per tree in the population being considered.

The single distribution of susceptibility in Figure 8 can be used to give a satisfactory prediction (Chi-square) of the observed distribution of galls per tree in all the

Table 1. A comparison of the ability of the additive and the multiplicative models to predict the distribution of western gall rust infection in 20 blocks of a single lodgepole pine population.

	Additive	Multiplicative
Minimum total Chi-square	474.7	152.8
Total degrees of freedom	93	115
Chi-square _{0.01}	127.3	153.0
Optimum p	0.027	0.824
Optimum B (unit load)	1.61	3.21
Optimum S_0 (unit load)	0.130	9.52 X 10 ⁻¹⁰
Number of blocks (out of 20) with a calculated Chi-square (3-6 df)		
< Chi-square _{0.50}	1	9
< Chi-square _{0.25}	2	13
< Chi-square _{0.05}	4	17
< Chi-square _{0.01}	6	19

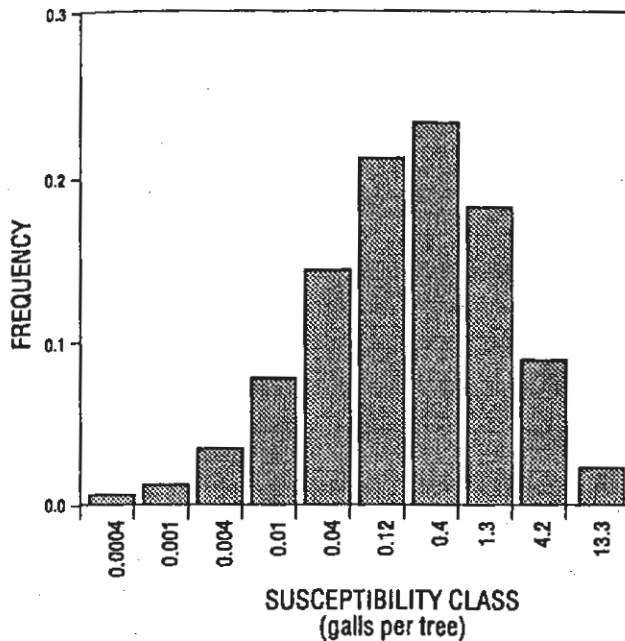


Figure 8. The distribution of relative susceptibility to gall rust predicted by the multiplicative model for the lodgepole pine population. The mean for this distribution is 1 gall per tree.

20 blocks. In fact, it didn't do a bad job of predicting the disease distribution in a natural stand that had 18 times as much infection as the average of those 20 blocks. What we have then, in Figure 8, is the underlying distribution of susceptibility that was postulated to exist in the introduction. The expression of that distribution depends, of course, on disease hazard.

The second thing to notice in Figure 8 is the range of susceptibility. We can now answer the question posed in the introduction about the relative susceptibility of the least and most susceptible 10% of the population. That difference turns out to be 800-fold! That's much larger than I expected. You will have noticed by now that an assumption has crept in, namely that there is no significant host-parasite interaction in this pathosystem. There is some good internal evidence for that assumption, but I'll have to refer you to the Phytopathology paper for the details: it gets a little complex. I would like to suggest that the lack of host-parasite interaction in this pathosystem arises because the western population of gall rust is genetically very uniform (as Det Vogler's

work suggests), although I would be the first to admit that we can use some more work on this question. At any rate, it is clear that the wide range of resistance leaves room for some pretty major resistance mechanisms. The model can easily accommodate several resistance mechanisms that reduce infection by a factor of 4, and such mechanisms would surely have to be regarded and 'major'.

The third 'problem' that is solved by Figure 8 is the 'incidence-severity' relationship, or the relationship between number of infections per tree and percent of trees infected. The methods used predict the proportion of trees free of infection for any hazard level (i.e. average number of infections per tree in the population.) Fig. 9 shows the predicted and observed values. Not a bad fit! In fact, the model gives a good prediction for a natural stand with an average of 40 infections per tree. Even more extreme, the model also does a good job on the data of Blenis and Pinnell (1988) (Fig 10).

If you accept the model presented here, it is obvious that the relative susceptibility of a tree (defined as the mean level of infection (or expected infection rate (EIR) when the average disease severity in the population is 1 gall per tree) is the proper measure of resistance. The actual number of galls that appear on a tree gives only a rough estimate of the EIR of that tree. This leads to an unavoidable difficulty in identifying the most resistant trees in a population, especially at low disease severity, or among sets of trees with low numbers of infection.

The variation in relative susceptibility within full- or half-sib families is also expected to be very wide (perhaps a 100-fold difference between the most and least resistant 10 percent of the individuals within such families). The proper measure of a family resistance is the mean relative susceptibility for the family. However, some acution is required. The arithmetic mean can be misleading, because the distribution of relative susceptibility is strongly skewed (Try plotting Fig. 8 over a linear scale!) Most trees will have an infection rate well below the family mean. The median of a distribution of relative susceptibility is perhaps a more meaningful measure.

Percent infected (widely used) is a derived measure, and has two major difficulties associated with it. The first is that it is rather insensitive, particularly at high diseases severity. Fig. 9 shows that at 65% infected, a further doubling of EIR results in an increase in percent infected to 75! The second difficulty is that percent infected is commonly misinterpreted to mean that the population can be divided into two distinct classes, one resistant

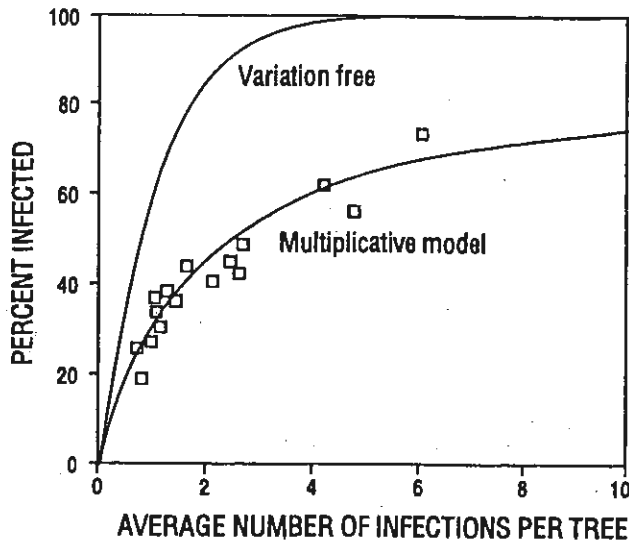


Figure 9. The relationship between incidence (percent infected) and severity (average number of galls per tree) predicted by the multiplicative model. Data points represent the 20 blocks. For comparative purposes, the predicted relationship for the case in which there is no variation in resistance (upper curve) is also included.

and one susceptible. Thus the parameter 'percent infected' may be useful in cases where, because of a major resistance gene, a population can be divided into two such classes, but that is certainly not the case in the lodgepole pine-gall rust pathosystem.

Before I stop, two more points. First, if my interpretations are correct, Fig. 9 also represents a disease progress curve for the pathosystem. Second, Fig. 8 predicts that over a very wide range of hazard conditions, the distribution of disease on trees will look similar, with a few heavily infected trees and a large number of lightly infected or disease free trees. That is certainly in accord with all the data on gall rust distributions that I have

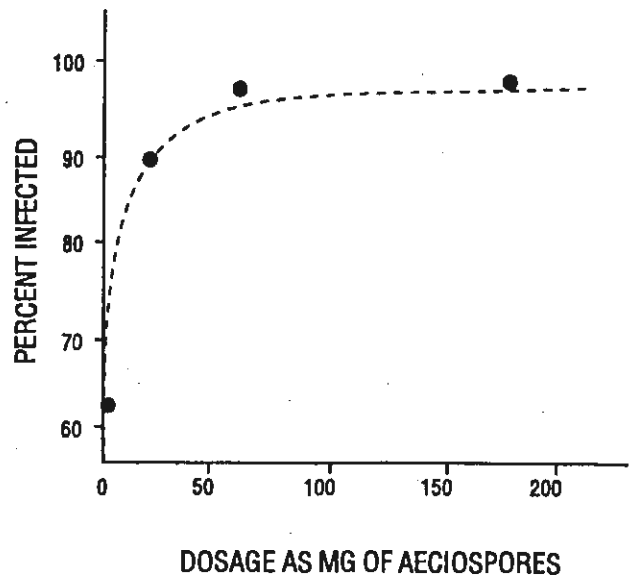


Figure 10. The multiplicative model tested against the data of Blenis and Pinnell, 1988 CJFR 18:1123-1126.

seen. You never find a normal distribution (i.e., a distribution that has lots of trees with medium infection levels and fewer trees with either very high or very low numbers of infections).

Finally, much remains to be done. One of the jobs I want to do this fall is to explore the consequences of the model for selection of resistant trees from natural pine populations, and for the calculation and meaning of heritability of resistance. Inoculation work to confirm the wide range of resistance predicted by the model is also under way. I have found the solution to the problems posed in the introduction immensely satisfying, and I hope that I have got you to share some of that satisfaction.

Port-Orford-Cedar Graft Compatibility with Alaska Yellow-Cedar and Western Redcedar Rootstocks

by Michael G. McWilliams and Earl E. Nelson
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Port-Orford-cedar (*Chamaecyparis lawsoniana* {A. Murr.} Parl.) is one of the most valuable conifers growing in the Pacific Northwest. Prices for Port-Orford-cedar range from \$800 to over \$2800 per thousand board feet on the stump, and individual 40 root logs can sell for over \$12,000 (Ken Lickens, pers. comm. 1991). The U.S. demand for Port-Orford-cedar is low, but Japan imports large numbers of logs, where the wood is used as a replacement for their native hinoki cypress (*Chamaecyparis obtusa* {Sieb. and Zucc.} Endl.).

Port-Orford-cedar is native to a small area in southwestern Oregon and northwestern California, and is extensively planted as an ornamental. The species is threatened by the introduced fungus *Phytophthora lateralis* Tucker and Milbrath, which kills trees and spreads in a stand through root contacts and motile, water-borne spores (Roth *et al.*, 1957, Zobel *et al.*, 1985). Researchers have identified Port-Orford-cedar trees exhibiting resistance expressed as slow advance of the fungus in diseased tissue. Immunity has not been demonstrated, although a few individual trees have survived for up to 20 years in highly infested sites (Hansen *et al.*, 1989).

Grafting Port-Orford-cedar scions to disease resistant rootstocks would allow cultivation of resistant trees in a seed orchard situation without the potential of loss due to *P. lateralis*. Grafted trees could also enable planting of Port-Orford-cedar in infested forest and ornamental sites.

Several researchers have investigated grafting on resistant rootstocks. Torgeson *et al.* (1954) grafted a horticultural variety of Port-Orford-cedar, *Chamaecyparis lawsoniana* Parl. var. *alumi* (R. Smith) Beiss, onto three varieties of *C. pisifera* (Sieb. & Zucc.) Endl., two varieties of *Thuja occidentalis* L., *Juniperus procumbens* Sarg. (= *J. chinensis* L., var. *Sargentii* Henry), and *Thuja plicata* Donn ex D. Don. They report that "good union occurred" with these rootstocks, although grafts on *J. procumbens*

later proved incompatible. When inoculated with a pea broth culture of *P. lateralis* in a field plot, all of the trees on *Alumi* rootstocks died, and all grafted trees remained healthy. No information is given regarding the timing or method of grafting.

More recently, Hunt and O'Reilly (1984) attempted grafting Port-Orford-cedar onto rootstocks of *Chamaecyparis formosensis* Matsumura, *C. thyoides* (L.) B.S.P., *C. nootkatensis* (D. Don) Spach, *C. pisifera*, and *Cupressocyparis leylandii* (Dallim. & Jacks.) Dallim. Grafts onto *C. thyoides* and *C. formosensis* were considered successful. None of the grafted plants, and 96% of the controls, died from *P. lateralis* infection in an inoculation trial. A side graft was used in Hunt's study, and scions were collected and grafts performed within a few days in early march onto the *C. nootkatensis* rootstocks (R. Hunt, pers. comm, 1991), which resulted in less than 1% successful unions after two years on this rootstock.

My study was designed to further test the compatibility of Port-Orford-cedar with two rootstocks resistant to *P. lateralis* and adapted to Northwest growing conditions: Alaska yellow-cedar (*C. nootkatensis*) and western redcedar (*T. plicata*). Alaska yellow-cedar rootstocks were 2-0 seedlings from the Wind River Nursery, grown from seed collected on the Mt. Baker/Snoqualmie National Forest. Western redcedar rootstocks were 2-1 seedlings from the Webster Nursery near Olympia, grown from "low elevation" seed. Rootstocks were potted in a standard greenhouse soil mix in early February, and grown for one month at 18 degrees C. before grafting.

Scions consisted of tips of lower branches from six Port-Orford-cedars growing in Corvallis, Oregon. Scions were collected in early January, and stored in sealed plastic bags at 2 degrees C. until used. Three of these cedars have been identified as resistant to *P. lateralis* (Hansen *et al.*, 1989), and three have unknown levels of

resistance. From each scion source, 18 grafts were attempted on 10 Alaska yellow-cedars (two grafts on each of eight seedlings, and one graft on each of two seedlings), and 12 grafts were attempted on 4 western redcedars (3 grafts on each of four seedlings). Side, or veneer, grafts were performed, wrapped with a rubber grafting band, and sealed with green grafting paint. Humidity was maintained at 80-85% through the use of continuous mist in the growing room for two months after grafting. Care was taken not to get mist directly on the seedlings. Controls consisted of scion from two Alaska yellow-cedars. Each scion source was grafted once onto 10 Alaska yellow-cedars.

Results are given in Table I. Grafting success varied widely between scion sources, with several of the resistant Port-Orford-cedars being nearly 100% compatible with both rootstocks. The scions from older trees, and those with poor or shaded crowns, tended to form fewer compatible grafts. Young, vigorous trees (sources 4 and 5) had the highest compatibility. The Alaska yellow-cedar seedlings used as rootstocks were small, and had suffered

frost injury in the nursery. Better results could be expected with larger seedlings for rootstocks. For successful grafts, scions must be collected while dormant, and grafting must be done when root growth has started in the rootstocks (Don Carson, pers. comm. 1989). These results indicate that, with careful scion selection, both Alaska yellow-cedar and western redcedar are compatible rootstocks for use with Port-Orford-cedar scions.

Graft combinations that show early compatibility sometimes prove incompatible in later years. Torgeson (1954) recommends a 4 to 5 year field trial before conclusions are drawn, and also notes that rootstocks can affect growth and form of grafted scions. Using resistant rootstocks does not prevent the susceptible scions from becoming infected through rain splash of spores onto foliage and bark (Trione & Roth, 1957). If grafts are performed high on a seedling, and if these early results are confirmed by continued compatibility, the use of Alaska yellow-cedar and western redcedar rootstocks provides one more tool for Port-Orford-cedar management.

Table I

Scion source	Alaska yellow-cedar rootstock		Western redcedar rootstock	
	no. grafts	% success	no. grafts	% success
POC1	18	28	12	42
POC2	18	89	12	58
POC3	18	5	12	25
POC4	18	100	12	100
POC5	18	100	12	92
POC6	18	39	12	42
AYC1	10	90		
AYC2	10	100		

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Epidemiology of *Inonotus tomentosus* in North-Central British Columbia.

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Inonotus tomentosus, a pathogen of spruce and pine in north-central British Columbia, can spread by root contacts and possibly by spores. Regeneration trees in plantations are at risk of infection by *I. tomentosus* in old growth stumps, particularly spruce stumps. Trees within 200 cm and 50 cm of spruce stumps and pine stumps respectively have a 25% chance of becoming infected. Vegetative compatibility groups and protein banding patterns of *I. tomentosus* isolates both showed consistent genetic variation within stands and within putative disease centres. New infection centres created from sexually-produced inoculum could explain the variation and may contribute to disease development in young stands. The means by which spores may initiate new root infections remains an interesting research topic.

In small (<5.0 cm diameter) spruce roots, *I. tomentosus* was often observed colonizing the bark and occasionally

penetrating the cambium where brownish lesions would result. Access to the root wood was facilitated by colonization of small feeder roots and other disruptions in the bark surface such as root junctions. In larger roots the fungus colonized the heartwood and did not colonize the bark or cambium until the root was dead.

Spores of *I. tomentosus* have a chilling requirement in order to germinate. It is hypothesized that this requirement may be the limiting factor in the range of the fungus. Alternatively, the degree and type of damage caused by *I. tomentosus* differs between hosts. Therefore *I. tomentosus* may be limited by the range of its preferred hosts. Host susceptibility studies, particularly the effect of host combinations on disease development, are very important research topics for management of this root disease.

Double Stranded RNA Viruses as a Possible Cause for the Inactivation of *Phellinus weirii* Root Rot Centers

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ABSTRACT

Fifty-eight isolates of *Phellinus weirii* from B.C., Oregon, and Washington were screened for the presence of double stranded RNA. Double stranded RNA was not detected in any of the isolates.

INTRODUCTION

P. weirii root rot is an important disease of Douglas-fir *Pseudotsuga menziesii* (Mirb.) Franco) in British Columbia.

Considerable variation exists in the activity or rate of spread of *P. weirii* root rot centers. As well, in many cases the spread of a root rot center may be confined to or much greater along one side of the center.

This paper looks at the possibility that hypovirulence caused by a double stranded RNA (dsRNA) virus may be the cause of the inactivation of *P. weirii* root rot centers. The possibility that such a virus might exist was suggested by the observation of some virus like symptoms in cultures of *P. weirii*.

Viruses have been reported in a large number of fungi. While most fungal viruses do not appear to have any obvious debilitating effects on their hosts, some may cause altered cultural characteristics, such as:

- 1) altered pigmentation
- 2) non concentric growth
- 3) slower or in some cases faster than normal growth
- 4) a reduction in the frequency or a complete absence of sporulation

dsRNA viruses comprise the largest group of known fungal viruses. Transmissible dsRNA particles that are not associated with any coat protein or lipoprotein (and

hence do not fit the definition of a virus) are also known in some fungi. Since large quantities of dsRNA are not normally found in virus free fungal cells, dsRNA viruses can be detected by the presence of dsRNA in the host fungus.

Table 1 gives a list of some plant pathogenic fungi in which hypovirulence has been associated with dsRNA. For a recent review of the topic see Nuss and Koltin, 1990.

In an effort to establish whether dsRNA viruses occur in *P. weirii*, 30 isolates representing 13 areas in B.C., 6 isolates from 3 areas in Washington, and 22 isolates from 4 areas in Oregon, were screened for dsRNA using a variation on the technique of Morris and Dodds (1979) developed at the Agriculture Canada Vancouver Research Station. It was decided to approach the question of whether hypovirulence in *P. weirii* exists by looking for a virus rather than by looking for hypovirulence directly, because of the relative ease with which fungi can be screened for dsRNA and because at present there are no methods for measuring the virulence of *P. weirii* isolates.

All of the isolates were collected from infected Douglas-fir with the exception of two isolates that were collected

Table 1: Fungal pathogens in which dsRNA has been associated with hypovirulence.

Fungus	Disease
<i>Endothia parasitica</i>	Chestnut Blight
<i>Ophiostoma ulmi</i>	Dutch Elm Disease
<i>Helminthosporium victoriae</i>	Oat Blight
<i>Gaeumanomycese graminis</i>	Wheat Take All
<i>Ustilago maydis</i>	Corn Smut
<i>Rhizoctonia solani</i>	damping off

from white pine (*Pinus monticola*) and one that was collected from red cedar (*Thuja plicata*)¹

As well as looking for dsRNA an attempt was also made to isolate virus particles from two of the isolates. All cultures were examined for the presence of any virus like symptoms.

METHODS

a) dsRNA extraction

P. weirii mycelium was grown in flasks containing G-YE-P (2% glucose- 1% yeast extract- 1% peptone) The flasks were inoculated by adding two PDA cultures (approx. 1 week old) to 200 ml of media, blending for 5 seconds in a sterile 950 ml Waring® blender, and then pouring the contents into four 250 ml flasks. The flasks were shaken at room temperature for approximately 1 week before the mycelium was harvested.

Pleurotus pulmonaris, *Ustilago maydis*, and *Sclerotinia sclerotiorum* isolates, known to contain dsRNA were used as controls. *U. maydis* and *S. sclerotiorum* were grown in G-YE-P medium. Tissue for extraction of dsRNA from *P. pulmonaris* was obtained from fruiting bodies frozen at -20°C.

The mycelium was separated from the media by centrifuging at 10,000 RPM for 10 minutes at 4°C using a Sorval® SS-3 automatic centrifuge. The mycelium was washed by resuspending the pellet in 2x STE (100 mM NaCl, 50 mM Tris-HCl, 1mM EDTA) and centrifuging for another 10 min.

Twenty grams (wet weight) of mycelium per sample was extracted in 2 volumes of 2x STE, 1.5 volumes of phenol, 0.02 volumes of 2-mercaptoethanol, and 0.5 volumes of sodium dodecyl sulphate. Tissue from all samples except for those of *P. pulmonaris* was homogenized using a Polytron®. *P. pulmonaris* tissue was ground up in liquid nitrogen prior to extraction.

The phenol and aqueous phases were separated by centrifuging at 10,000 RPM for 10 minutes. The aqueous phases were pipetted into falcon tubes and made up to 16% ethanol by the addition of 0.2 volumes of 95% ethanol. 2.5 grams of CF-11 Whatman® cellulose were then added to each sample. The tubes were shaken briefly and centrifuged at 3500 RPM for 2 minutes in a Baxter® megafuge to pellet the cellulose. The cellulose was washed by repeatedly resuspending the pellet in

fresh STE-ethanol and recentrifuging. This was necessary because of the viscous nature of the aqueous extracts. The cellulose was then poured into a column and eluted with three 5 ml aliquots of STE.

Following elution of the column DNA and ssRNA present in the elutant were digested using DNase I and T1 RNase respectively.

After the digestions had been carried out the samples were adjusted to 20% ethanol, 0.3 g of cellulose APX (Serva®) was added per sample, and the samples were shaken for 20 minutes. The solutions were then poured into columns, washed with 30 ml of STE-ethanol and eluted with 2.5 ml of STE.

The elutant was collected in 1.5 ml eppendorf tubes and spun at 10,000 RPM to remove any cellulose that washed through the column. 2.5 volumes of a 25:1 solution of 95% ethanol: 3M sodium acetate were added to each tube to precipitate any dsRNA present in the elutant. The tubes were stored at -20°C overnight.

The following day the tubes were spun at 14,000 RPM to pellet any dsRNA. The pellets were dried, resuspended in loading buffer, and electrophoresed on a 1% agarose gel for 2 hours at 60 V. TAE (40 mM Tris, 40 mM acetate, 2 mM EDTA) was used as the electrophoresis buffer. The gels were stained with ethidium bromide and examined under U.V. light for the presence of dsRNA bands.

b) virus purification

An attempt was made to purify virus particles from two *P. weirii* isolates. One of the isolates was from a large active center and the other was from a nearby small, apparently inactive center.

Approximately 300g (wet weight) of tissue from each of the isolates was homogenized in 50 ml/g of 0.1 M di-Sodium orthophosphate buffer (pH 7.0) and 0.1% 2-mercaptoethanol using a Polytron®. The homogenized tissue was shaken for 1 hour at 4°C, and then centrifuged for 20 minutes at 10,000 RPM. The supernatant was centrifuged at 30,000 RPM for 2 hours using a Sorval® L8-70M ultracentrifuge.

The pellets from the 30,000 RPM centrifugation were resuspended in one tenth of the original volume of phosphate buffer, mixed briefly with the Polytron®, and shaken overnight at 4°C.

¹ The *P. weirii* that infects cedar may be a separate strain, distinct from the one that infects Douglas-fir.

Each sample was divided into two equal portions. 0.2 volumes of chloroform were added to one of the portions. The portion to which the chloroform was added was then shaken for 15 minutes and centrifuged at 10,000 RPM for 20 minutes to separate the aqueous phase from the chloroform.

The aqueous phase and the portion to which no chloroform was added were then centrifuged separately at 40,000 RPM for 2 hours. The pellets were resuspended in phosphate buffer and shaken overnight at 4°C. Cesium chloride was added to all of the resuspended pellets (4 g CsCl/ml) and then they were spun at 60,000 RPM for approximately 16 hours in the ultracentrifuge. Bands visible in the CsCl gradients were collected with a syringe. Phosphate buffer was added to the samples and then they were spun for 90 min at 55,000 RPM to remove any CsCl. The pellets were resuspended in phosphate buffer and viewed under the electron microscope.

C) rate of growth

In an effort to detect slow growing isolates, the rates of growth of 28 isolates of *P. weirii* from 14 centers were measured on Difco® malt agar (approx. 12.5 ml/petri plate). Plates were inoculated with an agar disk removed from the actively growing edge of a colony with a #1 cork borer. Measurements were taken after 2 and 7 days. Five plates were measured per isolate.

Cultures were also examined for other virus-like symptoms.

Results

a) dsRNA extraction

dsRNA was not detected in any of the *P. weirii* isolates, but was detected in the control fungi. Mixing of *U. maydis* and *P. weirii* tissue prior to extraction had no effect on the ability to detect dsRNA in *U. maydis*.

b) virus purification

Large diffuse bands were collected from near the middle of the CsCl gradients, and very faint bands were collected near the top and bottom of the gradients. When these bands were viewed under the electron microscope they

were found to contain a large amount of cellular debris. No virus particles could be detected in any of the bands.

C) rate of growth and cultural characteristics

Based on 14 centers the average rate of growth for all isolates over a five day period was 3.2 ± 0.5 cm (upper and lower limits define a 95% confidence interval). The distribution in the rate of growth of isolates from different centers was tested for normality using a chi-squared test. The distribution in growth rate was not significantly different from what would be expected from the normal distribution ($\alpha=0.05$, $0.5 < P < 0.6$).

Cultures of one of the isolates showed virus like symptoms (dark pigmentation and non-concentric reduced growth). However, subsequent attempts at sub culturing the cultures yielded normal looking cultures in which no dsRNA could be detected.

Discussion

There was considerable variation in the rate of growth of different isolates. However, there is no reason to suspect that the variation observed is any greater than would be expected as a result of normal genetic variation.

The reason for the temporary appearance of virus like symptoms in some cultures of one of the isolates is unclear. Perhaps the symptoms were caused by a plasmid, transposon, or non dsRNA virus.

From this survey of isolates it does not seem very likely that dsRNA viruses occur in *P. weirii*, despite their wide occurrence in a number of other fungi. It is possible that in fungi like *P. weirii* in which spores do not seem to play a significant role, the opportunity for the spread of viruses may be limited.

Acknowledgements

I would like to thank Bob Martin for his help and the use of his lab without which this work would not have been possible. I would also like to thank Earl Nelson, Everett Hansen, Charles Dorworth, Jim Kronstad, and Greg Boland for supplying me with cultures.

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Population Structure and Intersterility Groups of *Heterobasidion Annosum* in Grand Fir Habitat Types on the Nezperce National Forest, Idaho Preliminary Results

B. Lockman, E. Hansen, and S. Hagle¹

Annosus root disease (*Heterobasidion annosum* (Fr.) Bref.) is causing notable conifer mortality in grand fir habitat types in central Idaho. The most significant mortality is occurring in Douglas-fir trees of all age classes. A project is in progress to study the general biology of *H. annosum* on the Elk City and Clearwater Ranger Districts of the Nezperce National Forest, Idaho. The two main objectives of the study are: 1) determine the population structure of *H. annosum* in clearcut and uncut stands; and 2) determine which intersterility group(s) are present in the area. Two pairs of stands in the grand fir habitat series were examined intensively during the summer of 1990. A third pair is being examined during the summer of 1991. Each pair consists of a 10 to 30 year old clearcut and an adjacent 80+ year old uncut stand.

Basic stand data were collected from 1/20th acre plots. These plots were then rated for root disease severity using the following guidelines: 0= no evidence of root disease; 1= *H. annosum* fruiting bodies and/or decay present; and 2= symptomatic trees present. Three plots from each of these ratings were then randomly selected for intensive sampling.

Intensive sampling involved three techniques: 1) stumps were sawed to ground level and wood samples and/or *H. annosum* fruiting bodies were collected; 2) trees 5 inches dbh or larger were drilled with a gas powered drill and the resultant chips were collected; and 3) trees

less than 5 inches dbh were excavated and two roots were collected. All isolations were placed on a selective medium for *H. annosum*.

The intersterility group(s) of all collected isolates were identified by examining 13 isozyme systems using starch gel electrophoresis. Preliminary results indicate all isolates belong to the "S" intersterility group.

Vegetative compatibility tests between isolates were used to describe the population structure of *H. annosum* in the study areas. All possible pairings within stands were performed, as well as all possible pairings between adjacent stands. Preliminary results from one pair of stands indicate a large vegetatively compatible group in the uncut stand and numerous incompatible isolates in the cut stand. Preliminary results from the second pair of stands indicate a large vegetatively compatible group in the cut stand, and another large vegetatively compatible group in the uncut stand that extends into the uncut stand. There are also numerous incompatible isolates in this uncut stand.

These preliminary results imply that *H. annosum* has been in the area for quite some time and vegetative spread is fairly extensive in both areas. If these results hold true, then stump treatments to prevent spore infections may be ineffective, and management efforts should be concentrated on outplanting non-host species, such as pines.

¹ Master's student, Dept. Forest Science, Oregon State University; Professor, Dept. Botany and Plant Pathology, Oregon State University, Corvallis, Oregon; and Plant Pathologist, USDA Forest Service, R-1 Forest Pest Management, Missoula, Montana, respectively.

The Forest Insect and Disease Survey and ARNEWS

B. Callan
Pacific Forestry Centre

ARNEWS, or the Acid Rain National Early Warning System, was initiated in British Columbia by Forestry Canada in 1984 in order to monitor the long-term health of nationally standardized study plots in forested areas. The objectives of ARNEWS are:

- to assess the damage in Canadian forests which cannot be attributed to natural causes or management practices.
- to monitor vegetation and soils on a long-term basis to detect changes attributable to air pollutants and natural stresses in representative forest systems.

Over a period of three years, 1984-1986, the Forest Insect and Disease Survey (FIDS) has established fifteen 10 x 40 m ARNEWS permanent plots throughout British Columbia. There are a total of 106 such plots across Canada. Plot locations in British Columbia were randomly selected within middle-aged stands chosen for long-term security from disturbance, representing major commercial tree species, with wide geographical distribution and various altitudes. Emphasis was placed on areas judged to be at greatest risk from sources of regional pollution (i.e. downwind from major population centres).

FIDS is also responsible for regularly monitoring ARNEWS plots, and eleven experienced field technicians assess insect and disease conditions, and assist in the collection of foliage and soil samples for chemical

analysis. At the time of plot establishment, trees are stem mapped and inventoried, with height, diameter, crown measurements, vigour, needle length and retention recorded, along with conifer regeneration and ground cover. During establishment and at five year intervals, annual tree ring measurements as well as pH, C.E.C., and nutrient analyses are made. These tests are then repeated at five-year intervals.

Lichen presence and frequency of occurrence is also noted, and five coastal plots were inventoried, with photo plots and some transplants made. Mineral ash analysis of transplanted lichens showed a higher lead accumulation in one plot, but sulphur levels were unchanged.

After seven years of ARNEWS plot monitoring, there has been no observation of damage yet attributable to acid rain: the majority of plot trees appear healthy with full crowns of green foliage. Where chlorosis or defoliation occurs, it is attributable to disease, defoliators, or other natural factors. The ARNEWS system is currently providing baseline information on forest health, but to date has not detected acid rain damage in B.C.

Future ARNEWS plots will be established with emphasis on hardwood stands in northern British Columbia. Current plots are in predominantly coniferous stands such as Douglas-fir, western hemlock, amabilis fir and white spruce.

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Poster Session: Forest Pest Management Research—An Industrial Perspective Poster Session

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Current emphasis is being placed on applied research on a diverse array of pest management topics, including: seed orchard pests, nursery diseases, fungicide testing, disease and pests of young managed stands, and pests of

lumber products. This poster is designed to illustrate some observations and approaches taken to answer critical needs by operations personnel.

Seedling Storage Pathology

OBSERVATION: Fungi such as *Pythium* and *Fusarium* have been shown to be associated with decline of seedling quality while in storage. The rate of seedling decline and methods to detect and control this problem have been poorly studied.

METHODS: The incidence and severity of *Pythium* and *Fusarium* were determined on a subsample of seedlings under cooler or ambient storage conditions. Roots from individual seedlings are cut and plated on V8-Juice agar or Komada's media respectively for *Pythium* or *Fusarium*. The percentage of seedlings within each root infection class are used to detect storage decline problems.

RESULTS: *Pythium* levels were found to vary greatly on the four Ponderosa pine seedlots tested. Seedlots

#269 and #266 were found to have significantly higher incidence and severity of *Pythium* after cooler storage than seedlots 501-50 and #268.

Similar results are shown for a slash pine seedlot place in one week of cooler and ambient storage conditions. After one week of cooler storage some 40% of the seedlings in the lowest *Fusarium* disease infection class have moved into higher disease classes.

These tests confirm that sampling prior to storage and subsequent to storage can be useful in detecting pathogen build-up. The rate of pathogen build-up may be sufficiently fast enough to degrade seedling quality before outplanting.

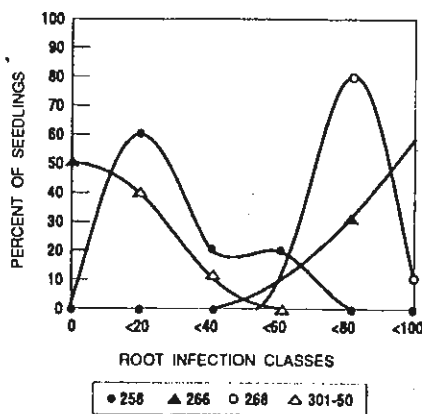


Figure 1. *Pythium* levels on ponderosa pine seedlots after cooler storage.

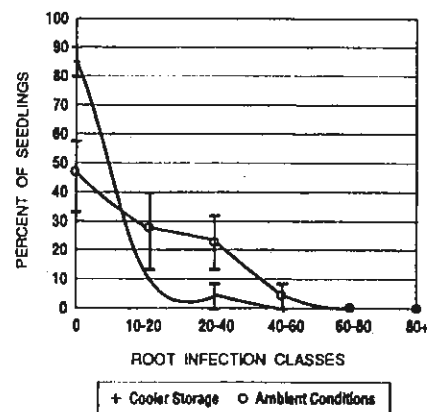


Figure 2. *Fusarium* levels on slash pine roots after 1 week of storage.

Fungicide Testing

OBSERVATION: Agribrome normally used as a water treatment for control of algae was found to greatly decrease the likelihood of disease outbreak when used as a drench over seedlings. The mode of action of this product was tested against nursery pathogens.

METHODS: Cultures of *Botrytis* and *Fusarium* were used to prepare spore suspensions equal to 10,000 spores/ml (high level) and 1,000 spore/ml (low level). Agribrome product was used to prepare fresh solutions equivalent to 0.33, 3.3, 33, and 330 ppm (Br). Spores were spread onto a petri dish and flooded with 2 ml of Agribrome solution. The percentage control at various concentrations of Agribrome was recorded.

RESULTS: Agribrome was more effective in the inhibition of *Fusarium* spore germination at low concentrations (ppm Br), when compared to *Botrytis* spores. Complete control of spore germination of both pathogens was achieved at 33 ppm Br. Subsequent tests using Agribrome as a mist (30 ppm Br) were successful at controlling *Botrytis* on Douglas-fir rooted cuttings.

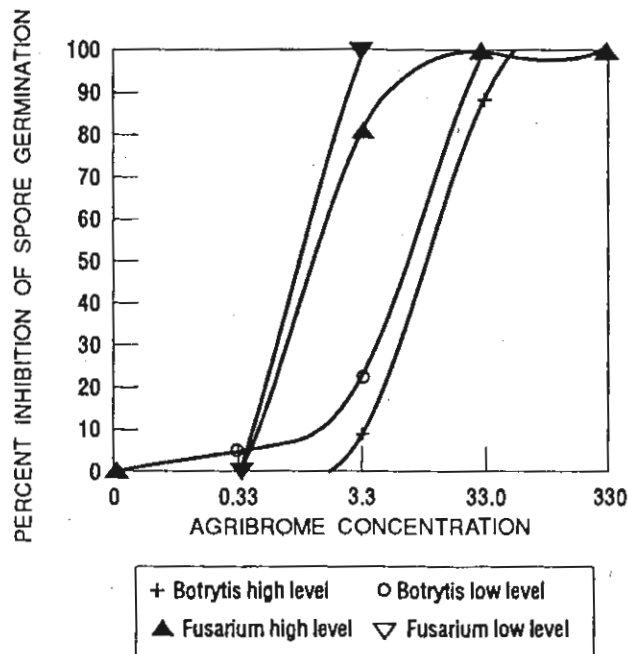


Figure 3. Agribrome levels (ppm Br) and levels of pathogen spore germination.

Nursery Seedling Pathology

OBSERVATION: Losses from diseases caused by *Fusarium oxysporum* vary by nursery seedling crop and soil pathogen levels. The relative disease susceptibility of various conifer species is poorly understood.

METHODS: Levels of *F. oxysporum* on seedlings roots and soil were established using Komada's media. Seedling roots (1-2 mm diameter) are first surface sterilized and latter plated to determine the incidence of *F. oxysporum* infection on each seedling. Soils are sieved and diluted in sterile 0.1% water agar and mixed with Komada's media.

RESULTS: The graph shows the relative level of seedling roots infected by *F. oxysporum* at given soil propagule counts. These results suggest that Ponderosa pine is the most susceptible species of those tested, while Noble fir is the least susceptible. Current research is being focused on developing pathogen threshold levels (a level below which disease symptoms do not appear) for species being grown in company bare-root nurseries.

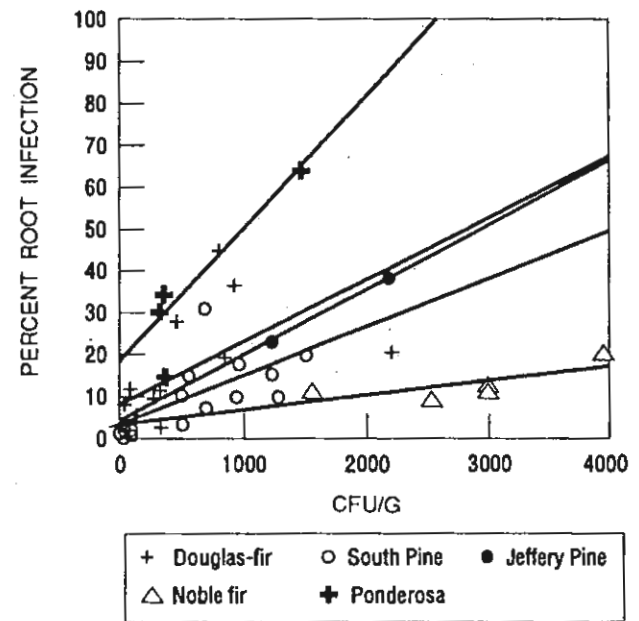


Figure 4. Seedling root infection levels at various soil propagule counts.

Seed Orchard

OBSERVATION: Gall midge eggs are laid in upright Douglas-fir cones in the spring. Insecticide applications applied just prior to cones going pendent have not always been effective in controlling this seed orchard pest. Tests were conducted on the efficacy of barrier traps to detect gall midge adults.

METHODS: Plexiglas barrier traps suspended in orchard trees near conelets were used to passively trap insects throughout the cone development period. Trap contents were collected weekly and insects were identified.

RESULTS: Trap results show that barrier traps placed near developing conelets can be used to quantify the timing and severity of pests like the gall midge. Other insects known to infest cones were also collected.

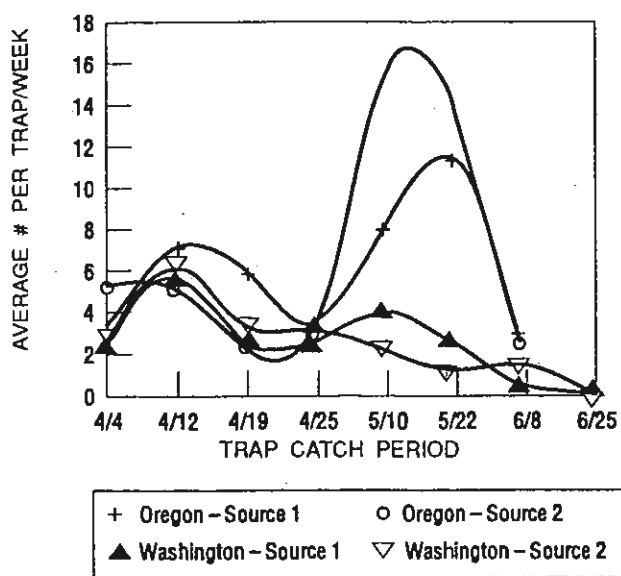


Figure 5. Gall midge catches in seed orchards in Oregon and Washington.

Blackstain Root Disease

OBSERVATION: Insects which vector the disease are attracted to cut stumps of thinned stands. Disease centers in stands develop from residual tree contact with infected cut-stumps and from direct insect attack.

Disease avoidance prescriptions call for thinning during July, August, and September so as to miss the main in-

sect flight season. The utility of this prescription to reduce the incidence and severity of black stain in PCT age Douglas-fir stands has not been verified.

METHODS: Forty-five Douglas fir stands situated in southwest coastal Oregon were selected at random to determine the levels of black stain root disease. The stands were precommercially thinned when stands were between 13-18 years of age and represented 4500 acres of PCT. The disease survey was conducted 5-10 years post-PCT.

Discrete disease centers were identified in each stand as being more than 1/2 chain (33 ft) apart from adjacent centers and separated by at least three non-infected residuals. The number of disease centers were compared on a thinned stand basis (#Centers/stand) and on an area basis per 100 acres thinned (#Centers/100 ACT).

RESULTS: The survey showed that neither the incidence nor the severity of black stain root disease in PCT Douglas-fir stands appears to be related to "time-of-thinning". This finding appears to hold if disease is based on a per stand thinned or area thinned basis.

These findings suggest that factors other than time of thinning may be important in black stain root disease development in PCT stands in coastal Oregon. Future research will concentrate on stand and site variables related to insect behavior and to update stand loss data.

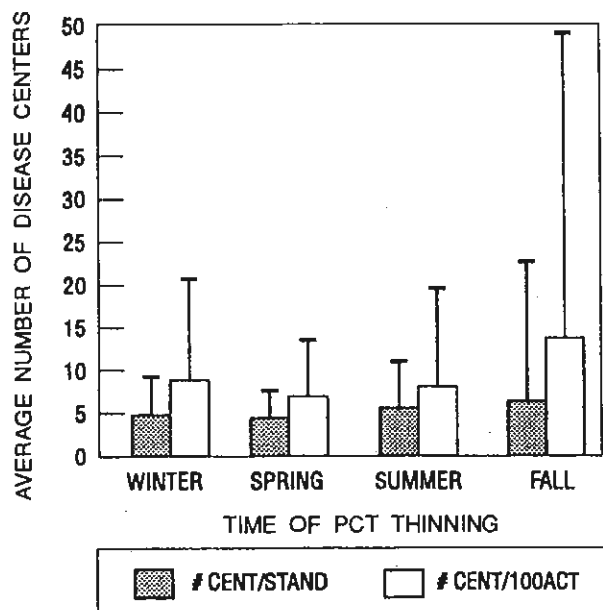


Figure 6. Black Stain disease centers in stands thinned during various months.

Manufacturing Process

OBSERVATION: Insect damage to high value pole logs increases with late summer processing and results in unacceptable levels of log rejection. Members of the wood boring beetle families Cerambycidae and Buprestidae are responsible. Pole industry standards do not allow for any insect holes larger than 1/16 of an inch.

METHODS: Visits were conducted at logging sites and storage facilities to determine the level of infestation in logs destined for the pole manufacturing facility.

RESULTS: The increase in the levels of wood borer damage results from the "turndown" of cambial feeding larvae as logs begin to dry. Larvae enter the outer sapwood and proceed to deeper depths. The prevention of damage is dependent on speedy delivery (30-60 days of felling) of poles during the peak infestation period (May-August), coupled with timely processing (peeling) into poles before "turndown" occurs.

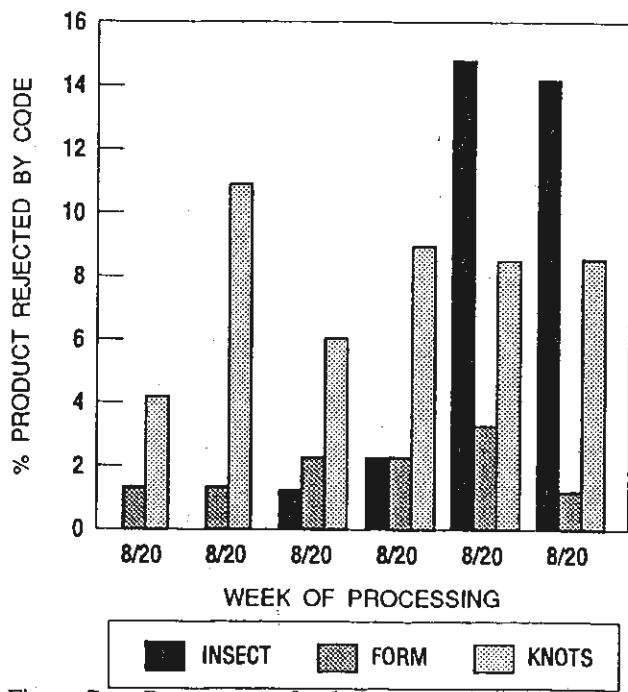


Figure 7. Percentage of pole logs lost due to insect damage, form, or knots.

Log Storage Facilities

OBSERVATION: Ambrosia beetles attack and degrade significant volume of decked logs in storage facilities during the spring and early summer months. Ambrosia beetle activity in mill facilities can be quantified using pheromone traps, and the need for suppression based on average trap counts.

METHODS: Pheromone traps baited with "lineatum" were placed in three mill locations to estimate the level of *Trypodendron lineatum* during the spring. Trap contents were dumped weekly.

RESULTS: Trap catches at various mill locations can be used to determine the timing for suppression of ambrosia beetles, and ideal location for replacement of additional traps. Average trap catches below 3,000 beetles/trap/week usually do not indicate a need for additional suppression trapping. Log decks are adequately protected with water misting systems.

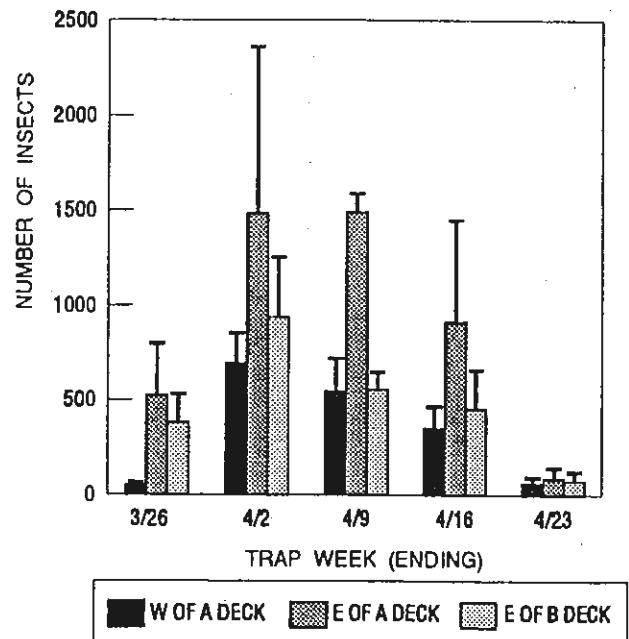


Figure 8. Percentage of pole logs lost due to insect damage, form, or knots.

39TH Annual Western International Forest Disease Work Conference Field Trip

STOP 1 Ninety Year-Old Transitional Douglas-fir

Transitional Interior Douglas-fir to Interior Cedar Hemlock ecosystems enjoy relatively good Douglas-fir timber volume production. Unfortunately for the timber manager, other floristic components revel in this ecosystem. Both phellinus and armillaria root disease are active and ancient inhabitants.

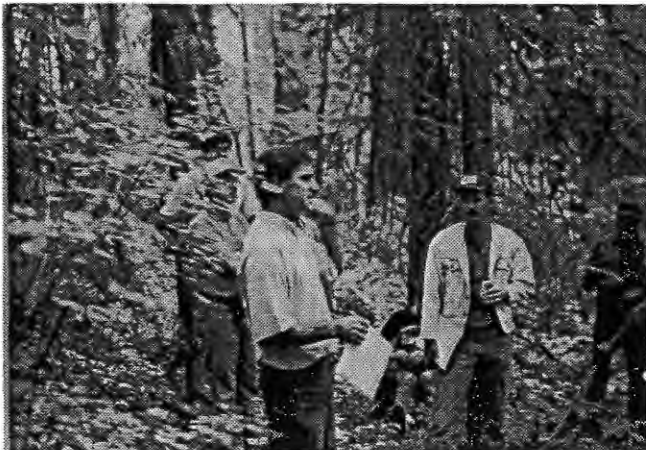
Probably following a catastrophic event, such as fire, near the turn of the century, this stand regenerated with an even cover of Douglas-fir. It was 'cat-logged' in the late 1950's and has been losing Douglas-fir volume since.

STOP 2 Skimikin Stumping Trial

Considered for National Monument Status, this very important trial is setting the mood for proper forest practices by giving consideration to disease management. Duncan Morrison will lead this discussion.

STOP 3 Stretching the Limits for Lodgepole Pine

Many old growth Redcedar/Hemlock stands in the Vernon area were high-graded in the 1950's and 60's. Residual volumes are low and of poor quality, preferred species have largely been removed and abundant natural regeneration has often occurred. Replacement or improvement of these high-graded stands is required in order to realize the productive capabilities of these sites. Several approaches have been attempted within this area.



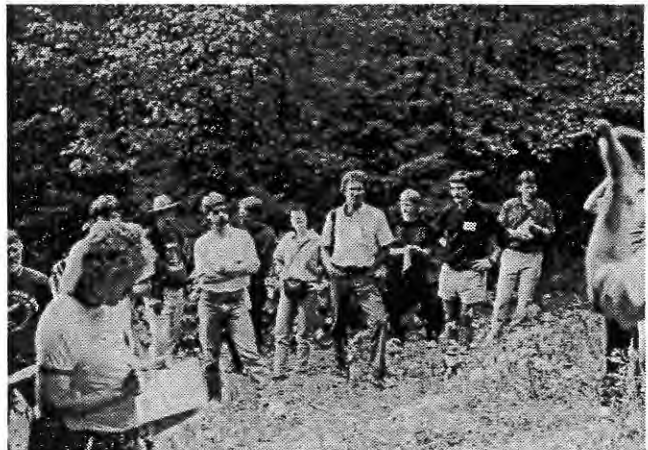
Species control to a more desirable component is one approach. This entails mechanical site preparation and planting. Today we shall look at a plantation of plug stock lodgepole pine, established in 1983 after site prep in 1981.

Bart van der Kamp will lead a discussion as to whether the lodgepole pine is out of the woods, so to speak.

STOP 4 Money + Silviculture = Healthy Stand???

This title introduces the danger of sudden windfalls of capital to apply toward increasing "forest productivity" and resulting in the decrease of "stand vigour".

Large areas of immature western hemlock/western redcedar occur in the Vernon Area. Until recently, many such stands were considered to be Not Sufficiently





Restocked and were often treated as the previous stop. Both of these climax species are now acceptable (and even preferred) species on many site units, and emphasis has shifted towards actively managing these stands.

In 1990, 270 hectares were juvenile spaced in one forest district.

With FRDA funding in 1987 this site was 'brushed and weeded' to promote advanced redcedar/hemlock. This included backpack spraying of Vision, cut stump application of Ep and pruning of whatever western white pine was found on the block.

Silvicultural intentions for this stand are to have a hemlock/redcedar/Douglas-fir ratio of 6:3:1. Is this wise? Duncan Morrison will lead a discussion of some old and not so old western hemlock decay studies.

Rich Hunt will discuss the efficacy of pruning western white pine in general, since both examples of pruned trees on this site have armillaria.

Table 1. Mortality by cause among planted trees from 1973 to 1991 at the Skimikin experiment.

Tree Species	Treatment	Live Trees 1973	Number of trees killed									Live trees 1991	Cumulative Mortality		
			1973-1981			1982-1987			1988-1991				Ao	Pw	O
			Ao	Pw	O	Ao	Pw	O	Ao	Pw	O				
Fd	Treated	1086	21	1	7	11	1	32	5	0	7	1001	37	2	46
	Untreated	925	61	20	8	66	20	6	19	20	2	703	146	60	16
Pl	Treated	1131	11	0	17	3	0	37	3	0	16	1044	17	0	70
	Untreated	1072	96	0	13	63	0	23	21	0	2	854	180	0	38
Cw	Treated	582	0	0	10	0	0	12	0	0	0	560	0	0	22
	Untreated	622	3	0	2	10	0	5	13	0	0	590	26	0	6
Ep	Treated	492	0	0	1	0	0	15	0	0	1	475	0	0	17
	Untreated	240	0	0	0	12	0	6	0	0	1	232	1	0	7
Lw	Treated	119	2	0	0	1	0	4	0	0	0	112	3	0	4
	Untreated	130	15	0	0	17	0	2	3	0	0	933	5	0	2
Sx	Treated	124	2	0	0	0	0	0	0	0	0	122	2	0	0
	Untreated	65	3	0	0	3	0	0	4	0	0	551	0	0	0

Fd Douglas-fir
 Pl lodgepole pine
 Cw western redcedar
 Ep paper birch
 Lw western larch

Ao *Armillaria ostoyae*
 Pw *Phellinus weirii*
 O Other

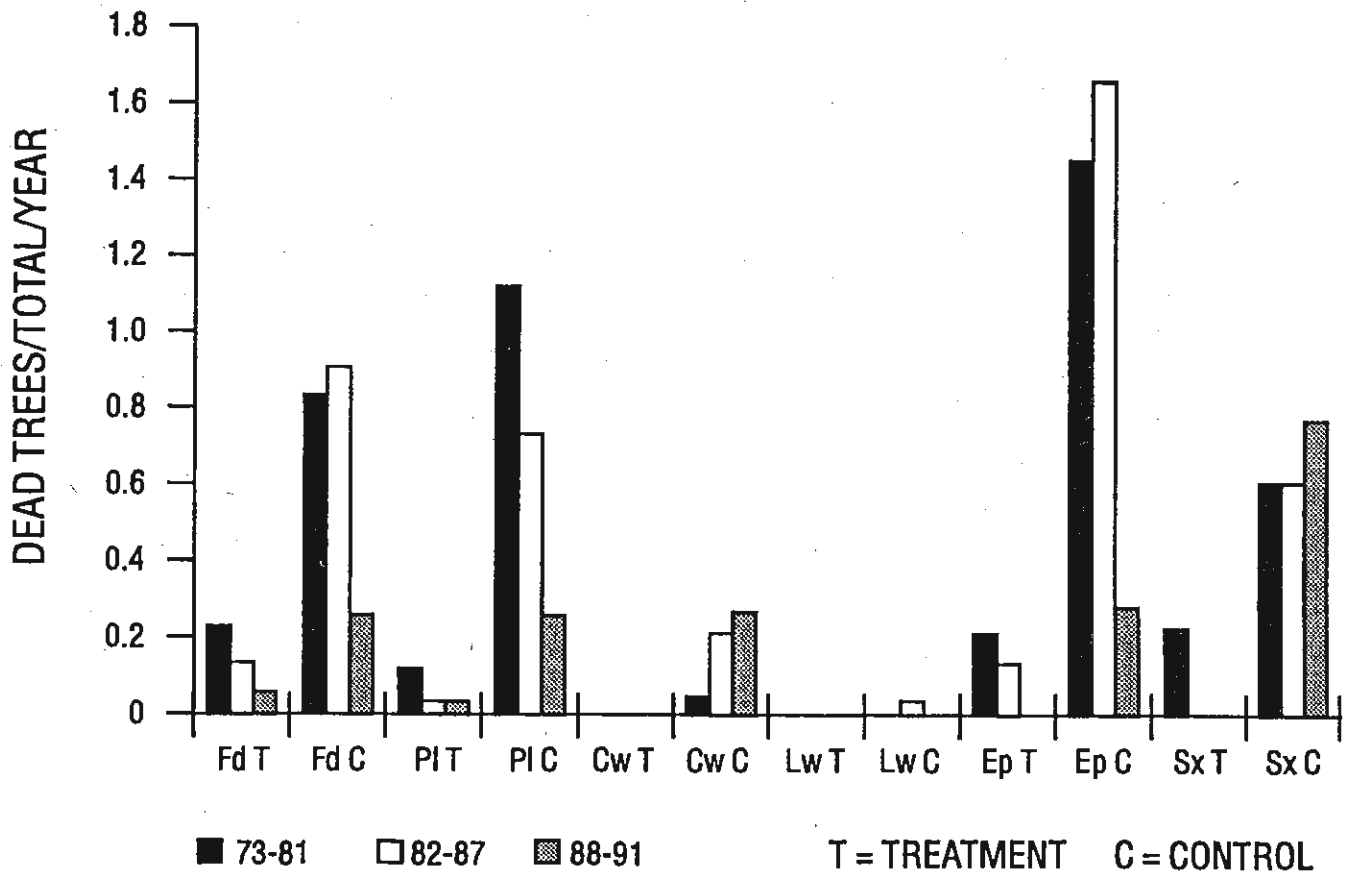


Figure 1. Amillaria caused mortality by era.

Yield Predictions for Juvenile Spacing of Western Hemlock

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The graphs and tables below serve as a starting point for discussions about the treatment of this stand and similar stands elsewhere in the ICH. Specifically, we should ask questions like the following:

- What have we gained by juvenile spacing?
- Should we have left more or fewer trees?

A simulated experiment using the *Tree and Stand Simulator* (TASS) was designed to investigate some alternative spacing regimes for a productive site (site index 25m at 50 years breast-height age) and a less productive site (site index 15m). The simulated stands all start at 6000 stems per hectare of pure hemlock and are spaced to 1600, 900 or 600 stems per hectare at age 17. The actual stand at this location has been juvenile spaced from approximately 6200/ha. The simulated results are displayed on the attached graphs of volume and diameter growth.

Notes

With so few permanent plots established in interior hemlock, we assume that hemlock in the ICH grows the same as coastal hemlock on similar sites.

The calibration of TASS for hemlock is not complete. Yields in the final version may be different from those shown here, but the ranking of alternatives should not change.

TASS simulations reflect the yields observed in research plots. Operational yields, on average, will be about 15% lower.

Site index is height at 50 years breast-height age based on Wiley's (1978) site curves.

Table I. Culmination Statistics for Site 25m

Treatment	Age	MAI	Vol (17.5+)	DBH	Stems
Natural 6000	67	11.9	797	23.5	1536
Space to 1600	75	12.2	917	29.2	1096
Space to 900	80	12.0	958	36.0	736
Space to 600	87	11.3	982	41.5	554

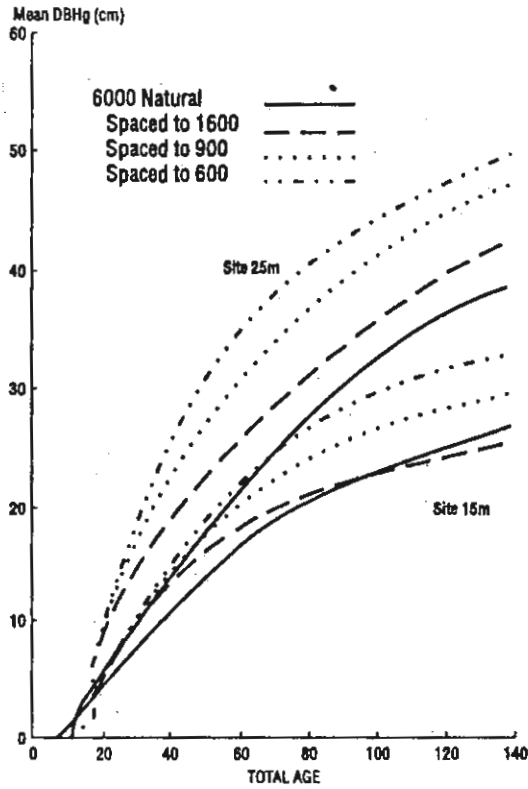


Figure 2. DBH Distributions — TASS Hemlock Aug/90

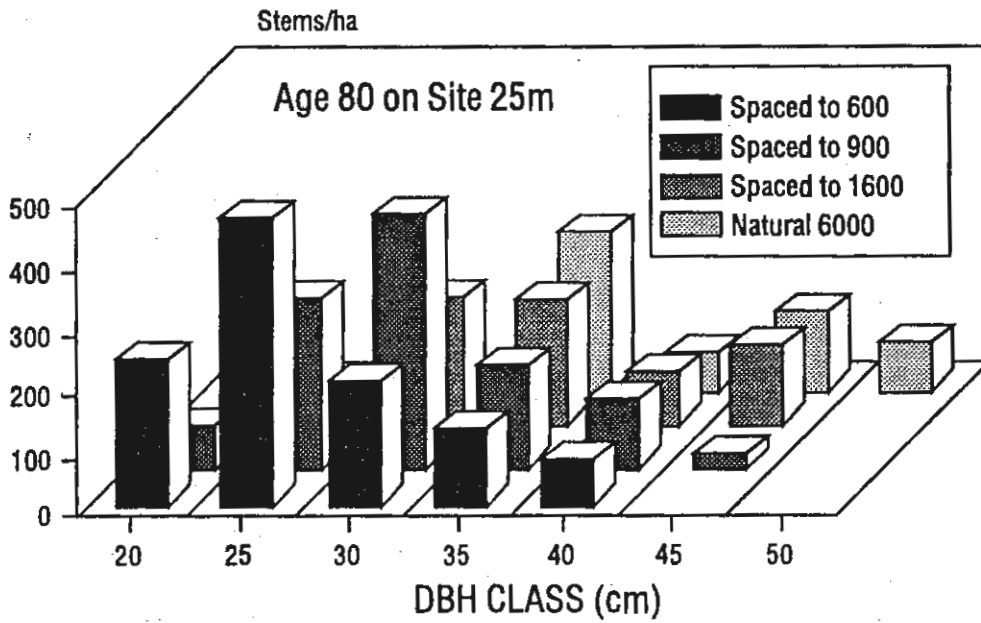


Figure 3. TASS Hemlock Aug/90 — First Approximation

Acceptability of Hemlock Regeneration in the ICH

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Forestry Canada
August, 1990.

In 1954, Foster, Craig and Wallis published a paper "Decay of western hemlock in the upper Columbia region" in which they reported results of stem analysis of 833 trees ranging in age from 100-430 years on six sites. Fifty-two percent of the cubic foot volume was decayed by 26 fungi with *Echinodontium tinctorium* (*ET*) causing 62% and *Fomes pini* (*Fp*) 25% of the decay volume. It is noteworthy that both the incidence of diseased trees and percentage of decay by *ET* decreased as site index increased; whereas, values of these parameters for *Fp* increased as site index increased. Decay volumes were related to tree age, there being 15% defect at 150 years, 50% at 250 years and 75% at 400 years. *ET* was the principal decay fungus in 100 and 150 year old trees, having cull values of 13 and 20%, respectively. Given the history of hemlock stands in the ICH, many of these trees regenerated under an overstory.

The process of infection of hemlock by *ET* was determined by Etheridge and Craig (1976). Basidiospores infect through branchlet stubs about 1 mm in diameter on living, shade-suppressed branches and the stem of trees more than 40 years old. A major determinant of susceptibility in hemlock is a slow rate of healing of branchlet stubs. Stubs 1 mm in diameter must be exposed for a minimum of two years. For this to occur, a low rate of radial growth is required. Slow radial growth is characteristic of shade-suppressed lower branches and understory trees. (In *ET*-free hemlock stands on the coast, branchlet stubs callused over in one year.) After callusing of the stubs, *ET* may remain dormant for 50 or more years without causing

decay. A small proportion of *ET* infections on branches reach the stem. Activation of the fungus in the stem and development of decay appear to depend on improved aeration following wounding or branch sloughing. Etheridge re-examined Foster's data and found further evidence of a link between host vigour and the occurrence of infection courts. The time and duration of periods of suppressed growth apparently determined tree susceptibility to *ET* and the location and extent of heartrot columns.

FRDA Project 3.28 (Anon, 1990) found that incidence of heartrot in hemlock, due primarily to *ET*, is related to tree age. Incidence was less than 7 in trees younger than 90 years, but it increased rapidly after that age. Similar results were reported for alpine fir advanced regeneration by Smith and Craig (1968). They found that incidence and amount of decay was related primarily to tree age, with trees up to 50 years old and lacking suspect indicators having negligible decay.

Tree age is the most important factor in evaluating acceptability of hemlock regeneration. Trees more than 40 years old which were in the understory are probably infected by *ET* and younger understory trees will have potential infection courts. These trees should not be considered for crop trees. The key to maintaining trees free from *ET* is to ensure that radial growth rates are such that branchlet stubs are callused over in less than two years. Stands must be spaced to remove older advanced regeneration and ensure rapid growth of an optimum number of crop trees.

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Biological Control of Weeds Workshop

The Pacific Forestry Centre Mycoherbicide Program Principals and Practice

Charles Dorworth

The Pacific Forestry Centre, Forestry Canada, initiated research and development in microbiological control of forest weeds in 1986. Staff of the Program has since been expanded from a single pathologist to three pathologists, one physiologist, one tissue culture specialist and one support technician. Additional input has been realized by the addition of visiting scientists and a postdoctoral associate during the past several years.

Research has emphasized the use of fungi as biological control agents but viruses are also considered and a major project involving the use of rhizobacteria was initiated in 1991. Regardless, the goal of the program is to facilitate forest weed biocontrol operations in British Columbia through the use of environmentally benign agents. All biocontrol agents will have one safety characteristic in common:

Biocontrol agents will be native or indigenous to the biogeographic zone in which they are tested and employed.

These pathogens are generally in balance with their native weed-host population. As such, they must often be locally and temporarily promoted in virulence or the physiologic condition of the weed population must be reduced (or both) in order to gain infection and tissue colonization. When the job is completed and trees are free to grow, the microorganism stimulant or facilitator, or the plant debilitating agent, each of which will differ

in various cases, need no longer be applied and the biocontrol agent becomes automatically reduced once more to its natural balance in the biosphere. The biosphere is the ultimate buffer or safety check on any indigenous pathogen which is promoted to extraordinary activity on a native plant species. The overall process of biocontrol using native pathogens is environmentally benign.

The second major guiding principal in the P.F.C. forest weed biocontrol program is:

Apply the minimum biocontrol pressure necessary to achieve the desired vegetation management goal.

The goal in agricultural weed control with chemicals is usually 100% kill, particularly when crops are produced through direct, no-till seeding. For forestry, it is sufficient merely to constrain the growth of weeds to the point they do not compete to the detriment of the forest crop species: By definition, such plants are no longer weeds, once controlled, but rather become an often useful part of the natural flora. Furthermore, the minimum vegetation management activity required to permit newly planted trees to achieve free-growing status in the least time possible is probably the most cost-effective vegetation management as well.

My colleagues will follow with some examples of the manner in which we hope to achieve our objectives.

Integrating Forest Protection with Silvicultural Planning and Practice

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Abstract

Forest management has become increasingly complex and challenging over the last several decades in response to the dwindling supply of natural forests and increasing demands for a variety of resource values. The general changes in forest resource management have been accompanied by a shift in philosophy toward forest protection. Historically, forest managers responded to pest problems when they arose, often with direct controls. The current emphasis in forest protection is on the development and implementation of integrated forest pest management programs. This approach relies on a

thorough knowledge of the ecological relationships among pests and host trees to prevent the occurrence of pest problems. Silvicultural treatments and systems are designed to meet management objectives while simultaneously maintaining or enhancing natural control of pest populations. Vegetation management activities are one component of an integrated pest management program and must be compatible with the total forest resource management system. Findings from vegetation management research are used to illustrate the need for an interdisciplinary approach to understanding and solving forest pest problems.

Vegetation Management In British Columbia

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Summary

Site preparation and brushing treatments are used to improve the survival and growth of conifers in B.C. In 1989 site preparation treatments were applied to 147,500 hectares of crown forest land. These treatments were used for debris removal, vegetation management and other purposes. Mechanical site preparation, prescribed burning, and chemical site preparation can all be useful in achieving initial control of competing vegetation. Grass and legume cover crops may also be seeded to reduce future competition, to provide forage for livestock and for erosion control.

Brushing activities have increased substantially over the past decade. In 1981 3,000 hectares of crown forest land were brushed. In 1989 61,000 hectares was brushed to

improve the performance of established conifers. Herbicides were used on 62% of the area brushed in 1989, 36% of the area was treated manually, and sheep browsing was used in less than 2% of the area brushed. VISIONR herbicide was used on 92% of the area that was chemically brushed.

In the future it is expected that site preparation and brushing activities will remain close to current levels. To support operational programs there is a need for continued testing and evaluation of available and promising new treatments. The Ministry of Forests, Forestry Canada, and other agencies are supporting research on treatment options, and on the prediction and diagnosis of vegetation management problems.

Sheep Grazing—A Biological Tool for Controlling Competing Vegetation in Spruce Plantations

Craig Sutherland, Teresa Newsome, and Nola Daintith

Abstract

The objective of this report was to evaluate domestic sheep grazing as a biological tool for controlling competing vegetation in spruce plantations. Two sheep grazing trials were established in the Cariboo Forest Region of British Columbia; the Hendrix Lake Pilot Trial established in the 100 Mile House Forest District in 1984 and the Doreen Creek Provincial Trial established in the Horsefly Forest District in 1986. The pilot trial measured an operational sheep grazing program whereas the provincial trial was designed to test five treatments, a June grazing, a July grazing, an August grazing, a Glyphosate herbicide ground application and a control. In both trials target and total vegetation was assessed for, percent cover, height, damage and control. The crop seedlings were assessed for total height, annual height growth,

stem diameter, vigour, degree of overtopping and any seedling damage including damage due to sheep grazing.

Preliminary five year results from both trials indicate that sheep grazing can effectively reduce fireweed thereby reducing vegetation competition and press damage resulting in improved seedling condition. Other vegetation will however re-invade and completely occupy the site to pre-treatment levels. Damage to seedlings from sheep grazing varied considerably from 7 to 50 % but on average has decreased over time with better sheep management. Sheep grazing has not increased seedling height and only slightly increased seedling diameter.

Craig Sutherland, Forest Sciences Officer; Teresa Newsome, Research Silviculturist; Nola Daintith, Assistant Research Silviculturist; Forest Sciences section of the Ministry of Forests, Cariboo Forest Region.

The Potential for Biological Control of Bluejoint (*Calamagrostis canadensis* {Michx.} Beauv.) in Reforestation Areas in British Columbia¹

Bluejoint (*Calamagrostis Canadensis* {Michx.} Beauv.) causes problems in Northeastern B.C. reforestation areas that range from competition to snow press.

There are at least seven subspecies of bluejoint, but the primary problem in Northeastern B.C. seems to be *C. canadensis* var. *canadensis*. Where bluejoint is dominant, it can delay stand development for up to a decade and seriously impair the quality of the timber. Bluejoint primarily competes for light and nutrients. The dense litter from this weed is a serious secondary problem. During snowpress, the litter can suffocate seedlings or cause them to grow laterally for long distances. The litter can also prevent soils from thawing quickly in the Spring and can harbour seedling-eating mammals. In view of the fact that chemical controls such as glyphosate are increasingly unavailable due to public pressure, alternative methods such as biocontrol are needed.

At the Pacific Forestry Centre, local natural enemies are being studied as one possible source of control agents. Frequently termed "bioherbicides", these agents have shown promise for a range of other reforestation problems in Canada. At least 90 species of fungi are reported on bluejoint, 30 of which appear to cause some type of epidemic or disease. These diseases range from various leaf spots, lesions, and stripes to sterility diseases, rusts,

smuts, twists, chokes, root rots, scalds, speckles, blasts and snow molds. It seems probable that some type of fungal or bacterial agent could serve as a suitable candidate for a biocontrol agent. For this type of reforestation, our primary objective is to eliminate competition, not vegetation. Other vegetation can play a highly beneficial role in the developing forest if it is not competing—biocontrol seems ideally suited to reduce biomass without necessarily eliminating plants altogether.

This project is still in the discovery phase. We have surveyed much of Northeastern B.C., including the Peace River and Fort Nelson areas, for bluejoint diseases and seed collections. Collecting from land vehicles and aircraft, we have identified and/or isolated about 30% of the approximately fifty major bluejoint pathogens. The pathogens will be screened for pathogenicity on bluejoint. The most promising pathogen or pathogens will be screened again for pathogenicity using a wider host range, including bluejoint from different parts of B.C.; virulence will be assessed under a variety of conditions. Virulence will be enhanced with formulation components, if necessary. This standard approach to mycoherbicide development will hopefully lead to small, preliminary field trials by next year.

¹ This work is supported partially under the Canada Green Plan with financial and technical cooperation from the B.C. Ministry of Forests. The project is under the direction of Dr. Charles E. Dorworth.

Biological Control of Forest Weeds by Natural Herbicides (Phytotoxins)

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Introduction

- Phytotoxins are biorational compounds derived from other organisms e.g. microbes or higher plants that suppress the weed growth.
- Five phytotoxins (4 derived from microorganisms) and one from higher plant (wormwood) were tested in lab. and greenhouse expts.
- Three phytotoxins were derived from fungi *Cylindrocarpon destructans*, *Fusarium oxysporum* and *Colletotrichum dematium*.
- One phytotoxin is derived and commercialized from *Streptomyces viridochromogenes* and is sold as Bialaphos. A chemical analog of this is HOE 039866.
- One phytotoxin which is derived from wormwood (*Artemisia annua*) is sold as artemisinin.

Methods (Bioassay of Phytotoxins)

- Culture filtrates from 3 fungi and commercial preparation of Bialaphos, HOE 039866 and artemisinin were tested on (a) leaf discs of red

alder (*Alnus rubra*) thimbleberry (*Rubus parviflorus*) and fireweed (*Epilobium angustifolium*) (b) whole plants of soyabeans and lettuce (c) aquatic plant (*Lemna minor*) and (d) seedling trees of thimbleberry.

Results

- Culture filtrates of 3 fungi inhibited leaf disc growth of the three forest weeds.
- Phytotoxins produced by *Cylindrocarpon* were most inhibitory on soyabean plants.
- Bialaphos and HOE 039866 were extremely phytotoxic to thimbleberry seedlings @1000 ppm.

Conclusion

- i) Purification and identification and further testing of toxins from *Cylindrocarpon* is needed.
- ii) Bialaphos and HOE 039866 show great promise in controlling thimbleberry.
- iii) Crop tolerance tests of conifer species (Douglas-fir, western cedar, Sitka spruce) is in progress.

Isozyme Analysis of Candidate Plant Pathogens Used as Mycoherbicides¹

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The Pacific Forestry Centre has begun research to develop essential biological control strategies in forest management. Traditionally, chemical herbicides or burning has been used as silvicultural tools in forest renewal efforts, but increasing public opposition to these methods has caused much research to be directed towards the development of biological control agents (mycoherbicides). The use of potential plant pathogenic fungi as mycoherbicides would require more knowledge of host and geographic specialization, stability in culture and risks involved in transcontinental movement to satisfy registration and labelling requirements.

Recently, *Chondrostereum purpureum* (Pers.:Fr.) Pouzar has been tested as a potential mycoherbicide to selectively remove unwanted brush species by treatment of cut stumps. Proteins from mycelial extracts of Canadian isolates of *C. purpureum* were electrophoretically tested for the activity of 13 isozyme systems and 8 of the systems produced positive activities: acid phosphatase, alkaline phosphatase, β -esterase, β -glucosidase, malate dehydrogenase, Peroxidase, phosphoglucomutase, and polyphenoloxidase. The relative migrations of the bands were generally similar among isolates for a given enzyme system, suggesting the existence of monomorphic loci. However, they varied noticeably in their intensities. These biochemical markers may be related to virulence on basis of ongoing pathogenicity studies. Using Polymerase Chain Reaction (PCR) on nucleic acid extracts, common restriction sites were found among Canadian and European isolates but not the New Zealand isolate, indicating little genetic variability in the species.

So far, search for candidate biocontrol agents was limited to isolations of fungi from diseased plants. Some *Melanconium* spp. are known to occur in Red Alder

(*Alnus rubra* Bong.) either as Symptomless Endophytes (SE), i.e.; fungi that inhabit apparently healthy tissues, or as Disease Syndrome Associated (DSA) microorganisms, i.e.; fungi associated with cankers and necrosis of stems and twigs. Currently, these fungi are under intensive investigations to assess their usefulness as potential biocontrol agents for Red Alder in British Columbia. The biochemical characterization of 20 isolates of *Melanconium* spp. was examined by isozyme analysis. Ten of these isolates were *Melanconium apiocarpum* Link (Synonym: *Melanconium sphaeroideum* Link: Fr., anamorph of *Melanconis alni* Tul. & C. Tul.), of which 5 were DSA and 5 were SE. The other 10 DSA isolates were *Melanconium marginale* Wehmeyer [anamorph of *Melanconis marginalis* (Peck) Wehmeyer], five of which were isolated from *A. rubra* and five from *A. viridis* (Chaix) DC. Native proteins from mycelial extracts of the isolates were electrophoretically tested for the activity of 13 different isozyme systems on polyacrylamide gel. Seven of the systems produced positive activities: acid phosphatase, β -esterase, β -glucosidase, malate dehydrogenase, peroxidase, phosphoglucomutase, and polyphenoloxidase. Banding patterns showed no differences between SE and DSA isolates of *Melanconium apiocarpum*. Two isozyme system; β -esterase and peroxidase were most useful biochemical markers to differentiate between *M. apiocarpum* and *M. marginale* isolates, suggesting that they are taxonomically two different species.

These findings will be discussed in relation to the development of biocontrol agents (mycoherbicides) for forest weeds.

¹ The author gratefully acknowledges the support by a grant from the Science and Technology Opportunities Fund, Forestry Canada, Ottawa, the scientific cooperation of Drs. A.K.M. Ekramoddoullah, C.E. Dorworth, F. Sieber-Canavesi, T.N. Sieber, T.C. Vrain, and R.E. Wall, and the technical support of T.A.D. Woods, D.C. Thom, M. Pollard, and Dan O'Gorman.

Integrating Plant Pathogens into Weed Management Systems.

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Abstract

The successful integration of plant pathogens (as biocontrol agents) into weed management systems will require progress in research to ensure product efficacy and stability. Inconsistency in achieving economic weed control levels is a bottleneck currently constricting commercialization of a number of promising fungi as mycoherbicides. The inconsistency in efficacy can be attributed largely to unfavourable environments at periods critical for infection. To overcome this problem, one systemized approach is to provide a favourable microclimate for the fungi through formulation, the use of specialized diluents or carriers, and specialized application techniques. The favourable microclimate can be provided, at least for some fungi, by use of an invert (water-in-oil) emulsion as a carrier to protect the propagules against des-

iccation. However, the invert-emulsions are mayonnaise-like in consistency and so must be applied with air-atomizing nozzles. Although technologically successful, the invert emulsions have some disadvantages that offer opportunities for further research: they create problems with cleanup of spray rigs; sometimes they are phytotoxic to desirable plants, and the treatments may require too much volume/unit area for practicality. None of these problems is insurmountable. A slow-drying granule sprayable with conventional equipment has been developed and is being evaluated in our lab; preliminary results indicate that these granules may provide at least a partial improvement in this technology. Additional research is ongoing in our lab and elsewhere to evaluate possible combinations of mycoherbicides with low rates of various herbicides.

Field Experiments in Forest Weed Biocontrol

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Small field trials were undertaken over the past decade to test the possibilities of stressing a forest weed (*Rubus parviflorus*) through defoliation, and of preventing weed hardwood regrowth by applying a pathogen after manual cutting.

Thimbleberry (*Rubus parviflorus* Nutt.) was manually defoliated during the early part of July and subsequent measurements made of cover, density, height, intensity of foliar disease symptoms and growth of underplanted Douglas-fir seedlings. Other plots were sprayed with culture suspensions of *Septoria rubi* at different times during the growing season. Neither treatment has so far measurably affected % cover, density or height of *Rubus* but foliar disease intensity was increased in the defoliated plots during the year after defoliation and underplanted Douglas-fir has shown a positive response in both treatments.

Hardwoods (*Acer* spp, *Alnus rubra*, *Betula* spp, *Fagus grandifolia*, *Populus* spp, and *Prunus pensylvanica*) in New Brunswick and B.C. were felled and the stumps treated with mycelial cultures of *Chondrostereum purpureum*. Subsequent records were kept of regrowth through stump sprouting and the formation of *C. purpureum* basidiocarps on the stumps. Trees were also fully or partially girdled (shallow frills made with a hatchet) and *C. purpureum* inserted into the wounds. Stumps infected with *C. purpureum* usually failed to produce sprouts or sprouts formed and subsequently died, while regrowth often occurred in uninfected controls. In fully girdled and inoculated trees, mortality exceeded that in the controls.

It is concluded that biological controls using native pathogenic fungi can be developed. Improvements in efficacy and consistency are needed.

Biochemical Characterization of a Potential Mycoherbicide *Chondrostereum purpureum*

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Introduction

It is evident from the previous presentations of my colleagues on mycoherbicide program at our centre that if a fungus has to be registered for its use as a mycoherbicide, there is a need to have a clear understanding of the fungus in terms of how it works, how their various isolates are related. Is there any variation based on their geographical origin. The isolates of *Chondrostereum purpureum*, which are now being actively examined by R. Wall for its ability to control vegetation are morphologically indistinguishable. Biochemical methods such as zymogram as Simmon mentioned in his talk or total mycelial protein profile of fungi are widely being used to distinguish fungi. In this presentation, I have decided to analyze the total protein profile rather than a group of selected enzymes. Using this approach, we have shown previously that the isolates of an insect pathogenic fungus *Beauveria bassiana* could be distinguished. Similarly, work in collaboration with Charles Dorworth and Thomas Sieber showed that the isolates of endophytic fungi could also be distinguished by their protein profiles. In this study, I examined a total of 18 isolates kindly provided by Dr. Ron Wall of our centre, two isolates were from New Brunswick, four isolates were from south-east corner of this province and the rest were from Vancouver island.

Methods

Isolates of *Chondrostereum purpureum* were first grown in agar plates, a small section from the periphery of the actively growing culture was used to inoculate liquid culture. Mycelia were harvested, lyophilized. Acetone powder was prepared from the lyophilized mycelia. The whole process was repeated on three different occasions which is the basis of three experiments to be described later. To extract protein, 5 mg of acetone powder was extracted with a buffer consisting of SDS, an ionic detergent and mercaptoethanol—a reducing agent, first boiling for 5 minutes followed by another 5 minutes at room temperature with constant stirring. After centrifugation, the supernatant was stored frozen. This method of extraction allowed to solubilize a large number of

membraneous proteins, the heating of the sample also would inactivate proteolytic enzymes that might have been activated during the extraction and degrade proteins which might have given rise to the artificial protein pattern. Prior to electrophoresis, the protein content of each extract was determined by a method which was developed in-house. Thus, to allow comparative analyses of the isolates, each sample on an equal protein basis was subjected to SDS-polyacrylamide gel electrophoresis. Although, it is an electrophoretic separation, because of the presence of SDS, proteins were indeed separated based on their size. Since we used low amount (*3 microgram) of protein sample for maximum possible resolution, we used silver stain which detects proteins in the nanogram range. Stained gels were scanned, quantitated, molecular weight of each of the band was determined from the standard marker. All 18 isolates of a given experiment were on the same gel.

Results and Discussion

A total 50-56 protein bands were detected in a given isolate. Similarity coefficient of a pair of isolates was calculated as the number of matched bands between the two isolates divided by the total number of bands detected in two isolates multiplied by 200. On the basis of three different experiments, the average similarity coefficient was in the range of 75-91. The variation between three experiments was as low as 1% and as high as 15%. In another set experiments, the replicate cultures of a given isolate was compared on the same gel and similarity coefficient was calculated on the basis of a band being detected at least in one of the triplicate cultures of a given isolate, and the similarity coefficient was shown to be much higher (in the range of 85-97). A dendrogram was constructed based on average linkage cluster analysis of similarity coefficients. There were two major clusters. The cluster analyses revealed that although the isolates can be classified into groups, this grouping has no bearing on their sources or geographical origin. These results indicated that *Chondrostereum purpureum* isolate from one region may be used as a mycoherbicide in another region within Canada.

Disease Control Committee 1990-91 Investigations

Robert L. James
Chairperson

The Disease Control Committee met on August 6, 1991 to discuss current and recently-completed control projects. Those in attendance included: Art McCain, Leon Lamadeleine, Willis Littke, Jim Allison, Don Norris, Ken Russell, Susan Frankel, Alan Kanaskie, and Bob James. Listed below are the disease control projects submitted by those in attendance. The list probably only covers a portion of the projects actually conducted.

Seedling Diseases—Nurseries

- 1. Leaf Blight—Stem Canker**
Host: Red Alder
Causal Organism: *Septoria* sp.
Control: Chemical—benomyl, daconil, and Bordeaux mixture alternated at 14-day intervals on crop.
Development Stage: Operational
(W. Littke, Weyerhaeuser Company)
- 2. Root Disease—Bareroot Seedlings**
Hosts: Several Conifer Species
Causal Organisms: *Fusarium* spp., especially *F. oxysporum*
Control: Different types of cover crops with and without polyethylene tarping. Till in cover crops prior to sowing of conifers.
Development Stage: Field Trial
(W. Littke, Weyerhaeuser Company)
- 3. Root Disease—Bareroot Seedlings**
Hosts: Several Conifer Species, especially *Pinus*.
Causal Organisms: *Macrophomina phaseolina*, *Fusarium* spp.
Control: Summer cover crops such as rye, brome, alfalfa, vetch, peas, etc. in conjunction with solarization with polyethylene tarping.
Development Stage: Field Trial
(A. H. McCain, University of California, Berkeley)
- 4. Basal Rot of Rooted Cuttings**
Hosts: Loblolly and Slash Pine, Douglas-fir, and Yew (*Taxus*)
Causal Organisms: *Fusarium oxysporum*, *F. roseum*, other imperfect fungi including *Cladosporium*, *Penicillium*, etc.
Control: Pre-treatment of cuttings with Apribrome®; also use iprodione as a drench after placement of cuttings in growing media.
Development Stage: Operational
(W. Littke, Weyerhaeuser Company)
- 5. Seed Treatment**
Hosts: True fir (*Abies*)
Causal Organisms: *Fusarium* spp.
Control: Pre-sowing treatment with Agribrome®
Development Stage: Field Trial
(J. Browning, Weyerhaeuser Company)
- 6. Biological Control of Root Disease**
Hosts: Douglas-fir container-grown seedlings
Causal Organisms: *Fusarium* spp.
Control: Application of commercial preparations of *Gliocladium virens* either as a top dressing or incorporated into growing media of container-grown seedlings.
Development Stage: Field Trial
(R. L. James, USDA Forest Service, Coeur d'Alene, ID)
- 7. Meria Needle Cast**
Hosts: Western Larch—Bareroot Seedlings
Causal Organisms: *Meria laricis*

Control: Chlorothalonil applied at two-week intervals in the spring and early summer.

Development Stage: Operational

(R.L. James, USDA Forest Service, Coeur d'Alene, ID)

8. Root Disease—Container-grown Seedlings

Hosts: Several conifers including Douglas-fir, western larch, western white pine, Engelmann spruce, ponderosa pine, lodgepole pine, and grand fir.

Causal Organisms: *Fusarium* spp.

Control: Hot water treatment of containers to eliminate pathogen inoculum when containers are re-used to grown several crops of seedlings.

Development Stage: Operational

(R.L. James, USDA Forest Service, Coeur d'Alene, ID)

Foliage Diseases

1. Swiss Needle Cast

Host: Douglas-fir

Causal Organism: *Phaeocryptopus gaumanni*

Control: Aerial application of Bravo 720 with helicopter on chlorotic Douglas-fir plantations near

Tillamook, Oregon. Application in June. Development Stage: Field Trial

(A. Kanaskie, Oregon Dept. of Forestry)

2. Chlorosis/Poor Growth

Host: Douglas-fir

Causal Organism: Possible nutrient deficiency

Control: Applications of nitrogen, phosphorus, and a combination of the two to Douglas-fir plantations in coastal areas of Oregon. Other conifer species are non-symptomatic.

Development Stage: Field Trial

(A. Kanaskie, Oregon Dept. of Forestry)

3. Needle Cast

Host: Douglas-fir

Causal Organism: *Rhabdocline pseutosugae* and *R. weirii* Control: Applications of chlorothalonil in the spring and early summer to tree improvement plantations in Montana.

Development Stage: Operational

(R.L. James, USDA Forest Service, Coeur d'Alene, ID)

Dwarf Mistletoe Committee Report

J. Muir, Chair

The dwarf mistletoe committee met at lunch, August 6th, and discussed recent activities.

Although there was little response to the pre-meeting request for reports on dwarf mistletoe projects, the participants supported the continuation of the committee, and the report, to foster communication and co-operative activities.

They recommended that a request for reports be prepared by the committee chair, and distributed by the WIFDWC secretary as part of the pre-meeting notices. The traditional headings were recommended:

1. Taxonomy, hosts and distribution
2. Physiology and anatomy
3. Life cycle studies

4. Host-parasite relations
5. Effects on hosts
6. Ecology
7. Control—chemical
8. Control—biological
9. Control—silvicultural
10. Surveys
11. Miscellaneous

The following reports were received from the Rocky Mountain Region.

Dwarf Mistletoe Report—1991 Rocky Mountain Region

IV. Control—Silvicultural

Plans are to treat 2,814 acres of dwarf mistletoe infested stands on the Arapaho and Roosevelt; Grand Mesa, Uncompahgre and Gunnison; Medicine Bow; Pike and San Isabel; and White River National Forests (D. Johnson, USFS, R-2).

VI. Dwarf Mistletoe Surveys

Presuppression surveys for dwarf mistletoe are planned for 12,697 acres on the Arapaho and Roosevelt; Grand Mesa, Uncompahgre and Gunnison; Pike and San Isabel; and White River National Forests (D. Johnson, USFS, R-2).

VII. Control—Chemical

Control of lodgepole pine dwarf mistletoe with ethephon—Evaluations on the effects of the growth regulator ethephon on lodgepole pine dwarf mistletoe continued on the Arapaho National Forest in Colorado. Visual inspections on control plots on the Frazer Experimental Forest and at the Cutthroat Bay Campground were conducted in the summer of 1989. In separate tests, ethephon, at a rate of 2500 ppm in water with a surfactant, was applied during August with a bottle sprayer in 1983, a back pack mist blower in 1984, and a hydraulic sprayer in 1985. While more shoots were observed in 1989 than in 1988, many sprayed infections

failed to resprout. It thus appears that additional spray applications may have the potential to reduce the overall number of active infections, and thereby reduce the number of subsequent new infections. Additional tests will be required to prove the above hypothesis.

VII. Control—Chemical

b. Evaluation of field tests of the plant growth regulator, ethephon, has shown that significant abscission of dwarf mistletoe shoots occurs within a few weeks after application. Tests conducted in the Black Forest north of Colorado Springs, Colorado in 1988 on ponderosa pine dwarf mistletoe showed abscission rates of 73 to 98 percent with mid-June, mid-July and mid-August applications of the chemical at rates of 2200 and 2700 ppm ethephon in water with a spreader-sticker.

Examination of trees three years following treatment showed some development of immature shoots on all treatments, but insignificant numbers of mature shoots with fruits on all infections including controls (non-chemically treated trees). The reduction in numbers of infections with shoots observed in the controls is attributed to a combination of natural control agents including, drought, branch mortality, and insects. Observations are planned for several more years to determine when mature shoots will develop on ethephon-treated trees (D. Johnson, USFS FPM R-2).

Projects Status, USDA Forest Service Region 1 (Northern)

R.L. James

New Projects

- White pine blister rust—remeasurement of old permanent plots (J. Schwandt)
- Effects of nutrition on *Armillaria* root disease in Douglas-fir (J. Schwandt, T. Shaw)
- Impact of *Armillaria* root disease in ponderosa pine plantations (J. Schwandt, R. Mathiasen)
- Biological control of root diseases of container-grown conifer seedlings (R. James, K. Dumroese, D. Wenny)
- Sphaeropsis blight of ponderosa pine in northern Idaho (R. Mathiasen, R. James, J. Schwandt)

- Effects of overstory removal and precommercial thinning on growth impacts, spread and intensification and mortality caused by dwarf mistletoe in western larch at the Flathead Indian Reservation, Montana (J. Taylor)

Terminated Projects

- 88-C-4 Efficacy of sodium metabisulphite in reducing root disease inoculum on seedling containers. (R. James, K. Dumroese, D. Wenny, C. Gilligan)

Publications 1990-1991

- Dumroese, R. K., R. L. James and D. L. Wenny. 1990. Trial of a granular etridiazole and thiophanate-methyl mixture to control *Fusarium* root disease of container-grown Douglas-fir seedlings. *New Forests* 4:231-236.
- Entry, J. A., S. K. Hagle and K. Cromack, Jr. 1990. The effect of *Armillaria* attack on the nutrient status on Inland Douglas-fir. *European J. For. Pathol.* 20:269-274.
- James, R. L., R. K. Dumroese and D. L. Wenny. 1990. Approaches to integrated pest management of *Fusarium* root disease in container-grown conifer seedlings. In: Rose, R., S. J. Campbell and T. D. Landis (des.). *Target Seedling Symposium: Proceedings, Combined Meeting of the Western Forest Nursery Associations*. USDA Forest Service, Gen. Tech. Rept. RM-200. PP-240-246.
- James, R. L. and C. J. Gilligan. 1990. Root decay of container-grown western white pine seedlings—Plum Creek Nursery, Pablo, Montana. USDA Forest Service, Northern Region. *Timber, Cooperative Forestry and Pest Management*. Rept. 90-10. 18p.
- James, R.L., S. Metzger and C. J. Gilligan. 1990. Effects of soil fumigation on conifer seedling production at the USDA Forest Service Nursery, Coeur d'Alene, Idaho. USDA Forest Service, Northern Region. *Timber, Cooperative Forestry and Pest Management*. Rept. 90-11. 18p.

1991 Rocky Mountain Region Report

New and Continuing Projects

A. Forest Disease Surveys—General

88-A—Evaluation of site factors involved with aspen sprout mortality (P. Angwin, W. Jacobi).

D. Root and Soil Diseases or Relationships (including Mycorrhizae)

90-D—Root disease impact monitoring (P. Angwin, J. Lundquist, D. Johnson).

79-D-1 Surveys of root diseases in managed conifer stands in R-2 (p. Angwin, J. Lundquist).

79-D-5 Spread of *Armillaria* spp. disease centers in managed pine stands (P. Angwin, J. Lundquist).

F. Stem Diseases: Malformations, Witches'-Brooms, Dwarf Mistletoes, Etc.

85-F-5 Silvicultural control of dwarf mistletoe in young lodgepole pine stands (F. Hawksworth, B. Geils, D. Johnson).

86-F-1 Evaluation of ethephon as a control of dwarf mistletoes in high use recreation forests (D. Johnson, F. Hawksworth).

K. Miscellaneous Studies

90-K—Vegetation management planning in developed recreation sites (D. Johnson, P. Angwin).

Terminated Projects

C. Cone, Seed, and Seedling Diseases

89-C—Field trials on larger scale comparing MC-33, Basamid, and solar heating for effects on soil-borne *Fusarium* spp., weeds, and seedling growth and survival of fall-sown eastern redcedar at Bessey Nursery, Nebraska (D. Hildebrand, G. Dinkel).

K. Miscellaneous Studies

86-K-2 Development of a Tree Health Management Series (THMS) for recreational and urban and community forestry—multivolume slide video tape (M. Sharon).

Recent Publications (as of July 1991)

- Angwin, P.A. 1990. Pest conditions and potential hazard trees in selected campgrounds on the Taylor River Ranger District, Gunnison National Forest, Colorado. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Biol. Eval. R2-90-1. 36 p.
- Angwin, P.A. 1990. Pest conditions and potential hazard trees in Chapman Campground, Chapman Group Camp and Elk Wallow Campground, Sopris Ranger District, White River National Forest, Colorado. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Biol. Eval. R2-90-2. 38 p.
- Angwin, P.A. and E.M. Hansen. 1990. Pairing tests to determine mating compatibility of single-spore isolates of *Phellinus weirii*. In: Proceedings 4th International Mycological Congress, August 28- September 3, 1990, Regensburg, West Germany.
- Averill, R.D. 1991. Potential pest problems in windbreaks, p. 48-50. In: Insecta of windbreaks and related plantings: Distribution, importance, and management. Conference proceedings; 1988 December 6; Louisville, KY. USDA For. Serv. Gen. Tech. Rep. RM-204. Rocky Mountain For. and Range Exp. Sta., Fort Collins, CO. 50 p.
- Forest Pest Management, Rocky Mountain Region. 1990. Guidelines for the use of FPM funding for suppression of dwarf mistletoe in recreation areas. USDA For. Serv., Rocky Mountain Region, May 1990. 7 p.
- Hawksworth, F.G. and D.W. Johnson. 1989. Panel—Mistletoe control with ethephon, p. 29-45, In: Proceedings 36th Western International Forest Disease Work Conference, September 20-23, 1988, Park City, UT. 153 p.
- Hildebrand, D.M. 1991. Comparisons between solar heating, MC-33 fumigation, and Basamid with water seal, for fall-sown eastern redcedar, Bessey Nursery, Halsey, Nebraska. USDA, For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Tech. Rep. R2-48. 6 p.
- Hildebrand, D.M. and W.R. Jacobi. 1990. Comparisons between aspen harvest units with and without adequate resprouting in the Rocky Mountain Region. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Tech. Rep. R2-46. 38 p.
- Johnson, D.W. 1990. Agroforestry, plant pathology and the future, p.51-53. In: Trees Are The Answer: 42nd Annual Meeting, Forestry Committee GPAC, June 1990 Colorado Springs, CO., P.J. Hoefler et al, tech. Coords. Great Plains Agricultural Council Pub. 132.
- Johnson, D.W. and D.M. Hildebrand. 1990. Effects of application rate and timing of ethephon treatments on abscission of ponderosa pine dwarf mistletoe two years following treatment. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Tech. Rcp. R2-47. 9 p.
- Lundquist, J.E., G.A. Tuskan, and J.A. Walla. Progress in developing early screening techniques for resistance of ponderosa pine to western gall rust. In: Proceedings International Rusts of pine Working Group Conference, September 18-27, 1989, Banff, Canada (In press).
- Lundquist, J.E., J.A. Walla, and T.A. Tuskan. Description of two vegetative types of western gall rust. Proceedings International Rusts of Pine Working Group Conference, September 18-27, 1989, Banff, Canada (In press).
- Pasek, J.E. 1990. Douglas-fir beetle infestation following the Clover Mist fire on the Clarks Fork Ranger District, Shoshone National Forest, Wyoming. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Biol. Eval. R2-90-1. 10 p.

- Pasek, J.E. 1991. Sampling windbreaks for borers and defoliators, p. 28-38. In: Insects of windbreaks and related plantings: Distribution, importance, and management. Conference proceedings; 1988 December 6; Louisville, KY. USDA For. Serv., Gen. Tech. Rep. RM-204. Rocky Mountain For. and Range Exp. Sta., Fort Collins, CO. 50 p.
- Pasek, J.E. 1991. Populations of Douglas-fir beetle in scorched and green trees two years following the Clover Mist Fire on the Clarks Fork Ranger District, Shoshone National Forest, Wyoming. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region Biol. Eval. R2-91-01. 20 p.
- Pasek, J.E. 1991. Overwintering egg populations of a pine sawfly, *Neodiprion autumnalis*, on ponderosa pine near Ft. Meade in South Dakota. USDA For. Serv., Renewable Resources Staff, Rocky Mountain Region Biol. Eval. R2-91-02. 16 p.
- Pasek, J.E. and P.A. Angwin. 1990. Forest Pest Conditions in the Rocky Mountain Region 1989. USDA For. Serv., Timber, Forest Pest and Cooperative Forestry Mgmt., Rocky Mountain Region. 34 p.
- Tuskan, G.A., J.A. Walla, and J.E. Lundquist. 1991. Genetic-geographic variation in *Peridermium harknessii* in the north-central United States. *Phytopathology* 80:857-861.
- Tuskan, G.A., J.A. Walla, J.E. Lundquist, C.G. Wang, and P. McClean. The use of molecular markers in studying ponderosa pine-*Peridermium harknessii* interactions. Proceedings International Rusts of Pine Working Party Conference, September 18-27, 1989, Banff, Canada (In press).
- Walla, J.A., G.A. Tuskan, and J.E. Lundquist. 1991. Comparison of white- and orange-spored *Peridermium harknessii* in native North Dakota *Pinus ponderosa*. *Mycologia* 83: 251-256.

Panel: New Perspectives and Forest Health—An Ecosystem Perspective

Jim Byler, Moderator

Introduction

Major changes have taken place in western forests since European settlement. Logging, particularly selective logging of high value timber species, has brought changes in species composition during the past 100 years or so. Fire control has also affected species composition and density during the past 70 years. The changes have occurred slowly, so they have been largely unnoticed. Forest and fire ecologists have documented the changes, and recent research on western spruce budworm and Douglas-fir tussock moth attribute an increased frequency and intensity of outbreaks to some of these changes. The response of forest pathogens to forest changes is not so well documented. But increasing evidence suggests that pathogens have also responded to these altered forests, particularly to changes in species composition. These pathogens have, in turn, brought about further changes.

The response of pathogens to disturbance has a number of implications for pathologists. The implications bear on our research and forest pest management strategies.

The topic also has important implications for current discussions on “new forestry” and “new perspectives.” So we will try to relate our discussions to these topics.

Phil Aune gave an in-depth discussion of New Perspectives in his keynote address, so it won't be necessary to repeat that discussion. I have prepared the following short list of major components of New Perspectives. Several authors suggest New Perspectives means managing forests for:

- forest communities, not timber crops,
- biodiversity, not maximum timber production,
- long-term sustainability of timber and other resources, and
- landscapes, not fragmented stands.

NP is about better application of science, but also about political issues, i.e., the values for which we manage forests.

A major controversy is waging. Various special interest groups and publics are questioning forest management objectives and methods. This is true to some degree on public and private forests in Canada and the United States. Some of the issues relate to Forest Health and to forest ecosystem health. The purpose of our panel is to stimulate thought and discussion on some of the issues that relate to forest pathology. We will present several “case histories” of ways that pathogens have responded to man-caused changes of the present century, and suggest some conclusions that relate to Forest Health and New Perspectives.

Implications of New Perspectives on Forest Pest Management in Westside Pacific Northwest Forests

by Don Goheen

Old Forestry in the Pacific Northwest

- 1) Mature forests harvested by clearcut logging.
- 2) 25 to 60 acre cutting units scattered over the landscape in dispersed pattern.
- 3) Units often cleaned of almost all large-sized unusable material and snags; large down material frequently yarded and piled at landings.
- 4) Units burned for site prep, frequently hot enough to consume most of the slash.
- 5) Units replanted with Douglas-fir at close spacing.
- 6) High capital investment in the first few years for animal damage control, competing vegetation control, etc.
- 7) Precommercial thinning scheduled at age 10-15.
- 8) Commercial thinning frequently scheduled at fairly early age.
- 9) Overall goal was fast growth and full utilization of the site by Douglas-fir; A DEFINITE DOUGLAS-FIR MENTALITY.

In Recent Years, Major Rumbblings of Change

- 1) Increase awareness, interest, and participation by the public in determining forest management direction.
- 2) Attendant increase in concerns about objectives other than timber production.
- 3) Concerns about health and safety effects of old methods.
- 4) Concerns about long-term ecological effects of old methods.
- 5) Controversy about status of old-growth forests as a limited resource.
- 6) Concern about possible extermination of plant and animal species.

It Is Now Becoming Increasingly Difficult to Practice Business as Usual! What Is the Alternative? A New Perspective.

To quote from Jerry Franklin—advocate of a new approach to forest management in the Pacific Northwest:

Forestry is at a crossroads. For decades we thought we knew all that we really needed to know about forests. But in fact our level of knowledge is remarkably superficial.

The more time I've spent studying forests, the more I've come to appreciate their richness. The traditional approach to the management of forestland has reflected a simplistic attitude that has homogenized these complex systems. The result has made them efficient at producing the products and amenities that interest us. But in the search for that efficiency, we've sacrificed other values.

Is there an alternative to the stark choice between tree farms and total preservation?

My associates and I in the Andrews Ecosystem Research Group believe that an alternative does exist, and we call it "The New Perspective Forestry." We view the new approach as a kinder and gentler forestry that better accommodates ecological values, while allowing for the extraction of commodities. The focus in New Forestry is on the maintenance of complex ecosystems and not just the regeneration of trees.

What Is the New Perspective?

- 1) An ecological approach to forest management.
- 2) Discussed earlier in the meeting in some detail by Phil Aune.
- 3) "New Perspectives" is a philosophy or attitude, not really a tightly defined approach... But there are some general ideas that many of the people thinking about "New Perspectives" at least sort of agree on:

- a) On large area level, there should be a system of interconnected reserved areas to provide old-growth habitat and study areas.
 - b) Retention of large snags and down trees should be a concern everywhere.
 - c) Species diversity and vertical diversity should be of special concern and it's likely that many trees (8-15 per acre) will be left on most harvest areas.
 - d) Riparian ecosystems should be protected.
 - e) Canopy closure should be delayed—planting and thinning will be at wider spacing.
 - f) Fragmentation should be minimized—cutting units will not be dispersed as in the past. There may be large sloppy clearcuts with groups or many individual trees reserved.
- 2) Recommended management has involved delineating diseased areas and treating them by inoculum removal or by favoring less susceptible tree species than Douglas-fir.
 - 3) A real benefit of the "New Perspective" approach as far as pest management is concerned would be the commitment to diversity—an escape from the old "Douglas-fir is the only worthwhile species" mentality. This should allow the species manipulation approach to root disease control to be embraced with greater enthusiasm.
 - 4) Some things wouldn't change, however. Good root diseasemanagement requires good inventory information and quality record systems. These are currently lacking in many cases and "New Perspectives" will not necessarily remedy the situation.
 - 5) Also, if "New Perspectives" is truly to be an ecosystem approach to forest management, an understanding of the ecological roles and significance of pests (especially laminated root rot in the case of Westside stands) should be an integral part of the package. So far, in my opinion, this has not been the case. Insect and disease implications have largely been ignored by the main proponents of "New Perspectives."

What Would Be The Effect of This Approach on Pest Management?

- 1) Laminated root rot is really the big forest pest concern in the Westside Pacific Northwest.

Eastern Oregon Forests

by Gregory M. Filip

Before the turn of this century, the forests of eastern Oregon and much of the interior West were typically open-grown stands of Ponderosa pine. Through fire-prevention policies and selective harvesting of the more valuable pines, these forests evolved into stands composed largely of fire-intolerant and less valuable Douglas-fir and true fir. Only infrequently did such forests exist before. As a consequence of this unprecedented biomass of fir, forest pests such as root pathogens, stem decay fungi, dwarf mistletoes, defoliating insects, and bark beetles are causing growth loss and tree mortality at alarming levels. In the traditional sense, our forests are sick!

Root diseases caused by *Armillaria ostovae*, *Phellinus weirii*, and *Heterobasidion annosum* are common especially in Douglas-fir and true fir in mixed-conifer stands. Pine and larch are much more resistant to these pathogens (the "P" strain of *H. annosum* is damaging to pine primarily in some pine sites in southern Oregon). Stem decays caused primarily by *Echinodontium tinctorium* and *H. annosum* are common in the true firs, especially wounded and suppressed trees. The dwarf mistletoes, *Arceuthobium douglasii* and *A. abietinum*, are abundant in Douglas-fir and true fir, respectively. *Arceuthobium douglasii* is the most damaging disease of Douglas-fir in eastern Oregon, and *A. abietinum*, together with the canker fungus *Cytospora abietis*,

cause growth loss and mortality in true firs in the Cascade Mountains.

The traditional emphasis on forestry in eastern Oregon as well as most of the West has been on timber values; agents that reduced growth and yield of timber were considered only as "pests." Only recently has the role of "pests" been viewed as possibly contributing to forest productivity and stability. Fire historically has been suppressed but now is viewed as beneficial because low-intensity frequent fires return dead wood to the soil as nutrients and reduce forest susceptibility to certain insects and diseases by selectively removing host tree species. In the absence of fire, insects and diseases themselves may actually contribute to forest health by tailoring tree density and species composition to site conditions and recycling nutrients through defoliation, decay, and death. An increasing body of data suggests that non-traditional values such as wildlife habitat and biodiversity may be improved by certain pests: dwarf mistletoe brooms in Douglas-fir are used for nest sites by spotted owls, stem-decayed trees provide nesting and roosting sites for pileated woodpeckers, and root diseases open forest canopies that create biodiversity and improve habitat for deer. The forests of eastern Oregon are "dying to be better." Through proper silviculture, we can help our forests help themselves to maintain better forest health.

Montana and Idaho Forests

by Jim Byler

I should begin by acknowledging the contribution of Sue Hagle. Sue was scheduled to present this paper, but was unable to attend the meeting. Some of the observations, literature citations and concepts in this section are Sue's or the results of joint efforts of the past several years.

Ponderosa Pine Forests

We have a situation in western Montana similar to eastern Oregon that Greg described. Frequent surface fires once maintained open stands of mature Ponderosa pine. These have been converted to dense stands of Douglas-fir, the climax species, through selective cutting of the high-value pine and fire control. The stands are now seriously damaged by *Armillaria* root disease, western spruce budworm and sometimes Douglas-fir dwarf mistletoe.

I believe the implications for Forest Health are clear. The problems created by disease (and insects) can be managed, perhaps can be only managed economically, by silvicultural methods. The only long-term, economically viable solution to the "pest" problems is to recreate pine forests on these sites. This can be done through various forms of intermediate and regeneration cutting, the use of prescribed fire, or combinations of the two.

What about New Perspectives? We now have forests that are "unnatural" in a successional sense. We have produced new climax forests where they did not naturally occur. Insects and pathogens are having a major effect on the long-term timber productivity. What will the effect be on wildlife species that presumably adapted to the pine forests? We have few true old growth forests, and Douglas-fir understories are developing in these.

One of the values the public is very concerned about is visual quality. Perhaps we have an opportunity to practice uneven-aged management on these sites. Group selection, supplemented with prescribed fire, may be a suitable way to achieve and create healthy forests. Planting pine and favoring pine through precommercial thinning may be closer to nature's way than large clearcuts—many of which have failed on these sites. Shelterwoods also have been used with success. The challenge is to recreate the open stands of Ponderosa pine that many find so beautiful, and that will also be healthy and productive.

Western White Pine Forests

The literature indicates that several million acres of pure or nearly pure western white pine forests were present in northern Idaho in the 1880's. The present stands on these sites are now largely composed of Douglas-fir and grand fir. They were converted to these species by white pine logging, mountain pine beetle, and white pine blister rust. We have also planted Douglas-fir, using logging practices that were developed for coastal forests. Root diseases, particularly *Phellinus* root disease, have caused heavy losses to timber and watershed values. The successional patterns have been altered in a major way, and the "golden age of western white pine" that once occurred from stand age 150-250 has been omitted altogether.

This example also has important implications for Forest Health. Timber losses can be reduced somewhat by risk-rating stands for root disease and accelerating the harvest in these stands. Some stands with white pine can be brought to merchantable size by pruning. But the long term approach must be to manage for healthy stands of site-suited species, including western white pine. This will require a major remedial effort in many stands now so severely affected by root disease that little remains to support the costs of regeneration. It will also require a long-term commitment to the rust-resistant white pine breeding program.

Lodgepole Pine Forests

The result of the changes that have taken place in lodgepole pine forests was dramatically illustrated by the fires of 1988. Wildfire is the primary natural recycling agent in lodgepole stands in the northern U.S. Rocky Mountains. Stand replacement fires occurred historically every 70 to 150 years. Mountain pine beetles dramatically set the stage for fires in mature stands. The role of disease is less dramatic and less clear. But it is known that dwarf mistletoes increase fire intensity. And observations suggest that these agents and others like *Commandra* blister rust kill mature pines in old-growth stands that were not so affected by the beetles, and increase the risk and intensity of wildfires.

Fire has been withheld from many of these stands for the past 70 years or so. Many believe the increased fuel accumulation over large acreages set the stage for the severe fires in the Glacier and Yellowstone ecosystems in 1988. Lodgepole pine forests also continue to change in other ways, in part due to pathogens. The change is to a climax forest of subalpine fir in some habitat types. Stands of short-lived, severely diseased subalpine fir now cover large areas in the northern Rocky Mountains.

What are the implications of Forest Health and New Perspectives for lodgepole pine forests? The most damaging pest is dwarf mistletoe, and approximately half the acreage is affected. Left alone, the forests will continue to change, either as the result of wildfires or with-

out them. The "no action" alternative seems undesirable, particularly since millions of dollars are periodically spent trying to control the resulting wildfires. The let-burn policy can be used in wilderness areas, but natural ignitions may be insufficient to produce the desired outcome. Some of the acreage can be managed through regeneration cutting. If regeneration cutting is used, dwarf mistletoe must be dealt with, and clearcutting with natural regeneration or planted stock is often the only option to maintain productivity. Some forests with increasing fire hazard due to pathogens and insects are outside of wilderness areas or areas managed for timber—and no actions are planned.

Discussion and Conclusions

Jim Byler

I'll suggest several ideas/conclusions/opinions to start the discussion:

- Forest pathologists should emphasize Forest Health through Silviculture, not Forest Pest Management through Integrated Pest Management. We, like the entomologists, speak of managing forest pests through IPM. But, with few exceptions, silvicultural manipulation is the cost-effective, lasting approach to managing native forest pathogens in natural forests. We need to match the strategy to the system being managed and the values at stake. IPM is most effective for the management diseases in high value, easily manipulated systems, and nursery diseases, for example.
- A Forest Health strategy must have an ecological basis. We have given examples of serious disease problems that have been created by the way our forests have been managed. My three examples illustrate mismanagement, the introduction of an exotic pathogen, and nonmanagement. In each case we have upset community stability or ecological balance, and disease outbreaks are the result.
- The knowledge needed for sound management comes from an understanding of pathogen and ecosystem ecology. The better we understand our ecosystems, the better we will be able to manage for healthy forests that will meet our needs for wildlife, fire hazard, watershed, timber and other values. In the meantime, we will have the best chance of success if we stay pretty close to nature's ways. Some of the problems we have referred to could have been predicted and prevented. Others might not have been—and the results of these long-term experiments have only become apparent after several decades.
- The application of principles of New Perspectives will vary greatly by ecosystem. Ecological PRINCIPLES will be valid everywhere, but forest PRACTICE will vary. Our examples show this. New forestry practices Don described may be appropriate for Coastal forests, but the interior Ponderosa pine, white pine, and lodgepole pine forests each require very different treatment. We need better information on ecological processes involved in different forest and habitat types, the effects of different pathogens in those types, and the response of the pathogens to stand treatments.
- We pathologists and foresters need a long-term perspective. The problem is with our time scale. The disease outbreaks have developed over decades. The solutions will require decades. Public opinion and the politics of forest management change frequently. We need to be a part of the current dialogue, and indeed, the dialogue gives us an opportunity to discuss forest disease and forest health that we may never have had before. But we need to keep a long-term perspective and maintain a long-term strategy of forest health, forest health through sound silviculture based on a thorough knowledge of our forest ecology and the response of pathogens to silvicultural treatments.

So, What Is Forest Health Monitoring?

Charles G. Shaw III¹

Abstract

The USDA Forest Service and Environmental Protection Agency have designed a national system to annually monitor the health of forests in the United States. This system has three tiers—each with a different intensity of activity and with specific, complementary goals. **Detection Monitoring** will collect field data on thousands of sites coupled with remote sensing surveys throughout the nation's forests to document ecosystem condition and to detect changes in condition over time. **Evaluation Monitoring** will begin when Detection Monitoring uncovers unexpected changes in forest condition; it will obtain more detailed information through special studies designed to establish specific causes of changes in condition. **Intensive-site Ecosystem Monitoring** will be conducted on about 20 research sites representing major forest types. Its purpose is to provide long-term data that will advance our understanding of ecosystem processes so that changes can be understood and predicted.

Keywords: forest monitoring, indicators, permanent plots

Introduction and Background

The United States has recently initiated an ambitious inter-agency program to document status and trends in the ecological health of its forests (Radloff *et al.*, 1991). This program developed from the 1988 Forest Ecosystems and Atmospheric Pollution Research Act (Public Law 100-521). PL 100-521 directed that "The Secretary (of Agriculture), acting through the United States Forest Service shall —(a) increase the frequency of forest inventories in matters that relate to atmospheric pollution

and conduct such surveys as are necessary to monitor long-term trends in the health and productivity of domestic forest ecosystems—." The intent is to design a program relatively uniform in measurement protocols so that data can be examined, compared, and reported on a national or regional basis. The monitoring will provide data on current forest conditions, so that changes can be documented and meaningful inferences drawn about causes of change.

We define monitoring as the repeated recording of pertinent data over time for comparison with a reference system or identified baseline. Monitoring is always concerned with the determination of changes over time. We define Forest Health as the state of the forest as measured by its functioning and with reference to its normality at any given time.

The Forest Health Monitoring program has been developed in close coordination with and assistance of the Environmental Protection Agency, Environmental Monitoring and Assessment Program (EMAP) (Palmer *et al.* 1991). The EMAP program was designed to monitor ecological resources of the United States. The Forest Health Monitoring Program described here is only one of seven resource categories monitored in a coordinated national program (Palmer and Jones 1992).

From a forest resource management perspective, the goals of Forest Health Monitoring are threefold:

1. To detect changes and to establish a baseline to determine if, when, and where changes are occurring and to quantify those changes.
2. To evaluate possible causes of change. If a change is undesirable, unexpected, or unexplained, it is im-

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portant to evaluate the cause of the change to decide if remedial action is indicated. If a change results from a planned manipulation, it is important to document the cause/effect relationship to evaluate the management practice. For example, management practices could be related to control of air pollution or forest harvest practices. Natural and desirable changes should be evaluated to enhance understanding of the resource for future management.

3. To increase our ability to anticipate or predict changes in forest resources. This is achieved by understanding the processes that are involved in regulating the function and controlling the structure of forest ecosystems. Forest ecosystems change rather gradually because they are dominated by long-lived individuals (trees). Therefore, many forest ecosystem processes can be understood only by repeated, long-term observations. Even the development of researchable hypotheses is often possible only after many years of observing the state of the ecosystem. Finally, a better understanding of the processes that control the functioning of forests will make it possible to better define baseline conditions.

The Three Tiers of Forest Health Monitoring

The program has three tiers of interrelated monitoring activities: Detection Monitoring, Evaluation Monitoring, and Intensive-site Ecosystem Monitoring. Detection Monitoring records the condition of forest ecosystems, estimates baseline conditions, and detects changes from those baselines over time. Evaluation Monitoring determines the causes of detected changes, if possible, or hypothesizes causes that can be tested experimentally or with information from Intensive-site Ecosystem Monitoring. Intensive-site Ecosystem Monitoring provides high quality, detailed information that can be used (1) for a rigorous assessment of cause/effect relationships, and (2) to support experimental research on a small set of representative ecosystems. All three tiers are needed to fully understand the state of health of forest ecosystems.

A fourth component of the program, which applies to all three tiers of monitoring activity, is research on monitoring techniques (Lund, 1992). This activity necessarily involves research on topics such as: sampling methods, sampling design, statistical analysis, assessment, remote sensing and other measurement procedures, and indicators of forest health. Research on monitoring techniques

ensures that Forest Health Monitoring will continue to be effective and efficient.

DETECTION MONITORING consists of a network of permanent plots distributed throughout the forests of the United States, coupled with remote sensing observations and pest surveys. The sampling frame for the permanent plots connects an existing Forest Service network of inventory sample locations to a hexagonal grid of some 12,600 points across the contiguous United States (Palmer & Jones, 1992). This design allows for augmentation with additional sample locations as needed to represent all forest lands in the United States. From this augmented network, a subset of some 4,000 "sentinel plots" in forested lands, which comprise roughly one-third of the land base in the contiguous United States, will be visited annually. Sentinel plots are selected to closely conform with the EMAP network of 40 km² hexagons (Palmer & Jones 1992). The amount of information collected on sentinel plots will be greater than that collected during regular forest inventories.

A component critical to this phase of the program is selecting attributes to measure on the plots (Hunsaker & Carpenter 1990). EPA has developed a process for testing and selecting these attributes, called indicators (Knapp *et al.*, 1990; Riitters *et al.*, 1992), and the FHM program follows these procedures. Desirable features to look for in indicators include: an early and observable response to perturbation events; a high precision (low variation) for measurement recording; capable of being successively remeasured; known inferences can be drawn from changes that occur over time; and relatively inexpensive to implement. Some general indicators that have been evaluated in pilot tests in major regions of the U.S. over the past two years are: landscape attributes; visual symptoms of damage on trees or other vegetation; growth efficiency; foliar nutrient status; and soil characteristics.

Landscape characterization of vegetation and land use patterns likely will be initiated through thematic mapping from satellite imagery or aerial photography, and then ground-checked on the plots (Czaplewski, 1992). Evaluation of visual symptoms involves checking for biotic and abiotic effects on vegetation, primarily foliage. Specific measurements include crown ratio, crown diameter, crown density, crown dieback, and foliage transparency and retention. These attributes must be described so that repeated observations over time can be evaluated to determine if changes in them, individually or collectively, represent impacts on forest health: Growth efficiency currently is determined primarily

through tree ring analyses. Nutrients are currently evaluated from foliage collected in the upper portion of tree crowns, and soils are evaluated for physical, chemical, and biological components.

These "core indicators" may be augmented by several potential indicators currently under test. These include:

- Lichens (characterization and chemistry)
- Photosynthetic Active Radiation (PAR)—may emulate leaf area and is a part of the growth efficiency indicator
- Tree Height Growth
- Understory Vegetation and Wildlife Habitat
- Tree Core Dendrochronology and Chemistry
- Bioindicator Plants (i.e., ozone impacts, etc.)
- Root Diseases
- Soil Microbiology (mycorrhizae)

For whatever indicators are measured, several subsamples are taken on each sentinel plot for each indicator to account for within-plot variation. Information derived from indicators on the sentinel plots will be coupled with information collected during routine forest pest surveys and other specifically focused monitoring activities. All information will be spatially linked (Czaplewski, 1992) to provide a more complete, annual estimate of forest condition.

Over 700 sentinel plots have been established in 12 states during the first two years of the FHM Program. Each plot established represents 640 km² of forest land. Preliminary results indicate that the EMAP grid network provides for a representative sample of forest types and stand/age class distribution. Furthermore, except for the American beech situation noted below, no unexpected phenomena have been detected during this baseline establishment period. As indicated earlier, we anticipate the need to collect data over several years before any inferences concerning change can be drawn.

EVALUATION MONITORING will usually be activated by the results of Detection Monitoring. When Detection Monitoring reveals changes that represent areas or problems of concern, a specific evaluation will be made to determine necessary follow-up activities.

The details of Evaluation Monitoring cannot be specified in advance and thus have not yet been fully developed. By definition, Evaluation Monitoring will be implemented where unexplained changes have been detected, and it will be tailored to the specific nature of the problem. Activities could include additional targeted

surveys, site-specific evaluation visits, more detailed temporary monitoring, and specific research studies.

Detection Monitoring plots identified an unusual amount of dieback in American beech during the 1990 field season in the New England States. An Evaluation Monitoring program has subsequently been initiated to survey this problem.

INTENSIVE-SITE ECOSYSTEM MONITORING will be designed to provide a more complete understanding of the mechanisms of change in forest ecosystems. Monitoring at this level provides data from a group of precisely measured parameters to better understand causal relationships and predict direction and rates of changes in forest condition.

Ecosystem Monitoring sites will represent key forest ecosystems throughout the United States. Ten to 20 primary sites likely will be established to represent major forest ecosystems. These sites will be centers for collecting detailed information on all components of the forest ecosystem. The purpose of these detailed monitoring sites is to supplement Detection and Evaluation Monitoring and to support mechanistic research to identify, describe, or model tree and forest processes in ways that: (1) increase basic understanding of causal relationships; (2) provide explanations or projections of observations in the other levels of the Forest Health Monitoring system; (3) help anticipate changes in forest health; and (4) provide the understanding necessary to develop management responses to unexpected changes. The sites differ from Detection Monitoring sites in the frequency of measurement (i.e., daily vs. annual) and the number of parameters measured (many vs. few).

In some cases, the availability of this detailed information might resolve questions that were raised but not answered by Detection or Evaluation Monitoring. Information from Intensive-site Ecosystem Monitoring will contribute to better understanding of intra-site variability as well as better understanding of relationships between Detection Monitoring indicators and other ecosystem characteristics.

More importantly, Intensive-site Ecosystem Monitoring will provide long-term data and the sampling infrastructure that will support research on mechanisms and processes that shape forest ecosystems. In this sense, Intensive-site Ecosystem Monitoring sites are similar to the United States National Science Foundation's Long-Term Ecological Research (LTER) sites (Franklin *et al.*, 1990). Information from Ecosystem Monitoring sites can be augmented with additional short-term measure-

ments or it can be expanded by measuring new variables during specific studies. Such studies, along with ecosystem process modeling efforts, will be needed to enhance the value of the Intensive-site Ecosystem Monitoring information in context with the more extensive aspects of the Detection and Evaluation Monitoring data and analyses.

Together, data from all three tiers of monitoring should provide a statistically reliable basis from which to determine the nature and direction of change in forest condition and if any such changes have resulted in a deterioration of the system's health. If so, then the Forest Service can use the data to determine if certain land management practices need to be changed. Similarly, the data also may allow the Environmental Protection Agency to evaluate if further regulations may be necessary to control possible off-site pollutants.

The experience gained in establishment of a forest health monitoring program provides several concepts for future consideration. Different types of permanent plots can be established, based upon the objectives of the monitoring program and associated spatial and temporal resolutions. A sampling design that provides unbiased regional estimates is critical to the success of forest assessments. A continuous indicator evaluation process is needed to improve the effectiveness of the monitoring program. A sound information management program facilitates the evaluation of the field data and its rapid dissemination to clients. Cooperation between agencies will extend resources and improve the overall utility of the information derived.

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