PROCEEDINGS OF THE 29th ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

Vernon, British Columbia
September 1981

Proceedings of the 29th Annual Western International Forest Disease Work Conference

Vernon, British Columbia
September 1981

Compiled by:
Charles G. "Terry" Shaw III
USDA Forest Service
Rocky Mountain Research Station
Fort Collins, Colorado

Proceedings of the Twenty-Ninth Western International Forest Disease Work Conference
Vernon, British Columbia September 1981

Compiled by Charles G. "Terry" Shaw III

TABLE OF CONTENTS

SPECIAL PAPERS

WIFDWC BUSINESS AND COMMITTEE REPORTS

Foreword

The Twenty-ninth Annual Western International Forest Disease Work Conference was held September 15-18, 1981, in Vernon, British Columbia. The theme of the conference, "Is it worth it?," provided the basis for panel discussions on dwarf mistletoe control, disease problems in management of true fir regeneration, root disease control strategies, and surveys for forest diseases. A spirited keynote address by our own Norm Alexander, reports on new and modified projects, several special papers, committee meetings, a most informative field trip, the traditional banquet with its associated ceremonies, and a brief business meeting rounded out the formal program.

Eighty-nine registered for the conference, an attendance within the range now expected for a WIFDWC held in the "Golden Triangle" (see p. 86 of last year's Proceedings). There was a good turnout of "oldtimers," and graduate student interest seemed particularly high--a good sign for the future of our profession.

Officers for the 29th conference were:

Larry Weir	Chairman
Terry Shaw	Secretary-Treasurer
John Schwandt	Program Chairman
Duncan Morrison and Rich Hunt	Local Arrangements

Our thanks for their efforts in developing and providing an interesting and worthwhile conference.

In Memory

Charles Donald Leaphart
1922-1981

Dr. Charles Donald Leaphart, "Don" to many of us, was killed in an automobile accident, March 13, 1981. He was a charter member of the Western International Forest Disease Work Conference and a highly respected professional colleague of all forest pathologists who were privileged to know him. The entire membership of the WIFDWC is counted among those deeply saddened by his death.

Dr. Leaphart was born in Sheridan, Wyoming, September 19, 1922. The family moved to Missoula, Montana, in 1929 where Don attended local schools and college. He served as an officer in the infantry of the U.S. Army during World War II.

Don received a Bachelor of Science degree in Forestry from the University of Montsna in 1948. In 1954, he earned the degree of Doctor of Philosophy in Plant Pathology from Yale University. Thus, he joined the ranks of John Shaw Boyce trained forest pathologists who were to shape the destiny of forest pathology in the western United States for many years.

Dr. Leaphart actually began his career with the Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, United States Department of Agriculture, in Missoula, Montana. In 1954, the Division of Forest Pathology was incorporated into the research branch of the USDA Forest Service, where Don spent most of his career investigating diseases of conifers in the western United States. He was soon recognized by his superiors and contemporaries alike as a conscientious and dedicated employee, a potential and rapidly developing leader in his chosen field of endeavor. His many scientific publications on a variety of forest tree diseases--dwarf mistletoes, needle diseases, root rots, abiotic diseases, blister rust, and pole blight--attest to his versatility, flexibility, and diverse interest. To all who know or have read of his works, his soundness of judgment, logic, reasoning, and intuition are evident. His innovative and systematic investigations of the etiology and epidemiology of pole blight in western white pine distinguished him as the authority on the subject. Even today, his published works on pole blight remain the most significant contribution to our understanding of this disease complex. In 1960, Don was transferred to the Forestry Sciences Laboratory at Delaware, Ohio, to spend 3 years investigating decays of hardwoods, mainly oaks. In 1963, he returned to the Intermountain Station, Ogden, Utah, as an assistant research administrator. He moved to the Forestry Sciences Laboratory, Moscow, Idaho, in 1965, where he led a team of research scientists investigating biological, chemical, and silvicultural controla for white pine blister rust. Don retired from the Forest Service in 1976 and became a commercial fisherman. His base port was Westport, Washington, where he resided with his wife, Mary.

Dr. Leaphart meant many things to many people in different walks of life. Some of us knew him as a true friend, a loysl companion, a colleague, a mentor, and even as a brother. While he will be missed by some more than by others, he is certain to be missed by all who knew him because Don inspired a messure of hope, pride, and happiness in all the hearts he touched along his journey in life.

ED F. WICKER

Clarence C. Gordon
1928-1981

Dr. Clarence C. "Clancy" Gordon died of cancer in Winthrop, Washington, July 12, 1981. He is survived by his wife, Nancy Ward Gordon, Missoula; two daughters, Rebecca Gordon, Seattle; and Julia Gordon, Missoula; and one son, Barry Gordon, Missoula.

Clancy was born July 26, 1928, in Seattle, Washington. He graduated from Queen Anne High School in 1947. From 1947-50 he worked for the Nakat Packing Co. of Seattle, first as 2nd engineer and finally as 1st mate on a cannery tender. In 1950, Clancy entered the armed services and in 1952 was discharged with the rank of sergeant after serving with the 140th Tank Battalion 40th Division in Korea. He obtained his B.S. degree in botany from the University of Washington in 1956 and his Ph. D. in plant pathology from Washington State University in 1960.

In 1960, Clancy began his teaching career as a forest pathologist in the Botany Department of the University of Montana.

His first work in mycology and fungal diseases of trees soon broadened to problems concerning environmental quality. He was instrumental in creating the Environmental Studies Program at the University and was its first director. Clancy's efforts in behalf of environmental qualiity are best summed up in a resolution by the Board of Regeants of Higher Education (Montana):

> Dr. Gordon's consuming efforts have been involved in the protection of the environment and as such he was advisor and consultant to many concerned state and federal agencies and as an expert witness in hearings and litigations. He also served with such private groups as the Rachel Carson Trust for a living Environment (as a member of the National Board of Consulting Experts), Scientists' Institute for Public Information (as a member of the Board of Directors), Environmental Defense Fund (as Scientific Advisor and Board of Directors Member), Northern Rocky Action Group (as a member of the Board) and many professional organizations as well. As Professor of Botany, Director of the Environmental Studies Program, advisor to private and government agencies and active researcher, he contributed unsparingly of his time, efforts and experience to the academic well-being of his colleagues and students. He enhanced the educational opportunities at the University of Montana and he influenced the quality of the environment for the citizens of Montana and across the country. His tremendous capacity for work, his high ideals and dedication to principles of respect for the environment earned him the gratitude of friends and professional associates throughout the Nation.

An endowed scholarship to aid University of Montana graduate students who have demonstrated ability and effectiveness in working on environmental problems has been established as a living memorial to Clancy. Contributions to the Clancy Gordon Scholarship Fund should be sent to the UM Foundation, 600 University Ave., Missoula, MT 59812.

Clancy--we'll miss you!

TOM LAURENT

Welcome

Duncan Morrison
Co-Chairman, Local Arrangements

Mr. Chairman, Ladies and Gentlemen:

It is indeed a pleasure to welcome you, on behalf of Forest Pathologists in British Columbia, to Vernon and the 29th meeting of WIFDWC. We are pleased to have the opportunity to show you some of our problems and to discuss what we are doing about them.

It is 16 years since the conference met at Kelowna, a few kilometers down the road. Out of curiosity, I looked at the proceedings of that meeting to find out what transpired. The usual uninhibited enthusiasm prevailed throughout the pre-banquet happy hour, a well balanced performance won the Hansborough-Nordin trophy and the three panels discussed needle casts, insect-disease relationships and growth impact and economics of dwarf mistletoe control.

Many of the problems that concerned us 16 years ago are still with us; we are again discussing economics of mistletoe control. The difference is that now we are almost exclusively dealing with these problems in second-growth instead of in old-growth stands. Biologically sound, economically feasible guidelines for management of diseases in second-growth stands are urgently required. We are making progress, however, my impression is that demand exceeds supply. We have an opportunity over the next few days in the formal sessions and in discussions with colleagues to get up to date in a number of problem areas.

In conclusion, I would like to extend a special welcome to everyone who is attending their first WIFDWC, particularly the contingent from the B.C. Ministry of Forests led by Bob De Boo.

Opening Remarks

Larry Weir, Chairman

On checking back through previous proceedings to try and determine the tenor of my remarks this morning, I found an increasing disregard for publishing the deathless prose expounded by conference chairmen. This would lead me to infer that my words, normally of high moral tone and cogent besides, will be treated with the same callous disdain. Be that as it may, I do have three things of importance to get across. The first is that it is heartwarming to note the presence at this conference of so many of the founding fathers. Secondly, for the benefit of you newcomers who have not been exposed as yet to the relatively unique qualities that make this conference a success, you must participate.

Reed Miller
A founding father

Reticence, shyness, and other like virtues have little place here. Freewheeling discussions that may at times become arguments are the order of each day of this week. You are urged to voice your opinions pro or con on any of the topics program chairman John Schwandt has placed on the agenda. The "oldtimers" will show the way.

The 29th annual Western International Forest Disease Work Conference is now officially under way.

John Schwandt
Program Chairman

Agenda

Monday, September 14, 1981

Evening: Registration, hospitality room

Tuesday, September 15, 1981

8:00 am Registration

9:00 Welcome: Duncan Morrison
Introductions
Keynote Address: Norman E. Alexander

10:00 Appointment of Interim Program Chairman
New, modified, and terminated projects
Coffee

11:15 SPECIAL PAPER:
Maintaining and protecting long-term forest research experimental plots: Bob Scharpf

11:30 Lunch
Dwarf Mistletoe Committee meeting

1:30 pm PANEL: DWARF MISTLETOE CONTROL--IS IT WORTH IT?
Dwarf mistletoe control economics in the Northern Region: Oscar Dooling (moderator)
Lodgepole pine dwarf mistletoe control in the Cariboo Forest Region: Ted Wilford
Economics of dwarf mistletoe control in California recreation areas: John Pronos
Coffee

3:40 SPECIAL PAPERS:
Economics of dwarf mistletoe control in black spruce stands: Fred Baker
Association of black stain root disease with pre-commercial thinning of Douglas-fir: Tom Harrington
Phaeocryptopus gaeumanii on Douglas-fir in New Zealand: Ian Hood
Yellow-cedar decline/dieback in southeast Alaska: a preview: Terry Shaw

5:00 Adjourn

8:00 CLINIC/WORKSHOP:
Christmas tree and nursery problems: Open discussion

Wednesday, September 16, 1981

8:00 am SPECIAL PAPERS:
Comandra blister rust on lodgepole pine in the Rocky Mountain region: Brian Geils
The pinewood nematode, *Bursaphelenchus xylophilus*, in Minnesota, Iowa, and Wisconsin: Mike Wingfield

8:30 PANEL: DISEASE PROBLEMS IN MANAGEMENT OF ADVANCED TRUE FIR REGENERATION
Management of Pacific silver fir and subalpine fir advance regeneration in British Columbia: Les Herring
Problems of dwarf mistletoe in advance regeneration of true firs: Bob Scharpf
Root-disease problems in true fir: Dick Parmeter
Decay in grand and white firs: Paul Aho (moderator)
Coffee

11:30 Lunch
Root Disease Committee meeting

1:30 pm PANEL: ROOT DISEASE CONTROL STRATEGIES--ARE THEY WORTH IT?
Ongoing research for the control of laminated root rot: Walt Thies
Comments on vibro stump puller: Ken Russell
As a forest manager, when should I consider control for root diseases: Gordon Wallis
What are some ecological consequences of root disease control?: Dick Smith
How can I justify control costs?: Ken Russell (moderator)
Armillaria in New Zealand: Ian Hood
Coffee

4:15 SPECIAL PAPER:
Chemical and biological means of reducing laminated root rot inoculum: Earl Nelson

4:45 Business meeting
New business: WIFDWC Proceedings--are they worth it?
(See John Schwandt or Larry Weir for subjects you feel need discussing.)

5:45 Adjourn

6:00 Happy hour

7:15 Banquet

Thursday, September 17, 1981

8:30 am Field trip

6:00 pm Adjourn

Friday, September 18, 1981

8:30 am SPECIAL PAPERS:
- The effects of ozone on Colorado front range ponderosa pine: William Aitken
- The anatomy of drooping aspen: Valerie Scarpa
- Thyronectria canker of honey locust: Bill Jacobi

9:30 PANEL: SURVEYS FOR FOREST DISEASES--ARE THEY WORTH IT?
- Estimation and prediction of losses caused by *Phellinus weirii* root rot in second-growth fir stands in coastal British Columbia: Bill Bloomberg (moderator)
- Disease surveys related to forest management planning: Rick Clevette
- The value of surveys for *Phellinus weirii* from an industrial perspective: Dick Heath

Coffee

11:30 Concluding remarks: Larry Weir

Keynote Address

Norman E. Alexander
B.C. Institute of Technology

Mr. Chairman, Ladies and Gentlemen, Pathologists:

Before we get started on the business of this year's meeting I would like to clear up a couple of issues left over from last year. First of all I would like to welcome our friends from south of the border, and I hope they will take advantage of this trip into Canada in order to learn the correct and simultaneous use of knife and fork. Then I would like to remind certain of our colleagues from the same noble country that extensive research indicates that the Mississippi River does indeed originate north of the 49th, in the Province of Manitoba. So much for that.

It's absolutely amazing to me that a person such as I who makes his living talking to masses of people can be as confused as I am at this moment, attempting to speak to you. Those damned entomologists have released some of their beasts in my stomach!

Seriously though, it is an awesome thing to stand before a group of prominent scientists and forest practitioners such as this and have the audacity to air my opinions. Thank gosh it was by invitation.

That invitation, from Dunc Morrison, was to raise some reasonably contentious issues for discussion. Terry Shaw wanted me to give you all hell. That's all very well for him to say, safe and snug up there behind a wall of fog, rain, blackflies, mosquitoes, and big brown bears, but this peasant has to live down here amongst people. And some of those people are pathologists. So I think I will temper my remarks with a great deal of discretion.

Now, it may come as a surprise to some of my old associates out there, who have been here forever, that I too have been in this pest business some 30 years now. Time does indeed slip away. And 30 years has a way of influencing your thought patterns, hopefully for the better, though that may be questioned.

I started out in this business as ye olde student assistant, doing all of those slave-like jobs which characterize the position, then and now. My first visit to this fair city of Vernon was as a helper to M. G. (Gerry) Thomson, an ecologist before most people had even heard of the word. I dug soil pits for Gerry all over southeastern British Columbia, learning the business from the ground up, so to speak.

Later on I came on with the old Division of Forest Biology as a Forest Biology Ranger. Take note of that name. I was not an Insect Ranger, that term had passed before my day. I was not a Pathology Ranger, as I don't think there ever was such a thing. It was fortunate for me that my job entailed work in both disciplines, and that has shaped my opinion ever since.

Fifteen years later I went to teach at the B. C. Institute of Technology. One of my first moves was to have the courses consolidated into one, from Forest Entomology and Forest Pathology into Forest Pestology. That was back in about 1969. You can see from that how my mind worked then and now. I believe in the common purpose of these two disciplines, and I believe we should give more prominence to that common goal.

The years of teaching at the interface between academia and industry has done nothing to diminish my belief in this common purpose. It colours my remarks to you today.

Last year at Pingree Park, Colorado, as we all sat gasping for air at some 10,000 feet elevation, a profound thought struck me. Perhaps it was the proximity to heaven, who knows. But looking at and listening to the people around me I suddenly realized that you Pathologists are a strange bunch. Strange indeed.

Who else could hang in there for year after year, following a profession that had so very little glamour to it? There are very few spray planes in pathology, there are few spray projects to remind one of the good old days in the Army, etc. There are few, if any, violent encounters with the public that characterize so many insect control efforts. There are no Mediterranean Fruit Flies, Screwworms or Fire Ants to capture the imagination of the public and thus further your cause. You have no Bambi's nor big bad wolves to gobble up Little Red Riding Hood on her way to Grannies. The pathologist works with organisms that by and large lack the "flash" that is so essential to enlist the support of the public and the bureaucrats.

But you still carry on, and that must tell us something.

You remind me of a bunch of oldtime prospectors. Always hoping to find the Mother Lode. If only someone will grubstake you to explore one more bend in the river!

Well, that perserverance can be a marvelous and admirable trait. It can also be a cover-up for a lack of purpose and progress. Despite the highfalutin language and statistics that surround many efforts, one gets the impression that much of the seemingly patient work is in reality a rather desperate holding action in the hope that "something" will crop up to save the day and justify the expense.

It is quite alright for a grizzled prospector to wander about the hills and deserts with his pick-axe, beans and burro, hoping to strike it rich. It is quite something else for a $30,000 plus scientist to behave in the same way for 30 odd years, at the public expense.

The same character traits that enable a pathologist to dedicate years and years of his or her life to the pursuit of an elusive goal can sometimes be the same traits that enable a person to always offer results - TOMORROW! Tomorrow is a very convenient time to get most things done.

The classical definition of WORK requires not only that you push, but that something moves. This discipline must ask itself very carefully, what have we moved?

The forest land manager of today needs information that he or she can use today. Sure, we all know that information isn't perfect, when have we ever known all about anything? But perhaps it's the best knowledge that you have on the topic. Perhaps it can be of some use until better knowledge is developed. Yes, we all know that a little knowledge is a dangerous thing, but doesn't almost all knowledge turn out to be but a little in light of what is learned later? Is the world supposed to stop and wait while the researcher strives for that big breakthrough that will give tenure and reclassification? Is that really what it's all about?

The forest land manager is forced to make decisions today that will profoundly influence us tomorrow. Those decisions have to be made, with or without all the desired information. Surely we can see the importance of giving that manager the best of what we do know, little though it might be. Is it really such a crushing event to have your publication criticized? I venture to suggest that if land managers have made even slightly better decisions regarding the treatment of thousands of hectares in the meanwhile, because of your contribution, then you need not be ashamed. You are not entitled to take skills developed at public expense, use facilities built at public expense, on time paid for from the public purse, to hoard information until such time as you can cash it in for personal gain. All types of public employees, professors, scientists, pest managers, instructors, and all the rest, have an obligation, a professional obligation, to achieve some degree of success, and to invest that success to the public good.

Nor does the scientist, etc., have the slightest right to "stake out" problems with the intent to capitalize on the research at a later date. So far as I know, none of us were ordained into our jobs, we were hired into them. Someone is paying us to do a job, not to put a fence around the problem for later personal gain. Everyone should be encouraged to do as much as they can toward the solution of any and all pest problems. We should be busy doing our jobs, not protecting them.

The theme of this conference is "IS IT WORTH IT?" It's a good question. And it's a question that politicians and money managers must be asking too. What are we getting out of those people known as forest pathologists? You should have no hesitation or difficulty in answering that question, individually or collectively.

Today one sees a frantic effort to get on the bandwagon of "technology transfer." We see persons of unequalled scientific talent striving mightily to score a few brownie points with their agencies by devoting a large part of their efforts to the task of personally communicating information. A job for which few are trained and even fewer are competent. In the meanwhile a lot of questions go unanswered, and only they are in a position to answer them. Is too much of this a wise thing? Is it always necessary for the developers of information to be the sole communicators as well? Does this really express a sincere interest in having the job done in the best possible way, or is it an attempt to hog all the glory? Ask yourself that question, and ask it carefully. Could not a lot of this "technology transfer" be just as well done by persons of lesser training, or even greater training in the field of communications? Is is possible that it might even be better done, while the researcher gets on with doing the job that only he or she can do, and without which there can be no transfer of technology? Think about it.

Ladies and gentlemen, you represent some of the finest minds in the country, and without doubt you are the finest minds in this discipline. You have amassed a phenomenal wealth of knowledge and skills.

Speaking as one who sees a constant stream of persons in need of better information regarding pest problems, I implore you to bend your skills to the provision of these answers. Don't huddle about in dark caves asking your fellow cavemen if it's worth it. Worse yet, don't squander your talents in endless journal publications which only serve to tell your already knowing colleagues more of what they already know. Get out there, in appropriate ways, and let your knowledge be shared by those who need it and can use it. Channel your knowledge through the most efficient channels to get the job done. Encourage all those who would help. Make a little progress if you can't make a lot.

There is no question in my mind about the worth of your efforts. There can be no worthwhile forest land management without the ongoing input of forest pathologists. You are one of the few disciplines that appreciates the meaning of the word "when" as well as the word "now." Your work will continue to gain in value, it will continue to move toward "perfection." Please don't let self doubts divert you from your goals.

Your work IS WORTH IT! I wish you every continued success. Thank you.

Panel: Dwarf Mistletoe Control—Is It Worth It?

Oscar J. Dooling, Moderator

worth (wûrth) n. 1. The quality of something that renders it desirable, useful, or valuable. 2. The material or market value of something.

There is no one true answer to our question; it depends on which definition we use. If definition 1 means biologically or socially desirable, useful, or valuable, the answer is probably yes.

But if we use definition 2, we raise other questions that we'd better answer before we answer our original question: Can I afford it? What will it cost? Will it increase output? How long before the increased output? Will the output have a dollar value? Another question? Another question? Another...?

The answer for definition 2 is a sort of multiple choice. Pick one:

☐ Yes
☐ No
☐ Undecided
☐ None of the above

We hope that by the time we finish our discussion, you'll have a better chance of picking the least wrong choice for your conditions.

DWARF MISTLETOE CONTROL ECONOMICS IN THE NORTHERN REGION

Oscar J. Dooling[1]

Prevention and suppression of dwarf mistletoe are parts of good silviculture; if stand values justify silvicultural treatment, dwarf mistletoe control should be part of the prescription, and not increase treatment costs. But, for projects that do require additional funding, or are done in the absence of other cultural work, we make economic evaluations to determine their cost effectiveness.

I'd like to take you through an economic evaluation of a typical project in our area, and then show how drastically things change as we vary discount rates, stumpage values, or length of time to rotation age.

In western Montana, infested mixed stands of western larch and Douglas-fir are growing at an average of about 50 percent of their potential. [2] [3]

By combining dwarf mistletoe control practices with thinning, infested stands should yield about 90 percent of their potential. If we treat a 40-year-old mixed stand, we can recover the following per acre loss in successive 20-year cuttings:

Cutting age	Healthy stand potential (MBF)	Infested stand potential (MBF)	Managed infested stand potential (MBF)[a]	Growth loss w/o treatment (MBF)	Growth recovery w/treatment (MBF)[b]	Value/MBF ($)[c]	Total recovery value ($)
60	8	4	7.2	3.2	2.56	125	320
80	14	7	12.6	5.6	4.48	125	560
100	18	9	16.2	7.2	5.76	125	720
Total	40	20	36.0	16.0	12.80	--	1,600

a/ 90 percent of healthy stand potential
b/ Assuming 80 percent recovery of growth loss.
c/ From recent timber sales, species weighted.

We calculate the net present worth (npw) of the benefits derived from the project by applying a 10 percent discount rate as required by the Office of Management and Budget (OMB):

Time (n)	Dollar value	Discount factor[a]	npw ($)
20	320	0.1486	47.55
40	560	0.0221	12.38
60	720	0.0033	2.38
Total	$1,600		$62.31

a/ Present value of $1 for n years @ 10%, from compound interest tables.

The benefit/cost ratio (B/C) is calculated by dividing the npw of the benefits by the treatment cost. If, for example, treatment costs are $75 per acre, the B/C is 0.83/1, or only $0.83 return for each $1 invested.

This is a negative return, so the answer to our original question is no, dwarf mistletoe control <u>is not</u> worth it, <u>based on timber values only</u>.

These values assume that stumpage values will remain constant for the next 60 years. A more realistic analysis should include a forecast of increased stumpage value or the use of a discount rate lower than the 10 percent required by OMB. I have opted to use a 4 percent discount rate rather than forecast an increase in stumpage values.

By applying a 4 percent discount rate to the values from our example, the npw of dwarf mistletoe control is:

Time (n)	Dollar value	Discount factor[a]	npw ($)
20	320	0.4564	146.05
40	560	0.2083	116.65
60	720	0.0951	68.47
Total	$1,600		$331.17

a/ Present value of $1 for n years @ 4%, from compound interest tables.

---

[1] Plant pathologist, Forest Pest Management, USDA Forest Service, Missoula, Montana.

[2] Haglund, S. A., and O. J. Dooling. 1972. Observations on the impact of dwarf mistletoe on Douglas-fir in western Montana. USDA Forest Serv., N. Reg. Insect and Disease Rpt. D-72-1.

[3] On, D., and O. J. Dooling. 1969. A study on the effect of dwarf mistletoe infection on the growth of western larch. USDA Forest Serv., N. Reg., Div. of Timber Mgmt. and State and Priv. Forestry. Unpublished rpt.

Things are looking up! If the treatment cost is still $75 per acre, the B/C is now 4.42/1, or a $4.42 return for each $1 invested.

This is a positive return, so in this case the answer to our original questions is yes, dwarf mistletoe control is worth it.

But if we must carry our investment for an entire rotation, and assume we will get the same recovery values, but at 80, 100, and 120 years, the picture changes drastically, even at the 4 percent discount rate:

Time (n)	Dollar value	Discount factor[a]	npw ($)
80	320	0.0434	13.89
100	560	0.0198	11.09
120	720	0.0090	6.48
Total	$1,600		$31.46

[a] Present value of $1 for n years @ 4%, from compound interest tables.

Back to a negative return, 0.42/1, or only $0.42 return for each $1 invested. In this case, no, dwarf mistletoe control is not worth it.

The B/C fluctuates widely if:

1. Stumpage values rise or fall.
2. Commercial thinnings are delayed or not made.
3. Volume predictions are wrong.
4. Rotation age changes.

Because of this wide fluctuation, we usually approve dwarf mistletoe control projects for reasons other than economic returns or positive B/C. We haven't had a positive B/C for several years. But we feel the overall benefits of reducing or eliminating dwarf mistletoe for more than a single rotation, and the social benefits of increased present and future employment, outweigh strict financial considerations.

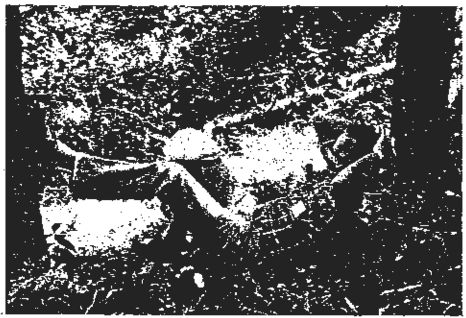
Recovery of volume losses through dwarf mistletoe control generates additional employment in the forest products industry. This results in what economists call "value added." While value added cannot be used in benefit/cost analyses, it is substantial enough to be considered when determining overall benefits. Each million board feet of timber cut creates 10.56 person years of employment[4] paying an average of $16,784 per year.[5]

What this translates to in our example is the generation of 0.027, 0.047, and 0.061 years of employment in 20, 40, and 60 years respectively (or 80, 100, and 120 years in the long rotation example). This increased employment will add $2,265.84 to the economy for each acre in the treatment area.

---

[4] Personal communication; Howard McDowell, Inland Forest Resource Council, Missoula, Mont.

[5] Personal communication; Paul Polzin, Bureau of Business and Economics Research, University of Montana, Missoula, Montana.



LODGEPOLE PINE DWARF MISTLETOE CONTROL IN THE CARIBOO FOREST REGION

Edward Harry Wilford
Forest Pathologist

ABSTRACT: The purpose of this paper is to show what efforts are being made in the Cariboo Forest Region to reduce the impact of lodgepole pine dwarf mistletoe. The discussion covers the Regional policy, control cost payments and development of guidelines for the management of mature, immature and non-merchantable infected stands.

INTRODUCTION

The range of lodgepole pine (*Pinus contorta Dougl*) in the Cariboo Forest Region is closely matched by the distribution of the parasite dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm). The lodgepole pine are generally located west of the Fraser River in the dry subzones of the Sub-boreal spruce zone (SBSa) and the Interior Douglas-fir zone (IDFb). The area of lodgepole pine stands (pure and mixed) is 2.4 million hectares and accounts for almost one half of the Cariboo Forest Region land base. The Canadian Forestry Service has undertaken sampling studies that show 72% of the lodgepole pine stands in the Region are infected (highest level of lodgepole pine dwarf mistletoe in North America [Hawksworth 1973]) with 85% of the Chilcotin stands infected (Van Sickle 1975). The cause of the high level of infection is believed due to the fire history of extensive pure lodgepole pine stands. The infected stands have experienced low intensity spring and summer fires which acted as thinning agents. The surviving infected trees responded to release and seeded areas cleared by fires. The infected trees then showered the regeneration with dwarf mistletoe seeds thereby perpetuating the disease. Where the fires were more destructive and no infected trees survived, uninfected stands developed.

Protection Branch has estimated loss caused by lodgepole pine dwarf mistletoe to be 1,019,000 m^3 per year. The loss estimate may be too high but it is the only figure we have. The reported Cariboo cut in 1980 of lodgepole pine was 3,387,574 m^3 (Anon 1980).

Dwarf mistletoe also affects lodgepole pine by decreasing vigor and resistance to insects and disease (Hawksworth 1978) but the degree to which the parasite affects these characteristics in the Cariboo has not been investigated. A study indicated there were no differences of practical importance between infected and non-infected lodgepole pine lumber yields and quality (Dobie and Britneff 1975). The widespread occurrence of dwarf mistletoe and the corresponding losses were the justification for the creation of a regional control policy and the development of control guidelines.

Edward Harry Wilford
Forest Pathologist
Ministry of Forests
Williams Lake, British Columbia

DISCUSSION

Policy

By virtue of the "pest" status of dwarf mistletoe, responsibility for control of the parasite was given to Protection. Subsequesntly a Regional policy for dwarf mistletoe control was drafted. (The policy is based on sections 125, 126 and 127 of the Forest Act of British Columbia which empowers the Forest Service to control forest insects and diseases). The policy statement is: "it is the policy of this Region to reduce the impact of dwarf mistletoe in lodgepole stands by the application of site specific treatments."

Control Cost Funding

There are three ways to pay for dwarf mistletoe control projects. First, control projects at the time of harvest are paid for in stumpage appraisals (Sec. 82, Forest Act). Second, projects by companies after logging are covered by stumpage credits (Section 88, Forest Act). Third, contracts paid directly by the Forest Service.

Management Guidelines

Three types of infected pure pine stands are found in the Cariboo, mature, immature and non-merchantable, and differences exist in the management of these stands.

Mature stands.--Once harvesting plans are made for a mature stand, a cruise determines volume and among other items the presence of dwarf mistletoe.

The cutblock boundaries in infected stands are set to the maximum permitted size, regularly shaped (to reduce spread from infected margins) and make use of natural infection breaks (lakes, meadows, rights of way).

In the course of harvesting a large proportion of the parasite can be removed. The determining factors for removal are the utilization standard, the degree of mechanization used in harvesting, the knock-down clause and Forest Servise supervision. Present utilization standards take stems over 6.1" d.s.h. leaving small poles and advance regeneration to be removed by some other method.

Supervision ensures that utilization specifications are met and the planned cutblock boundaries are followed. The presence of Forest Service staff allows for changes in cutblock boundaries to remove infected stems (at minimal cost) not apparent prior to harvesting. Supervision also ensures the protection of lodgepole pine dwarf mistletoe resistant species such as Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco var. *menziesii*) and interior spruce (*Picea* spp.).

Following the harvesting operations three infection sources remain: advance regeneration and small poles, islands of immature in the cutblock and unavoidable infected stand edges. There are four control methods (mechanical, manual, fire and chemical) available for dealing with residual infection sources (Table 1, Figure 1). Mechanical control methods utilize one of the following pieces of equipment: Marden Duplex Brush Cutter, Kershaw brushcutter, Hydro axe, chains or shark finned barrels and chains.

Trials have shown the Marden to be generally the most effective mechanical device in the Cariboo. Advance regeneration is destroyed, scarification is acceptable for natural regeneration and costs are relatively low even for very dense residual stands with snags and windfall (Figure 1). The Marden gives best results at low temperatures $(< - 5^{o}c)$ and on frozen ground. At temperatures above $0^{o}c$ stems are too supple (and do not break) and mud can decrease the effectiveness of the machine. Manual eradication methods include hand pulling, clippers and brush saws. Height limits are set below which regeneration is saved. The cost of manual eradication methods rises with density (Figure 1).

A chemical control method utilizing a herbicide spray would be possible but the cost is high and it is expected that public pressure would be strongly opposed to the extensive use of silvicides methods (fig. 1).

Prescribed burning for eradication is not usually used because fuel loadings are too low after logging and because burning during the desirable fall period destroys the pine seed source for natural regeneration (Clark, 1974).

Experiments with spring - summer burning were conducted (1976 - 1977) to see if low intensity fires could be used to kill residual stems without depleting the seed source but preliminary observations are not favourable and some form of artificial regeneration is required. The possibility of an escape fire during or after the operation can be prevented only by the use of trained crews. The crew must also be able to burn at intensities high enough to destroy regeneration but low enough so as not to destroy the seed source.

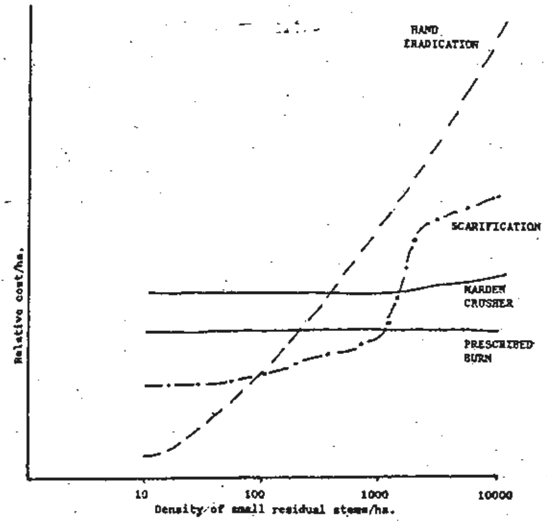


Figure 1. Relative costs of destroying mistletoe infected advanced regeneration and immature patches on cutblocks. 1/

Notes:

1. Hand eradication costs rise steeply because time to complete a cutblock is strongly influenced by number of stems to be removed whereas prescribed burning will cost much the same whether or not residual stems are present.

2. Scarification costs are lower than Marden crusher costs at lower densities because rental cost of towing machine is lower; at higher stem densities scarification costs increase rapidly because of need to complete a double pass to ensure destruction.

Immature stands.-- Infected immature stands usually start with infected overstory trees which shower the immature trees with dwarf mistletoe seeds. As most immature stands are too dense a spacing operation can be used to reduce the stocking (preferentially removing infected stems and also down any infected overstory trees). (A single tree herbicide (glyphosate) injection system is being examined for treating residuals, which is cheaper than cutting the trees down, but is in the development stage.)

1/ Vyse, A. 1981

Table 1--A key to selection of post logging treatments for the removal of small residual stems and islands of immature in dwarf mistletoe control operations1/

This key should be applied to cut blocks with a moderate to high level of overstory infection (≤50% overstory stems infected).

1a	2 years or less since logging	
2a	High density of Pl advance regeneration	
3a	Sufficient fuel for prescribed burn	
4a	Trained burning crew available	Spring burn and seed*
4b	Crew not available	Marden drum chopper
3b	Insufficient slash for burn	Marden drum chopper
2b	Low density of Pl advance regen.	
5a	Mineral soil exposure adequate	Hand Eradicate all stems ≥50cm
5b	Mineral soil exposure inadequate	Scarify 50% of area and hand eradicate all stems>50cm or remaining area
1b	More than 2 years since logging	
6a	High density of Pl advance regeneration	
7a	Sufficient fuel for prescribed burn	
8a	Trained burning crew available	Spring burn and seed*
8b	Crew not available	Marden drum chopper and seed*
7b	Insufficient fuel for pres. burn	Marden drum chopper and seed*
6b	Low density of Pl advance regen.	
9a	Adequate stocking of natural regen (or good potential if 5 years since logging)	Hand eradicate all stems ≥1m
9b	Inadequate stocking of natural regen (or poor potential if 5 years since logging)	Scarify 50%, seed and hand eradicate all stems ≥1m

---

*Direct seeding is proposed in case natural regeneration fails, it should be successful based on experience in other regions, but operational trials are required before large scale applications take place. If seeding is not successful the areas will have to be planted if natural regeneration does fail. Prescriptions would be made 5 years after treatment.

1/ Vyse, A. 1981

Hawksworth et al (1977) and Van Sickle and Wegwitz (1978) have shown that infection levels can be reduced by spacing but eradication of dwarf mistletoe is unlikely. There is also the possibility of the number of infections increasing with spacing (Van Sickle and Wegwitz 1978).

Eradication of immature stands (or portions thereof) would not be undertaken unless a high proportion of the stems are infected and/or yield information suggests a new infection free stand would be merchantable before the infected but established immature stand.

Non-merchantable stands.--The presence of dwarf mistletoe alone does not make stands non-merchantable from an appraisal point of view. Rather the combination of haul distance, number of stems, and volumes per hectare make a stand non-merchantable from an appraisal point of view. However, the parasite may contribute to low volumes per hectare.

There are three alternatives for non-merchantable stands management: First, waiting for economic conditions to improve making the stand merchantable. Second, release the stands as off-quota wood in the form of direct sales. Third, eradicate the stand and regenerate the area at minimum cost.

A survey of the extent and condition of the non-merchantable stands is required. If possible an estimate of the gain (following rehabilitation) to the annual increment would also be made for each stand to assist in choosing the best alternative. The alternative chosen will be made on a stand basis using the information obtained from the survey and the gain estimate.

CONCLUSION

The Cariboo Forest Region is making a serious attempt to reduce the impact of dwarf mistletoe in lodgepole pine stands in the Cariboo. The creation of a Regional policy and development of guidelines will enable effective control programs to satisfy the resource stewardship responsibilities of the Forest Service.

LITERATURE CITED

Anonymous, Ministry of Forests Annual Report, year ended December 31, 1980. Province of British Columbia, Ministry of Forests, 60 p.

Clark, M. B. Effects of cutting method, slash-disposal treatment, seedbed preparation and cone habit on natural regeneration of lodgepole pine in the south-central interior of British Columbia. BCFS Res. Notes No. 67. 1974.

Dobie, J. and Britneff, A. A. Lumber grades and volumes from lodgepole pine infected with dwarf mistletoe. Wood and Fiber 7(2): 104-109; 1975.

Hawksworth, F. G. Basis for Control. In: Proc. Symp. Dwarf Mistletoe Control Through Forest Management, April 11-13, 1978: 5-15. Scharp, R. F.; Parmeter, J. R., eds. Berkeley, Cal., Gen Tech Rep. PSW-31.

Hawksworth, F. G. Dwarf mistletoe and its role in lodgepole pine ecosystems. In: Proc. Manage. Lodgepole Pine Ecosystems Symp. D. M. Baumgartner, ed. pp. 242-258; 1973.

Hawksworth, F. G.; Hinds, D. P.; Johnson, D. W.; Landis, T. D. Silvicultural control of dwarf mistletoe in young lodgepole pine stands, USDA For. Serv. R.M. Tech. Rep. R2-10. 13 p. 1977.

Van Sickle, G. A. Feasibility of roadside surveys for assessing the extent and severity of lodgepole pine dwarf mistletoe. Pac. For. Res. Centre. Unpublished Report. 16 p. 1975.

Van Sickle, G. A., Wegwitz, E. Silvicultural control of dwarf mistletoe in young lodgepole pine stands in Alberta and British Columbia. C.F.S., Pac. For. Res. Centre. BC-X-1978.

Vyse, A. Managing Lodgepole Pine Dwarf Mistletoe in the Cariboo Forest Region. BCFS Cariboo Research Brief No. 17, 28 p. Internal Report, Research Section, Cariboo Region. 1981.

ECONOMICS OF DWARF MISTLETOE CONTROL IN CALIFORNIA RECREATION AREAS

John Pronos

ABSTRACT: Three proposals for dwarf mistletoe suppression in California campgrounds used different approaches to economically justify the projects. The approaches differed in the method used to estimate the benefits derived from dwarf mistletoe control. Techniques for evaluating treatment benefits included estimating: (1) individual tree values, (2) total value of the recreational experience, and (3) the effect of treatment on visitor use receipts.

INTRODUCTION

Between 1979 and 1981 the Forest Pest Management (FPM) Staff of the Pacific Southwest Region received three project proposals requesting funds for dwarf mistletoe control. All of the suppression projects were to be completed in established Forest Service campgrounds. Figure 1 shows the locations of the campgrounds.

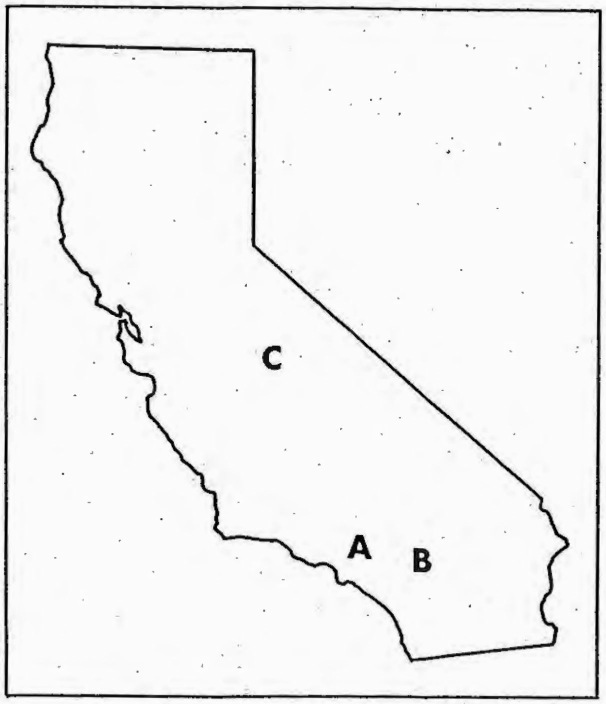


Figure 1. Locations of three U.S. Forest Service recreation areas in California with dwarf mistletoe control projects.

Prior to the requests, the FPM Staff had completed biological evaluations that determined dwarf mistletoe control was both warranted and feasible. The National Forests and Ranger Districts involved had received biological information that described the expected adverse effects of dwarf mistletoe on conifers and the beneficial effects of thinning, pruning and removing witches' brooms. With this information, District personnel developed their own economic analyses as part of the project Environmental Assessment (EA). This paper describes and compares the different approaches that were used to economically justify the control projects.

CAMPGROUND A

This is a heavily used recreation area in southern California with visitors mainly from the Los Angeles area. The stand consists of an overstory of mature ponderosa (Pinus ponderosa) and Jeffrey pine (P. jeffreyi) and an understory of Jeffrey pine, bigcone Douglas-fir (Pseudotsuga macrocarpa), sugar pine (P. lambertiana), incense-cedar (Calocedrus decurrens) and canyon live oak (Quercus chrysolepis). Western dwarf mistletoe (Arceuthobium campylopodum) was the major disease problem in the overstory pine.

Management objectives for the area include: (1) maintaining vigorous all-aged mixed species stands, (2) retaining old-growth trees as long as possible, and (3) reducing mortality. With respect to the dwarf mistletoe situation, three action alternatives were considered for the campground. They included no treatment, broom pruning, and total pruning. The no-treatment alternative was undesirable because it would do nothing to increase tree vigor or reduce mortality. The total pruning alternative was unacceptable because large old-growth trees with infections on almost all branches would have to be removed. Therefore, the decision was made to remove only witches' brooms.

Two hundred sixty-eight pines were selected for broom pruning. The trees ranged in diameter at breast height (dbh) from 10 to 50 inches, with an average of 29 inches. The cost of treatment was estimated at $35.41 per tree.

The economics considered in justifying the project focused on estimating the value of individual trees and asking whether it was worth spending $35.41 per tree. Two approaches were used and are summarized

---

John Pronos is Plant Pathologist with the Forest Pest Management Staff, USDA Forest Service, Pacific Southwest Region, San Francisco, Calif.

as follows:

1. The publication "Shade Tree Evaluation" produced by the International Shade Tree Conference, Inc., established a cost for high-value shade trees at $10.00 per square inch of basal area. [1/]

Judged by this rule, each tree included in the project had an average value of over $6,600.00. This is undoubtedly an exaggerated figure for campground trees, but illustrates the potential high value of shade or ornamental trees.

2. A second approach to evaluating the project assumed that removing witches' brooms would extend the average tree life by 10 years. Inventory data for the campground indicated that each tree would produce 28.5 square inches of basal area during the next 10-year period. Using these figures and a value of $10.00 per square inch of basal area, broom pruning would produce a $285.00 increase in value for the average tree, representing a 23% return on an initial investment of $35.00. Even if a campground tree had only one-half the value of a shade tree, there would be a $142.50 increase in tree value over the next decade.

CAMPGROUND B

This campground is also located in southern California in the San Bernardino Mountains east of Los Angeles. It is an uneven-aged pure Jeffrey pine stand with western dwarf mistletoe infections in all age classes. In 1979 the area received 39,000 visitor use days.

Important concerns for the management of the area include maintaining a healthy tree cover and maintaining the recreational character of the campground. Faced with a serious dwarf mistletoe situation, the District recognized only two alternatives: (1) take no action and (2) treat the campground through a combination of pruning, removal of heavily infected overstory trees and thinning the dense infested understory. Dwarf mistletoe treatment was identified as the preferred alternative because of the desire to increase the health and vigor of both young and old growth pines and to reduce the incidence of dwarf mistletoe. The cost of treating 40 acres in the campground was judged to be $36,000.00

The approach to determining the economic effectiveness of this project was based on comparing project costs with user receipts plus the value of the recreational experience. The immediate annual receipts from users was $18,000.00 while Region 5 Economic Guides placed the recreational experience of one visitor day at $5.00, or $195,000.00 per year for the campground. Annual dollar loss due to dwarf mistletoe was not known. The project was deemed justified because of the very large dollar difference between project costs and estimated recreational benefits.

CAMPGROUND C

The third recreation area included two adjacent campgrounds in the southern Sierra Nevada, northeast of Fresno. Vegetation cover was dominated by ponderosa pine and incense-cedar with small amounts of white fir (Abies concolor), sugar pine, California black oak (Q. kelloggii), and canyon live oak. The two campgrounds support a total of 20,500 recreation visits per year and generate approximately $13,000.00 annually.

The recreation management plan's basic objective is to provide a setting with an attractive near-natural appearance, which at the same time would permit privacy and reduce the risks from hazards and losses from insects and diseases. These objectives require a healthy, vigorously-growing multi-storied stand. The understory would provide the necessary screening and the replacements for normal mortality occurring in the overstory. The overstory would provide shade.

Concentrations of dominant and predominant ponderosa pine heavily infected with western dwarf mistletoe were scattered throughout both campgrounds. The disease was spreading from overstory trees into the pine regeneration. Three alternatives were identified: (1) do nothing, (2) broom prune infected dominant and predominant ponderosa pine, and (3) broom prune infected dominant and predominant ponderosa pine, remove overstory trees that would not have a minimum of 30 percent live crown after pruning and thin the infected understory. The third alternative was selected as best meeting the area's long-term management objectives.

The project work plan included pruning witches' brooms from 46 trees between 12 and 42 inches dbh. Thirty trees were marked for removal. Average treatment cost per tree was $54.50.

The economic analysis consisted of calculating the present net worth (PNW, Table 1) from a "timeline" constructed for each alternative. Each timeline covered a 50-year period and compared anticipated treatment costs to estimated revenue from visitor use. Treatment costs were dependent upon projected dwarf mistletoe-caused tree mortality for each alternative. This expected mortality in turn caused a reduction in visitor use revenue. The third and preferred alternative was the most cost effective at both 10 and 15 percent interest rates.

[1/] A more recent guide published in 1979 by the International Society of Arboriculture entitled "Guide For Establishing Values of Trees and Other Plants" establishes a maximum value of $18.00 per square inch of basal area, but states that recreational or picnic area trees have no more than 60-70% of that value.

Table 1. Present Net Worth for Three Dwarf Mistletoe Control Alternatives

Alternative	Interest Rate 10%	 15%
1	$132,638	$96,313
2	133,683	94,134
3	138,062	96,821

SUMMARY

Specific management objectives in California recreation areas determine what course of action the U.S. Forest Service will take to alleviate dwarf mistletoe problems. Currently, there is no single Region-wide approach used to evaluate the economic effectiveness of dwarf mistletoe projects. The main difficulties are how to quantify the benefits of treatment and evaluate the consequences of no treatment. Three techniques for determining benefits used in Region 5 included estimating: (1) the value of individual trees, (2) the total value of the recreational experience, and (3) the effect of treatment or no treatment on visitor use.

Panel: Disease Problems In Management Of Advanced True Fir Regeneration

Paul E. Aho - Moderator

The genus Abies is a significant resource in western North America. The 6 commercial species of true firs; noble fir, Pacific silver fir, white fir, California red fir, grand fir, and subalpine fir are widely distributed geographically and altitudinally over this region. Volume of true firs on commercial forest lands in western North America is approximately 82 billion cubic feet. In Oregon and Washington alone these species account for 15 percent of the available timber volume.

Abies species are ecologically significant since they provide cover in high mountain watersheds, they are aesthetically pleasing on recreation sites and can tolerate severe environments and still produce high timber volumes. True firs are sought for greenery and Christmas trees, produce high volumes which are desirable for pulpwood and lumber, and since most species are shade tolerant they offer many silvicultural options. They also have some undesirable characteristics including; slow initial growth, sensitivity to disturbance, and most species suffer significant pathological problems. True fir management, in comparison to Douglas-fir, involves longer rotations, higher stocking levels, fewer intermediate stand entries, and greater use of advance regeneration.

The purpose of this panel is to discuss disease problems in management of advance true fir regeneration. Advance regeneration can be defined as the saplings and poles remaining after the overstory has been removed. The age and sizes of advance regeneration can vary widely. Today's speakers will address the impact of root diseases, dwarf mistletoes, and decays in management of advance regeneration. Unfortunately, Gary Fiddler, Silviculturist with a Silvicultural Development Unit located in Burney, CA was unable to attend. In place of his talk on logging damage we will show a slide-tape program entitled "Reducing injuries to residual trees during stand management entries." This program was authored by Paul E. Aho, Gary Fiddler, and Greg Filip. It can be purchased from:

Forestry Media Center
School of Forestry
Oregon State University
Corvallis, OR 97331

MANAGEMENT OF PACIFIC SILVER FIR AND SUBALPINE FIR ADVANCE REGENERATION IN BRITISH COLUMBIA

LES J. HERRING

ABSTRACT: Successful management of pacific silver fir and subalpine fir advance regeneration in British Columbia depends on three factors: appropriate selection of site to ensure adequate growth; the presence of advance regeneration growing stock of small size to ensure minimal risk of defect through wound parasite and Indian paint fungus infection; and an adequate distribution of acceptable trees after logging to ensure reasonable site occupancy. Implementation of advance regeneration management appears limited only by the rejection by many forest managers of Abies species as timber producers, an attitude which may prove temporary as our understanding of forest ecosystems improves.

INTRODUCTION

This paper deals with the two most important native British Columbia true fir species, pacific silver fir (Abies amabilis) and subalpine fir (Abies lasiocarpa). A third native species, grand fir (Abies grandis) is not considered in this discussion due to its very limited range on the southern coast and southeastern interior of the province. Throughout the paper emphasis will be placed on the three principle factors essential to sound management of the advance regeneration of these two major true fir species: site; stock; and stocking.

These three factors represent a hierarchy in terms of importance to successful management, although all three must be considered together. Limitations imposed by any one will determine management decisions, and failure to consider any one factor could reduce the return on silvicultural investment in advance regeneration management.

PACIFIC SILVER FIR MANAGEMENT IN COASTAL BRITISH COLUMBIA

Management of Pacific silver fir advance regeneration appears to be approaching that of a silvicultural science. This is a considerable improvement over past management which was often based on poor information and overgeneralizations. Decades of observations of silver fir growing off-site at the lowest elevations of its range and exhibiting the syndrome commonly referred to as the "green illusion" contributed to a feeling amongst foresters that the species, and particularly its advance regeneration state, was utterly useless as a timber producer. Over the last decade, however, two situations have done much to change these earlier concepts. The most important is undoubtably the development of a workable field level approach to the identification of forest ecosystems. The work of Dr. Karel Klinka in the Vancouver Forest Management Region has provided an excellent silvicultural decision-making tool with which to fit stand and site treatments to site characteristics. It has improved the level of advance regeneration management significantly.

The second development in coastal silviculture which helped to modify attitudes towards advance silver fir regeneration came as reforestation experience moved into the higher elevations. With increasing frequency unsatisfactory and often ecologically disasterous results with low elevation prescribed burning methods were experienced. The "King Fir" syndrome (Douglas fir) was soundly shaken as seedling survival, stem form and growth of plantations established in the true fir-hemlock forests of the coastal mountains produced poor results. Our experiences parallel those of foresters in the Pacific Northwestern United States. Francis Herman (1972) described many of the same silvicultural problems in what he termed the "high country" of western Washington and Oregon, and was among the first in the early 1970's to suggest the use and management of advance regeneration, particularly Pacific silver fir, as an alternative to the conventional low elevation techniques of burn and plant.

Today the management of silver fir can well be included in the silviculturist's bag of tricks, subject only to consideration of those three important factors; site, stock and stocking and, perhaps, the silvicultural skill of the forester.

Les Herring is Regional Research Forester for the Prince George Forest Region, B.C. Ministry of Forests.
1011 - 4th Avenue, Prince George, British Columbia.
V2L 3H9

Site Selection

The ecological and timber production significance of Pacific silver fir is now recognized only in three biogeoclimatic subzones within the coastal B.C. forests; the Submontane and Montane Amabilis Fir-Western Hemlock and the high elevation Amabilis Fir-Mountain Hemlock subzones (Klinka, 1977). Within each of these subzones the edaphic requirements of silver fir have been identified and the combinations of soil moisture and nutrition which promote optimum growth have been summarized in an edatopic grid format.
(fig. 1)

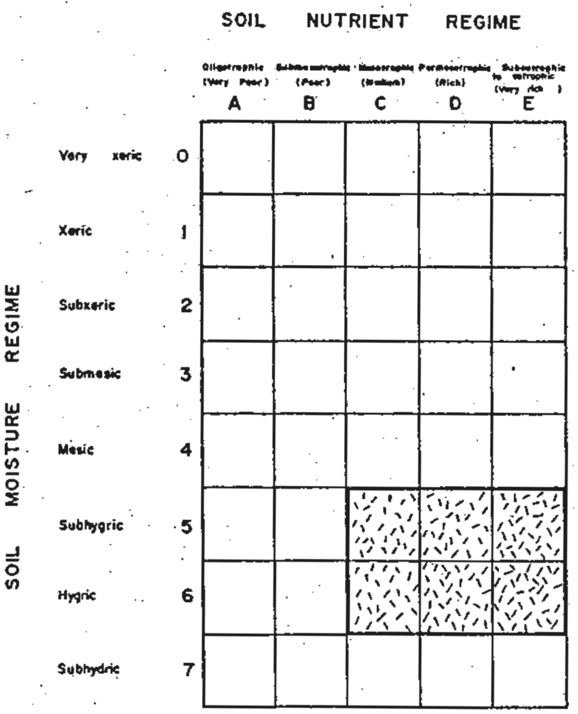


Figure 1 -- Edatopic grid matrix showing the soil moisture (hygrotope) and soil nutrient (trophotope) positions preferred for growth by Pacific silver fir (adapted from Klinka, 1977)

Krajina (1969) reported that Pacific silver fir requires very wet climates and constantly moist soils for optimum growth. In the words of Dr. Klinka it is "...a heavy drinker" (Klinka, personal communication). It prefers nutritionally rich soils, thriving where calcium and magnesium are abundant. Kotar (1972), in studies at the University of Washington, reported that silver fir is not physiologically adapted to resist drought conditions, and that growth improves with increases in elevation in response to more favourable moisture conditions.

For all three biogeoclimatic subzones where pacific silver fir is found, the same edatopic grid position is preferred for growth. Growth is optimized at 6E, or subeutrophic to eutrophic nutrition and hygric soil moisture regime shown in figure 1.

The management of advance Pacific silver fir is considered as a reforestation option only in the Montane Amabilis Fir-Western Hemlock and Amabilis Fir-Mountain Hemlock biogeoclimatic subzones. While occurring in the Submontane Amabilis Fir-Western Hemlock subzone, advance regeneration of the species has not been found in sufficient quantity to be a viable option (Klinka, personal communication).

Advance Regeneration Stock Quality

The quality of the advance regeneration is the next consideration of management, only after appropriate site selection has been made. The ability of the advance regeneration to form a second rotation crop is the obvious desirable characteristic, and stock quality is therefore best considered in terms of postlogging growth vigor; its susceptibility to wood defects; and the growth form of its stem and crown. Several studies have addressed these topics, and form the basis of the criterion used to assess stem quality in coastal B.C.

Most research on the postlogging release of true firs indicates a short delay period in growth response. Our own study (Herring and Etheridge, 1977) indicates a radial growth response delay of about one year, while significant height growth responses may be delayed for several more years. With minor exception this trend has been observed for other Pacific Northwest true firs (Gordon, 1973; Herring, 1978) and suggests a gradual physiological and morphological change from partial to full light conditions by the advance regeneration plant. Once released from overstory suppression, the rate of growth response appears to be determined mainly by site quality. There does not appear to be a direct relationship between the age of advance regeneration and its growth response (Herring and Etheridge, 1976). Individual tree competitive stress, however, does appear to adversely affect growth response.

Once fully released on a site best suited for the growth of the species, there appears to be no question of the excellent growth potential of Pacific silver fir advance regeneration. Providing competition levels are kept reasonable , silver fir is capable of maintaining an annual height growth increment of from 0.4 to 0.5m over a 30 year release period, as indicated by our data. It is reasonable to expect it to meet its best site index growth class of 40-50 m in 100 years, as indicated by Krajina (1969).

Susceptibility to defect and decay is a critical factor in the management of true fir advance regeneration. Three of the four panelists today will be dealing specifically with the pathological aspects of the true firs, and at a level much more detailed than I will in this paper. The most obvious area of concern to the forester appears to be that of overstory logging damage, and decay infections by wound parasite fungi. The rather "soft skinned" true firs are quite susceptable to shallow, bark-removal injuries associated with the falling and yarding activities of logging. Our study of Pacific silver fir indicated that stems larger than 2.5 cm basal diameter (inside bark) suffered considerably more logging associated damage than smaller trees. What is more important, however, is that these larger trees were more at risk to the initiation of active decay infections than small trees. Success of wound parasite infection and decay appears to depend on the size of the stem wound and the rate of callus tissue growth, or wound healing. Small trees tend not to sustain large stem wounds, and their vigorous postlogging growth tends to minimize the time required for wound healing, thus limiting defect development. Large size advance regeneration often sustains extensive damage at release and undergo a lengthy wound healing period during which time defect can develop and spread. The principle of smaller is better appears to be valid for advance regeneration management.

A much more subtle pathogen, to the foresters eye in any case is the Indian paint fungus (<u>Echinodontium</u> <u>tinctorium</u> E. & E.). Studies by <u>Etheridge and Craig (1976)</u> on the mode of infection by this heartrot pathogen indicate that long periods of suppressed growth are conducive to the development of infection entry courts. Further work on Pacific silver fir (Etheridge and Craig, 1975) suggested that the risk of dormant infections in advance regeneration increased for trees experiencing heavy suppression for in excess of 60 years. Since dormant Indian paint fungus infections can be reactivated in a tree through injuries, such as logging damage, the heartrot hazard to advance regeneration is a function of stem age and size at release. Since the correlation of age and tree size is a poor one at best, it is difficult to come up with a field level morphological standard for high and low risk trees. Based on our data, we considered advance regeneration up to 5 cm basal diameter, or approximately 2 m in top height could be considered safe from Indian paint fungus defect.

The final aspect of advance regeneration quality, that of growth form, is rather a subjective one and based entirely on tree appearance. Prior to release by logging most advance regeneration have poor form. They have small, flat topped crowns with little or no apical dominance. They also commonly suffer from basal stem sweep or crook, likely the result of understory snow loads. Many of these minor deformities are quickly outgrown and disappear after release and postlogging growth response. More serious deformities such as excessive sweep or broken stems may not easily be outgrown, making these trees unacceptable as a future crop. Acceptable form does not easily lend itself to precise definition. Attempts have been made, however, to describe what is acceptable and unacceptable form in suppressed advance silver fir regeneration in the Vancouver Forest Management Region (Vancouver Forest District, 1977). The approach used was a pictorial description of various acceptable and unacceptable morphological and damage characteristics by tree size class. Tree size was stratified into three height groups in the guide;
0 - 1.4m, 1.5 - 2.9m and 3.0m and larger and was an attempt to recognize relative disease risk classes based on the pathology studies previously described. This type of field guide is particularly useful in prelogging understory assessments or immediate postlogging surveys when stand treatment prescriptions are being developed.

Advance Regeneration Stocking

Advance regeneration stocking is best described in terms of the extent of stocking and density of acceptable seedlings or saplings in a harvesting area, and whether that stocking will ensure a replacement stand (Alexander, 1974). Any form of harvesting is likely to destroy a substantial proportion of the advance regeneration on a site, although total destruction is rare. Many studies have been undertaken to determine the extent of understory destruction through logging. Nearly all deal with tractor logging systems, however. Inferences from this literature to the cable logging systems used almost exclusively on the coast are consequently very limited.

More important than total density of advance regeneration is their distribution. Generally the postlogging stocking is clumpy, with non-stocked openings of variable size common where logging disturbance is severe, such as on cable roads, or where advance regeneration was absent prior to logging.

In order to summarize the framework of a strategy for the management of advance Pacific silver fir regeneration it would be necessary to stress the selection of a suitable site stocked with acceptable trees of an adequate density and distribution prior to harvesting the overstory. This prelogging planning would preceed a carefully designed logging plan to minimize damage to stock and stocking, which would then be followed by a postlogging evaluation and whatever appropriate improvement cuttings or stocking adjustments were deemed necessary. At this point, however, it is appropriate to describe the actual level of advance regeneration management being practised in the true fir hemlock stands of the Vancouver and Prince Rupert Forest Management Regions of B.C. In reality, ours is not some higher order silvicultural system, but rather what might be described as a "free lunch" system. For apparently sound ecological reasons many mature forest ecosystems supporting silver fir advance regeneration are not considered for slashburning. Logging proceeds in the normal cost-efficient manner, and what is left, namely a variably stocked, variable quality stand of silver fir and its associated species is accepted as a component of the second growth forest. Planting, or fill planting is only just beginning to be a companion silvicultural treatment; however, improvement cuttings are rarely undertaken to maximize the quality of the advance regeneration. Our "free lunch" system is a far-cry from the classical European concepts of silviculture, but it is a considerable advancement from the "green illusion" philosophy prevalent as few as ten years ago.

MANAGEMENT OF SUBALPINE FIR ADVANCE REGENERATION IN THE INTERIOR OF BRITISH COLUMBIA

If the level of Pacific silver fir management can be called a "free lunch" strategy, then the management of subalpine fir in the interior of the province must be recognized for what it is, haphazard to say the least. Over the years recognition of the species developed as a result of the natural regeneration systems in vogue from the 1940's through the 1960's. Rather than a rigorous silvicultural system these natural regeneration methods, largely partial cuts of all description, consisted of a common logging strategy known simply as "log the best and leave the rest". This practise was widely used in all biogeoclimatic zones and subzones where spruce-fir stand types are found. The resulting second growth stands all have similar characteristics; they are highly variable in stock and stocking. On many sites, particularly the dry ecosystems of the high elevation and continental biogeoclimatic zones, these mixed bag second growth stands made a poor showing and epitomized the expression "silvicultural slum". Out of these failures a general mistrust of subalpine fir as a species, and a contempt for its advance regeneration form developed for many decades. Morbid curiosity gradually developed, however, and led to several research investigations into its pathology and growth. From these studies we now have the basis for a management plan for advance subalpine fir regeneration; a paper plan at least.

Site Selection

Recent advances in ecosystem identification and knowledge have improved recognition of the ecological role of subalpine fir in the interior. Though present in a wide range of biogeoclimatic subzones and ecosystems, it achieves a dominant timber production significance in relatively few. For instance, in the Nelson Forest Management Region in the southeast, subalpine fir is recommended as a species suitable for regeneration in only the moist and wet climatic regions. In only three out of eight subzones where it occurs as a major climax species is its growth considered adequate for timber production objectives (Utzig et al, 1978). A similar limited role is suggested in the Kamloops (Monchak, personal communication), Cariboo, Prince George, and interior portions of the Prince Rupert (Lloyd, personal communication) Region. A further ecological limitation within favourable subzones occurs at the edaphic level. The sites most favourable to growth of subalpine fir tend to be at the same edatopic grid position as for Pacific silver fir (fig. 1). Development of the ecological framework to silvicultural management should do much to explain the poor, past performance of the species on many ecosystems, as well as point clearly to where advance regeneration may provide a viable regeneration alternative.

Advance Regeneration Quality

The same criteria for assessing the advance regeneration quality of Pacific silver fir applies to subalpine fir: good vigour, resistence to defect and acceptable growth form. Smith and Craig (1968, 1970) studied the incidence of decay in advance regeneration in the Prince George and Kamloops areas. On the basis of their results three broad, increasing size classes of advance regeneration were identified, each representing a successively greater risk of not producing a merchantable crop as a result of defect. They found trees less than 8 cm diameter (bh) at release to be of the highest quality; trees8 - 15 cm exhibited higher defect and removal of individuals with defect indicators was récommended; advance growth larger than 15 cm represented the highest risk and were not recognized as crop trees. My own study of advance subalpine fir regeneration in the Kamloops Forest Management Region (1977) reached similar conclusions. The frequency of severe logging wounds was highest for large size classes, as was the incidence of wound parasite infections. Similarly, in most other relationships between tree size, growth and disease, including infection by the Indian paint fungus, subalpine and Pacific silver fir were found to be similar.

The concept of risk size classes introduced by Smith and Craig is a valuable one. I attempted to interpret these size classes in terms of tree height at release, and arrived at three height classes: trees less than 1.3m top height at release present the greatest potential for future management since they sustain minimal logging damage and exhibit a low frequency of defect; trees 1.3m to 3m top height at release have less potential since they exhibit a higher rate of decay associated with prelogging growth suppression and logging damage; trees larger than 3m top height at release present little crop tree potential with few exceptions and were differentiated from the more valuable advance regeneration by applying the term "residuals".

Within the 0 - 3m height range of acceptable advance regeneration the concept of stock quality is based entirely on tree appearance, as in the case of Pacific silver fir - described previously. Subjective guidelines for assessing stem quality have been prepared for use in understory surveys before and after logging, and in determining regenerated stand improvement treatments in the Cariboo Forest Management Region (Cariboo Research Section, 1977)

Advance Regeneration Stocking

The factor of advance regeneration stocking is no less important to subalpine fir management as it has been described for Pacific silver fir.

Alexander (1974) considered pre-harvest understory stocking to be a critical component of the advance regeneration management system, since harvesting losses are inevitable.

In order to elaborate on advance growth destruction through logging, the following breakdown of understory losses in a Russion spruce forest is provided by Protopopov (1959): 8 to 18 percent of existing advance growth is destroyed during logging preparation (road and landing construction); 32 to 54 percent of remaining advance growth is destroyed during the falling phase of logging; 56 to 70 percent of the advance growth remaining after falling is destroyed during the skidding phase. The quantity of advance regeneration destroyed by all phases of the logging operation was between 70 and 86 percent of that which existed in the uncut stand. Other research studies conducted in British Columbia and the United States indicate the following range of advance regeneration destruction: 50% after tractor logging aimed at preserving advance growth at Bolean Lake (Smith, 1954); 66% after horse logging with no special care (Alexander, 1957); 50% after horse logging in Colorado (Alexander, 1963); 50% after selection cutting and 65% after clearcutting by tractor logging aimed at advance growth preservation in Arizona (Gottfried and Jones, 1975). The most detailed account of advance growth destruction for a broad range of forest types and logging methods is provided by Webber et al (1969) and Frisque et al (1978) and are valuable background studies to this subject. Clearly, between half and two-thirds of the advance regeneration existing in a stand is destroyed during the logging operation.

The postlogging stocking and density of advance subalpine fir regeneration usually assumes the uneven, clumpy distribution already described for silver fir, making some type of artifical stocking improvement, and perhaps improvement spacing necessary in most cases.

To maximize advance growth survival and optimize its distribution, several studies have recommended careful logging practices and modified extraction systems (Herring, 1977; Smith and Clark, 1974; Kamloops Forest District, 1976; Seidel, 1977). Recommended logging methods are well documented (Jakubjok and Hramon, 1968; Koroleff, 1968: Alexander, 1974; Roe et al, 1970; Gottfried and Jones, 1975; Webster, 1965) and provide a complete review of the factors causing excessive understory disturbance and advance growth destruction. A carefully planned overstorey harvest is also essential in minimizing logging injuries and associated future defect in surviving advance regeneration (Bergstrom, 1980), particularly where the large residual size class of subalpine fir is to be retained.

Again, it is time in this discussion to qualify this management scheme with reality. With only rare exception, a conscious, well planned advance regeneration management is not being applied in the interior of B.C. Where the species is being left as a second-growth component it is usually due to failure of another silvicultural system; a management of circumstance only. In most Forest Management Regions, however, concern for the silvicultural future of hundreds of thousands of hectares of ten to thirty year old partial cuts has led to limited scale improvement cuttings. Accurate ecosystem identification will help to identify where the subalpine fir species component will provide a timber crop, and well directed improvement treatments will help reduce future volume downfalls in these stands. Other sites less well-suited to support the growth of subalpine fir, and accounting for perhaps the majority of these old areas, must await some other treatment stategy.

ADDITIONAL CONSIDERATIONS

Why has subalpine fir advance regeneration management not been adopted in B.C.? Three reasons come to mind:

1. There are still serious misgivings about the longterm pathological resistance of released advance regeneration.
2. From a timber production standpoint subalpine fir is widely accepted as being only a poor second to the growth potential of its associated preferred species.
3. There is concern about the soundwood properties of the species being significantly lower than other commercial species.

Some recently acquired data from a sixty year old growth and yield study may help to shed some light on some of these questions. The study I refer to was begun at Aleza Lake, near Prince George, B.C. in 1926 by the Research Division of the Provincial Forest Service.[1] Located on a good site for subalpine fir growth, permanent sample plots of 0.16 ha in size were established in a mature spruce-fir forest which was horse-logged in 1919. The objectives of the study were to assess the growth and regeneration of a residual stand after logging. Plot reassessments with individual tree records were carried out approximately every five years until 1963. We have continued that reassessment schedule this year, and the data from two such plots is contained in table 1.

The sixty year pathological performance of this stand tends to confirm our shorter term studies which indicated the smallest size classes of advance subalpine fir regeneration were relatively resistant to decay fungi defect. The principle pathogen resulting in defect at Aleza Lake was the Indian paint fungus. It seems

---

[1] Herring, L.J., 1981. Data on file at Prince George Forest Region,
Prince George, B.C. and the Research Branch,
Ministry of Forests,
Victoria, B.C.

Table 1. Stand defect frequency and mean growth performance for selected trees in 4 relative size-at-release classes of Spruce and Subalpine Fir advance regeneration released in 1919 at Aleza Lake, British Columbia.

STAND AND TREE CHARACTERISTICS

Size Class (at release) (breast ht. diam. o.b.)	Frequency of Defect (%)		Mean Periodic Ht. Growth Performance of best 10% of surviving stems. (m)		Mean Total Diam. of best 10% of surviving stems (cm)	
	Subalpine Fir	White Spruce	Subalpine Fir	White Spruce	Subalpine Fir	White Spruce
0–2.49 cm (0–.9 in)	2	0	16.9	20.8	20.0	31.1
2.5 - 7.49 cm (1-2.9 in)	4	0	22.7	22.8	29.1	29.9
7.5 - 14.99 cm (3-5.9 in)	26	0	22.8	22.8	36.8	39.5
15 cm +	77	18	14.0	17.5	34.2	52.6

reasonable to assume that had improvement cuttings been carried out at the time of release, the pathological condition of the stand would be better today.

The 60 year growth performance of both species of advance regeneration in the stand casts a curious light on the second question regarding the relative growth rates of subalpine fir and white spruce. As can be seen in Table 1, the periodic height growth since 1926 for both species within all four size-at-release classes are not widely ranged. In particular, the height growth performance within the middle two classes appears remarkably similar. While no statistical significance can be placed on the data due to the method of sampling, it does suggest that on good sites, the growth performance of the two species over a relatively short cutting cycle may not be dissimilar. Figure 2 provides a graphic illustration between the size of the sampled trees in 1926 and their periodic growth to 1981. The somewhat poorer growth by the smallest size at release class is likely due to the partial overstorey influence of the larger advance regeneration throughout the growth period. Figure 2 also suggests that growth potential of the "residual" size class (15 cm + dbh) was somewhat lower than the smaller advance regeneration classes. This appears consistent with observations in other stands in B.C., and further strengthens the case for rejecting residuals in advance regeneration management.

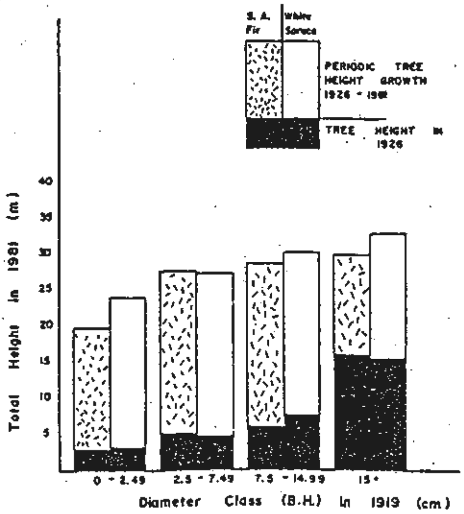


Figure 2 -- Total height in 1926 and 1981 for selected subalpine fir and white spruce advance regeneration within four size-at-release classes at Aleza Lake, B.C.

As for the third question, regarding the soundwood properties of both species, I don't intend to answer this other than to suggest that perhaps the soundwood of any commercial species will likely be valued in 100 years, and that the physical properties of the juvenile wood of spruce and fir on a short rotation may be less different than their mature wood properties are today.

To conclude, I have left unmentioned enough facts and factors to conduct yet another entire panel discussion. A decision to manage advance regeneration depends as much on our experience with; and the effectiveness of alternate, more conventional regeneration techniques as it does on our knowledge of advance regeneration itself.

At the present time we seem caught up with an honest, though perhaps overambitious desire to site prepare and plant with spruce every hectare of spruce-fir forest land in the province. I believe, however, the silvical characteristics of the species and the silvicultural properties of advance regeneration specifically, can provide a valuable reforestation option in a variety of forest management situations.

LITERATURE CITED

Alexander, R. R. 1957. Damage to advance Reproduction in Clearcutting Spruce-Fir. Rocky Mountain Forest and Range Experiment Station Research Note No. 27.

Alexander, R. R. 1963. Harvest Cutting Old Growth Mountain Spruce-Fir in Colorado. Journal of Forestry. Vol. 63, p. 115.

Alexander, R. R. 1974. Silviculture of Sub-Alpine Forests in the Central and Southern Rocky Mountains: The Status of our knowledge. USDA Forest Service Research Paper, RM-121.

Bergstrom, Dorothy. 1980. Logging Injuries Increase Decay in True Fir. USDA Forest Service, Forestry Research West, Nov. 1980.

Cariboo Forest District, Research Section 1977. A Survey Method for Residual Subalpine Fir Stands in the Bowron, Big Valley and Cottonwood P.S.Y.U.'s. B.C.F.S. Cariboo Region Report.

Cariboo Forest District, Research Section 1977. A Silvicultural Guide to the Rehabilitation of Residual Abies Stands in the Bowron, Big Valley, and Cottonwood P.S.Y.U.'s B.C.F.S. Cariboo Region Report.

Etheridge, D. E. and H. M. Craig. 1975. Decay Hazard in Advance Regeneration of Amabilis Fir After Logging in the Southern Portion of the Vancouver Forest District of B.C. Dept. of Environment, Can. For. Serv. File Report.

Etheridge, D. E. and H. M. Craig. 1976. Factors Influencing Infection and Initiation of Decay By the Indian Paint Fungus (Echinodontium tinctorium) in Western Hemlock. Can. Journal of For. Res. 6(3):299-318.

Frisque, G., G. E. Weetman, and E. Clemmer. 1978. Reproduction and Trial Projected Yields 10 Years after Cutting 36 Pulpwood Stands in Eastern Canada. Forest Engineering Research Institute of Canada. Technical Report No. TR-23.

Gordon, D.T. 1973. Released Advance Reproduction of White and Red Fir...Growth, Damage, Mortality. Pacific Southwest Forest and Range Experiment Station Research Paper. PSW-95:

Grottfried, G.J. and J.R. Jones 1975. Logging Damage to Advance Regeneration on an Arizona Mixed Conifer Watershed. USDA Forest Service Rocky Mountain Forest and Range Experiment Station Research Paper RM-17.

Herman, Francis, R. 1972. Regeneration and Silviculture in the Pacific Northwest High Country. Paper Presented at Silvicultural Conference, Seattle, Washington, Jan. 19,1972.

Herring, L.J. 1977. Studies of Advance Subalpine Fir in the Kamloops Forest District. B.C.Forest Service Research Note 80.

Herring, L.J. and D.E. Etheridge 1976. Advance Amabilis-Fir Regeneration in the Vancouver Forest District. B.C.Forest Service/Canadian Forestry Service Joint Report No. 5.

Jakubjok, A.N. and M.V. Hramov 1968. The New Techniques of Logging with Preservation of Advance Growth, Forest Abst. 30:646.

Kamloops Forest District 1976. Silvicultural Guidelines B.C. Forest Service. Unpublished Report.

Klinka, K. 1977. Guide for the Tree Species Selection and Prescribed Burning in the Vancouver Forest District - Second Approximation. Ministry of Forests, Province of B.C.

Klinka, K. 1981. Vancouver Regional Pedologist, Personal Communication.

Koroleff, A. (translator) 1968. Instructions for Work Organization in Logging in Lespromhoza. Pulp and Paper Research Inst. of Canada Woodlands Paper No. 2.

Kotar, J. 1972. Ecology of Abies Amabilis in Relation to its Altitudinal Distribution and in Contrast to its Common Associate Tsuga heterophylla PhD. Thesis, University of Washington.

Krajina, V.J. (editor) 1969. Ecology of Western North America. Dept. of Bot. U.B.C. 2(1).

Lloyd, G. Prince Rupert Regional Silviculturist, Personal Communication.

Monchak, D. Kamloops Regional Forester, Personal Communication.

Protopopov, V.B. 1959. The Influence of Mechanized Logging on the Natural Regeneration of Spruce. Works of the Institute of Forestry Vol. 40 Acad.Sci., U.S.S.R. (translated by J.K. McEwan, Ont.Dept.Lands and Forests, Port Arthur).

Roe, A.L., R.R. Alexander and M.D. Andrews 1970. Englemann Spruce Regeneration Practices in the Rocky Mountains. U.S.Dept. Agric. Prod. Res. Report 115.

Seidel, K.W. 1977. Suppressed Grand Fir and Shasta Red Fir Respond Well to Release. U.S.D.A. Forest Service Pacific Northwest Forest and Range Expt.Sta.Research Note. PNW-288.

Smith, J.H.G. 1954. A cooperative Study of Englemann Spruce-Alpine Fir Silviculture and Management. Northwest Science. Vol. 28, No. 4.

Smith, J.H.G. and M.B. Clark 1974. Results of Cutting and Related Studies Initiated in Englemann Spruce-Subalpine Fir Forests Near Boleau Lake, B.C. in 1950. B.C.F.S.

Smith, R.B. and H.M. Craig 1968. Decay in Advanced Alpine Fir Regeneration in the Prince George District of B.C. Forestry Chronicle. Vol. 44, No. 3.

Smith, R.B. and H.M. Craig 1970. Decay in Advanced Alpine Fir Regeneration in the Kamloops District of B.C., Forestry Chronicle. Vol. 46, No. 3.

Utzig, G., D. McDonald & P.Comeau 1978. Ecological Classification for the Nelson Forest District - Second Approximation. Ministry of Forests, Province of B.C.

Vancouver Forest District 1977. Regeneration Survey Guidelines for Advance Amabilis Fir Regeneration. B.C.Forest Service Limited Publication.

Webber, B., J.I. Arnott, G.F. Weetman & G.C.R.Croome 1969. Advance Growth Destruction, Slash Coverage and Ground Conditions in Logging Operations in Eastern Canada, Pulp and Paper Research Institute of Canada, Woodland Papers. W.P. No. 8.

Webster, A.D. 1965. A study of the Effects of Rubber-tired vs Tracked Skidders on the Advance Growth of a Forest. Pulp and Paper Mag. Can. 66(12).

PROBLEMS OF DWARF MISTLETOE IN ADVANCE REGENERATION OF TRUE FIRS

Robert F. Scharpf

Dwarf mistletoes are widespread and are serious disease agents of true firs in the western United States. About 20 million acres of forests with firs are infected by these parasitic plants and on about 4 million acres more than 40 percent of the trees are infected (Bolsinger 1978). A single species of dwarf mistletoe (Arceuthobium abietinum) infects firs, but this species is composed of two host-specific forms. One form, concoloris, infects mainly white fir (Abies concolor) and grand fir (A. grandis) and can be found from southern Washington to southern California and northern Arizona. The other form, magnificae, grows principally on red fir (A. magnifica) and noble fir (A. procera) and occurs from southern Oregon to central California. The greatest proportion of fir forests infected by these parasites occurs in California.

The true firs often grow in pure stands and are the climax species on many sites, but they grow in mixture with many other species in the West. The parasitic dwarf mistletoes are well adapted to grow in pure stands of fir.

The most common pattern of infection encountered in the fir forest is spread of the parasite from heavily infected old-growth overstory to surrounding reproduction and advance regeneration. Because firs are tolerant species, they often comprise a major part of the understory and as such eventually become infected by overstory dwarf mistletoe. As the overstory dies out and the infected understory replaces it, the cycle of dwarf mistletoe spread from overstory to understory is perpetuated. So far as we know, this cycle of infection can go on indefinitely in the climax fir forest unless something takes place to disrupt it. As I will point out later in this paper, there are ways to manage fir forests so that the overstory to understory infection cycle of dwarf mistletoe can be broken.

Before I discuss the effects of dwarf mistletoe on advance regeneration, some important facts about fir regeneration should be emphasized. Advance fir regeneration under an overstory, even without dwarf mistletoe, is growing very slowly, has poor vigor, often has sparse foliage, has a weak, perhaps diseased root system, and is suffering from other stresses--like moisture and nutrient deficiencies. All these stresses mentioned are found in the highly competitive understory environment. As a result, added stresses, such as those from dwarf mistletoe infection or insect attack, may be more than the already weakened trees can tolerate. Yet amazingly enough, many understory firs do tolerate and survive the intense competition and stresses placed on them. Often, removing the competition and/or one or more of the stress factors allows weakened firs to recover, regain energy, and increase growth. Proper management of advance true fir regeneration requires an understanding of the factors stressing trees and the ways in which the stresses can be mitigated.

Another fact to keep in mind is that the stress brought on by dwarf mistletoe in advance regeneration does not occur suddenly but has been building up for a long time--sometimes for a hundred years or more. As a result of the long exposure to overstory dwarf mistletoe, even trees that might otherwise have escaped infection when young have become infected. Therefore, advance regeneration may not only be old and stressed but also be heavily infected by dwarf mistletoe.

A. Impact of dwarf mistletoe

The effects of stress on firs by dwarf mistletoe is manifested in several ways. The main effect is reduction of growth. Both radial and height growth are reduced (Scharpf 1979). For the most part reduction of growth is slight until dwarf mistletoe builds up to heavy levels of infection (Hawksworth rating of 5 or 6). On suppressed advance regeneration, the effect on growth is usually not easy to measure because in these cases even growth of uninfected trees is extremely slow. In released firs, however, impact of dwarf mistletoe on radial and height growth can be readily measured.

Tree mortality or mortality of tops and portions of the crown of advance regeneration is also associated with dwarf mistletoe infection. Small suppressed trees infected in the trunk often die above the site of infection. This condition results in deformed trees or more often in death of the tree. In these cases, death of the tree or portions of the tree is not always caused directly by dwarf mistletoe but usually by the invasion of

---

Robert F. Scharpf, is Plant Pathologist at the Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, Berkeley, Calif.

Cytospora canker (Cytospora abietis) and other fungi that attack at the dwarf mistletoe infection site. For reasons unknown, much less top killing occurs in larger released firs with trunk infections.

Loss of apical dominance from dwarf mistletoe infection also is detrimental to growth and survival of advanced regeneration. In many instances, particularly in suppressed regeneration, infected lateral branches turn up and become the dominant top, or compete strongly with the top for dominance. This competition for dominance among branches and tops usually reduces height growth of the tree and makes it less able to grow and survive within the developing stand. Reduction of height growth in understory regeneration usually is not caused by heavy levels of dwarf mistletoe. Rather, the reduction is caused by disruption of the tree's hormonal balance and the diversion of energy into a few infected branches that eventually grow and compete for height growth.

Some infected branches develop into brooms but the large, well developed brooms found on other tree species infected by dwarf mistletoe are seldom found on true firs. However, even poorly developed brooms, like those on firs, may have a marked growth impact on advance regeneration.

B. Spread of Dwarf Mistletoe

1. Lateral spread. Spread of dwarf mistletoe from one tree to another is greatest from large trees (overstory) to surrounding regeneration (understory). This applies not just to fir dwarf mistletoe but to all dwarf mistletoe-host species combinations. Past research has shown in California that regeneration less than 3 feet tall seldom becomes infected by overstory dwarf mistletoe (Scharpf 1969) unless it is old and suppressed and has been exposed to infection for many years. Although not precisely known, maximum distance of spread from infested overstory to understory trees is considered to equal about the height of infection in the overstory trees.

Lateral spread of dwarf mistletoe among young firs has not been studied but from nearly 20 years of observation of population buildup and vertical spread of the parasite within the crowns of trees, I feel that lateral spread is very slow and probably somewhat less than the 1 to 2 ft a year reported by Hawksworth (1961) for pines.

2. Vertical spread. Vertical spread of dwarf mistletoe within the crown of infected trees has been studied for several host species combinations and has been shown to vary on the average from about 3 in to about 1.5 ft per year (Scharpf and Parmeter 1976). Fir dwarf mistletoe is one of the slow spreaders--moving upward in tree crowns on the average of about 3 inches per year. The dense, persistant foliage of firs is one reason why dwarf mistletoe spreads slowly. The discharged seeds are often trapped by nearby foliage and are not readily dispersed at great distances. Other factors limiting spread will be discussed in the following section, "Population Buildup."

C. Population Buildup of Dwarf Mistletoe

One question often asked by forest managers of infested fir stands is, "How fast will dwarf mistletoe build up in infected, release regeneration?" Managers are rightly concerned that small infected trees may become so badly infected over time that they will either die or be severely reduced in growth. Results of nearly 20 years of study on the buildup of dwarf mistletoe on firs in California have recently been summarized [1] and should provide information useful for management of infested fir stands. In general, results of the studies indicate that dwarf mistletoe populations do not intensify nearly as rapidly as orginally expected. Several reasons were found for the slow rate of intensification:

1) Dwarf mistletoes are dioecious plants (separate male and female plants); therefore, not all plants produce fruit. Like other dwarf mistletoes, the male to female ratio was found to be 1 to 1.
2) Very few of the seeds produced by female plants result in infection. Of about 7000 seeds placed on branches over 5 years, only 3 to 4 percent resulted in infection. Percentage of infection would probably be even lower for naturally dispersed seeds.
3) A long time period is required between infection and the development of fruit-bearing plants. This period, on the average, was found to be about 8 to 9 years.
4) Not all female plants produce fruit in any one year. In general, we observed that fewer than 50 percent of all the female plants in the study produced fruit at any one time. Yearly production of fruit varied widely among female plants, however.
5) Relatively few of the female dwarf mistletoe plants bear abundant fruit. Only about 10 to 15 percent of all fruit-bearing plants produced abundant fruit (100 or more fruit per year) in our studies. Most of the abundant fruit-bearing plants were on vigorous main branches, whereas the poorer fruit-producing plants were on weaker suppressed branches or on small lateral twigs. Thus, a large proportion of dwarf mistletoe seeds is produced by a small proportion of the female plants.
6) Some years are unfavorable for fruit development. Not only are dwarf mistletoe plants sporadic in fruit production, but climatic and other factors limit fruit development. In one year we observed that an early frost caused abortion of nearly all the

---

[1] Unpublished studies by R. F. Scharpf and J. R. Parmeter, Jr. on "Population dynamics of dwarf mistletoe on young firs in the central Sierra Nevada."

developing fruit on plants, and in other years we noticed that the parasitic fungi. *Colletotrichum gloesporioides* and *Cylindrocarpon gillii* killed the shoots and fruit of many plants. These unfavorable years undoubtedly help keep population buildup of the parasite in check.

7) Death of dwarf mistletoe plants limits fruit production. Although dwarf mistletoe plants can live for many years on their hosts, many are killed. Cytospora canker kills infected fir branches and is the cause of much of the mortality. Tree squirrels girdle some branches in search of stored starches and sugars at the infection site and some infections die because a main branch bearing several proximal infections is killed. Results of our studies showed that for red fir about one-third, and for white fir about one-half, of the original population of dwarf mistletoe plants were dead after 10 years.

Over 17 years of study, some second generation infections did develop. However, the dwarf mistletoe population was only about double what it was from inoculation. Dying of infections appeared to be an important factor in keeping the population of dwarf mistletoe at relatively low levels in infected trees.

D. Managing Infected Advance Regeneration

The first consideration in the management of either infected or uninfected advance fir regeneration is to release it from suppression by surrounding overstory or from competition by overstocked stand conditions. Research has shown that with larger advance regeneration, many dwarf mistletoe-infected and noninfected trees survive and increase in growth rate after release (Scharpf 1979). In the stands studied, several factors were involved in how well trees grew after release, but release alone was the most important factor. After release, live crown ratio was the most important variable in how well trees responded in growth. Trees with good live crown ratios (50 percent or more of the tree's height with living crown) showed much better growth 5 to 10 years after release than did trees with poorer live crown ratios.

Also, larger trees grew better after release than smaller ones, and noninfected and lightly infected ones grew better than heavily infected ones. Therefore, the results of our studies on larger released firs indicated that release and a good live crown ratio were the most important variables, but that tree size and dwarf mistletoe intensity were also involved in how well advance regeneration grew after release.

Other important considerations in the management of infected fir regeneration are:

1) Establishment and maintenance of as even-aged a stand as possible. Dwarf mistletoe spreads slowly among trees of the same size but larger residual regeneration may act as infected overstory for the spread of dwarf mistletoe to small regeneration.
2) Management of mixed species stands if possible. Dwarf mistletoes are very host-specific. Including other species in the stand will not only provide trees resistant to infection but to the spread of dwarf mistletoe.

Several other factors should be taken into account regarding management of infected fir regeneration. Bole infections, commonly considered a problem in old growth firs, will probably not be a problem in the management of young growth stands [2]. It appears unlikely that large bole swellings will develop and cause loss of growth or volume in vigorous, well managed young firs.

Growing site should be considered with regard to both tree growth and dwarf mistletoe spread and impact. Fast growing trees on good sites will likely outgrow the spread and buildup of dwarf mistletoe with little or no growth impact or mortality, whereas on poor growing sites the parasite is more apt to spread and build up to damaging levels within the tree crown, both reducing tree growth and vigor and possibly predisposing it to mortality from cytospora canker, fir engraver, or other agents.

A final cautionary note is in order. Most of the results and information presented here have been based on a limited number of studies of a few species over a fairly small geographical area. Therefore, the conclusions reached may not apply exactly to all dwarf mistletoe-infested fir stands in the west. Additional studies are under way and pilot tests have been initiated to apply the information from studies to operational management situations. In time, the results of these tests should provide managers with better information on how best to manage dwarf mistletoe-infected fir regeneration under a wide range of conditions.

LITERATURE CITED

Bolsinger, Charles L. The extent of dwarf mistletoe in six principal softwoods in California, Oregon, and Washington, as determined from forest survey records. Proceedings, symposium on dwarf mistletoe control through forest management; 1980 April 11-13; Gen. Tech. Rep. PSW-31. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture; 1980; 1980; p. 45-54.

Hawksworth, Frank G. Dwarf mistletoe of ponderosa pine in the Southwest. Tech. Bull. 1246 Washington, DC: U.S. Department of Agriculture; 1961. 112 p.

---

[2] Unpublished information by J. R. Parmeter, Jr. and R. F. Scharpf on "Effect of bole infections on young growth firs."

Scharpf, Robert F. Dwarf mistletoe on red fir--infection and control in understory stands. Res. Paper PSW-50. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station. Forest Service, U. S. Department of Agriculture; 1969. 8 p.

Scharpf, Robert F., and J. R. Parmeter, Jr. Population buildup and vertical spread of dwarf mistletoe on young red and white firs in California. Res. Paper PSW-122. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, 1976. 9 p.

Scharpf, Robert F. Dwarf mistletoe infected red fir: Growth after release. Res. Paper PSW-413. Berkeley, CA: Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture; 1979. 9 p.

ROOT-DISEASE PROBLEMS IN TRUE FIR

J. R. Parmeter, Jr.

True firs have been among the "poor relations" of western conifers, even suffering the ignominy of vulgar and uncomplimentary appellations. While papers on root diseases of more esteemed associates are plentiful, few studies dealing directly with root diseases on fir are available. We are thus left with *argumentum ex silentio* in discussing these diseases and their implications in the management of firs.

Rational incorporation of root-disease information into stand management prescriptions should involve at least four phases:

1. Evaluation of impacts and needs for research or management action.
2. Collection of basic information on disease/stand/site/management interactions as they relate to methods for predicting and manipulating changes in impact under various situations.
3. Development of management tools and strategies to minimize unacceptable impacts.
4. Evaluation of the efficacy of these tools and strategies and the development of needed refinements.

Logically, these phases should proceed *seriatim*, since results of one phase may obviate succeeding phases. However, the impact potentials of root diseases are such that management mistakes today may mushroom (figuratively) into various degrees of catastrophe. For this reason, the best tactic may be to proceed with efforts on all phases as a matter of caution or "insurance." I hope here to provide a brief assessment of where we stand and where we should be going with respect to these phases of root-disease research and development in fir.

I would have preferred to expound or elaborate with customarily thorough attention to detail and perhaps with just the right amount of slightly bombastic but not too pompously eloquent circumlocution, but owing to recently expressed concerns regarding surplus verbiage associated with some contributions to the *Proceedings*, I will endeavor to achieve terse, succinct, concise, sententious, laconic (perhaps even aphoristic) reduction in repetitious redundancy.

PATHOGENS AND THEIR IMPACTS

Root diseases of western firs have been mentioned by various authors over the years, but systematic identification and appraisal is relatively recent. Miller (1963) found *P. schweinitzii* and *A. mellea* respectively in 0.2 and 64.0% of 1229 blown-down firs in California. Most of the fir root-disease mortality in the Inland Empire was associated with *P. schweinitzii*, *A. mellea*, *P. weirii*, and *F. nigrolimitatus* (Partridge and Miller 1972; Miller and Partridge 1973, 1974; Hertert *et al.*, 1975). Similarly, Lane and Goheen (1979) found *P. weirii* and *A. mellea* to be the main fir root pathogens in Region 6. In contrast, *P. annosus*, with lesser amounts of *A. mellea*, predominated in Colorado (James and Goheen 1981) and in California (Byler *et al.* 1977; U.C. unpubl.). Present data suggest that the relative importance of various fir root pathogens changes in different regions, with a gradual shift from *P. weirii* and *A. mellea* in the north to *F. annosus* in the south. *P. tomentosum* and *C. wageneri* appear to be rare in firs.

The impact of root diseases on the productivity of fir stands is largely unknown. Most surveys have involved samples of dead and dying trees, where root-disease incidence is high. But dead trees have impact only when the ultimate value of the stand is reduced, and this has rarely been demonstrated. Where random samples of stands have been made, root disease occurrence has been low. Partridge and Canfield (1980) found only 2% of *A. lasiocarpa* and none of *A. grandis* (based on examination of 89 trees) had root disease. In California, we found about 4% of 453 live *A. concolor* and *A. magnifica* (from 300 random cells on 30 km^2 "green" plots and 153 "mortality" cells on 25 km^2 "mortality" plots) were infected with *F. annosus* (based on stump disc incubation).

On an area basis, we found about 19% of the 300 "green" cells and about 37% of the mortality cells had confirmed or probable presence of *F. annosus* (based on its occurrence in any tree or stump on the cell). These few data do not provide impact evaluation, but we hope to use them to develop methods for determining and predicting impacts.

DISEASE/STAND/SITE/MANAGEMENT INTERACTIONS

Few studies on root diseases in fir have been published, but presumably pathogen behavior is similar to that in more intensively studied hosts. Fir stumps are susceptible to spore colonization (Morrison & Johnson 1970; Wallis and Reynolds 1970; U.C. unpubl.). Trees near stumps are often infected (James and Goheen 1981; Ferrell and Smith 1976; U.C. unpubl.). Both *P. weirii* and *F. annosus* cause expanding "centers" in fir.. Infected trees are predisposed to bark beetle attack (Miller and Partridge 1974; Cobb *et al.* 1974; James 1979). In short, basic root-disease pathology and epidemiology demonstrated for other species likely applies at least generally to firs. This assumption needs verification.

The utility of available information and extrapolations in developing predictive capacities and control strategies is not clear, but it is probably fair to say that we have very little specific data that provide guidelines for management of fir stands liable to root-disease damage. We know that fir stumps are colonized readily by *F. annosus* (Wallis and Reynolds 1970; U.C. unpubl.) and that the incidence of *F. annosus* in fir stands can be associated with the presence of stumps (James and Goheen 1981; Ferrell and Smith 19766; U.C. unpubl.). Borax will prevent stump colonization in fir (U.C. unpubl.), but we don't know that preventing stump colonization reduces future root-disease damage.

John R. Parmeter is
Professor of Plant Pathology,
University of California, Berkeley.

As an approach to stand risk rating and to identification of factors that are associated with root disease levels in fir stands, we (U.C. unpubl.) have analyzed survey data with the following results.

1. On an individual tree basis, the presence of more F. annosus than statistically expected was highly significant ($p < 0.01$) associated with:
a. trees over 120 years old
b. DBH above 41 cm
c. trees with more than 10% increase in radial growth during the past 10 years
d. trees within 5 M of a stump
e. codominant, as opposed to dominant or suppressed trees;
and was significantly ($p > 0.01 < 0.10$) associated with:
a. live crown ratios below 60%
b. presence of wetwood.

2. On a stand basis, highly significantly ($p < 0.01$) more F. annosus was associated with:
a. basal areas above 80 M/ha
b. history of logging
c. no evidence of past brush cover;
and was significantly ($p > 0.01 < 0.10$) associated with:
a. compositions exceeding 80% fir
b. red fir type (as opposed to mixed conifers or ponderosa pine types)

These tentative, interim, preliminary results suggest that further studies could provide guidelines for optimum stand structure, composition, rotation, etc. to minimize root-disease damage.

On a broader scale, Williams (1971) reported that fir root-disease damage was prevalent in specific habit types in Region 1 and we have found marked differences in occurrence among the ecological provinces of California. These observations suggest that future studies could define those regions, probvinces, habitat types, etc. in which root-disease hazard in fir is high. This could in turn provide a basis for concentrating treatment efforts in stands that would yield greatest returns for the effort.

DEVELOPMENT OF MANAGEMENT TOOLS AND STRATEGIES

Although suggestions for the management of other timber species to control root-disease damage will likely provide useful guidelines for fir, I am unaware of any published information dealing directly with data on root-disease reduction in fir. Partridge (1977) suggested that dynamite might be useful in stump removal and Williams (1971) indicated that timing of thinning, prevention of mechanical injury, and prevention of fire would reduce root disease in fir. No data were presented. Obviously, fir management skills will not advance until treatments have been developed and tested.

REFINEMENT OF TREATMENTS

This is not possible until we have something to evaluate and refine. It may be possible to gain some information by ex post facto evaluation of various thinnings and other silvicultural treatments undertaken for other purposes, but this approach usually is inadequate because of the lack of baseline data on root-disease conditions.

CONCLUSIONS

I conclude from this very brief overview (and I apologize for its brevity) that:

1. Root diseases have the potential to cause serious impacts in second growth fir stands. Assessment of this potential is urgently needed to avoid making mistakes today that may jeopardize future productivity of fir stands.

2. Much of the information that is absolutely, categorically essential (if I may indulge in a minor bit of verbal overkill) to the rational management of fir stands has not been collected. Will thinning increase root-disease damage by creating infection courts or will it decrease damage by increasing host vigor? Will thinning increase or decrease insect activity that may directly or indirectly affect root diseases? Are there host-specialized forms of pathogens on various conifer species? Can firs safely be planted in pine, hemlock, or Douglas fir centers? Are mixed stands less liable to root disease? It is difficult to see how we can manage fir stands responsibily without answers to these and many other questions.

3. Current efforts to obtain essential information on root diseases of fir (and most other species) are woefully inadequate, unsystematic, and uncoordinated to the point of near or actual negligence (just to throw in a bit more colorful pontification). Future costs of current omissions may be very high.

4. Someone will say the same things at the 49th WIFDWC.

LITERATURE CITED

Bergstrom, D. Logging injuries increase decay in true fir. USDA For. Serv. For. Res. West, Nov.:8-11, 1980.

Byler, J. W.; Caylor, J. A.; Hart, D. R.; Ollieu, M. M.; Wood, R. E. The pest damage inventory. USDA For. Serv., Reg. 5, For. Insect and Disease Manage. Tech. Rep. 2, 1977.

Cobb, F. W., Jr.; Parmeter, Jr., J. R.; Wood, D. L.; Stark, R. W. Root pathogens as agents predisposing ponderosa pine and white fir to bark beetles. 4th Int. Conf. in *Fomes annosus*. IUFRO Sect. 24: For. Prot., Athens, GA, pp. 8-15, 1974.

Filip, G. M.; Schmitt, C. L.. Susceptibility of native conifers to laminated root rot east of the Cascade Range in Oregon and Washington. For. Sci. 25:261-265, 1979.

Ferrell, G. T.; Smith, Jr., R. S. Indicators of *Fomes annosus* root decay and bark beetle susceptibility in sapling white fir. For. Sci. 22:365-369, 1976.

Hertert, H. D.; Miller, D. L.; Partridge, A. D.. Interaction of bark beetles (Coleoptera: Scolytidal) and root-rot pathogens in grand fir in northern Idaho. Can. Entomol. 107:899-904, 1975.

James, R. L. *Fomes annosus* on white fir in Colorado. Plant Dis. Reptr. 63:129-130, 1979.

James, R. L.; Goheen, D. J. Conifer mortality associated with root disease and insects in Colorado. Plant Dis. 65:506-507, 1981.

Lane, B. B.; Goheen, D. J. Incidence of root disease in bark beetle-infested eastern Oregon and Washington true firs. Plant Dis. Reptr. 63:262-266, 1979.

Miller, D. L.; Partridge, A. D. Fungus associations in root rots of grand fir. Plant Dis. Reptr. 57:346-348, 1973.

Miller, D. L.; Partridge, A. D. Root rot indicators in grand fir. Plant Dis. Reptr. 58:275-276, 1974.

Miller, D. R. Root disease survey of blowdown timber in Northern California. USDA For. Serv., Reg. 5, Unpubl. Rep., 1963.

Morrison, D. J.; Johnson, A. L. S. Seasonal variation of stump infection by *Fomes annosus* in coastal British Columbia. For. Chron. 46:1-3, 1970.

Partridge, A. D.; Canfield, E. R. Frequency and damage by forest-tree pests in Southern Idaho. Univ. Idaho For. Wildlife and Range Exp. Sta. Note 34, 1980.

Partridge, A. D.; Miller, D. L. Bark beetles and root rots related in Idaho conifers. Plant Dis. Reptr. 56: 498-500, 1972.

U.C. unpublished. Results of surveys funded by R-5 and conducted by Garey Slaughter, Mark Schultz, Jeanne Mihail, Cindy Macedo, and Dick Parmeter.

Wallis, G. W.; Reynolds, G. *Fomes annosus* root and butt rot: a threat in managed stands in coastal British Columbia. For. Chron. 46:1-4, 1970.

Williams, R. E. The root rot problem in the Northern Region. USDA For. Serv., Northern Region Rep. 71-43, 1971.

DECAY IN GRAND AND WHITE FIRS

Paul E. Aho and Gregory M. Filip

ABSTRACT: Large acreages of advanced true fir regeneration are available for management in the ponderosa pine subregion in Oregon and Washington. Forest managers would like to use this regeneration to save reforestation costs but are concerned that if they do decay may be a significant problem before rotation ages are reached. Echinodontium tinctorium was not expected to be a major problem in second-growth true fir stands. Preliminary results of our studies indicate the opposite may be so since the biology of this fungus is closely related to past development and management of stands of advanced true fir regeneration. Several factors are discussed which we hope can be used by foresters to rate the expected future decay hazard of various stands of advanced grand and white fir regeneration.

INTRODUCTION

Grand fir (Abies grandis (Dougl. ex D. Don) Lindl.) and white fir (A. concolor (Gord. & Glend.) Lindl. ex Hildebr.) are important species in several forest cover types and in the ponderosa pine (Pinus ponderosa Dougl. ex Laws.) subregion of Oregon and Washington. Old-growth forests of these species are known to be highly defective. More than a third of the merchantable board-foot volume of sawtimber size (11.0+-inch) grand firs on 66 fifth-acre plots systematically sampled in 11 old-growth stands in the Blue Mountains was cull, mainly because of decay (Aho 1977). The Indian paint fungus Echinodontium tinctorium E. & E., caused nearly four-fifths of the decay. Old-growth white fir stands in southcentral and southwestern Oregon are also highly defective and a high proportion of the cull is caused by the Indian paint fungus (Aho and Simonski 1975, Aho 1976). Pathologists and forest managers thought that harvesting the old-growth forests and replacing them with vigorous, young stands would minimize decay, particularly that caused by E. tinctorium, in the next rotation. Wound invading fungi, such as Pholiota sp., Hericium abietis (Weir ex Hubert) K. Harrison, and Fomitipsis (Fomes annosus) annosa (Fr.) Karst. would probably be the most important decay fungi in young managed stands (Aho 1977). These two assumptions would probably be correct if the true firs replacing the old-growth forests were indeed young and vigorous. However, large acreages in the ponderosa pine subregion are converting, because of effective fire control and past harvesting practices, to grand or white firs which had been present in the understory. Many of the true fir understories had been suppressed and often are of advanced ages.

Forest managers are faced with the decision of whether or not to utilize the advance true fir regeneration. By doing so, large savings can be made in costs of removing the advance regeneration, slash disposal, site preparation, and planting. In addition, less time will be required to obtain another crop from the site (on harsh sites regeneration may never again become established). From a pathological viewpoint, the main concern in making the decision is the present or future extent of decay in the residual trees. This concern stems from the knowledge that old-growth true fir stands are often highly defective, the advance true fir regeneration is often quite old, and that past stand entries may have resulted in logging damage to many potential crop trees. These conditions, especially considered in relation to the life cycle of the Indian paint fungus, could mean that use of suppressed true firs for forest regeneration in eastern Oregon and Washington may lead to decay problems in the future.

BIOLOGY OF ECHINODONTIUM TINCTORIUM

Grand and white fir generally form mixed uneven-aged stands with various combinations of Douglas-fir (Pseudotsuga menziesii Var. glauca (Beissn.) Franco), western larch (Larix occidentalis Nutt.), Engelmann spruce (Picea engelmannii Parry ex Engelm.), subalpine fir (A. lasiocarpa (Hook.) Nutt.), ponderosa pine and lodgepole pine (P. contorta Dougl. ex Loud.) in the ponderosa pine subregion. Many stands have two layers consisting of a mixed conifer overstory, and a true fir understory. Repeated entries have been made in most stands to harvest the desirable timber species. As a result, a scattered overstory of very defective trees, many bearing E. tinctorium

---

Paul E. Aho is Plant Pathologist at the Pacific Northwest Forest and Range Experiment Station, USDA Forest Service, Corvallis, Oregon. Gregory M. Filip is Plant Pathologist in Forest Pest Management, State and Private Forestry, USDA Forest Service, Region 6, Portland, Oregon.

sporophores, has been left as a source of inoculum to infect the advanced regeneration.

Etheridge and Craig (1976) found that Indian paint fungus sporophores produce viable basidiospores throughout the year, but maximal sporulation occurs in the spring and fall when average daily temperatures range from 4.5 to 16° C (40 to 60°F). They postulated that the main infective period of western hemlock by E. tinctorium is in the spring since maximum basidiospore germination occurs after temperatures fall below 0°C during the winter months.

Large dead branches and branch stubs are not important infection courts on host tree species for E. tinctorium as was previously thought (Thomas 1958). These habitats are generally rapidly colonized by microorganisms which are antagonistic to the Indian paint fungus (Etheridge et al. 1970). Shade-killed twiglets, less than one mm in diameter, are the predominant infection courts for E. tinctorium (Etheridge et al. 1972). Infection occurs when a basidiospore comes in contact with a twiglet stub. The spore germinates and hyphae become established in the buried portion of the stub. Infection cannot take place if the small twig traces are grown over in less than two years. Suppression or poor site delays healing of the twiglet stubs, providing excellent conditions for infection by Indian paint fungus spores for several years. Other decay fungi may also invade trees through these small dead branchlets (Aho and Hutchins 1977).

Conditions become unfavorable for continued growth of the fungus after the twig stub heals. The infection becomes semidormant and may remain in tissues near the branch or stem pith for 50 or more years (Etheridge et al. 1972). During this period the infected tissues are usually not discolored or decayed. Numerous shade-killed internodal twigs less than one mm in diameter usually occur on living branches or the stems of Indian paint fungus host tree species. A given tree may have many dormant infections scattered throughout its stem and crown. Large decay columns can develop rapidly if several infections become active and coalesce within a tree.

Wounds in the immediate vicinity of dormant infections provide conditions that activate the fungus and initiate the decay process (Etheridge and Craig 1976). If the activated infection is close to the base of a branch, the fungus can develop into the stem. In other cases, branch infections are encased in the stem by diameter growth of the tree. Most Indian paint fungus decay columns, within stems, are apparently associated with infection courts formed in the trunk when trees underwent periods of suppression (Etbridge and Craig 1976).

Little is known about the conditions, time, and extent of decay development required for production of E. tinctorium sporphores on infected trees. Decay develops in the heartwood and is easily recognizable when conks are produced. Although Indian paint fungus conks have been observed on the faces of wounds they usually are attached to the undersides of dead branches. Branches are the bridges, which mycelium of this fungus use, to move from the heartwood through the sapwood to the exterior of trees where sporophores are produced.

EVALUATION OF DECAY IN RELEASED STANDS OF ADVANCED GRAND AND WHITE FIR REGENERATION

We recently studied the extent of infection and decay by E. tinctorium and other fungi in previously suppressed, advanced grand and white fir regeneration. Sampled stands had been released by overstory removal and precommercial thinning. In some stands, however, a few scattered old, defective true firs bearing E. tinctorium sporophores were left, apparently for use as bird or animal habitat.

Methods

Twenty four stands were located and sampled in 20 ranger districts/ in 10 eastside National Forests of Oregon and Washington. Twenty trees were sampled in each stand, except for one, from which only four were taken. The following data were recorded while the trees were standing: d.b.h., size, position, and condition of visible wounds, and location and description of other defect indicators. The trees were felled, dissected, and carefully examined for wounds and decay. Approximately a half of the tree, from the ground line to three feet above the base of the live crown, was taken to the laboratory. Numerous isolations were made from stem and encased twig piths, sound-appearing heartwood, and any wetwood, stain, or decay that was observed. Tree age was determined by a ring count at ground line using a dissecting microscope.

Results

Of 464 trees sampled over 50 percent had one or more wounds. Decay was associated with 53 percent of the injuries. In a given stand, wound ages varied considerably indicating that most stands had been entered with logging equipment several times in the past. Many wounds had not healed over yet, thus were still subject to infection by decay fungi.

Nearly 24 percent of the sample trees were infected by the Indian paint fungus. We feel that this figure is conservative because of the difficulty in isolating the Indian paint fungus in culture and unavoidable delay in sampling trees in the laboratory. More than half of the Indian paint fungus infections were actively causing decay. The percentage of E. tinctorium infections increased with increasing tree age and size. Nearly half of the Indian paint fungus isolations were from healthy-appearing wood. More than 70 percent of the apparently dormant infections were in unwounded trees. These data suggest that the mode of infection and injury activation of decay by the Indian paint fungus in grand and white firs is the same for these species as was determined for western hemlock by Etheridge et al. (1972).

Approximately 3 and 4 percent of the cubic and board foot volumes, respectively, of the sample trees were decayed. Although sample trees averaged 80 years of age they only averaged 5.9 inches in diameter outside bark at breast height and 31 feet in height. Decades will be required for these trees to reach desired merchantable sizes, At this time we cannot accurately predict the extent of decay losses in these stands at rotation age, but indications are that they may be serious.

Discussion and Recommendations

It is apparent from our data that management of the mixed conifer types in eastern Oregon and Washington has created conditions in many stands which could lead to development of severe decay losses in the future if advanced true fir regeneration is used for reforestation purposes. Leaving old, defective true firs, bearing E. tinctorium sporophores, as animal habitat has provided an excellent source of inoculum for infection of susceptible hosts. Long periods of suppression have produced the infection courts needed by the Indian paint fungus. Frequent logging activities in these stands have caused injuries on a high proportion of the residual trees. These injuries are necessary for activation of dormant E. tinctorium infections and may also be invaded by other fungi. Forest managers need a system by which various stands of advanced regeneration can be rated so that future decay hazard can be predicted. With this system high risk stands can be identified and treated to minimize volume losses.

We cannot at this time provide a decay hazard system, but can point out the factors which we feel will be useful in developing one. Some factors, of course, are more important than others and will be given more importance when we attempt to develop our rating system. Stand risk factors will probably include; percent of residual crop trees wounded, presence of Indian paint fungus conks in the previous or present overstory, average age and d.b.h. of residual trees, and composition of the previous overstory tree species. Decay risk for a given stand will increase with increasing proportion of crop trees with injuries, if trees bearing E. tinctorium conks are or were present in the overstory, with increasing age and d.b.h. of residual trees, and in stands where the previous overstory was comprised mainly of true firs. We feel that preventing injuries is especially important to minimize decay.

LITERATURE CITED

Aho, Paul Eugene. Fungal and bacterial associations in heartrots of Abies concolor (Gord. and Glend.) Lindl. and techniques for estimating damage in southwestern Oregon. Corvallis, OR: Oregon State University; 1976. 202 p. Thesis.

Aho, Paul E. Decay of grand fir in the Blue Mountains of Oregon and Washington. Res. Pap. PNW-229. Portland, OR: USDA For. Serv. Pac. Northwest For. and Range Exp. Stn.; 1977.

Aho, Paul E. and Anita Hutchins. Micro-organisms from the pith region of suppressed grand fir understory trees. Res. Note PNW-299. Portland, OR: USDA For. Serv. Pac. Northwest For. and Range Exp. Stn.; 1977.

Aho, Paul E. and Philip Simonski. Defect estimation for white fir in the Fremont National Forest. Res. Pap. PNW-196. Portland, OR: USDA For. Serv. Pac. Northwest For. and Range Exp. Stn.; 1975.

Etheridge, D. E. and H. M. Craig. Factors influencing infection and initiation of decay by the Indian paint fungus (Echinodontium tinctorium) in western hemlock. Can. J. For. Res. 6:299-318; 1976.

Etheridge, D. E., H. M. Craig, and S. H. Farris. Infection of western hemlock by the Indian paint fungus. Dep. Environ., Can. For. Serv. Bimon. Res. Notes 28(1):3-4; 1972.

Etheridge, D. E., H. M. Craig, and L. D. Taylor. Factors affecting suitability of western hemlock as a substrate for spore germination and growth of the Indian paint fungus. Northwest Sci. 44:244-252; 1970.

Thomas, G. P. Studies in forest pathology. XVIII. The occurrence of the Indian paint fungus, Echinodontium tinctorium E. & E., in British Columbia. Can. Dep. Agr. For. Biol. Div. Publ. 1041; 1958.

Panel: Root Disease Control Strategies--Are They Worth It?

Kenelm Russell - Moderator

It wasn't too many years ago when most of the root diseases were identified by the pathologist who then draped a consoling arm over the sad eyed manager's shoulder and said "Well, there are worse things!" Nothing seemed feasible or practical, especially dollar-wise back then. "Second generation" pathologists like Tobey Childs, Lew Roth and others began to change all that. Much of their early background work laid a solid foundation for distinct root rot "control" or management possibilities today. At a Northwest Forest Pest Action Council Disease Committee meeting in Olympia some years ago, the "third generation" pathologists decided to take steps to establish numerous and varied trials, experiments and operational projects to see if something would pan out.

The 80's decade is seeing many encouraging results from those trials. Root disease management does appear feasible! The major hurdle now is to sell this idea to recalcitrant and tight fisted managers. I think the best way to sell root disease management is in the manager's own terms. Terms like site prep - not stump removal. Emphasis has to be placed on the care of the medium - the soil. Keep it disease free! I've seen managers spend $500/acre to regenerate a stand, but $500/acre to push out big stumps? - Never! In this panel we have tried to present some strategies and "tools" to help managers decide. Let's find out.

ONGOING RESEARCH FOR THE CONTROL OF LAMINATED ROOT ROT

by Walter G. Thies

I. Introduction

Phellinus weirii (Murr.) Gilb. (laminated root rot) infects nearly all commercially important conifers in the western U.S. and Canada. It reduces forest productivity primarily by directly killing trees or by predisposing them to wind-throw, bark beetle attack or other secondary agents. This disease causes an estimated west-wide annual loss of 4.5 million cubic meters (Nelson et al 1981) with 0.9 million cubic meters of loss in west-side Douglas-fir alone (Childs and Shea 1967). When infected trees die, the pathogen continues to live saprophytically in dead roots for as long as 50 years (Childs 1963, Hansen 1979) and may remain viable for 100 years (Childs 1963). Infection in a young stand begins when roots of young trees contact residual infested stumps and roots from the preceding stand. The infection spreads between living trees via root contact (Wallis and Reynolds 1965). As the fungus advances along a tree's roots, the roots distal to the fungus are killed, denying the tree water and nutrients necessary for growth. Crown symptoms may appear 5 to 15 years following initial infection (Wallia 1976). As roots decay, a tree is robbed of structural support and, eventually, is wind-thrown. Although viable basidiospores are formed and cast they have not been successfully used to inoculate stumps or roots and their role in spread has not been defined.

Immediate replanting with Douglas-fir on a site infested with P. weirii often results in continuation of the disease and subsequent losses in the new stand. Time honored responses to disease losses, such as shortened rotation or intensive salvage programs, capture much of the mortality loss but do little to reduce inoculum on the site or to reduce impact of the disease on the next crop. Unfortunately, proven management strategies for reducing inoculum potential while maintaining desirable species for a full economic rotation on the site are lacking. Opportunities to control laminated root rot are best at final harvest when heavy equipment is available and has room to maneuver, when harvest and reforestation options are available, and when stump treatments or soil amendments can most easily be applied.

This paper will discuss strategies now being field tested for the control of laminated root rot. It seems like a good time to inform ourselves of the existence of these studies. Although foresters are showing an increasing concern for control of laminated root rot, economic conditions may dictate that most of these studies will not be further replicated for years to come. Additionally, although most of these studies were initiated within the past five years, their long term nature dictates that they likely will not be mentioned in the literature for many years. In most cases the success of the proposed control will be determined by performance of the new stand (requiring 20 to 30 years) or development of a significant amount of laminated root rot in the new stand (requiring 15 to 20 years).

The study areas (installations) vary in size from 1- to 24-ha. To my knowledge, all ongoing P. weirii control studies have been included. It is with permission of the following Northwest pathologists that I have included their work: G. W. Wallis and W. J. Bloomberg, Canadian Forestry Service, Victoria, B. C. (CFS); E. M. Hansen, Oregon State University, Corvallis, Oregon (OSU); C. H. Driver, University of Washington, Seattle, Washington (UW); L. C. Weir, Oregon State Department of Forestry, Salem, Oregon (OSDF); K. W. Russell, Washington State Department of Natural Resources, Olympia, Washington (WDNR). N. E. Martin, Intermountain Forest and Range Experiment station, Moscow, Idaho (INT); E. E. Nelson, W. G. Thies, C. Y. Li, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon (PNW);

II. Control Strategies

A. Stump Removal

1. Stragegy: Before reforestation remove inoculum to avoid carry over of the disease to the new stand. Removal of infected stumps and large roots removes the bulk of the inoculum from the soil. Small infested roots that remain are disrupted by tearing, and breaking during the removal process. The longevity of residual P. weirii should be reduced by breaking roots and allowing invasion by competing organisms.

2. Study Approach: Study areas were examined and data collected to identify size, species and location of diseased trees and stumps. The areas were stratified and blocked to provide replicate plots of similar inoculum density. Stumps were removed from some plots and left in others. The area was then planted, usually with Douglas-fir seedlings but also with other conifers on some installations. The study areas will be observed for growth of the trees and disease development for 20 years or more. The first such study area was established by L. C. Weir in 1968 (Weir and Johnson 1970).

3. Installations: PNW - 7; CFS - 2; OSDF - 2; WDNR - 2. OSU-1.

B. High Nitrogen Fertilization

1. Strategy: Apply high N fertilizer to reduce the viability of buried P. weirii inoculum before reforestation of an infested site.

Walter G. Thies is Research Plant Pathologist at U.S. Department of Agriculture, Forest Service Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oreg.

Nitrogen applied as either NH_4Cl or $NaNO_3$ dramatically reduced the viability of P. weirii in buried wood cubes in laboratory tests (Nelson 1970). The adverse effects on P. weirii survival with application of urea were demonstrated in field tests (Nelson 1975). While the exact cause of reduced P. weirii survival was not determined it has since been correlated with increased populations of species of Trichoderma (Nelson 1976). Trichoderma spp. were shown earlier to be the primary fungi invading wood colonized by P. weirii (Nelson 1964).

2. Study Approach: Study areas were examined and data collected to identify the size, species, and location of diseased trees. One-tenth acre, circular treatment areas were established and stratified by infection hazard based on mapped inoculum. Treatments, application of various amounts of ammonium nitrate, were randomly assigned within strata. The areas were planted the winter following fall fertilization, or in the case of an INT study, application of urea and planting were done the same spring. Data will be collected starting at stand age 5 years and will be repeated at regular intervals for 20 years.

3. Installations: PNW - 6, INT-1.

C. Chemical Agents

1. Strategy: Eliminate inoculum from the site by treating infested stumps with a chemical that can eradicate P. weirii from the stump and root system. Several soil fumigants have been reported to eradicate pathogenic fungi from infested wood buried in soil: Chloropicrin (Godfrey 1936), carbon disulfide (Bliss 1951), methyl bromide (Rackham et al. 1968), and Vapam (Houston and Eno 1969). Decay fungi were effectively eliminated from power transmission poles injected with chloropicrin, Vapam, methyl bromide, or Vorlex (Graham 1975, Graham and Corden 1980). Allyl alcohol has shown promise in wood block studies but not in poles (Graham and Corden 1980). Armillariella mellea was effectively eradicated from infested stumps injected in situ with methyl bromide, carbon disulfide, Vorlex, chloropicrin, or Vapam (Filip and Roth 1977). Carbon disulfide, chloropicrin, methyl bromide, Vapam, and Vorlex were effective in eliminating P. weirii from 5-cm cubes in soil in plastic containers.[2/] Lauricidin, a long-chained fatty acid, successfully inhibited growth of P. weirii in the laboratory (Li and Kabara 1978) and protected stumps from infection by Fomes annosus (Nelson and Li 1980).

2. Study Approach: Fresh P. weirii infested stumps were tagged and stratified based on stump top diameter and amount and stage of decay. Treatments, including a check, were assigned at random to the stumps in each stratum creating a randomized complete block experimental design. Chemicals were applied by drilling holes in stained portions of the stump tops, pouring in the test chemical, and plugging the hole with a wooden dowel. Chemicals were applied at either the same volume for each stump or an amount proportional to the estimated biomass of the stump and root system. Treatment effectiveness will be evaluated by removing the stump and root system from the ground and attempting to culture P. weirii from root samples collected at regular intervals along each major root. Results are available from one installation: Four fumigants (chloropicrin,[3/] allyl alcohol, Vapam, and Vorlex), applied to holes in P. weirii-infested Douglas-fir stumps eliminated the fungus from the stumps and most roots. No significant difference in effectiveness was noted among the chemicals. Stump size (biomass of stump and roots) and condition (amount of sapwood decay if any) were probably the factors which most influenced treatment effectiveness. (Thies and Nelson 1981).

3. Installations: PNW - 3

A second approach to the use of fumigants involves the introduction of the chemicals into living trees. Preliminary evidence indicates that living trees can tolerate the introduction of some fumigants. Current tests are an attempt to define a therapeutic dosage for a limited number of chemicals. Installations: PNW - 1; CFS - 1.

D. Biological Agents

1. Strategy: Introduce into P. weirii-infested stumps organisms that will eliminate P. weirii from the stump and root system thus reducing inoculum potential on the site. Trichoderma viride and other species in that genus are known to have rapid growth, abundant spore production, ability to utilize cellulose, and antagonism to other fungi. Antagonism may be caused by volatile (Dennis and Webster 1971b) or non-volatile (Dennis and Webster 1971a) antibiotics, direct parasitism of hyphae (Dennis and Webster 1971c) or competition for those simple carabohydrates which allow rapid growth of fungi in wood (Hulme and Shields 1970). The ability of Trichoderma to grow in wood, and its antagonistic properties toward other fungi including several hymenomycetes, have led to attempts to use this organism for biological control of tree disease. The fungus apparently

---

[2/] From an office report (12/10/75) on file at the Pacific Northwest Forest and Range Experiment Station, Corvallis, Ore: George M. Harvey, Office Report: A laboratory screening test of soil fumigants for the control of P. weirii. 7 p.

[3/] This paper reports the results of research only. Mention of a pesticide does not constitute a recommendation for use by the USDA nor does it imply registration under FIFRA as amended. Also, mention of a commercial or proprietary product does not constitute recommendation or endorsement by the USDA.

occurs naturally in Fomes annosus-infected Picea abies and perhaps other conifers. The more advanced the decay, the greater the chance of Trichoderma being present and the more likely the elimination of F. annosus (Delatour 1976). In some instances Trichoderma may displace established fungi from wood: Fomes annosus was displaced from living trees (Delatour 1976) and P. weirii was displaced from buried wood (Nelson 1973).

2. Study Approach: Phellinus weirii infested stumps created during a recent clear-cutting operation were tagged and stratified based on stump top diameter and amount and stage of decay. Treatments, including a check, were assigned at random to the stumps in each stratum creating a randomized complete block design. Application is by drilling holes into the stump tops, placing inoculum in the holes and plugging the holes. Current tests involve T. viride used in several different application techniques.
3. Installations: PNW - 4

E. Species Manipulation

1. Strategy: Maintain a particular species or mix of species on P. weirii infested sites that will reduce inoculum on the site or hold impact of the disease within acceptable limits. Although direct evidence of the relative susceptability of various species is limited, a listing of relative susceptability for northwest species is available that represents a consensus of forest pathologists from the northwest (Hadfield and Johnson 1977). Observations of surviving species in infected mixed conifer stands support the general ranking (Filip and Schmitt 1979, McCauley and Cook 1980). Quanitative information on growth, yield, and species susceptability can only come from long term plots established on areas with defined inoculum levels. Although testing growth and disease resistance for a variety of species is a long-term endeavor, the attractiveness of species manipulation as a control has caused considerable effort to be focused on this approach. Many of these studies will not yield any results for 15 years and cannot be expected to yield definitive results for 30 years.

2. Study Approach: Several approaches asking slightly different questions are being used:
a. Individual Trees: Various species are planted in circles around known P. weirii infested stumps. Evaluation will be based on disease development in individual trees. Results will be used to sharpen our knowledge on relative susceptability of various species. Installations: PNW - 4; CFS - 1.

b. Blocks of one species: Each study area was examined and the locations of P. weirii infested stumps or infected trees were mapped. Each area was clearcut and the merchantable volume removed. Cut stumps were examined and those infested with P. weirii were mapped. Plots within each study area were stratified by infection hazard based on the density of mapped inoculum. Each test species was planted on one plot in each inoculum strata. Success of each species will be determined from survival and growth data recorded from the plots. Study areas will be visited and data collected periodically for a period of 20 to 30 years. Some study areas were treated by removing all stumps before planting, in which case inoculum consists only of residual (small lateral) roots. Installations: PNW - 3; CFS - 1; OSU - 1; WDNR - 2.

c. Mixed Species. Study areas have been set up much as was described for the monoculture tests. Again, survival and volume production will be the measure of success. There are two types of studies: one in which a mix of conifers is planted and a second in which hardwoods (immune to P. weirii) are interplanted within conifer plantings. In both cases, the intent is to break up the continuity of susceptable root systems thereby slowing spread of the disease and reducing impact on the stand. Installations (mixed conifers): INT - 2; WDNR - 1. (interplanting conifer plantation with hardwoods): WDNR - 2, PNW-OSU-1, PNW-1

d. Crop rotation: Study areas were set up as for the monoculture test. A treatment involved planting a hardwood species on a plot, growing the crop for one rotation, harvesting the hardwoods, and planting susceptable conifers (Douglas-fir) back on the site. Success of the treatments will be based on the growth and survival of the Douglas-fir. Installations: (Hardwoods) PNW & OSU - 1, (Game browse) INT-1.

III. Disease Resistance:

Disease resistance of Douglas-fir to P. weirii is included bere because several workers are pursuing this aspect of control and it is an area often suggested by foresters. The end goal is to select trees with some resistance to attack by P. weirii. Study approaches include the following: collecting seed from apparently resistant trees growing in areas of high inoculum density; collecting and maintaining cultures of P. weirii from scattered geographical areas to be used to test potentially resistant seedlings; developing mass screening techniques; and testing candidate seedlings by direct inoculation of their root systems. Installations: PNW; CFS; UW, WDNR; #INT.

VI. Application Equipment

There is often a separation between the development of a particular control concept and the operational application of that control. A failure to recognize this separation often leads individuals to prematurely conclude that a particular control will be too expensive, or too disruptive, or too difficult, or too time consuming, or... This conculsion may in the end be valid but is often based on observing an application as it must be carried out to answer specific research questions. Questions concerning operational application are often answered after the control has been developed and its efficacy demonstrated. While it is desirable to answer both sets of questions simultaneously, it may not be practical to do so.

Evolution of equipment used in our stump removal studies is an example of convergence of control concept and operational application. Initial stump removals were done using a bulldozer with a solid blade. As a result more soil was moved than desirable. Large holes were created and topsoil was mixed into the subsoil. Subsequent work was done with a brush blade. Again the stumps were removed but with much less movement and mixing of soil and few large holes. Our most recent work was done using log hooks on a tracked bulldozer. Log hooks are large (1 m long) tusk-like projections that point foreward and curve up slightly. After pushing the hooks into the soil on either side of a stump the stump can be either pushed or pryed from the soil. As the stump is lifted much of the soil clinging to the root system falls back into the hole. Because of the leverage gained from the hooks a much lighter bulldozer can be used in the stumping operation than would be required using other types of blades. Additionally, we observed that using the hooks resulted in smaller holes and less movement and mixing of soil than occured when using other types of blades.

A new concept of stump removal has been introduced with a vibrating stump puller. This equipment applies a combination of upward pull and vibrations to separate the stump and root system from the soil with a minimum of site disturbance. Although a promising new development, this equipment has not yet been tested for removing P. weirii infested stumps. (Additional comments about the vibrating stump puller, contributed by Ken Russell, follow this paper.)

Our experience leads us to believe that once the efficacy of a control concept is demonstrated the problems of application on an operational basis can be solved. Clearly, our first application of the stump removal concept was faulty, yet, during subsequent work better systems evolved. If stumping becomes a generally accepted control for P. weirii new equipment will probably be developed that will further reduce both cost and adverse impact to the site. We anticipate that similar improvements in application equipment and techniques will evolve for other control concepts currently being tested.

Summary

Phellinus weirii causes the most serious disease facing forest land managers in the Pacific Northwest. As yet, no operational control has been proven effective. Researchers from various organizations are working on Federal, State and private lands and with many private industry cooperators to develop and prove the efficacy of a variety of control strategies. Most of the field plots have been established within the past five years. While some may take 30 years to yield their final results, others will mature sooner. Some control strategies may be available within the next several years. The future looks bright, ongoing studies can be expected to develop a number of options for controlling laminated root rot in the northwest, thus providing the land manager flexibility in controlling this disease.

Literature Cited

Bliss, D. E. 1951. The destruction of Armillaria mellea in citrus soils. Phytopathology 41:665-683.

Childs, T. W. 1963. Poria weirii root rot. Phytopathology 53:1124-1127.

Childs, T. W. and K. R. Shea. 1967. Annual losses from disease in Pacific Northwest forests. USDA Forest Service, Resource Bull., PNW-20.

Delatour, C. 1976. Internal micro flora of the wood tissues of the standing Norway spruce Part I. Inventory of the natural micro flora. Ann Sci For (Paris) 33:25-39.

Dennis, C. and J. Webster. 1971a. Antagonistic properties of species-groups of Trichoderma. I. Production of non-volatile antibiotics. Trans Brit Mycol Soc 57:25-39.

Dennis, C. and J. Webster. 1971b. Antagonistic properties of species-groups of Trichoderma. II. Production of volatile antibiotics. Trans Brit Mycol Soc 57:41-48.

Dennis, C. and J. Webster. 1971c. Antagonistic properties of species-groups of Trichoderma. III. Hyphal interactions. Trans Brit Mycol Soc 57:363-369.

Filip, G. M. and L. F. Roth. 1977. Stump injections with soil fumigants to eradicate Armillariella mellea from young growth ponderosa pine killed by root rot. Can J For Res 7:226-231.

Filip, G. M. and C. L. Schmitt. 1979. Susceptibility of natural conifers to laminated root rot east of the Cascade range in Oregon and Washington. For Sci 25:261-265.

Godfrey, G. H. 1936. Control of soil fungi by soil fumigation with chloropicrin. Phytopathology 25:246-256.

Graham, R. D. 1975. Preventing and stopping decay of Douglas-fir poles. Holzforshung, 27:168-173.

Graham, R. D. and M. E. Corden. 1980. Controlling biological deterioration of wood with volatile chemicals. Elec Power Res Inst EL-1480, Proj 212-1, Elec Power Res Inst, Palo Alto, Calif. 72p.

Hadfield, J. S., and D. W. Johnson. 1977. Laminated root rot, a guide for reducing and preventing losses in Oregon and Washington forests. USDA-Forest Service, Pacific Northwest Region. 16 pp., illus.

Hansen, Everett M. 1979. Survival of Phellinus weirii in Douglas-fir stumps after logging. Can J For Res 9:484-488.
Botany 43:1-9.

Houston, D. R. and H. G. Eno. 1969. Use of soil fumigants to control spread of Fomes annosus. USDA For Serv Res Pap NE-123, 22 pp.

Hulme, M. A. and J. K. Shields. 1970. Biological control of decay fungi in wood by competition for non-structural carbohydrates. Nature 227:300-301.

Li, C. Y. and Jon J. Kabara. 1978. Effects of Lauricidin on Fomes annosus and Phellinus weirii. AOCS Monogr. 5:45-50.

McCauley, K.J. and S. A. Cook. 1980. Phellinus weirii infestation of two mountain hemlock forests in the Oregon Cascades. For Sci 26:23-29.

Nelson, E. E. 1964. Some probable relationships of soil fungi and zone lines to survival of Poria weirii in buried wood blocks. Phytopathology 54:120-121.

Nelson, E. E. 1970. Effects of nitrogen fertilizer on survival of Poria weirii and populations of soil fungi and aerobic actinomycetes. Northwest Science 44:102-106.

Nelson, E. E. 1973. Observations on the formation of zone lines in wood by Poria weirii. USDA For. Serv. Res. Note PNW-210. 4pp. Pac Northwest For and Range Exp Sta, Portland, OR.

Nelson, E. E. 1975. Survival of Poria weirii on paired plots in alder and conifer stands. Microbios 12:155-158.

Nelson, E. E. 1976. Effect of urea on Poria weirii and soil microbes in an artificial system. Soil Biol Biochem 8:51-53.

Nelson, E. E. and C. Y. Li. 1980. Preliminary test of two stump surface protectants against Fomes annosus. Research Note PNW 363.

Nelson, E. E., N. E. Martin, and R. E. Williams. 1981. Laminated root rot of western conifers. USDA-Forest Service, Forest Pest Leaflet (in press).

Rackham, R. L., W. D. Wilbur, T. E. Szuskiewicz and J. Hara. 1968. Soil dessication and fumigation for Armillaria root rot in citrus. Calif Agric 22(1):16-18.

Thies, W. G. and E. E. Nelson. 1981. Control of Phellinus weirii in Douglas-fir stumps by the fumigants chloropicrin, allyl alcohol, Vapam, and Vorlex. Manuscript submitted to Can J For Res.

Wallis, G. W. and G. Reynolds. 1965. The initiation and spread of Poria weirii root rot of Douglas-fir. Canadian Journal of Botany 43:1-9.

Wallis, G. W. 1976. Phellinus (Poria) weirii root rot. Detection and management proposals in Douglas-fir stands. Can For Serv For Tech Rep 12, 16 p.

Weir, L. C., and A. L. S. Johnson. 1970. Control of Poria weirii study establishment and preliminary evaluations. Forest Research Laboratory, Canadian Forestry Service, Victoria, B.C. Internal Report BC-14.

COMMENTS ON VIBRO STUMP PULLER

Kenelm Russell

The summer '81 test of the Drott/Case - L. B. Foster Companies' Vibro Stump Puller was completed on three different Armillaria infested ownerships in South Central Washington under a variety of conditions and species. The machine has definite potential pending a few design modifications. Improvement of lift capacity, grapple design and hose placement are under consideration. The Drott/Case folks seemed confident that they could improve the lift/pull capacity by 20 to 50%.

The advantages of the machine over the bulldozer are: minimum damage to residual stand, minimum soil disturbance, preparation of ideal planting or natural seed spots for regeneration, competitive cost to a D-8 size bulldozer and a soil free pulled stump with many potential uses. Pulled stumps could be used for energy production, naval stores or chip production. A market must be developed.

We felt that the machine should be able to tackle a twenty inch diameter stump with relative ease. The average stump diameter in the test was close to eighteen inches. The closer the average stump diameter to twelve plus inches, the easier the machine (as now designed) can handle them. Managers could easily optimize performance simply by choosing the right stand. The stump puller has only been tested in Armillaria infested stands and plans are being made to test it in laminated root rot infested stands of westside Douglas-fir.

Our test was done under the normal dry conditions of eastern Washington summer. The stump puller is known to operate more efficiently in wet soil conditions because it utilizes stump/soil boundary moisture for lubrication to allow the stump to come out with less pull. We intend to conduct new trials under wetter soil conditions. The machine could have potential for other nondisease stump removal projects as well.

The table below compares cost of a Case/Drott Vibro Stump Puller with a D-8 cat (courtesy of Dr. Peter Schiess, U. of Wash.).

	Drott 50	D-8
Total purchase	165,000	225,000
Estimated machine life 5 yr.		171,000
<u>Fixed Cost</u>		
Depreciation	19,800	27,000
Interest, taxes, insurance	30,096	41,040
Hourly fixed cost	38.38	52.33
<u>Operating Cost</u>		
Hourly maint. & repair cost per hour	15.23	20.76
Hourly fuel & oil cost	2.48	2.48
Total hourly operating cost	17.71	23.25
Hourly machine fixed plus operating cost	56.09	75.58
Hourly labor cost	15.38	15.38
Hourly cost plus labor	71.47	90.96
Cost per stump	2.60	2.43

AS A FOREST MANAGER, WHEN SHOULD I CONSIDER CONTROL FOR ROOT DISEASES

G.W. Wallis

A definitive answer to root disease control is still not within our grasp. However, within the next couple of years we will have some statistically bases prediction factors for at least Phellinus weirii, Armillaria mellea and possibly Fomes annosus. For the other root diseases, e.g., Polyporus tomentosus, Polyporus schweinitzii and black stain, the answers are still somewhere down the line.

As a forest manager, I am faced with root disease control decisions at each phase in stand development, precommercial thinning or spacing, thinning and harvest cut. The options and input are different at each phase so lets consider them separately.

Before we do this, however, lets look at a common requirement for all phases. The first requisite, and I cannot over stress this, is that I have a good appreciation of the problem in the stand I intend to treat before I attempt to make any decisions on control. A mensurational cruise, if undertaken by staff knowledgable of root diseases, will tell me if I have a problem. If a root disease is present in the stand, I must undertake a root disease survey to define the extent and distribution of the centers. The only exception to this would be when the stand is devastated and the only option open to me is stand removal. All root disease surveys must be done with crews intimately familiar with symptomotology as well as survey design. Its not easy; a poorly trained crew could produce data which would result in the unnecessary expenditure of large sums of money. Good survey methodology is available for P. wierii and A. mellea. Standard mensurational cruises, e.g., prism plots, will not provide reliable results because of the aggregated nature of the damage.

Precommercial thinning or spacing phase

There are a number of options open to me for treating a diseased stand at this young age: 1) Will I invest $500 + per hectare in spacing the stand? 2) Will I fertilize to enhance growth on the healthy trees with or without spacing? 3) Will I do nothing now and plan to enter the stand again in X years? 4) Will I isolate the disease by cutting a surround of healthy trees. 5) Will I remove the stand and start again?

Having undertaken a designed survey, I have an appreciation of the number and distribution of the disease centers in the stand. The area in disease centers in stands of this young age is difficult to define and not meaningful in most cases. The first thing the survey tells me is whether I have to treat the whole or just a portion of the stand. Having knowledge of the number and distribution of centers, I can apply spread figures, if such are available, to determine periodic disease impact. For example, I am told that the margin of mortality caused by P. weirii will increase at approximately a half meter a year to thinning age or approximately a third of a meter per year over an 80 to 100 year rotation. However, I must not forget that the number of diseased trees seen using above-ground symptoms are only half of those actually present. Infected trees not currently showing symptoms will start to lose growth 10 or more years before death. With this information, and knowing the capabilities of the site, I can reasonably closely estimate the period when losses to the disease will overtake increment added. Leaving a stand beyond this period would be a questionable practice. If the survey showed that the centers were numerous and close together and a harvest cut would be required in the not too distant future, I would certainly not invest monies in spacing the stand.

Thinning phase

Again, I have a number of options open to me: 1) Will I thin the stand? 2) Will I leave it for X years and do a harvest cut? 3) Will I fertilize to enhance the growth of healthy trees? 4) Will I enter the stand for salvage? 5) Will I do a harvest cut now and rehabilitate the site?

At this phase in the stand development, a root disease survey tells me not only the number and distribution of centers but also the area out of production. As at the precommercial thinning phase, an estimate of current and future depletion can be calculated. For example, where P. weirii is the cause of your problem, the margin of mortality will encroach into the surrounding stand at about a third of a meter per year. The number of infected trees and the affected area is about twice that seen using above-ground symptoms. Again, with this information and knowing the site capabilities, I can make a reasonable estimate of current and future periodic depletion and growth to arrive at the pathological rotation age at which time I would look to harvesting the stand. The results of the survey will provide the figures required in deciding on other options such as fertilization, salvage, etc.

Harvest cut

At this phase, my options are confined, of course, to some method of site rehabilitation.

G.W. Wallis, Forest Pathologist, Pacific Forest Research Centre, Victoria.

A preharvest survey will provide me with data on the incidence and distribution of the disease. The site quality and terrain will be the two major factors governing my choice of site rehabilitation.

On high site bottom land, where restocking with a species other than Douglas-fir would be second-best, I have no problem justifying the cost of stumping those portions of the site where the disease is common. The method of stump removal that I would chose will be discussed in following papers. Where I am faced with restocking diseased, steep terrain, erosion will negate stump removal and I have no choice but to change to a more resistant species. The species I use will be decided on the advice of an ecologist. On some poor, dry sites, even though the disease is extensive, economics will dictate that I be satisfied with salvaging the existing stand and leaving it to nature to restock the site.

For those of you who have a problem convincing your boss that monies for root rot control is both necessary and justified, try charging it to site rehabilitation. That way it will probably go through with little question, and, after all, isn't that what it is all about?

WHAT ARE SOME ECOLOGICAL CONSEQUENCES OF ROOT DISEASE CONTROL?

R.B. Smith

ABSTRACT: Silvicultural control of root disease involves considerable alteration of surface soil conditions with potential adverse impacts on site productivity and other resources. Major effects include soil displacement, soil compaction and predisposition to surface soil erosion. Adverse impacts can be reduced by utilizing soil information in planning operations, by conducting operations when soils are least susceptible to damage, by using rear-mounted raking or ripping equipment and by keeping actual displacement of soil during windrowing to a minimum.

INTRODUCTION

When we walk through a forest we cause some alteration to the forest floor and may even influence the mineral portion under the organic mat. Normally, the change is barely detectable and seldom results in a significant impact. Use of equipment such as during felling and yarding will cause considerably greater impacts in terms of both extent and degree of disturbance. Ground skidding in the Interior of British Columbia on steep slopes, for instance, has resulted in an average of over 40% mineral soil exposure of which approximately 70% (of the 40%) may be classed as very deep (deposits or gouges over a depth of 25 cm) (Smith and Wass 1976). Because of the nature of its objectives, mechanical site preparation usually involves an even greater percentage of disturbed soil. Similarly, root-disease control operations can disturb a very high proportion of the ground surface within the control area.

SOME FEATURES OF AGRICULTURAL AND FOREST SOILS

The extent and degree of disturbance associated with root disease control is similar to what farmers do to their fields, usually without dire consequences. However, the soil farmers deal with has been subject to this sort of perturbation annually and the action is generally a mixing or overturning rather than complete displacement. Further, amendments such as compost, manure and chemical fertilizer are routinely used to offset losses in organic matter and nutrients resulting from intensive agricultural cropping. The result of this annual mixing is that agricultural soils are relatively uniform at least to the bottom of the plough layer. In contrast, forest soils have the appearance of a multi-layered cake. Organic matter and nutrients are unevenly distributed throughout the profile. Nitrogen is concentrated in the humus at the top of the profile; whereas, cations such as calcium and magnesium may be displaced by iron and aluminum in the upper weathered portions of the profile and thus may be more available at deeper depths. Similarly, because of original deposition or by downward movement of clay particles, soil texture may vary greatly within a few centimeters. The upper horizons of a forest soil are generally populated by a greater assortment of soil organisms, have a stronger structure and a lower density than occurs at depth.

TYPES OF DISTURBANCE ASSOCIATED WITH ROOT DISEASE CONTROL

The major types of disturbance and the factors affecting the level of impact are as follows:

1. Soil Displacement or Truncation (removal of soil from one location and its deposit in another). Impact depends on soil type (e.g., calcareous soils are very sensitive) and extent (e.g., stump pulling alone might be acceptable but not combined with windrowing).

2. Soil Compaction (increase in soil density). Impact depends on extent, soil type (e.g., generally most serious in well graded, medium to moderately fine textured soils), soil moisture at time of operation (e.g., most serious in soils near field capacity) and load applied (the greater the load and frequency of contact, the greater the impact).

3. Surface Soil Erosion. Impact depends on extent, soil type (e.g., highly erodible soils may seriously erode on slopes less than 20%; whereas, stable soils might be worked safely on slopes up to 40%, slope (the greater the slope the greater the amount of soil material moved), rainfall intensity and duration and rate of snowmelt.

4. Puddling (the movement of wet soil outwards from under a load and a marked loss in soil structure). Impact depends on extent, load, soil moisture and soil type.

R.B. Smith is a Forest Ecologist with the Canadian Forestry Service, Pacific Forest Research Centre, Victoria, B.C.

5. Frost Action (responsible for frost heaving of seedlings). Impact depends on degree of soil compaction (frost heaving increases with increasing soil densities (Heidmann and Thorud 1975), degree of vegetative cover and organic matter content (frost heaving greatest for bare soil low in organic matter) and soil type (frost heaving least in coarse textured soils).

EFFECTS ON PRODUCTIVITY

Tree growth on skidroads in Interior British Columbia can be reduced 20-60% on certain soil types (Smith and Wass 1979, 1980). Overall prorated growth losses have been estimated as high as 15%. Extremely poor performance of Engelmann spruce and subalpine fir on blade scarified strips was reported by Herring and McMinn (1980) for central British Columbia. Because of the greater extent of disturbance on root disease control areas, overall growth losses are potentially higher. Compaction has been shown to significantly reduce rates of tree root growth (Minore, Smith and Woollard 1969; Pearse 1958). Reductions of up to 50% in height growth have been recorded for loblolly pine as a result of soil compaction (Perry 1964). Height-growth reductions of up to 35% have been observed in trees from the Pacific Northwest with increases in bulk density up to 70% (Froehlich 1981).

Losses in productivity from increased erosion are not well documented. Impacts on stream water quality may be more significant. In extreme cases, reductions in machine operability may result from rilling and gullying.

REDUCING IMPACTS

1. To reduce soil erosion and productivity impacts, use soil surveys, maps and field checks to determine maximum workable slope and to avoid treating areas with highly sensitive soils, e.g., calcareous ones.

2. To reduce compaction and puddling, conduct operations when soil moisture is low. Late summer is preferable. Avoid wet spots at all times. Conduct work as soon as possible after felling and yarding to take advantage of the drier soils.

3. To reduce soil displacement, do not scalp soil when windrowing. Roll, rather than push the load.

4. To reduce the area of compacted tracks, use rear mounted raking equipment. Consider using specialized ripper teeth if compatible with root-raking objectives.

5. To protect water quality, avoid water courses. Don't push material into drainage channels.

LITERATURE CITED

Froehlich, H. The effect of soil compaction on seedling growth and survival. Paper, Workshop on Managing Forest Stands to Minimize Soil Compaction. Forestry Intensified Research, Medford, Oregon. Mar. 25-26, 1981; 1981.

Heidmann, L.J. and D.B. Thorud. Effect of bulk density on frost heaving of six soils in Arizona. U.S.D.A., For. Serv. Res. Note RM-293; 1975.

Herring, L.J. and R.G. McMinn. Natural and advance regeneration of Engelmann spruce and subalpine fir compared 21 years after site treatment. For. Chron. 56(2):55-57; 1980.

Minore, D., Smith, C.E. and Woollard, R.F. Effects of high soil density on seedling root growth of seven Northwestern tree species. U.S.D.A., For. Serv., Res. Note PNW-112; 1969.

Pearse, P.H A study of the effects of soil compaction on the early development of seedlings of Douglas-fir and western hemlock. U.B.C., For. Club Res. Committee, Res. Note 16; 1958.

Perry, T.O. Soil compaction and loblolly pine growth. Tree Planter's Notes 67:9; 1964.

Smith, R.B. and Wass, E.F. Soil disturbance vegetative cover and regeneration on clearcuts in the Nelson Forest District, British Columbia. CFS, PFRC, Rep. BC-X-151; 1976.

Smith, R.B. and Wass, E.F. Tree growth on and adjacent to contour skidroads in the subalpine zone, southeastern British Columbia. CFS, PFRC, Rep. BC-R-2; 1979.

Smith, R.B. and Wass, E.F. Tree growth on skidroads on steep slopes logged after wildfires in central and southeastern British Columbia. CFS, PFRC, Rep. BC-R-6; 1980.

HOW CAN I JUSTIFY CONTROL COSTS?

Kenelm Russell[1]

Introduction

The toughest part of any costly forestry project is to justify to yourself, the manager, and the boss favorable economics of such an operation. Today's wood markets (barring perhaps the present lumber slump) can support increasing intensive forest practices on productive lands and reasonable expenditures necessary to secure a new healthy stand (Koss and Scott, 1980). These expenditures are made through proper Integrated Pest Management techniques that merge economic factors with biological factors, carefully weighing merits of each and then setting the stage for action. In root rot management biological factors must, in some cases, be more heavily weighted because of the consequences to the soil and future crops. Most economic analyses do not take this into consideration. They also do not take into consideration geometric expansion of root disease centers. The example presented here will be done without these two considerations. A refined model will contain these two important factors. In the interim, this approach will illustrate the principles of dealing with a loss.

Good yardsticks to measure economic benefits that are relatively easy to understand are present value and rate of return. I will use these in this exercise. The computer analysis method used is based on standard economic principles that were programmed by Stoffle and Larsen (1977).

Definitions and Method of Analysis

Present value, sometimes called Present Net Worth (PNW) or Net Present Worth is defined as discounted revenues minus discounted costs. PNW values are expressed in dollars returned per acre. The rate of return is defined as the annual interest rate (%) that an investment returns and is calculated as the interest rate used in discounting at which discounted costs just equal discounted revenues. Thus, when PNW equals zero at a certain rate of return, the investment has earned the desired rate. Any return above zero is pure gravy.

To illustrate, Mike M., resource manager of a district for the Department of Natural Resources, will make a root rot control-plus regeneration investment totaling $510/acre which will be carried to rotation from year zero. It doesn't matter what activity occurs then, since we are only concerned with total costs occurring at one point. Mike must carry this "front end loaded" investment over the entire rotation of sixty years. Throughout the rotation he will make other investments in the stand (Tables 1 & 2).

Table 1--A typical intensive management regime under Douglas-fir culture (site index 130).

Stand Age	Management Activities
0	Push stumps for root rot control
0	Plant Douglas-fir
5	Release-spray unwanted vegetation
13	Precommercial thinning (juvenile spacing)
13	Fertilize
23	Fertilize
30	First commercial thinning
33	Fertilize
40	Second commercial thinning
50	Third commercial thinning
60	Clearcut

Table 2--A typical management regime under western hemlock culture (site index 100).

Stand Age	Management Activities
0	Plant western hemlock
15	Precommercial thinning
60	Clearcut

Mike's calculations show that upon final harvest the zero PNW value lies somewhere between the nine and ten percent rate of return. A break-even point this high makes his investment look attractive. At nine percent rate of return Mike will earn $84.43 PNW per acre and at the ten percent rate he is in the hole at $179.44 PNW per acre. But, the "stockholders" only require a six percent rate of return which yields $2,544.44 PNW per acre! (Note: These figures were taken from Option III. Compare other PNW values in that option.)

There is one very important fact to consider about rate of return interest rates presented here and in many other analyses. These calculations are based on REAL INTEREST not CURRENT INTEREST. Real interes has had the high inflation factor removed. A curren interest rate comparable to the six percent real rate is what might be expected from a money market fund (yielding 18% in mid 1981). Different economists will give different answers, but the importance is that managers realize that deceptively low real interest rates are meaningful returns even though they appear puny compared to today's soaring current interest rates. Mike's six percent real interest return PNW isn't too shabby when we discover that it sits in the same league as the money market fund!

Cost-Income Analysis of an Infected Westside Douglas-fir Stand

I used projected estimated volumes from Mike's infected stand to illustrate the way the economic analysis will be interpreted. The following discussion examines several options and PNW returns from the same stand by computer simulation. Mike's "Low Down Root Rot" timber sale containing a typical stand of western Washington Douglas-fir (site index 130) was recently logged and now needs

---

[1] Forest Pathologist, Washington State Department of Natural Resources

to be regenerated. Mike put this sale up because excessive mortality (20%) from laminated root rot (Phellinus weirii) was decimating the stand. Replanting Douglas-fir without special treatment or species change will result in far greater mortality in the next crop.

Mike's simulations included a disease free future stand which became the standard the various treatments would be compared against. The no treatment simulation included replanting with Douglas-fir allowing production of a disease riddled stand. We estimated that about 40 percent of the volume produced each decade beginning with the third decade would be lost to laminated root rot under the no treatment option. The expensive treatment simulation consisted of a stump pushing operation to minimize root rot and costing about $300 per acre followed by planting to Douglas-fir. We estimated about 7% of this stand would be lost in later decades to root rot. The low cost treatment simulation involved conversion to western hemlock at reduced productivity and assumed no root rot. (One could argue that we should have allowed a small amount of mortality.)

The four management option simulations are presented below as they appeared on the computer using DNR's standard PNW program. We asked the computer to print interest rates from five to fifteen percent to provide a good range of PNW values. Compare the PNW values for each treatment against the disease free stand and draw your own conclusions as to which you could afford.

Option I

No root rot
Douglas-fir, site index 130 (50 yr.), rotation 60 years, plant DF, precommercial thin, release spray, fertilize, commercial thin, clearcut

```
PNWAC$   12:28PDT   09/11/81

REGIME NAME?
? DF130*8M
INPUT CAPITAL GAINS AND ORDINARY INCOME TAX RATES
  IN %
? 0,0
INPUT ROTATION
? 60
ANNUAL COST AND HARVEST TAX IN %
? 2,50,0
INPUT PRICE & COST IN %, REGEN. LAG, SHORT FORM=
  1, COMPLETE=2
(TO UPDATE TIME PERIOD TYPE 999,0,0,0 TO END RUN
  TYPE 9999,0,0,0)
? 3.5,3,0,2
INPUT STUMPAGE PRICES FOR THINNINGS 1,2,3,4,5,6
  AND CLEARCUT
? 96,175,190,0,0,0,212
PLANTING, PRECOMMERCIAL THINNING, FERTILIZATION
  AND SPRAYING COSTS
? 210,100,76,34 ——— Planting only
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,15,1
CLEARCUT AT 44344 BF AT 60 YEARS, AT $1670.16 PER
  MBF DISCOUNTED 60 YEARS
THINNING AT 4376 BF AT 30 YEARS, AT $269.452 PER
  MBF DISCOUNTED 30 YEARS
THINNING AT 8462 BF AT 40 YEARS, AT $692.87 PER
  MBF DISCOUNTED 40 YEARS
THINNING AT 10030 BF AT 50 YEARS, AT $1061.14 PER
  MBF DISCOUNTED 50 YEARS
PLANTING AT $210 AT 0 YEARS, DISCOUNTED 0 YEARS
REGENERATION LAG= 0 YEARS
PRECOMMERCIAL THIN AT $146.853 AT 13 YEARS, DIS-
  COUNTED 13 YEARS
FERTILIZE AT $111.609 AT 13 YEARS, DISCOUNTED 13
  YEARS
FERTILIZE AT $149.993 AT 23 YEARS, DISCOUNTED 23
  YEARS
FERTILIZE AT $201.578 AT 33 YEARS, DISCOUNTED 33
  YEARS
SPRAYING AT $39.4153 AT 5 YEARS, DISCOUNTED 5 YEARS
                  SINGLE ROTATION
INTEREST   DISCOUNTED   DISCOUNTED    PRESENT
  RATE       INCOME        COST      NET WORTH
  .05       5998.69       556.93      5441.76
  .06       3598.24       501.92      3096.32
  .07       2185.85       458.69      1727.16
  .08       1345.41       424.17       921.24
  .09        839.40       396.22       443.18
  .10        531.02       373.30       157.72
  .11        340.70       354.29       -13.59
  .12        221.70       338.36      -116.66
  .13        146.32       324.90      -178.58
  .14         97.91       313.42      -215.50
  .15         66.41       303.56      -237.15
```

Option II

40% loss to root rot
No treatment
DF SI 130
Same management regime as Option I

```
PNWAC$   13:00PDT   09/11/81

REGIME NAME?
? ROOTROT
INPUT CAPITAL GAINS AND ORDINARY INCOME TAX RATES
  IN %
? 0,0
INPUT ROTATION
? 60
ANNUAL COST AND HARVEST TAX IN %
? 2.50,0
INPUT PRICE & COST IN %, REGEN. LAG, SHORT FORM=1,
  COMPLETE=2
(TO UPDATE TIME PERIOD TYPE 999,0,0,0 TO END RUN
  TYPE 9999,0,0,0)
? 3.5,3,0,2
INPUT STUMPAGE PRICES FOR THINNINGS 1,2,3,4,5,6
  AND CLEARCUT
? 96,175,190,0,0,0,212
PLANTING, PRECOMMERCIAL THINNING, FERTILIZATION
  AND SPRAYING COSTS
? 210,100,76,34
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,15,1
CLEARCUT AT 26606 BF AT 60 YEARS, AT $1670.16 PER
  MBF DISCOUNTED 60 YEARS
THINNING AT 2626 BF AT 30 YEARS, AT $269.452 PER
  MBF DISCOUNTED 30 YEARS
THINNING AT 5077 BF AT 40 YEARS, AT $692.87 PER
  MBF DISCOUNTED 40 YEARS
```

```
THINNING AT 6018 BF AT 50 YEARS, AT $1061.14 PER
  MBF DISCOUNTED 50 YEARS
PLANTING AT $210 AT 0 YEARS, DISCOUNTED 0 YEARS
REGENERATION LAG= 0 YEARS
PRECOMMERCIAL THIN AT $146.853 AT 13 YEARS,
  DISCOUNTED 13 YEARS
FERTILIZE AT $111.609 AT 13 YEARS, DISCOUNTED 13
  YEARS
FERTILIZE AT $149.993 AT 23 YEARS, DISCOUNTED 23
  YEARS
FERTILIZE AT $201.578 AT 33 YEARS, DISCOUNTED 33
  YEARS
SPRAYING AT $39.4153 AT 5 YEARS, DISCOUNTED 5 YEARS
                SINGLE ROTATION
INTEREST    DISCOUNTED     DISCOUNTED     PRESENT
  RATE        INCOME          COST       NET WORTH
  .05        3599.18         556.93       3042.26
  .06        2158.93         501.92       1657.01
  .07        1311.50         458.69        852.82
  .08         807.24         424.17        383.07
  .09         503.64         396.22        107.42
  .10         318.61         373.30        -54.68
  .11         204.42         354.29       -149.87
  .12         133.02         338.36       -205.34
  .13          87.79         324.90       -237.10
  .14          58.75         313.42       -254.67
  .15          39.85         303.56       -263.71
```

Option III

7% loss to root rot
Treatment; remove stumps @ $300/acre
DF SI 130
Same management regime as Option I

```
PNWAC$   13:10PDT   09/11/81

REGIME NAME?
? ROTTRT
INPUT CAPITAL GAINS AND ORDINARY INCOME TAX RATES
  IN %
? 0,0
INPUT ROTATION
? 60
ANNUAL COST AND HARVEST TAX IN %
? 2.50,0
INPUT PRICE & COST IN %, REGEN. LAG, SHORT FORM=
  1, COMPLETE=2
(TO UPDATE TIME PERIOD TYPE 999,0,0,0 TO END RUN
  TYPE 9999,0,0,0)
? 3.5,3,0,2
INPUT STUMPAGE PRICES FOR THINNINGS 1,2,3,4,5,6
  AND CLEARCUT
? 96,175,190,0,0,0,212
PLANTING, PRECOMMERCIAL THINNING, FERTILIZATION
  AND SPRAYING COSTS
? 510,100,76,34        Planting + stump push
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,15,1
CLEARCUT AT 41239 BF AT 60 YEARS, AT $1670.16 PER
  MBF DISCOUNTED 60 YEARS
THINNING AT 4070 BF AT 30 YEARS, AT $269.452 PER
  MBF DISCOUNTED 30 YEARS
THINNING AT 7870 BF AT 40 YEARS, AT $692.87 PER
  MBF DISCOUNTED 40 YEARS
THINNING AT 9328 BF AT 50 YEARS, AT $1061.14 PER
  MBF DISCOUNTED 50 YEARS
PLANTING AT $510 AT 0 YEARS, DISCOUNTED 0 YEARS
REGENERATION LAG= 0 YEARS
PRECOMMERCIAL THIN AT $146.853 AT 13 YEARS, DIS-
  COUNTED 13 YEARS
FERTILIZE AT $111.609 AT 13 YEARS, DISCOUNTED 13
  YEARS
FERTILIZE AT $149.993 AT 23 YEARS, DISCOUNTED 23
  YEARS
FERTILIZE AT $201.578 AT 33 YEARS, DISCOUNTED 33
  YEARS
SPRAYING AT $39.4153 AT 5 YEARS, DISCOUNTED 5 YEARS
                SINGLE ROTATION
INTEREST    DISCOUNTED     DISCOUNTED     PRESENT
  RATE        INCOME          COST       NET WORTH
  .05        5578.76         856.93       4721.83
  .06        3346.36         801.92       2544.44
  .07        2032.84         758.69       1274.16
  .08        1251.23         724.17        527.07
  .09         780.65         696.22         84.43
  .10         493.85         673.30       -179.44
  .11         316.85         654.29       -337.43
  .12         206.19         638.36       -432.17
  .13         136.08         624.90       -488.82
  .14          91.06         613.42       -522.35
  .15          61.76         603.56       -541.79
```

Option IV

No root rot
Stand conversion to hemlock, SI 100
Plant, release spray, precommercial thin, clearcut

```
PNWAC$   13:28PDT   09/11/81

REGIME NAME?
? HEM100
INPUT CAPITAL GAINS AND ORDINARY INCOME TAX RATES
  IN %
? 0,0
INPUT ROTATION
? 60
ANNUAL COST AND HARVEST TAX IN %
? 2.50,0
INPUT PRICE & COST IN %, REGEN. LAG, SHORT FORM=
  1, COMPLETE=2
(TO UPDATE TIME PERIOD TYPE 999,0,0,0 TO END RUN
  TYPE 9999,0,0,0)
? 3.5,3,0,2
INPUT STUMPAGE PRICES FOR THINNINGS 1,2,3,4,5,6
  AND CLEARCUT
? 0,0,0,0,0,0,136
PLANTING, PRECOMMERCIAL THINNING, FERTILIZATION
  AND SPRAYING COSTS
? 210,100,0,34
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 5,15,1
CLEARCUT AT 55863 BF AT 60 YEARS, AT $1071.42 PER
  MBF DISCOUNTED 60 YEARS
PLANTING AT $210 AT 0 YEARS, DISCOUNTED 0 YEARS
REGENERATION LAG= 0 YEARS
PRECOMMERCIAL THIN AT $155.797 AT 15 YEARS, DIS-
  COUNTED 15 YEARS
```

```
                    SINGLE ROTATION
INTEREST    DISCOUNTED    DISCOUNTED    PRESENT
  RATE        INCOME         COST       NET WORTH
  .05        3204.25        374.79      2829.46
  .06        1814.40        347.57      1466.83
  .07        1032.90        326.54       706.35
  .08         591.10        309.97       281.13
  .09         340.01        296.67        43.34
  .10         196.57        285.82       -89.25
  .11         114.21        276.86      -162.65
  .12          66.68        269.37      -202.69
  .13          39.12        263.05      -223.93
  .14          23.06        257.68      -234.62
  .15          13.65        253.07      -239.42
```

Analysis of an Eastside Ponderosa Pine Stand

I used a slightly different approach for a PNW analysis of an Armillaria, <u>Armillaria mellea</u>, infested ponderosa pine stand to see if it could economically accept a stump removal operation at a reasonable rate of return. Stump removal in Armillaria infested ponderosa pine is slowly becoming accepted as one of the practical methods of producing relatively disease free stands.

Productivity, stumpage values and rotation are quite different from the westside Douglas-fir stand. Planting is not required as adequate natural regeneration occurs. This helps reduce "front loaded" costs and leaves room for other investments such as disease control. Precommercial thinning at age 15 is followed by three commercial thinnings beginning at 35 years and each 15 years thereafter. At 80 years the stand will be clearcut.

A single FNW analysis is presented for this stand. Root rot impact is not known but our PNW analysis indicates how much can be spent to reduce the root rot. This time, I will use the "gravy" above the 6% PNW zero value as a guide to how much per acre I can spend for control. The computer print-out below indicates $578.12 per acre could be invested in control and still earn the desired (6%) rate of return. Had I actually invested this amount for control under the "planting" slot at year 0, the 6% PNW value would be zero. This analysis demonstrates that a reasonably productive eastside ponderosa pine stand can support expenditures to reduce Armillaria.

Option I

Armillaria infected ponderosa pine
Infection not known, but significant
Objective: How much could be invested per acre to treat?
Mgmt. regime: No plant, precommercial thin, commercial thin, clearcut, 80 yrs.

```
PNWAC  12:48PDT   10/05/79

REGIME NAME?
? ARMIL
INPUT CAPITAL GAINS AND ORDINARY INCOME TAX RATES
  IN %
? 0,0
INPUT ROTATION
? 80
ANNUAL COST AND HARVEST TAX IN %
? 0,0
INPUT PRICE & COST IN %, REGEN. LAG, SHORT FORM=
  1, COMPLETE=2
(TO UPDATE TIME PERIOD TYPE 999,0,0,0 TO END RUN
  TYPE 9999,0,0,0)
? 3.5,3,0,2
INPUT STUMPAGE PRICES FOR THINNINGS 1,2,3,4,5,6
  AND CLEARCUT
? 23,59,83,0,0,0,200
PLANTING, PRECOMMERCIAL THINNING, FERTILIZATION
  AND SPRAYING COSTS
? 0,65,0,0
INPUT INTEREST RATE BOUNDS & INTERVALS IN %
? 4,10,1
CLEARCUT AT 9000 BF AT 80 YEARS, AT $3135.15 PER
  MBF DISCOUNTED 80 YEARS
THINNING AT 7000 BF AT 35 YEARS, AT $76.6726 PER
  MBF DISCOUNTED 35 YEARS
THINNING AT 8000 BF AT 50 YEARS, AT $329.511 PER
  MBF DISCOUNTED 50 YEARS
THINNING AT 8000 BF AT 65 YEARS, AT $776,606 PER
  MBF DISCOUNTED 65 YEARS
PRECOMMERCIAL THIN AT $101.268 AT 15 YEARS, DIS-
  COUNTED 15 YEARS
                    SINGLE ROTATION
INTEREST    DISCOUNTED    DISCOUNTED    PRESENT
  RATE        INCOME         COST      NET WORTH
  .04        2216.51         56.23      2160.28
  .05        1157.10         48.71      1108.39
  .06         620.38         42.26       578.12
  .07         342.04         36.70       305.33
  .08         194.05         31.92       162.13
  .09         113.28         27.80        85.48
  .10          68.00         24.24        43.76
```

These examples are somewhat simplified and will eventually have more sophistication, especially with regard to expansion of root rot over time. They indicate that disease control expenditures at year zero can be supported by growth of a reduced disease impacted stand on both high yield fast growing Douglas-fir and slower growing eastside ponderosa pine or mixed conifer stands.

This financial analysis method plays a major part of the Integrated Pest Management approach.

Literature Cited

Koss, William and Billy Dean Scott. Investment guidelines for Douglas-fir. Washington State Department of Natural Resources, DNR Report No. 36, 34 p., 1980.

Stoffle, Thomas L. and David N. Larsen. LEV II. Documentation and User Manual. Washington State Department of Natural Resources, DNR Note No. 22, 14 p., 1977.

ARMILLARIA In New Zealand

Ian Hood

Attack by *Armillaria* constitutes New Zealand's most important root disease problem in exotic forestry. At least two species are known (*A. limonea* and *A. novae-zelandiae*), and some isolates of each species were equally pathogenic in glasshouse inoculation tests. Both species occur naturally in podocarpous-dicotyledenous and southern beech indigenous forests. *Armillaria* attack is primarily a feature of areas on which logged, unproductive, podocarp.-dicot. forest has been converted to more economical radiata pine. Clear felling results in a rapid, saprophytic build up of *Armillaria* as the new pine crop is being established. Mortality begins in the first year from planting, peaks in the second and third years and declines after the fifth year.

Losses can reach 40-50% after 5 years. Mortality is widespread and is distributed in non-random, cluster pattern, frequently concentrated around stumps of the previous crop. Infection takes place by means of root or rhizomorph contacts in the soil. Subsequent mortality and windthrow may occur at a reduced rate, and in one study, 15% of surviving, 10 year old, final crop trees were severely infected and showing growth loss. Extensive mortality in second pine rotations has recently been observed in young plantations (2-14 years) formerly stocked with 50 year old, poorly growing contorta and ponderosa pines.

The most practical method of control, despite its cost, is that of stump and root removal. Uninfected land is often more expensive, and not always easy to obtain. Forest managers are reluctant to use alternate, more resistant species. Biological and chemical control methods appear unpromising. A widespaced, short rotation, saw-log regime, accompanied by cattle grazing, was proposed as an economic means of dealing with the irregular tree distribution following *Armillaria* attack. However, this proposal did not deal directly with *Armillaria* infection found to occur in final crop trees.

A theoretical study indicated that stumping and root raking prior to planting would be economical if treatment resulted in satisfactory control of *Armillaria*. Studies are currently underway to quantify more precisely the level of *Armillaria* control achieved using different land preparation treatments.

REFERENCES

Beveridge, A.E. (1973): Mortality in young plantations on sites cleared of indigenous forest. N.Z.F.S., F.R.I. Ann. Rept., 1972: 32-3.

Beveridge, A.E., Klomp, B.K. and Knowles, R.L. (1973): Grazing in young plantations of radiata pine established after clearing logged and reverted indigenous forest. N.Z.J. For. *18*:152-6.

Birch, T.T.C. (1937): *Armillaria mellea* (Vahl.) Quel. in relation to New Zealand forests. Aust. and N.Z. Assoc. for Advanc. Sci., Auckland.

Dingley, J.M. (1969): Records of plant diseases in New Zealand. D.S.I.R. Bull. 192.

Gilmour, J.W. (1954): *Armillaria mellea* (Vahl.) Sacc. in New Zealand forests I. In stands of *Pinus radiata* D. Don in Kaingaroa S.F. N.Z.F.S., F.R.I., For. Res. Notes *I*(9).

Gilmour, J.W. (1966): The pathology of forest trees in New Zealand. N.Z.F.S., F.R.I. Tech. Paper No. 48.

Mackenzie, M. and Shaw III, C.G. (1977): Spatial relationships between *Armillaria* root rot of *Pinus radiata* seedlings and the stumps of indigenous trees. N.Z.J. For. Sci. *7*(3): 374-83.

Shaw III, C.G., Sijnja, D. and Mackenzie, M. (1976): Toetoe (*Cortaderia fulvida*) - a new graminaceous host for *Armillaria* root rot. N.Z.J. For. *21*(2):265-8.

Shaw, III, C.G. and Calderon, S. (1977): Impact of *Armillaria* root rot in plantations of *Pinus radiata* established on sites converted from indigenous forest. N.Z.J. For. Sci. *7*(3):359-73.

Shaw III, C.G. and Toes, E.H.A. (1977): Impact of *Dothistroma* needle blight and *Armillaria* root rot on diameter growth of *Pinus radiata*. Phytopathol. 67:1319-23.

Shaw III, C.G., et al (In press).

Roth, L.F., Shaw III, C.G., Mackenzie, M. and Crockett, F.H. (1979): Early patterns of *Armillaria* root rot in New Zealand pine plantations converted from indigenous forest, an alternative interpretation. N.Z.J. For. Sci. *9*(3):316-23.

Stevenson, G. (1964): The Agaricales of New Zealand *V*. Kew Bulletin *19*(I):13-14.

Van Boven, R.J. (1974): Two unpublished reports. (N.Z.F.S., F.R.I.).

Van der Pas, J.B. (In press).

Panel: Surveys For Forest Diseases-- Are They Worth It?

W.J. Bloomberg, Moderator

The topic of our panel is "Surveys for forest disease - are they worth it?". We shall be dealing with this topic with special reference to root rot surveys, but the key considerations will be the same for all types of forest diseases, as we intend to show. The bottom line of the worth of forest surveys is obviously based on the cost/benefit relationship, i.e., survey costs vs survey benefits. (Fig. 1). Costs are relatively simple to establish. Our panelists will be presenting some cost data for various types of root rot surveys. Estimating survey benefits is more complex since in dynamic forest diseases such as root rot they must be projected over time. Even in episodic diseases such as frost damage or chronic ones like needle casts, time must be considered in discounting survey costs over the rotation.

One approach to estimating survey benefits is to examine the consequences of failing to conduct surveys (Fig. 2). As in any action premised on incomplete, inaccurate or totally absent information, two types of error can arise. Type I results from failure to recognize an effect and Type II from falsely assuming the presence of an effect. Applied to forest disease surveys, a Type I error results in failure to recognize disease presence, either because of improper survey methods or failure to conduct any survey at all. The consequences of this error are over-estimation of yield by failing to allow for growth decrement due to disease, removal of land from production due to tree mortality and failure to meet management objectives due to interference by disease with intensive management operations such as spacing, thinning and fertilizing. Panel members will illustrate these consequences of Type I error from the viewpoint as forest managers.

Type II errors, arising from faulty or absent forest disease data, result from the assumption that disease is present when in reality it is not (Fig. 3). This error usually takes the form of applying a standard growth loss, e.g. cull factor to all stands, regardless of their disease status. The consequences of this error are under-estimation of yield from a timber supply area, often premature harvest due to an invalid fear of losses and withholding of intensive management operations due to fear that the money will be wasted. These concerns will be discussed by the panel.

We will next consider the topic of cost/benefit optimization (Fig. 4). We can minimize survey costs by using the most efficient survey methodology available. For root rot in coastal forests, this means the selection of the appropriate ground-survey method relative to survey objectives, e.g. broad estimates over large timber supply areas, priorization of individual stands for silvicultural treatment, or detailed estimates for management purposes. Initial sorting or stratification of site and stand types by their risk rating e.g. by percentage of susceptible species, age classes, densities etc. will allow survey effort to be concentrated in types yielding the most information for management purposes.

Benefits of knowledge obtained from disease surveys can be maximized by the capture of infected volumes that would otherwise be lost to disease e.g. by shortening rotations and increasing the frequency of management interventions in the stand. With some knowledge of severity and distribution of disease in stands we can plan to manage against the disease by sanitation, e.g. stump removal, spot clearcutting or by stand manipulation e.g., planting density, species mixture. Results of disease surveys can also be used to identify and manage on a compartment basis stands or portions thereof having different disease status, rather than application ofblanket treatments. The panel will consider these aspects also.

Finally, we arrive at the difficult step of translating survey benefits into dollar terms and comparing them with survey costs. Again we shall attempt to do this on the basis of what will be the disbenefits of failing to obtain reliable information on disease levels in forest management units whether stands or timber supply areas. As I mentioned earlier, the time factor is a critical element in the estimation of these disbenefits. We shall discuss some ways of dealing with this problem.

The order of presentation will be as follows. I shall address the aspects of estimating losses over time, Rick Clevette, operations superintendent forestry, Duncan Forest District, B.C. Ministry of Forests will discuss the relationship of surveys to forest resource management planning, and Dick Heath, pest biologist, Pacific Forest Products Ltd., Victoria, will tackle their relationship to maximizing forest productivity. To repeat, we will be using Phellinus root rot to illustrate our points but we believe the approach is valid for all forest diseases.

W.J. Bloomberg, Forest Pathologist, Pacific Forest Research Centre, Victoria.

ESTIMATION AND PREDICTION OF LOSSES CAUSED BY *PHELLINUS WEIRII* ROOT ROT IN SECOND-GROWTH FIR STANDS IN COASTAL BRITISH COLUMBIA

W.J. Bloomberg

Disease surveys are the first step in assessing damage caused by a pathogen and in predicting future losses. Ground-survey methods for estimating incidence of root rot caused by *Phellinus weirii* (Murr.) Gilbertson (Bloomberg et al 1980) provide estimates of stand area occupied by trees with above-ground symptoms (Wallis 1976) and numbers and sizes of infection centers. The total area of infection can be estimated from its regression relationship to the above-ground symptom area (Wallis and Bloomberg 1981). Average rate of spread of above-ground symptoms in infection centers was about 30 cm/yr over a 26 yr period (Nelson and Hartman 1975). By applying spread rates to the distribution of infection centers determined by ground-survey, estimates can be made of disease incidence at future ages of a stand.

Reduction in tree growth resulting from infection by *P. weirii* has been estimated using height-diameter ratio trend (Bloomberg and Wallis 1979), paired-tree comparisons and regressions of healthy and infected tree growth on time (Thies 1981). These estimates are difficult to translate into growth reduction on an area basis because of variation in numbers, sizes and infection levels of trees within centers. In order to derive growth reduction in stands from ground-survey estimates of disease incidence it is necessary to quantify the reduction in whole centers. Current and future estimates of growth losses can then be obtained by application of growth reduction factors to the numbers and sizes of infection centers as determined by ground-survey and by simulating spread of centers. This report describes the estimation of growth reduction and spread in infection centers.

METHODS

Growth reduction in infection centers was estimated by measuring trees in transects through centers. A center line was marked through each center passing through the presumed origin of infection, as deduced from tree symptoms, outward through the visible margin of the center into the apparently healthy stand on opposite sides. Within 5 m on both sides of the center line the root collars and approximately 1 m of root surface were examined on trees beyond the visible margin for the presence of ecototrophic mycelium of *P. weirii*. The start and end of the transect were placed 10 m beyond the outermost trees with ectotrophic mycelium. Within this 10 m length on both ends of the transect four dominant or codominant trees were tagged and designated as healthy. All other dominant and codominant trees within the transect were tagged. Dominance and codominance was classified by comparison of each tree with its immediate neighbors. Lower crown classes were excluded from the sample because of the possible confounding of the effects of suppression with those of root rot on tree growth and because they were assumed to be omitted from the final crop trees.

The following information was recorded for each sample tree: distance from start of transect, dbh (diameter at 1.4 m height) and disease rating based on the following factors: crown thinning, crown yellowing and leader length reduction relative to neighboring healthy appearing trees outside the infection center. Each factor was given values of 0 to 3 for visual estimate classes of 0-25%, 26-50% 51-75% and 76-100% respectively. Trees with less than 26% in all classes were therefore rated as 0 or healthy; dead trees were rated as 10.

Two of the four healthy sample trees at each end of a transect were measured for height with a hypsometer. All other sample trees were felled and their heights measured by tape. Annual height increments were measured from internodal distances along the stem. Cross-sectional disks were cut at breast height and at 2-m intervals along the stem to a top diameter of 5 cm or less. On each disk inside bark diameters were recorded for the current year (1981) and 10 and 20 years ago. Dbh (inside bark) was measured and basal area calculated for these three years. Tree volumes were calculated for the three years using the sum of cone frustrum volumes in 2-m segments of stem. Average annual increment was calculated for dbh, basal area, height and volume for the previous and current decades, i.e. 1961-1971 and 1971-1981 respectively.

Growth parameters for each sample tree were plotted over distance from start of transect as individual points and as moving averages each representing the mean of four trees. Effect of root rot on tree growth was calculated for each infection center by averaging the signed vertical differences at 1-m intervals along the transect between the moving average trend line and the healthy reference datum line, i.e. the straight line joining the moving average points at opposite ends of the transect representing the healthy sample trees. Differences were expressed as ± percentages of the healthy datum. A total of 11 infection centers were sampled in two sites.

To predict future incidence of root rot in stands, a computer simulation model was constructed to calculate future sizes of infection centers using specified spread rates. Each

---

W.J. Bloomberg, Forest Pathologist, Pacific Forest Research Centre, Victoria, B.C.

simulation represented a sample of a stand containing 25 centers with initial size distribution obtained from ground-survey results. Spatial distribution of centers was either random, using a different random series for each sample, or specified by central coordinates for each center. Shape of centers was varied by specifying the ratio of major to minor axes, and orientation of major axes treating each center as an ellipse. For past, current and future stand ages the model calculated the above-ground symptom and total infected area for each center and for the stand and the percentage of stand area infected. Tree growth reduction and mortality within centers were calculated from specified average annual reduction factors and years to mortality since infection. These were expressed as per cent reduction of stand increment and per cent stand area occupied by dead trees.

RESULTS AND DISCUSSION

All infection centres showed disease rating trends as increasing fairly symmetrically from the opposite margins and peaking at approximately the presumed origin of infection. All centers showed reductions in average annual increments dbh, height, basal area and volume within the current decade and some showed reductions in the previous decade although to a lesser degree. Most centers showed reduction in tree height in the current year and some at 10 years previously. In several centers, current year dbh, basal area and volume were equal to or greater than the healthy datum due to the presence of infected large trees. As indicated by their sizes 20 years ago these trees had been dominant for most of the life of the stand. However, their increments during the current decade were below those of healthier trees.

Reduction of increment in the majority of centers only within the current decade indicated that the disease was absent or slight prior to that period when average stand ages were 30 yr or less. This rate of disease development is typical for coastal Douglas fir stands. Increment trends within the current decade generally declined from the healthy datum towards the presumed origin of infection although not always symmetrically from opposite ends of a transect. Trends in average increment during the previous decade and current year tree growth parameter trends were generally irregular and fell above or below the datum.

Incidence of P. weirii root rot in a 40-yr-old Douglas fir stand at Mackay Lake, Vancouver Island, B.C. was estimated by ground survey to total 9% of stand area in 180 infection centers ranging from 25 to 3750 m^2 in size. Total infection area was estimated by its regression relationship to above-ground symptom area to be 16% of the stand area. As predicted by the model, above-ground and total infection at stand age 60 were 31 and 54% of stand area respectively with center sizes ranging from 170 to 4740 m^2. Simulated infection centers were given a random distribution and were made to spread isometrically at 60 cm/yr the rate necessary to produce the center sizes estimated by ground-survey. Per cent increment reduction for five-yr periods following infection were specified as 5, 20, 40, 80 and 100 (dead) based on published data for individual trees (Bloomberg and Wallis 1980, Thies 1981) and the results for whole centers. Increment reduction within centers was 37 and 54% at ages 40 and 60 respectively and reduction for the stand as a whole 3.7 and 16.4% respectively. Per cent of stand area in mortality increased from 2.7 at age 40 to 15.8 at 60. According to variable density yield tables, prepared by the B.C. Ministry of Forests (Hegyi, personal communication) the annual volume increment of Douglas fir on medium sites at age 60 is about 6 m^3/ha. The model predicts that this would be reduced by 1 m^3/ha by P. weirii root rot. Predicted loss of increment would reach 70% by rotation age 100.

Spread rates of P. weirii and increment reduction due to root rot probably vary among stands and sites. Apparently 30 cm/yr was too low to produce infection center sizes encountered in the Mackay Lake stand. More precise estimates will result from additional sampling of stands and analysis of long-term disease plots. Current estimates of these values are considered satisfactory for assigning relative risk ratings to stands infected by P. weirii as a basis for priorizing treatment. More precise estimates should allow for adjusting allowable cut to maximize the yield.

LITERATURE CITED

Bloomberg, W.J. and Wallis, G.W. Comparison of indicator variables for estimating growth reductions associated with Phellinus root rot in Douglas-fir plantations. Can. J. For. Res. 9:76-81; 1979.

Bloomberg, W.J., Cumberbirch, P.M. and Wallis, G.W. A ground-survey method for estimating loss caused by Phellinus weirii root rot. I. Development of survey design. Can. For. Serv. Rept. BC-R-3. II. Survey procedures and data analysis. BC-R-4; 1980.

Nelson, E.E. and Hartman, T. Estimating spread of Poria weirii in a high elevation, mixed conifer stand. J. For. 73:141-142; 1975.

Thies, W.G. Measuring growth loss induced by Phellinus weirii. Proc. 28th Western Internatl. For. Dis. Work. Conf. p. 54-60; 1980.

Wallis, G.W. Phellinus (Poria) weirii root rot. Detection and management proposals in Douglas-fir stands. Can. For. Serv. For. Tech. Rep. 12.

Wallis, G.W. and Bloomberg, W.J. Estimating the below-ground extent of Phellinus weirii root rot centers using above- and below-ground disease indicators. Manuscript submitted to Can. J. For.; 1981.

DISEASE SURVEYS RELATED TO FOREST MANAGEMENT PLANNING

Richard E. Clevette

INTRODUCTION

I appreciate the opportunity to participate in todays panel discussion on "Surveys for Forest Disease - Are They Worth It." In my presentation, I hope to briefly elaborate on the need and benefits of disease surveys in forest management planning. As a way of introduction, perhaps some background information on the demands and concerns of my particular area will suffice to begin my presentation.

The Duncan Forest District has the distinction in British Columbia of possessing a relatively small portion of crown land in respect to area. The reversal of provincial picture; in that 95% of the land base is under private or licensee tenure. This leaves us with a scattered forested land base of approximately 11,000 hectares. This entity of forested crown land is entirely in second rotation. These stands are situated in medium to high sites, fifteen to sixty-five years of age, and entirely stocked with near to pure Douglas Fir. The Duncan Forest District is also committed to Provincial Timber Supply Analysis and the subsequent Annual Allowable Cut for each Supply Block. Within our boundary also lies a highly historic and active Small Business Program. The point I wish to make here is that the intensive management of these second growth stands becomes paramount to the existence and objectives of the Duncan Forest District. We have very little, so we had better be certain as to what it is we have. The most recent inventory gave us limited information for intensively managing our forest land base, so it was decided to augment photo interpretation and inventory information with a preliminary field recce in hopes of developing management objectives for our land base. The preliminary recce data hit us smack in the face, our district was blanketed with Phellinus weirii. To what extent and under what distribution we were uncertain. The available information on the disease pointed to the potential limitation in the intensive management of these second growth stands. Thus our perceived need to know more. In debating over the need for surveys, the pros and cons and the alternative consequences of failing to conduct surveys were given careful consideration. Which leads me to my first subject matter.

"CONSEQUENCES OF FAILING TO CONDUCT SURVEYS - TYPE I AND TYPE II ERRORS"

I refer to the Type I error as the failure to recognize the disease presence. This type of error signals a number of concerns in management planning. The significance of the apportionment of the Annual Allowable Cut to the Duncan District and the commitment to the Small Business Program directly influences a tightening or constraint on the timber supply over the long term. Failing to recognize the disease presence leads to the over estimation of yield due to the growth impact. The epidemiological nature of the disease increases this error over time.

Of major concern in the Type I error is the loss of the productive land base. The volume over age curve essentially reflects the healthy productivity of the site and does not adequately reflect the increasing land base out of production due to the disease presence. What that site is capable of producing, as compared to what it is currently and foreseeably losing to mortality, places severe limitations on the number of management options available. In failing to recognize the disease presence, the fungus has the potential for greatly reducing site productivity.

A final consequence in the Type I error is recognized in the potential failure of intensive forest management objectives in these second growth stands. The objective of juvenile spacing, fertilizing and the likes, depend on the health of the stand and a definite understanding of stand reaction to intensive operations. Intensive silviculture activities require an understanding of silvics, ecosystems, protection, harvesting etc., surely the presence of a disease is a need to know. Without understanding the extent and distribution of a disease, obtaining the desired silvicultural objectives appears as random as the disease. Interference develops on short and long term yield, and, as well, future silvicultural treatments, budgeting and Five Year Forest Program forecasting become inaccurate.

With these three major Type I errors in mind, (a) over estimation of yield due to growth impact, (b) land out of production due to mortality and (c) failure of management objectives due to interference with intensive silviculture objectives, the failure to conduct surveys for disease presence severely limits the options available for the manager. The result dramatically affects long term yield analysis, markets, small business and the sustained productivity of the land base.

I mentioned earlier that our preliminary recce hit us smack in the face as to the presence of Phellinus weirii. The extent of the fungus throughout the Duncan District might have

---

Richard Clevette is an Operations Superintendent, Forestry, with the Provincial Ministry of Forests at Duncan, British Columbia.

subjected us to the consequences of failing to conduct surveys under the Type II error. This type error assumes the presence of the disease by application of a growth loss factor to all stands. Undoubtedly, this conjures up all sorts of problems for management planning.

Firstly, by applying a growth loss factor to all stands there is an inherent problem of underestimating the yield. The short and long term timber analysis would have to consider this assumption in relation to other stands, reappropriating cuts and possibly moving a particular segment of the Small Business Program. Management planning would consist of progressive clearcuts balanced over the projected mortality and economic recovery of the merchantable timber. A costly endeavor as a consequence of failing to conduct surveys.

The application of a growth loss factor to all stands under the Type II error also puts undue stress on the forest manager to prematurely harvest the timber due to fear of losses. The fact that the disease itself is not stagnant but progressive, increases losses over the long run. Consequently, the forest manager might wish to harvest prematurely in order to minimize losses to mortality. In assuming a constant growth loss factor, healthy stands as well as heavily infected stands would be subject to the faller's axe. The development of management plans relating to site specific prescriptions and needs, no longer prevail. Minimizing losses by reducing the rotation age becomes the primary objective. The Type II error virtually eliminates alternative options to the manager.

A final consequence of assuming a growth loss factor to all stands, is the curtailment of intensive silviculture activities due to fear of loss of investment. This type error and its consequences cannot be overcome by any rational approach to management. Stands that are prime candidates for intensive management can withstand varying degrees of infection and distribution. Assuming a standard growth loss factor regardless of stand characteristics and treatment need, leaves fewer and fewer options for the manager. Thus a stand once considered for intensive silvicultural treatment, hence better productivity, remains untreated and subject to productivity loss.

The Type II error, summarized (a) the underestimation of yield, (b) premature harvest and (c) withholding of intensive management practices due to fear of loss of investment, illustrates that the assumption of disease presence through the application of a growth loss factor does restrict management planning. Management options, regimes and future considerations are severely hindered by this type of error in not conducting disease surveys.

After reviewing the consequences of failing to conduct surveys, the cost/benefit considerations had to be addressed, which brings me to my next subject matter.

COST/BENEFIT CONSIDERATIONS

In consideration of cost/benefit analysis we attempted to develop an operational plan for disease surveys. The different survey options were identified and incorporated into an operational survey plan. Also, a cost efficient analysis was undertaken to determine staffing levels, i.e. either a two or three man survey crew, by means of a field trial. Of particular interest to this conference might be the cost/benefit considerations we identified, and our survey costs incurred to date.

The cost/benefit considerations were identified on a per hectare basis. The survey cost considerations identified the availability of manpower, transportation, accessibility, training and to some extent seasonal timing. The consideration of survey costs were also linked to management plans, or management folios being developed for these areas. These management plans had identified by stand composition, site topography and accessibility, the character and rough delineation of the management units. The character and objectives of these management units would be fine tuned as our disease surveys and cutting ~~boundary layouts~~ were developed. However, once these areas were identified and the survey methodology picked, training was completed and the surveys were undertaken.

During this process we attempted to recognize the benefits that would be derived from the surveys. Initially, we recognized that the consequences of failing to conduct these surveys would severely limit the management options open to us as I have already discussed. Other benefits considered were; more site specific information, and a refinement of the layout treatment and management objectives designed for each management unit. From the survey we would obtain computer maps and a printout of the distribution and extent of the disease. This could eventually lead to a calculated volume loss and an actual realization of the optimum utilization of that site. Yield analysis, intensive silvicultural treatments, budgeting and the Five Year Program forecasting would have a higher degree of acceptability for the standards and objectives set.

The survey costs that we have incurred to date have been realized as follows:

TABLE 1

The calculated manhours and costs/manhour are based on the manhours of actual field and office work (i.e. travel time and associated costs not included) and cost per manhour of a Technician making $1,732/month, 1981 costs.

Survey Option	Intensity	Manhours	Cost per Manhour	Hectares Surveyed	Cost per Hectare
1	5 grids 4 lines	303	$11.38	146	$23.62

The option provides the most accurate estimate of size and number of infections.

Survey Option	Intensity	Manhours	Cost per Manhour	Hectares Surveyed	Cost per Hectare
2	4 grids 4 lines	261	$11.38	122	$24.34
	2 grids 4 lines	217	$11.38	105	$23.52

The option incorporated a mapping option.

Survey Option	Intensity	Manhours	Cost per Manhour	Hectares Surveyed	Cost per Hectare
3	2 grids 4 lines	116	$11.38	86	$15.35

Accuracy in this option depends on the ability of the crew to estimate centers and assign them to the most representative class. Mapping also included by size class.

The survey benefits on a per/hectare basis have not been fully realized. This is due, in part, to budget constraints, and the long term realization of the identified management goals and objectives. However, one definite survey benefit that has been identified is that we have been able to clarify the cost/benefit optimization for disease surveys. This then leaves me to my next subject matter.

COST/BENEFIT OPTIMIZATION

It becomes extremely important in labour intensive surveys that the two key issues of minimizing survey costs and maximizing benefits be addressed. The first issue is minimizing costs.

Of critical importance, is the selection of the appropriate survey methodology. Different survey options provide a range of detail and accuracy in the survey results. Also available is the incorporation of a mapping option. Each survey option requires varying amounts of manpower and time, dependent on your desired results. Thus, to minimize survey costs, the selection of the appropriate survey methodology relative to desired results is essential.

A further step in minimize costs is the stratification of site types by a risk rating factor. The choice of stand boundaries through photo interpretation and forest cover maps, will help stratify the site types. Further stratification by risk rating - or the probability of occurrence by site type, stand history and stand composition, in conjunction with the use of appropriate survey methodology will minimize operational costs. The risk rating indicates the probability of the occurrence of root rot and will subsequently enhance the manager's capability to set priorities and establish objectives in a cost efficient manner.

The second issue of key importance is the maximization of benefits. The manager must be concerned with minimizing his survey costs but must perceive this in relation to maximizing his benefits. The maximization of benefits can be manipulated by the manager in a number of ways. First, as mentioned, is the minimization of volume losses by harvesting or capturing infected volumes. This process suggests possible harvest rotation adjustments for infected stands. Selective logging, commercial thinning or intensifying growth promoting activities such as fertilization, all help to optimize volume harvested. These particular manipulations of the stand are developed once the extent and distribution of infection centers are identified through the various survey methodologies. Large aggregated pockets of infection suggest selective or pocket logging, whereas smaller, well distributed centers suggest fertilization, depending on site and stand characteristics.

Managing against the disease is another way the manager can maximize benefits. This can be accomplished through stand manipulation such as fertilizing or juvenile spacing. By varying the spacing regimes and/or the specie selection around infection pockets, the forest manager can help minimize future volume losses. Managing against the disease can also incorporate different methods of sanitation, such as stumping or root raking. Alternating planting specie selection, with or without a sanitation method, can also help to promote a healthier rotation. Regardless of how the manager selects to manage against the disease, the need for a long term commitment of funds and treatment is essential.

The very need for management planning suggests another form of maximizing benefits. The harvest, stand treatment or the sanitation method selected must be very specific to the site and to the objective selected for that site. Areas of root rot infection require intensive stratification by disease level or risk rating and subsequent objectives and treatments tailored to the more intensively managed site. Large clear cuts are going to give way to smaller intensively managed units.

My concluding subject matter is the relationship of the cost of the Type I and Type II error to survey costs, or simply, cost/benefit estimates.

COST/BENEFIT ESTIMATES

The Type I error of failing to recognize the disease presence has serious ramifications in all areas. The over estimation of the yield could result in the eventual re-allocation of the allowable cut, possible shut down of the timber supply to the local lumbering sector and an over extension of the allowable cut levied in other timber supply blocks. Of monumental concern is the failure or unfulfilled realization of intensive silviculture treatments. The silviculture objectives and investment of $500/hectare for juvenile spacing matched with repeated fertilizer application at $200/hectare can be drastically underachieved. The cost of the disease surveys surely offsets this potential loss of investment.

The Type II error of assuming the presence of the disease by the application of a growth loss factor has serious costs attached to it also. The premature harvest of timber can lead to a boom and bust local economy. The fear of investing in intensive silvicultural treatments due to the assumed presence of the disease can have serious consequences on future yield and on the capability of the land base to produce a healthy forest crop. The shrinking forest land base and the alienation of the single use forest management concept, such as parks, necessitates that we approach intensive silviculture as the saviour of the sustained forest yield. In order to meet this need, it is crucial that the productive forest land base we have is being intensively managed. And essential to that intensive forest management, is the disease survey.

THE VALUE OF SURVEYS FOR PHELLINUS WEIRII FROM AN INDUSTRIAL PERSPECTIVE

Richard H. Heath

INTRODUCTION

Forest companies in British Columbia are now involved in intensive second growth management and beginning to encounter significant levels of Phellinus weirii (Murr.) Gibb. in many otherwise productive areas. In the past, losses to the disease have largely been accepted as unavoidable, but many foresters are now becoming increasingly aware of disease losses and their effects on intensive forest management programs.

The main stumbling block to taking action against P. weirii is primarily a lack of hard information on its prevalence, distribution and impact in our affected stands. Conventional mensuration cruises are not designed to estimate the losses attributable to the disease and are of little value in assessing its impact. The P. weirii survey technique recently developed by Bloomberg et al. (1980) appears effective and is beginning to be used operationally in the province.

Failure to conduct these surveys in infected stands can lead to a variety of problems, including incorrect management strategies and ultimately, an unnecessary loss of stand productivity.

Consequences of Failing To Conduct Surveys For P. weirii

Failure to recognize disease presence -- Overestimation of yield is probably the most common consequence of failing to recognize the presence of P. weirii, especially in second growth stands. Most companies have effective, well developed techniques for estimating volumes and disease impact in relatively static old growth stands but have little experience in evaluating these phenomena in vigorous second growth stands.

There is often up to a 20 year interval between a final volume cruise and the initiation of harvesting operations. Most companys' 5 and 10 year planning projections are made on the basis of these cruises. It now appears that a heavily infected stand can lose a significant amount of its volume over those intervals - probably enough to at least partly invalidate fibre supply projections for a company's saw and pulp mills.

Most companies in the province use logging contractors to harvest a significant percentage of their timber. They are often paid on the basis of volumes logged and cruise data is normally used to establish price. The overestimation of a stand's net volume because of disease can negatively affect the agreement between a company and its contractor. This has already happened to my company, although the causal organism was Polyporus schweinitzii. The contractor ended up logging one-half the estimated volume and had to absorb a substantial loss.

It is becoming apparent that many of our most productive Douglas-fir stands are infected to varying degrees with P. weirii. Failure to survey for and identify at least the larger infection centers effectively removes relatively large areas of our best sites from full production. Surveys conducted to date in some older second growth stands have revealed losses in productive areas ranging from 10-20%. The affected areas will also increase in size over time if ignored. These are stands we are counting on to alleviate potential fibre supply shortages in the future and we can't afford to have them producing at less than their full potential.

Most logging companies in western North America now routinely space overstocked 15-25 year old stands. Spacing moderately-heavily infected stands without regard to P. weirii can lead to the development of intolerably large holes in the canopy as the disease takes out trees left after thinning. The problem is caused by inadequately trained spacing crews indiscriminately removing both healthy and diseased trees; thus the stand is understocked by the time it is ready for harvesting. If a stand is heavily infected, it is unlikely a company would get the return on investment needed to justify the operation.

Assuming presence of disease by application of a growth loss factor to all stands -- A pessimistic estimate of an infected stand's harvestable volume based on inadequate evaluation techniques is the flip side of the optimistic estimate and leads to similar problems with respect to planning and wood supply. This error is probably comparatively rare due to the difficulty many foresters have in identifying the disease and appreciating its potential impact.

It has been my experience that when loggers do identify P. weirii in older second growth stands, their natural inclination is to clearcut the works, regardless of how serious the problem is. For example, I was once called in to look at a 300 ha stand of 120 year old Douglas-fir that a logging manager felt should be quickly logged due to the presence of P. weirii. Aside from a couple of centers visible from a road, the stand was basically healthy. Harvesting such a stand before its optimum rotation age naturally inflicts severe economic penalties.

Foresters are naturally reluctant to commit scarce resources (both capital and labour) to areas where any increase in production arising from management operations doesn't justify their costs. If they lack the data required to make intelligent decisions with respect to managing infected stands, some areas will be unjustifiably deprived the benefits of intensive forest management. Stands containing

---

Richard H. Heath is Forester i/c Pest Management, Pacific Forest Products, Victoria, B.C.

only a few, small, discrete centers will have much of their potential needlessly wasted if passed over on the basis of inadequate data. The same would apply to pre-commercial and commercial thinning operations.

Cost/Benefit Optimization

Minimizing Costs -- Survey costs are a function of stand characteristics, topography, disease characteristics, crew experience and the type of information sought. Some examples of our survey costs per unit area appear in Table 1.

Stands approaching their rotation age probably should be more intensively surveyed than those 15-25 years old. In the case of the older stands, we would be after information on disease-induced volume losses to facilitate harvest schedule planning as well as maps delineating the larger infection centers to help develop post-harvest management programs. Surveys in younger stands would be designed to provide data on the number and approximate distribution of centers that are still in their incipient stages.

These stands can also be risk rated prior to a survey to help establish the intensity required. Stands with a significant component of partially resistant tree species would probably not need a survey of the same intensity as a pure Douglas-fir stand.

Maximizing benefits -- Properly designed surveys, done in conjunction with conventional volume cruises and/or growth and yield studies, will allow companies to harvest infected stands at their optimal rotation age, thereby capturing the maximum amount of healthy and infected volumes. For example, a 45 yr. old Douglas-fir stand that is moderately-heavily infected would almost certainly benefit from a relatively intensive survey. It is possible to calculate the revised rotation age of an infected stand if the following data is available:

(i) Volume annually accruing to the stand.
(ii) Volume annually lost to the disease (from survey).
(iii) Area infected by P. weirii and annual increases in infected area (from survey).
(iv) Market requirements with respect to relatively small second growth logs.

If the survey reveals heavy losses to the disease, an adjustment in the planned rotation period is probably required. The stand should be logged before disease-induced volume losses approach the increment accruing to the stand. Delaying harvesting operations will also result in an expansion of the infection centers, thus leading to increased post-harvest management costs or larger areas of land effectively out of production. The costs of conducting surveys in these situations are negligible compared to the potential losses involved if the problem is ignored.

It is also possible to use the surveys to compartmentalize forest management operations. The scenario below is designed to demonstrate the potential economic benefits of such a procedure.

Background data:
a. 25 yr. old Douglas-fir stand (100ha).
b. The stand is overstocked and requires spacing.
c. Some Phellinus weirii noted in stand.

Data required:
a. Map showing distribution of the infection centers.
b. Estimates of area currently infected and projections of affected area at probable rotation age.
c. Economic benefits of spacing.
d. Effects of spacing on disease spread.

Table 1 -- P. weirii survey costs in older second growth stands

Stand Number	Crew Size	Area	Topography	Degree of Infection	Survey Intensity	Crew Experience	Cost/ha 1/
1	2	140ha	steep	moderate	low	low	$ 2.74
2	3	100ha	mod-steep	moderate	high	low	$11.32
3	3	20ha	gentle-moderate	heavy	high	low	$14.14
4	2	44ha	gentle-moderate	moderate	high	high	$10.02
5	3	10ha	moderate	heavy	extreme	medium	$41.36

1/Costs are exclusive of travel time, computer charges, and office preparation.

Mensuration data suggests the stand should be harvested at a rotation age of 60 years. The progressive company in this scenario decides to run a survey through the stand rather than just write it off as unsuitable for spacing because of the P. weirii. The survey reveals that 20% of the stand is infected heavily enough to preclude spacing but the remaining 80 ha is only lightly infected and would benefit from the operation. We normally expect a 30% increase in yield as a result of spacing, thus the volumes in our theoretical stand would increase from 490 m^3/ha for a natural stand to 635 m^3/ha in the 80 ha spaced area. A current average gross stumpage value of $40/$m^3$ at 60 years is assumed. Our survey and spacing costs normally run $15/ha and $500/ha respectively. The costs are then compounded for 35 years (to the rotation age) at a real interest rate of 6% and the timber values at 2%.

Stand management costs at rotation if area surveyed and subsequently has 80 ha spaced - $318,940 (survey and spacing costs only).

Value of stand if not surveyed - 490 m^3/ha x 100 ha
x $80/$m^3$ = $3,920,000
Value of managed stand - [(635 m^3/ha x 80 ha) +
(490 m^3/ha x 20 ha)]x
$80/$m^3$ = $4,848,000
$4,848,000 - $3,920,000 -
$318,940 = $609,060

This represents an increase in gross value of $6,090/ha. These are somewhat rought estimates but should serve to demonstrate the value of doing the relatively low-cost (compounded to $115/ha at rotation) surveys in these situations. The survey allows the forest manager to concentrate his resources in areas that will yield the maximum benefit.

CONCLUSIONS

Although operational surveys for P. weirii are largely still in their formative stages, it appears they can play a valuable role in maintaining or increasing the productivity of our Douglas-fir stands. Some of the larger companys' foresters are still somewhat skeptical about the value of spending money to survey for a disease but should begin to appreciate its value as they encounter more and more problems in their second growth stands. Our productive forest land base is shrinking every year and both government and industry will have to intensively manage what remains to avoid future wood supply shortages. Root disease surveys should become an integral part of this effort.

LITERATURE CITED

Bloomberg,W.J.; Cumberbirch, P.M.; Wallis,G.W. A ground survey method for estimating loss caused by Phellinus weirii root rot.II. Survey procedures and data analysis. Can. For. Serv. Rept. BC-R-4;1980

MAINTAINING AND PROTECTING LONG-TERM FOREST RESEARCH EXPERIMENTAL PLOTS

Robert F. Scharpf

ABSTRACT: Long-term forest research plots on forest lands are subject to damage--primarily by man's activities and, to a lesser extent, from natural causes. Appropriate planning, maintenance, and protection of experimental areas can reduce loss of valuable research data. Some steps that can be taken to help reduce this loss are described.

INTRODUCTION

Forest research often requires the establishment of long-term experimental plots in order to obtain information needed for forest management. In forest disease research, for example, studies of disease incidence, spread buildup, and impact often require field plots that must be established, maintained, and checked periodically for several years. Other areas of forest research require long-term field studies as well.

Research is only one of many activities taking place on forest lands--particularly on public forest lands. Protecting and maintaining research plots on these areas has become a major problem. Even plots on experimental forests and private lands are subject to such problems. As the number of people entering the forests for hiking, hunting, fishing and other recreational activities increases, the chance for disturbance and damage to study areas increases. And, expanded programs in forest management in many areas increase the possibility that research sites may be inadvertently or carelessly disturbed.

Furthermore, there is always the potential problem of loss or damage to studies from natural catastrophies, such as fire, floods, blowdown, and similar phenomena more commonly known as "Acts of God".

This paper points out some of the problems in the maintenance and protection of experimental field plots, describes how the problems may be reduced, and outlines what problems might be expected in the future. Knowledge of the problems or catastrophies that may occur to long-term field plots can aid in the initial planning by scientist and manager so that a better judgment of appropriate study design and sample size can be made at the start of the study.

Case history of problems encountered

Over the past 20 years, I have experienced fifteen instances in which study plots have been either damaged or destroyed as a result of natural catastrophies or by man's inadvertent or deliberate activities. In nine instances damage occurred to plots on State Forest or National Forest Lands and six cases of damage occurred to plots on experimental Forest Areas.

Thirteen of the fifteen cases of damage were caused directly by man's activities, one indirectly by man and one by natural causes. Thus, the chances of damage in the future to experimental plots appear much greater from human activity than they do from natural catastrophies. Examples of man caused damage include seven instances in which plot trees were damaged by logging, thinning, dead tree salvage, or similar operations in or near the study areas; one instance of an incendiary fire destroying a study area; and six instances of vandalism of trees on study plots. The only instance of natural damage occurred when a large dead snag fell on-to trees in a research plot.

These cases are presented merely to illustrate some of the problems I have encountered over the last two decades and may not be typical of problems encountered eslewhere. Nonetheless, the problems in my case have been frequent enough that I feel others may have had similar experiences. Loss of research data was not precisely calculated but varied from total plot destruction to individual tree damage. The losses I incurred in some cases were serious. For example, once severe damage occurs to a study plot of long duration, the loss is often irretrevable. Not only is valuable data lost, but often years of time. Expense and effort in the maintainence of a study also is lost. Thus, the longer the duration of the study, the more valuable it becomes and the greater the potential loss of research information.

What can be done to protect study plots since most of the damage appears to result from man's activities?

Robert F.Scharpf is Plant Pathologist at the Pacific Southwest Forest and Range Experimental Station, USDA Forest Service, Berkeley, Calif.

First, let us consider the research plot areas I previously mentioned that sustained damage. In all cases, the damaged plots were marked in the field in some manner and in most cases plot information was recorded in the files of the local management agencies.
Several means were used to identify plots in the field. Research area signs were placed within or around some plots; some plots contained painted and tagged trees and on other plots tree branches were flagged and tagged. All of the above methods were used in one combination or another to delineate plot areas and test trees.

Why, then, were marked experimental areas disturbed in the field? Two general theories may be proposed: First, either the plot areas were not marked clearly enough, so that people entering the areas and causing damage were not aware they were in a research area or they were indifferent to the signs, tags or markings on test trees; second, well-marked test trees or plots attracted curious visitors to the area who then knowingly or unknowingly disturbed the areas.

In the cases described above, I believe that damage resulted from both situations. In five of the cases of man-caused damage, numerous individual tags were deliberately removed from test trees. Why this was done remains a mystery, but I suspect the trees were vandalized by some hiker or deer hunter who found them offensive and not part of the "natural environment". Had the research plot and trees been less conspicuous, the tags might not have been seen and disturbed. Or, had the plot been better marked and described as a research area, damage might have been avoided.

In eight of eleven plots, either the research signs or other plot markers were not seen, were ignored, or did not indicate to the persons involved that the area should remain undisturbed. Additional signing or research area designation may have prevented some of this damage. In one case, an incendiary forest fire which started several miles away destroyed one entire research site. Increased fire prevention activities or special protection, or both for high value research areas could help prevent this type of loss.

Five of the examples of man-caused damage occurred on U.S. Forest Service Experimental Forests--areas set aside specifically for forest research. Even these areas which are supposed to receive high levels of protection are entered for one reason or another and subject to potential damage by human activities.

Reducing experimental plot damage

How can loss from man-caused damage to research areas be reduced? After talking to colleagues with similar problems and to forest managers on whose land most research plots are located, some of the following ideas were proposed:

a. Some scientists, at least some I have come in contact with, feel that research plots can be established on public land without contacting the land manager. Common sense as well as common courtesy suggests it is essential that the scientist inform the appropriate persons or agencies on whose land research is being planned or conducted. Ideally, the land manager and scientist should agree on the suitability of a proposed site for long term research. Sometimes other more important management considerations preclude a site from being used for research, or the manager may not be able to guarantee the needed level of protection required for the duration of the study. These details worked outin advance are essential in the intitial selection of long-term plot areas. In addition, the type of field markings to be used to designate study plots, and similar relevant information such as the precise location of the plots, and duration, and purpose of the study should be agreed upon and recorded. This will allow the manager to document the study, and set it aside for protection or as an area to remain undisturbed.

b. Mark clearly all plots in the field. The degree of marking will vary according to the manager's wishes, but may consist of a well-defined border or buffer zone of signed or painted trees or something less conspicuous. Whatever the case may be, the plot should be not only delineated but described as a "research area". I believe the main reason why plots are vandalized is not because people want to pull tags off of trees, for example, but because they do not know why the tags are on the trees in the first place and are unaware that active research or study is underway in the area. To avoid this problem, research area signs might even include a description of the study and the agency involved.

c. Periodic contact with the agency on whose land research areas are located is essential. Scientists tend to think that the same land manager will remain on the job throughout the duration of his study. Movement or transfer of personnel is frequently the case in many agencies and the person responsible for protecting an experimental site may not be in the area any longer. I now contact most of the agencies yearly to insure that someone, either the same person or the new manager, is aware of and responsible for protection of the studies. At least some of the losses I experienced have resulted because a new person was not aware of the study plots in his area.

Another problem is that sometimes the best laid plans get lost in the files. Personal contacts yearly or at some appropriate interval takes little time, refreshes people's memories, and may prevent the loss of several years of research.

Conclusions

Damage and losses I experienced on field research plots were caused primarily by human activities and only occasionally by natural events. It seems likely, as forests become more accessible to the general public and as forest management activities intensify in the future, that man-caused losses to forest study areas will increase. Two practices should be kept in mind in planning long-term forest research. First, certain procedures can be taken by scientists and land managers to reduce the amount of man-caused damage. Second, the sample size and study design should be carefully considered if adequate results are to be obtained at the termination of the studies. The odds are that the longer the study duration, the greater the chance for loss or damage to field plots. Thus, one might consider establishing more plots or increasing the sample size above what is considered adequate for shorter term studies.

It is unlikely that damage to long-term field research plots can be eliminated altogether, but with proper planning and maintenance the probability of man-caused damage can be reduced to a tolerable level.

CHEMICAL AND BIOLOGICAL MEANS OF REDUCING LAMINATED ROOT ROT INOCULUM

E. E. Nelson and W. G. Thies

Laminated root rot (Phellinus weirii (Murr.) Gilb.) reduces productivity of western coniferous forests by reducing growth of diseased trees, killing trees, and predisposing them to windfall or insects. By occupying infested sites, it keeps them unstocked or understocked indefinitely. Estimates of loss in western North America range as high as 4.5 million cubic meters annually.

Continuation of the disease depends upon successful survival of the fungus in roots and stumps. The fungus spreads from infested roots to roots of regeneration. Spread by spores does not seem to be common.

Management options in precommercial stands are limited--infested areas are largely ignored or delineated and avoided in timber stand improvement plans. Operations in diseased portions of commercial timber stands are usually limited to salvage or early harvest. The best opportunities for control occur when the stand is harvested. Options include: (1) changing species composition of the succeeding stand, (2) removal of inoculum and return to susceptible species, (3) changes in land use to other than timber production, or (4) continue to accept reduced production of susceptible species on infested sites.

Since only hardwoods are "immune" to the disease, and resistant conifers are often of lesser value or less suited to the site, removal of inoculum is frequently the most attractive option, especially on highly productive sites. To date, this has meant mechanical uprooting of stumps, sometimes followed by ripping the soil to break up and surface residual roots. Though such operations can be expected to reduce disease incidence in future rotations (and evidence to date supports this), the amount of the reduction is open to question. Regardless of reliability of the method, with equipment now generally available, many sites are not well suited to this control measure because of topography, soil characteristics, erosion hazard, or aesthetics. Alternative methods of inoculum reduction are needed.

Recent Studies

We are presently testing two alternatives for reducing inoculum on infested, cutover sites: chemicals and antagonistic fungi. We will present here some of our early results in these two areas.

Stump fumigation

In October 1978, 40 Douglas-fir stumps were stratified into groups of 5 by stump size, and amount and stage of decay on the stump tops. Each stump was sampled for presence of viable P. weirii before treating. Stumps were treated with 1-liter of allyl alcohol, chloropicrin, vapam, vorlex, or left as controls. Each fumigant was poured into 8 or more 2.5-cm holes drilled to a depth of 30 cm. The holes were plugged with tight fitting dowels and the stump top covered with a double layer of asphalt roofing compound sandwiching a piece of fiberglass cloth.

In October 1979, stumps were carefully bulldozed from the soil to remove as many intact roots as possible. Sample blocks were taken from the upper 5-20 cm of stump at points most distant from application holes where decay or stain was evident. Root disks were removed at 30-cm intervals, beginning at the stump, from all roots 5-cm diameter or greater at their origin. Wood chips were transferred from 5 points within each root disk, and from 5-10 points within stump samples, onto malt agar containing 1 ppm benomyl to test for viability of P. weirii. In some instances, mycelium growing from disks stored in plastic bags at 2° C was in itself diagnostic of visble P. weirii.

Results from this first effort are encouraging. Of the 31 fumigated stumps which contained P. weirii prior to fumigation, none did one year after, whereas all control stumps still had viable P. weirii (Table 1). Root systems of 7 fumigated stumps contained some viable inoculum, and in 2 stumps treated with allyl alcohol, 48% of the root sections with signs of stain or decay still had viable P. weirii (Table 2). Viable P. weirii was found in only one of 81 root disks from stumps treated with Vorlex, and this disk was over 80 cm from the stump. In all of the 7 stumps where treatments were not completely effective, survival was associated with stumps having no advanced decay exposed on the stump top or with stumps of the 3 dead trees included in the trials.

Earl E. Nelson is Project Leader at the U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oreg.
Walter G. Theis is Research Plant Pathologist at the U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oreg.

Table 1--Recovery of P. weirii from stumps one year after fumigation

Fumgant	Stumps treated	Stumps with viable P. weirii	Root Systems with viable P. weirii
Allyl alcohol	8 1/	0	2
Chloropicrin	8 1/	0	2
Vapam	7 1/	0	2
Vorlex	8	0	1
Check	7	7	7

1/ Includes 1 stump from dead, standing tree.

Table 2--Recovery of P. weirii from roots one year after fumigation

Fumigant	Roots Sampled	Disks sampled		Disks with viable P. weirii	
		All trees	From Trees with viable P. weirii	All trees	From trees with viable P. weirii
Ally alcohol	42	96	21	10	48
Chloropicrin	36	129	45	4	11
Vapam	32	78	29	14	38
Vorlex	37	81	13	1	8
Check	42	69	69	59	59

Biological control

Our studies on biological control of P. weirii in stumps center on Trichoderma, a renowned fungal competitor, mycoparasite and producer of antibiotics. Initially we hope to define favorable conditions for establishment of Trichoderma viride in P. weirii-infested stumps: Which of 3 isolstes being tested are most effective? Are colonized dowels more effective than granular preparations of spores and nutrients? Are inoculations more successful in late winter, spring, or early fall? Is establishment more likely in sound, stained, or decayed stump wood? In the upper 30 cm of stump, is establishment more likely in the upper, middle or lower third? When these questions are answered, we will inoculate stumps under the best combination of circumstances and follow progress of the antagonist throughout the major roots. To data we have compared establishment of Trichoderma in stumps inoculated in February 1980 vs. June 1980, and success of inoculations into sound vs. stained vs. advance-decayed stump wood.

Three holes were drilled in the top of each stump to a depth of 30 cm with a 2-cm drill. Holes were as evenly spaced as possible within the bounds of the appropriate decay stage patterned on the stump top. Each hole was filled with pelleted Trichoderma spores/nutrient flour produced by Tate and Lyle, Limited, London, using 3 isolates of the fungus from western Oregon forest soil. Holes were then filled with water and plugged with a wood dowel. Those stumps selected to test season of inoculation were stained but had little or no advanced decay on the stump top.

One year later 3 successive 10-cm-thick sections were removed from each stump. Holes were numbered and each section sawn into 3 blocks, isolating a hole at or near the center of each. Blocks were split beginning on a line between the hole and the pith, and at 120° and 240° from that initial line. In some cases, lines varied somewhat from 120 or 240° to stay within the same stage of decay. On each of these aplit faces, small wood chips were removed aseptically as near as possible to the hole, and 2, 4, and 6 cm from it. Each chip was placed on malt agar in culture tubes where developing colonies of Trichoderma were identified. Stage of decay from which chips were taken was recorded.

When we compare recovery of Trichoderma from any one stump section/decay class/distance from inoculum category, it is apparent that inoculations were consistently more successful in February than in June (Table 3). Data comparing establishment in sound stump wood or stump wood in some stage of decay are displayed in Table 4. Establishment was good in advanced decay, less so in stained wood, and poor in sound wood. In general the further from the inoculum hole chips were taken, the lesser the chance that Trichoderma would be isolated (Tables 3 and 4).

In all cases Trichoderma had colonized more of the sample chips from the uppermost stump section than from middle or lowest sections. There appeared to be little difference in colonization between middle and lowest sections.

Table 3. -- Recovery of Trichoderma from stumps inoculated in February and June one year after.

		Decay Stage at Point of Sampling												
Stump Section	Month inoculated	Sound				Stained				Advanced				All
		1/+	2	4	6	1/+	2	4	6	1/+	2	4	6	
		Percent												
Upper	Feb	40*	21	30	6	58	41	38	46	54	66	81	78*	48
	June	26	11	8	3	53	39	25	15	18	18	22*	40*	22
Mid	Feb	0*	19	5	7	5	0	8	37*	24	18	27	13	17
	June	21	13	8	3	23	11	7	4	0	6	0	20*	10
Lower	Feb	12*	10	0	0	19	0	0	8	15	13	11	19	11
	June	8	0	3	0	20	4	0	7	0	0	0	0	3

1/ Distance from incoulum hole in centimeters. + indicates culture chip taken next to hole.

* Represents percentages based on fewer than 10 isolation attempts.

Though stumps receiving no Trichoderma inoculum have not been included in the comparisons so far, past experience has indicated low incidence of Trichoderma in stumps less than 2 years old. The final samples to be collected in October will include non-inoculated controls as well as inoculated stumps. Assuming all Trichoderma isolated thus far was from inoculum we introduced into bored holes, we have measured the success of Trichoderma in colonizing stump wood infested with P. weirii.

Implications of Results

We are hopeful that both effective chemical and biological means of reducing P. weirii inoculum in stumps can be developed. Ongoing research well determine better methods of application and minimum effective dosages of chemicals. Lack of effective control in stumps of dead trees requires further investigation to determine why treatments were not effective and to devise effective means of control for these sources of inoculum. Biological control work will determine if colonization of major infested roots will result from stump inoculations. While refinement of chemical control methods can be expected in the near future, establishment of Trichoderma as an effective biological control agent will likely take several years.

Table 4.--Recovery of _Trichoderma_ one year after inoculation from decayed stumps.

		Decay Stage at Point of Sampling											
Stump Section	Surface appearance	Sound				Stained				Decayed			
		1/+	2	4	6	1/+	2	4	6	1/+	2	4	6
Upper	Sound	6	2	6	3	-	-	-	-	-	-	-	-
	Stained	26	11	8	3	53	41	24	17	20	18	22*	40*
	Decayed	-	0*	33*	11	75*	56*	52	63	85	83	82	77
Mid	Sound	1	2	2	1	-	-	-	-	-	-	-	-
	Stained	21	13	8	3	23	11	7	4	0	6	0	20*
	Decayed	-	0*	33*	0	-	50*	31	17	41	41	32	25
Lower	Sound	0	0	0	0	-	-	-	-	-	-	-	-
	Stained	8	0	3	0	20	4	0	7	0	0	0	0
	Decayed	-	0*	0*	0	-	100*	15	10	44	35	39	41

1/ Distance from inoculum hole in centimeters. + indicates culture chip taken next to hole.

* Represents percentages based on fewer than 10 isolation attempts.

ASSOCIATION OF BLACK STAIN ROOT DISEASE WITH PRE-COMMERCIAL THINNING OF DOUGLAS-FIR

Thomas C. Harrington, Fields W. Cobb, Jr., Cynthia Reinhart, and Dale A. Thornburgh

INTRODUCTION

Since the first report of black stain root disease on Douglas-fir (Cobb & Platt, 1967), forest managers in California have become increasingly concerned with the threat of this disease, particularly in young-growth stands. Black stain, caused by *Verticicladiella wageneri* Kendr., appears to be the most important disease on Douglas-fir in northern California. As has been documented by Hansen (1978) in Oregon, the disease appears to be particularly severe along roads in California. The disease may be associated with disturbances other than road building and maintenance, such as thinnings (Goheen & Hansen, 1978), but there has been no data to support such observations.

In 1969, staff at Humboldt State University initiated a thinning study in a 15-year-old Douglas-fir stand on the North Coast of California. When stand measurements were taken 10 years after thinning, mortality caused by black stain was noted in thinned plots. This thinning study presented an excellent opportunity to collect data on the association, if any, of black stain with pre-commercial thinning of Douglas-fir.

METHODS

A 15-year-old Douglas-fir stand along a ridgetop (approx. 2000 ft. elev.) on the western edge of the Redwood Creek drainage (Humboldt County) was thinned in 1969. Some of the plots are on land owned by the Louisiana-Pacific Lumber Co., but most are now within the boundaries of Redwood National Park. Douglas-fir, redwood, and western hemlock comprised 88%, 7%, and 5%, respectively, of the live coniferous trees which averaged about 2600 stems per acre. Tanoak and Pacific madrone were also present before thinning.

Square plots of 0.2 acres were established in the area. Six replicates of four stocking levels and unthinned controls were assigned to these plots. Douglas-fir comprised 76%, redwood, which was the favored species, 18%, and hemlock 6% of the stand after thinning. All hardwoods were felled during the thinning.

In 1981, 12 years after the thinning, a 0.05 acre circular subplot was established in the center of each of the original 0.2 acre plots. The sapwood of all dead or dying (with thin or chlorotic crowns) trees within the subplot was chopped into and examined for the unique black-staining pattern characteristic of trees colonized by *V. wageneri*. Only the sapwood at the base of the tree was examined. No roots were excavated.

RESULTS

No disease was found in the six unthinned subplots, but 17 of the 22 subplots established in the thinned stands had black-stained Douglas-fir (Table 1). Of the 237 Douglas-fir crop trees examined in the thinned subplots, 54 (22.8%) were either dead or dying. Two of the 0.2 acre plots thinned to an 8' x 8' spacing could not be located, so data on black stain incidence were obtained for only four replicates of this stocking level.

Black staining was found in the sapwood of all but six of the dying and three of the dead Douglas-fir trees. In each of the nine trees unconfirmed for *V. wageneri* infection, black stain was found in the sapwood of their closest Douglas-fir neighbor. Therefore, each of the nine unconfirmed dead or dying trees was in an infection center and considered to be infected. No Douglas-fir mortality unassociated with black stain root disease was noted in the thinned subplots. No dead or dying redwood or hemlock were found within the subplots in thinned areas, even when interspersed with infected Douglas-fir.

A total of 78 dead conifers was found in the six unthinned subplots. In each case, the tree was obviously severely suppressed prior to death, and no other mortality factor could be associated with it.

There was no significant difference in the percentage of dead and dying Douglas-fir among the four spacings utilized in this study (Table 1). Three of the subplots in the 16' spacings and two of those in the 20' spacings were free of the disease. However, in four of these disease-free subplots, black stain was found on Douglas-fir immediately outside the subplot, i.e., within the original 0.2 acre thinned area. The small number of Douglas-fir in the 0.05 acre subplots of the widest spacings probably accounta for not finding the disease in these cases.

DISCUSSION

Black stain root disease on Douglas-fir was strongly associated with pre-commercial thinning in this study. Consistent with previous observations in Douglas-fir stands, redwood and hemlock were not affected by black stain. Because no black stain was found in the six subplots in unthinned areas, there was probably little, if any, of the disease in the stand before the thinning. However, the possibility that the disease was present but dormant before the thinning cannot be completely ruled out. There was a similar percentage of infected crop trees at each of the four stocking levels, so increased exposure per se is not suspected to have been responsible for the incidence of the disease in thinned areas. Stand disturbance during the thinning operation may be involved, however.

Department of Plant Pathology, University of California, Berkeley, 94720, and Department of Forestry, Humboldt State University, Arcata, California

Table 1--Incidence of black stain root disease in a Douglas-fir stand 12 years after pre-commercial thinning

Spacing	Average number of stems per acre	Number of plots[1]		Number of Douglas-fir		Percent Douglas-fir with black stain
		Total	With black stain[2]	Total	With black stain[3]	
8' x 8'	470	4	4	76	16	21
12' x 12'	333	6	6	76	21	28
16' x 16'	244	6	3	53	11	21
20' x 20'	142	6	4	32	6	19
All thinned plots		22	17	237	54	23
Unthinned	2330	6	0	606	0	0

1/Circular plots of 0.05 acre within a 0.2 acre treated area.

2/With at least one dead or dying tree with black stain.

3/Includes both dead and dying trees with black stain.

Hansen (1978) attributed the higher incidence of black stain along roads to disturbances during road building and maintenance. It was hypothesized that disturbances in Douglas-fir stands are attractive to vectors of V. wageneri although these vectors have not as yet been identified. Once established in a tree in such a disturbed stand, the fungus would be capable of spreading through the stand by growing from infected roots to healthy roots of adjacent trees.

In conjunction with the study we are reporting on today, we have established 0.1 acre thinnings in Douglas-fir stands to monitor insect attraction and black stain development. Traps (¼" mesh screen coated with "stickem special") placed in thinned plots have collected many Hylastes nigrinus Lec., but these root-feeding bark beetles are apparently not active in our unthinned control plots. We have found H. nigrinus to be the most common inhabitor of black-stained Douglas-fir roots in California, and, on one occasion, we have found conidiophores of V. wageneri in a H. nigrinus gallery. However, fruiting bodies of other Verticicladiella spp. and Ceratocystis-type fungi were much more abundant in H. nigrinus galleries. These other fungi, which seem to consistently contaminate adults of H. nigrinus, are able to grow on our selective medium at a faster rate than V. wageneri, which may explain in part our failure to isolate the latter from H. nigrinus. On the other hand, V. wageneri may not be vectored by H. nigrinus.

Further studies on vector relationships and associations with disturbances are needed to more intelligently advise foresters on the management implications of black stain root disease. However, the finding that over 20% of the crop trees may be infected only 12 years after a pre-commercial thinning warrants caution.

LITERATURE CITED

Cobb, F. W., Jr., and Platt, W. D. Pathogenicity of Verticicladiella wagenerii to Douglas-fir. Phytopathology 57:998-999; 1967.

Goheen, D. J., and Hansen, E. M. Black stain root disease in Oregon and Washington. Pl. Dis. Reptr. 62:1098-1102; 1978.

Hansen, E. M. Incidence of Verticicladiella wagenerii and Phellinus weirii in Douglas-fir adjacent to and away from roads in western Oregon. Pl. Dis. Reptr. 62:197-181; 1978.

ECONOMICS OF DWARF MISTLETOE CONTROL IN BLACK SPRUCE STANDS

F. A. Baker

Black spruce, Picea mariana (Mill.)B.P.S., occupy 1.6 million acres of commercial forest land in Minnesota (9). This species is the most valuable tree in Minnesota on the basis of total dollar income (4), and is preferred for its long fibered high quality pulp. Besides having desirable pulping qualities, black spruce are important to forestry in Minnesota because they occupy sites where few other species of commercial importance can grow.

The only disease problem of any consequence in black spruce stands is caused by the eastern dwarf mistletoe Arceuthobiun pusillum Peck. This parasite is well distributed throughout the range of black spruce in Minnesota (12). Although losses caused by dwarf mistletoe are considered serious, they have not been adequately quantified (1, 2, 3, 11). Even when the extent of the infestation in a stand was known, forest managers were unable to predict losses, in order to evaluate management alternatives. Recently, a computer simulator which projects losses in dwarf mistletoe infested black spruce stands was developed (6). This simulator, called DMLOSS, also performs an economic analysis, which is discussed in this paper.

Before performing an economic analysis, the typology of losses, i.e. the components of yield that are affected, must be understood. In the black spruce-dwarf mistletoe system, tree mortality is considered the most important component of yield loss, because the eastern dwarf mistletoe kills trees rapidly (5). Reduced growth, an important component of loss in other dwarf mistletoe-host systems, is of minor importance in black spruce stands. It has not been possible to demonstrate a reduction in diameter growth in comparisons of infected trees with uninfected trees, perhaps because black spruce grow slowly and are killed rapidly (5). Also, growth loss will be important only on trees alive and infected when management activities are attempted. Some of these trees, especially those with large brooms, are left by loggers, because the brooms must be cut from the tree, rather than broken off during skidding. Merchantable trees standing alone in the mortality center are frequently left because operators won't travel far for a single tree. This component of loss, where merchantable trees remain after harvesting, is classified as cull.

These are the major components of yield loss. In the economic analysis discussed here, only the mortality component is used because growth loss appears insignificant, and cull, though important, has yet to be quantified.

Management constraints must also be considered in an economic analysis. Management alternatives in black spruce stands are few. This species grows slowly, reaching maturity after 70-120 years, depending on the site. No alternative species can be used, because none can grow on the wet sites. Black spruce stands are subject to windthrow, thus clearcutting in strips or blocks is the only option for harvesting. Individual trees have a relatively low value, as pulpwood is the exclusive product from black spruce stands. Thus, treatment of individual trees is not economically feasible. Finally, access is very difficult and expensive, which tends to favor management practices requiring fewer entries into the stand. These constraints restrict management practices to "harvest and eradicate" activities, at least in the infested portion of the stand. This greatly simplifies the economic analysis, as activities at only a few times in the rotation need be considered.

Having examined the types of losses that will occur, and the constraints on management activities, a method of economic analysis can be chosen. Four financial criteria used to evaluate investments are: cost price, internal rate of return, benefit-cost ratio, and present net worth.

Cost price is the price at which timber would have to be sold to earn a specified average rate of return on the investment (10). Evaluation of disease management programs using this criterion requires the assumption that management costs incurred prior to application of the control activity are lost, cannot be recovered, and are not considered in the analysis. This assumption may not be considered valid by land managers. Without it, for example, the option of planting a site could be compared with the option of managing disease on a site where planting costs have already been incurred. This often favors the choice of planting a new site.

Internal rate of return is the rate invested capital increases (8). This criterion also requires the assumption that incurred costs are lost. Yield in infested stands is not likely to be greater than in uninfested stands, and will probably be less. Costs, however, will be greater in the infested stand if management is attempted, so the internal rate of return will be less.

Present net worth (and future net worth) evaluates whether income is greater than costs, and benefit-cost ratio is a measure of the degree that income exceeds costs. Both indicators are useful in economic analysis of disease management. Closely related to these is cost plus loss analysis, commonly used in evaluating levels of forest fire control (7). When management is at a low level, losses are great (Fig. 1). At high levels of management activity, losses are low, but management costs are great. At some intermediate level of management, the sum of costs and losses is minimal. This is considered the optimum level of control. This approach, along with the benefit-cost ratio, is used to evaluate the economic feasibility of eradicating dwarf mistletoe from infested black spruce stands. The question asked is: will the investment in control be exceeded by income from salvage activities and losses prevented, and if so, by how much.

F.A. Baker
Department of Plant Pathology
University of Minnesota
St. Paul, MN 55108

The following data are required for disease projection: location of mortality centers, stand boundaries, stumpage value, control cost, and discount rate. The computer program then determines the area of control by projecting the extent of the infestation, and adding to this the width of the control buffer (Fig. 2, see also 6). The difference between the area of control and the area of mortality is the area from which salvage volume will be harvested. Multiplying this figure by the unit volume, (determined from site index, basal area, and stand age), gives the salvage volume (Equation 1).

(1) Volume Salvaged =

$$(\text{Area}_{\text{control}} - \text{Area}_{\text{mortality}}) \text{ x Unit Volume}$$

If the growth loss associated with infection by <u>A. pusillum</u> was significant, or if the cull factor was known, this loss could be computed as follows:

(2) Volume Growth Loss =

$$(\text{Area}_{\text{infestation}} - \text{Area}_{\text{mortality}}) \text{ x (a) x Unit Volume}$$

where "a" is the average percent yield reduction in the infested area. Incorporating growth loss, salvage volume would be computed as follows:

(3) Corrected Salvaged Volume =

Volume Salvaged - Volume growth loss

However, since growth loss and cull are not quantified, the "a" term in equation 2 equals "0", and volume salvaged = corrected salvage volume. The salvage volume is then multiplied by the stumpage value, and discounted appropriately (Equation 4).

(4) Value Salvaged =

$$\frac{\text{Volume Salvaged x Stumpage Value}}{(1 + \text{Discount Rate})^{\text{Time}}}$$

Value salvaged is an income, or in the frame of cost plus loss analysis, a negative cost.

In addition to salvaging some of the current losses, controlling dwarf mistletoe prior to the normal rotation age prevents further losses. Future losses are obtained by projecting the area of mortality (and growth loss) to a selected rotation age, and multiplying by unit volume.

(5) Volume Loss =

$$\text{Area}_{\text{mortality}} \text{ x Unit Volume (+ a x Area}_{\text{infestation}} - \text{Area}_{\text{mortality}})$$

Stand volume is then determined as:

(6) Stand Volume Without Control =

Stand Area x Unit Volume - Volume Loss

If control operations were performed previously, the portion of the stand where control was not carried out will mature with a yield computed in Equation 7.

(7) Stand Volume With Control =

$$(\text{Stand Area} - \text{Area}_{\text{control}}) \text{ x Unit Volume}$$

The difference between volume with control and volume without control is the volume saved (Equation 8).

(8) Rotation Volume Saved =

$$\text{Stand Volume}_{\text{with control}} - \text{Stand Volume}_{\text{without control}}$$

Volume saved (Equation 9) is another income or negative cost. Volume saved, and thus value saved, may be negative, when the area of control exceeds the area of mortality at rotation.

(9) Value Saved =

$$\frac{\text{Volume saved x Stumpage value}}{(1 + \text{Discount Rate})^{\text{Time}}}$$

Costs are incurred when control activities are performed, and are computed as follows:

(10) Control Cost =

$$\frac{\text{Area of Control x Unit Time Control Cost}}{(1 + \text{Discount Rate})^{\text{Time}}}$$

Subtracting income (value salvaged + value saved) from control cost gives the present net worth of the control operation, or net savings. (Equation 11).

(11) Net Savings =

(Value Salvaged + Value Saved) - Control Cost

This criterion alone may not indicate the optimum time to perform control operations. From Table 1C, the volume saved at age 70 is 37.9 cords, at age 80, 36.4, and at age 90, 33.5. Corresponding net savings (present net worth) are $354.75, $201.60 and $102.86, suggesting that control would be most profitable at age 70. Waiting 10 years, however, reduces volume saved by less than 2 cords, while control cost is reduced by 78.40. Delaying control until age 90 increases losses by about 3 cords, while reducing control costs by almost $100. Thus, although the net savings (present net worth) of control operations differs greatly, delaying control operations can reduce the cost of control substantially, with only slight increases in losses. This response is primarily due to the effects of interest rate on volume salvaged.

A more useful criterion for decision making is the index of control priority, which is a benefit-cost ratio (Equation 12)

Table 1. Output from DMLOSS

```
A. Summary of inputs.

                                        SEC 19 T54 R23W
                        STAND ACREAGE =  25.78            STUMPAGE VALUE =  14.00
                        SITE INDEX    =  35.00            CONTROL COST   = 100.00
                        BASAL AREA    - 110.00            DISCOUNT RATE  =   0.08

B. Impact assessment output.

         VOLUME     VOLUME      AREA OF        AREA OF       AREA OF    DISC'TD    DISC'TD    PRESENT
STAND    PRESENT     LOST      MORTALITY     INFESTATION     CONTROL    CONTROL     VALUE      STAND
 AGE     (CORDS)    (CORDS)     (ACRES)        (ACRES)       (ACRES)      COST       LOSS      VALUE

  60          0          0       0.09           0.36          2.99      298.61         0          0
  70     608.19       5.37       0.23           0.78          3.66      169.68     34.83    3774.23
  80     677.10      13.49       0.50           1.20          4.25       91.26     40.51    1942.52
  90     723.33      22.60       0.78           1.68          4.81       47.79     31.45     958.57
 100     758.39      36.86       1.20           2.24          5.26       24.21     23.75     483.23
 110     780.54      56.96       1.75           2.88          5.71       12.18     17.00     220.81
 120     799.54      81.26       2.38           3.49          6.23        6.16     11.24     104.39

 C. Decision-making information.

                                           VOLUME AT ROT.                                          INDEX OF
 STAND              ACRES OF             WITH       WITHOUT      VOLUME     CONTROL       NET       CONTROL
  AGE        MORTALITY       CONTROL            CONTROL           SAVED       COST      SAVINGS     PRIORITY

   60          0.09            2.99      770.78      799.54      -20.78      298.61     -301.48      -1.01
   70          0.23            3.66      837.46      799.54       37.92      169.68      354.75       2.09
   80          0.50            4.25      835.93      799.54       36.39       91.28      201.60       2.21
   90          0.78            4.81      833.04      799.54       33.50       47.79      102.86       2.15
  100          1.20            5.26      828.08      799.54       26.54       24.21       42.72       1.76
  110          1.75            5.71      814.25      799.54       14.71       12.18       10.46       0.86
  120          2.38            6.23      799.54      799.54        0.00        6.16       -6.16       0.00
```

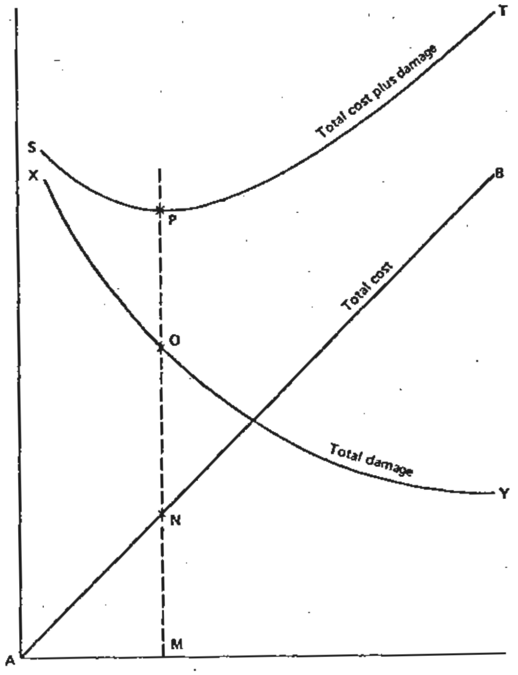


Figure 1. Cost plus loss function. (From 7):

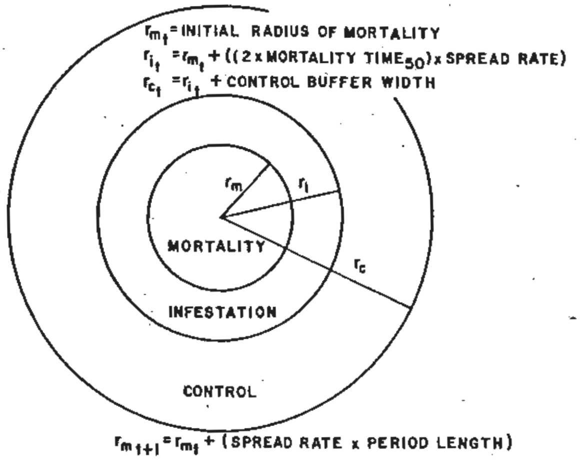


Figure 2. Schematic diagram of dwarf mistletoe infection center in a black spruce stand.

(12) $\text{Index of Control Priority} = \frac{\text{Net Savings}}{\text{Control Cost}}$

The index of control priority is the ratio of net savings (present net worth) to the investment needed to attain that income. It measures the return on the investment adjusted for the amount of the investment. Choosing the time for control by maximizing the index of control priority minimizes costs and losses in that stand. In the stand simulated in Table 1, control would be most profitable at age 80.

Allocating control dollars to stands with the greatest index of control priority will minimize costs plus losses for that level of control, and also provides the greatest return from a fixed control budget.

In this paper, several financial criteria have been discussed: cost price, internal rate of return, present net worth, benefit-cost ratio, and cost plus losses. The latter three are most useful in economic analysis of black spruce dwarf mistletoe control.

In summary, I would like to quote Allen Lundgren, economist with the U.S. Forest Service on the use of financial criteria (10):

"Each of these criteria measures an investment in a different way. All have their place in evaluating investment alternatives. The wise manager will not rely solely upon one criterion, he will . . . use several investment criteria, . . . before making his final decision".

LITERATURE CITED:

1. Anderson, R.L., and F.H. Kaufert. 1953. The control of dwarf mistletoe in black spruce. Mn. For. Notes No. 13, 2 pp.

2. Anderson, R.L., and D.G. Mosher. 1976. Occurrence of eastern dwarf mistletoe on black spruce in the upper peninsula of Michigan. U.S. Dept. Agric. For. Serv., For. Ins. and Disease Mgmt. Evaluation Rept. S-24-76, 3 pp.

3. Anderson, R.L., and D.G. Mosher. 1977. Occurrence of eastern dwarf mistletoe on black spruce in six national forests in the Lake States. U.S. Dept. Agric. For. Serv., State and Private Forestry Survey Rep. S-1-77, 8 pp.

4. Anonymous. 1977. Forest Pest Report, Mn. Dept. Nat. Res., 21 pp.

5. Baker, F.A. and D.W. French. 1980. Spread of Arceuthobium pusillum and rates of infection and mortality in dwarf mistletoe infested black spruce stands. Plant Disease 64:1074-1076.

6. Baker, F.A., D.W. French, and D.W. Rose. 1980. DMLOSS: A simulator of losses in dwarf mistletoe infested black spruce stands. 1980 WIFDWC Proceedings 28-39.

7. Brown, A.A., and K.P. Davies. 1973. Forest fire: Control and use. McGraw-Hill, p. 613-628.

8. Gregory, G.R. 1972. Forest resource economics. New York, Ronald Press Co. 58 pp.

9. Johnston, W.F. 1977. Managers handbook for black spruce in the north-central states. U,S. Dept. Agric. For. Serv. Gen. Tech. Rep. NC-34, 18 p.

10. Lundgren, A.L. 1973. Cost-price: a useful way to evaluate timber growing alternatives. U.S. Dept. Agric. For. Serv. Res. Pap. NC-95, 16 pp.

11. Mathieson, R.L. 1979. Survey for eastern dwarf mistletoe in the lower peninsula of Michigan. Plant Dis. Reptr. 63:532-535.

12. Tainter, F.H., and D.W. French. 1968. Dwarf mistletoe in Minnesota. Mn. Acad. Sci. 35:122-123.

THE PINE WOOD NEMATODE, BURSAPHELENCHUS XYLOPHILUS IN MINNESOTA, IOWA AND WISCONSIN

Michael J. Wingfield, Robert A. Blanchette,
Thomas H. Nicholls, and M. Kathryn Robbins

ABSTRACT: The pine wood nematode, Bursaphelenchus xylophilus was found on trees stressed by forest diseases and insects. In some areas dead tops and branches of otherwise healthy trees, that had apparently died due to fungal infection or insect attack also contained B. xylophilus. Rapid wilt symptoms associated with B. xylophilus infection in Japan, were not observed.

INTRODUCTION

The pine wood nematode, Bursaphelenchus xylophilus (Steiner and Buhrer) Nickle, formerly B. lignicolus Mamiya and Kiyohara (Nickle et al. 1981), causes a wilt disease of pines in Japan. Extensive losses to Japanese black pine (Pinus thunberghii Parl.) and Japanese red pine (P. densiflora Sieb et Zucc.) have occurred in Southwestern Japan (Tokushige and Kiyohara, 1969). B. xylophilus is vectored, primarily by longhorn beetles (Coleoptera: Cerambycidae) which emerge from dead trees carrying nematodes and transmit these to healthy trees during maturation feeding (Mamiya and Enda, 1976; Morimoto and Iwasaki, 1972). Nematodes multiply in the resin canals and result in reduced oleoresin flow, arrest of transpiration, chlorosis and death within three months after initial infection (Mamiya, 1972). Cerambycid beetles oviposit in dying trees and the life cycle of the nematode, closely coordinated with the beetle vector, is repeated.

B. xylophilus was reported from the United States in 1979 (Dropkin and Foudin, 1979) where it was first found on Austrian pine (P. nigra Arnold) in Columbia, Missouri. The nematode has now been found throughout the United States in 32 states on 20 pine species, atlas cedar (Cedrus atlantica Manetti), deodar cedar (Cedrus deodara (Roxb. Loyd.), European larch (Larix decidua Mill.), tamarack (Larix laricina Du Rail K. Koch) and white spruce (Picea glauca Moench. Voss.). Since the first report, concern as to whether B. xylophilus poses a similar threat to forests of the United States as it appears to be in Japan, has been expressed. This report documents the results of a two year field investigation to establish the relative importance of the pine wood nematode in a number of study sites in Minnesota, Iowa and Wisconsin.

MATERIALS AND METHODS

Areas in which B. xylophilus was found present in most dead or dying trees and where a considerable number of trees were affected were chosen for further examination. The following areas were examined during the summers of 1980 and 1981: (1) Zimmerman, Minnesota, 18-year-old Austrian pine and red pine (P. resinosa Ait.) in an old christmas tree plantation, Sherburne county, Minnesota; (2) Cloquet, Minnesota, 30-year-old eastern white pine (P. strobus L.), Cloquet Forestry Center, University of Minnesota, Washington county, Minnesota; (3) Durand, Wisconsin, 15-year-old Austrian pine and red pine in an old Christmas tree plantation, Pepin County, Wisconsin; (4) Black River Falls, Wisconsin, 20 year old jack pine (P. banksiana Lamb.), Gordon plantation, Jackson County, Wisconsin; (5) Black River Falls, Wisconsin, 15-year-old red pine, Shamrock plantation, Jackson County, Wisconsin; (6) Farmington, Iowa, 20 year old Scots pine (P. sylvestris L.) and red pine, Shimek state forest, Van Buren and Lee counties, Iowa.

Healthy, dead, and dying trees were examined for root, stem, branch and needle diseases. Where necessary, isolations for fungi were made on 2% malt extract agar (Difco malt extract 20 gm, Difco Bacto agar 20 gm/1000 ml water). Nematodes were extracted from 70 gm to 90 gm (wet weight) of wood using Baerman funnells. Samples for nematode extractions were taken from roots, bottom, middle and top thirds of the bole, lower branches, upper branches and small twigs. The general health of surrounding trees and the presence of insects on sample trees were documented.

RESULTS

Zimmerman Minnesota

Red pine were healthy whereas many Austrian pine on this site were dead and dying. Austrian pine were heavily infected with Dothistroma pini Hulb. and only held current year needles. Approximately half the Austrian pine in the area had dead tops or dead branches in the top of the crown, associated with severe infestation of the Zimmerman pine moth, Dioryctria zimmermani (Grote). Five healthy red pine were sampled and found free of B. xylophilus and other disease causing organisms. B. xylophilus was only found in dead portions of Austrian pine with dead tops or branches. All dead trees or trees which had chlorotic needles and were infested

---

Michael J. Wingfield is a Graduate Research Assistant, Department of Plant Pathology, University of Minnesota, St. Paul, Minnesota. Robert A. Blanchette is Assistant Professor, Department of Plant Pathology, University of Minnesota, St. Paul. Thomas H. Nicholls is Principal Plant Pathologist, North Central Forest Experiment Station, U.S.D.A. Forest Service, St. Paul, Minnesota. M. Kathryn Robbins is Forest Pathologist, N.A. State and Private Forestry, U.S.D.A. Forest Service, St. Paul, Minnesota.

Table 1--Insects and diseases associated with B. xylophilus infected trees in Minnesota

Tree Species and Location	Tree Health	Total Trees Sampled	Bark Beetles (Scolytidae)	Borers (Cerambycidae)	B. xylophilus		Other Diseases and Insects 1/
					Dead Wood	Healthy Wood	
Austrian Pine Zimmerman, Minnesota	Living	4	0	0	-	0	DNB
	Dead Top	8	8	8	6	0	DNB ZPM
	Dead Branches	4	4	4	3	0	DNB ZPM
	Dead or Dying	4	4	4	4	–	DNB ZPM
White Pine Cloquet, Minnesota	Healthy	2	0	0	–	0	0
	Dead Top	6	6	6	4	0	WPBR
	Dead Branches	2	2	0	0	0	WPBR
	Dead or Dying	3	3	3	3	–	WPBR ARR VRD

1/ ARR = Armillaria root rot; DNB = Dothistoma needle blight; VRD = Verticicladiella root diseases; WPBR = white pine blister rust; ZPM = Zimmerman pine moth.

by bark beetles (Coleoptera: Scolytidae) and wood borers (Coleoptera: Cerambycidae) contained B. xylophilus (Table 1).

Cloquet, Minnesota

A large number of the white pine had dead branches or dead tops resulting from white pine blister rust (Cronartium ribicola J.C. Fischer ex. Rhabh.) infection. In some cases blister rust infected trees were chlorotic and dying and these had Armillariella mellea (Vahl) ex. Karst. and Verticicladiella procera Kendrick root infections. B. xylophilus was not isolated from healthy trees or living parts trees with blister rust infections. The nematode was, however, present in dead tops and the rest of the boles of trees which were chlorotic and already infested by insects (Table 1).

Durand, Wisconsin

No mortality occurred in red pine whereas approximately 70 percent of the Austrian pine were dead or dying. Austrian pine needles were heavily infected with D. pini and branches only held the current year needles. In addition, most of the

Table 2. Insects and diseases associated with B. xylophilus infected trees in Wisconsin and Iowa

Tree Species and Location	Tree Health	Total Trees Sampled	Bark Beetles (Scolytidae)	Borers (Cerambycidae)	B. xylophilus		Other Insects and Diseases 1/
					Dead Wood	Healthy Wood	
Austrian Pine Durand, Wisconsin	Living	2	0	0	-	0	DNB
	Dead or Dying	5	5	5	5	0	DNB PRCW
Jack Pine Black River Falls, Wisconsin	Living	4	0	0	–	0	DPTB PRW
	Dead or dying	5	5	5	5	–	DPTB PRW
Red Pine Black River Falls, Wisconsin	Healthy	2	0	0	–	0	0
	Dead top	10	10	10	3	0	DPC
Scots Pine Farmington, Iowa	Living	3	0	0	0	0	DPC
	Dead or dying	4	4	4	4	–	DPC

1/ DNB = Dothistroma needle blight; DPC = Diplodia pinea canker; DPTB = Diplodia pinea tip blight; PRW = Pine root weevil; PRCW = Pine root collar weevil.

trees had advanced root collar weevil (Hylobius radicis Buch.) infestation. B. xylophilus was not extracted from trees with green needles but was present in all dying trees colonized by insects (Table 2).

Black River Falls, Wisconsin

Red pine in surrounding stands were generally healthy whereas 90 percent of the jack pine in the study area were dead. All living and dying jack pine had pine root weevil (Hylobius rhizophagus M.B.W.) infestation with associated fungal infection. The extreme mortality in this area has been attributed to the effects of H. rhizophagus (Krebill, 1962; Millers et al., 1963). Smaller twigs and branches of trees were damaged by hail and insect feeding and were infected by Diplodia pinea Kickx. Dead twigs of otherwise healthy trees were free of B. xylophilus. Dying trees, some with early bark beetle and borer attack, contained B. xylophilus. Trees with early tip weevil infestation and without crown symptoms and before bark beetle and borer infestation, did not contain B. xylophilus (Table 2).

Black River Falls, Wisconsin

Approximately 50 percent of the red pine in the study area had dead tops caused by Diplodia pinea infection. In three out of ten cankered trees sampled, dead tops contained B. xylophilus while healthy parts of the same trees were free of nematodes (Table 2).

Farmington, Iowa

Red pine and Scots pine had hail initiated D. pinea cankers on the boles and branches. Cankers on Scots pine were larger and more numerous, causing the death of smaller branches. Approximately 50 percent of the Scots pine in the area examined were dead or dying whereas the red pine appeared healthy. Bark beetles and borers had attacked severely cankered trees. These trees contained B. xylophilus (Table 2). Dead twigs and smaller branches which had not been infested by insects were free of B. xylophilus. In one otherwise healthy tree, however, a single branch had been colonized by insects and also contained B. xylophilus.

DISCUSSION

In Japan, B. xylophilus-infected trees die within three months after typical wilt symptoms such as chlorosis, and a cessation of oleoresin flow (Mamiya, 1976). Trees infected with B. xylophilus in the investigation presented here did not appear to die of a wilt disease. Tree death was gradual and associated with various fungal pathogens and insects. In many cases, pine species in the study areas not susceptible to the forest pathogens and insects observed were not dying. For instance, Austrian pine is highly susceptible to Dothistroma needle blight whereas red pine is resistant to this disease (Nicholls and Hudler, 1971) and less susceptible to root collar weevil infestation (L.T. Wilson, personal communication).

Fungal diseases, such as D. pinea canker and Dothistroma needle blight, and insects, such as pine root collar and pine root weevils, may stress trees, predisposing them to nematode infestation. Stresses such as poor site conditions and drought have previously been associated with B. xylophilus killed trees in Japan (Nishiguchi, 1970; Suzuki and Kiyohara, 1978; Takashita et al. 1975). In other parts of the United States such as Missouri and Delaware, however, Scots pine and Japanese black pine are thought to be dying primarily of B. xylophilus-infection (Adams and Morehart, 1981; V.H. Dropkin, personal communication). This apparent difference may be explained by the fact that Japanese black pine is extremely sensitive to nematode infection (Mamiya 1972) while both species are exotic to the United States and may be stressed.

B. xylophilus has been reported in single dead branches of otherwise healthy trees in Louisiana (V.H. Dropkin, personal communication). In this study, B. xylophilus was found in dead tops and branches. Mortality of branches or tops was, however, associated with an insect or pathogen (blister rust on white pine, Zimmerman pine moth on Austrian pine and D. pinea cankers on red pine) with the capacity to kill portions of a tree (Baker, 1972; Boyce, 1971 and Nicholls, unpublished). It is possible that B. xylophilus is only able to establish itself on these stressed parts of a tree. However, cerambycid vectors of B. xylophilus may also transmit nematodes to dead and dying trees or parts of trees during oviposition. Further studies, including field inoculations with B. xylophilus are necessary to elucidate the significance of the pine wood nematode in Minnesota, Iowa and Wisconsin.

ACKNOWLEDGEMENTS

We thank Kathy Zuzek, Jane Hess, Frank Morse, Wayne Fuhlbrugge and Roger Conklin for assistance.

LITERATURE CITED

Adams, J.C.; Morehart, A.L. Decline and death of *Pinus* spp. in Delaware. Phytopathology (Abstr.) 71:764; 1981.

Baker, W.L. Eastern Forest Insects. For. Serv., U.S. Dept. Agric. Misc. Pub. 1175; 1972.

Boyce, J.S. Forest Pathology. McGraw Hill, New York. 572 pp; 1961.

Dropkin, V.H.; Foudin, A.S. Report of the occurrence of *Bursaphelenchus lignicolus*-induced pine wilt disease in Missouri. Plant Dis. Reptr. 63:904-905; 1979.

Krebill, R.G. Etiology of a jack and red pine plantation decline characterized by a root weevil injury and fungal deterioration. Ph.D. Thesis, Univ. of Wisconsin, Madison. 89 pp; 1962.

Mamiya, Y. Pine wood nematode, *Bursaphelenchus lignicolus* Mamiya and Kiyohara as a causal agent of pine wilting disease. Rev. Plant Protection Res. (Japan) 5:46-50; 1972.

Mamiya, Y. Pine wilting disease caused by the pine wood nematode, *Bursaphelenchus lignicolus* in Japan. Jap. Agric. Res. Quart. 10:206-211; 1976.

Mamiya, Y; Enda, N. Transmission of *Bursaphelenchus lignicolus* (Nematode: Aphelenchoididae) by *Monochamus alaternatus* (Coleoptera: Cerambycidae). Nematologica 18:159-162; 1972.

Millers, I.; Benjamin, D.M.; Warner, R.E. A new Hylobius weevil associated with jack pine stand deterioration (Coleoptera: Curculionidae). Can. Ent. 95:18-22; 1963.

Morimoto, K.; Iwasaki, A. Role of *Monochamus alternatus* (Coleoptera: Cerambycidae) as a vector of *Bursaphelenchus lignicolus* (Nematoda: Aphelenchoididae). J. Jap. For. Soc. 54:177-183; 1972.

Nicholls, T.H.; Hudler, C.W. *Dothistroma pini* on *Pinus nigra* in Minnesota. Plant Dis. Reptr. 55:1040; 1971.

Nickle, W.R.; Golden, A.M.; Mamiya, Y.; Wergin, W.P. On the taxonomy and morphology of the pine wood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer, 1934) Nickle 1970. J. Nematol. 13:385-392; 1981.

Nishiguchi, G. Resistance of conifers to attack by secondary insects. J. Jap. For. Soc. 52:159-168; 1970.

Suzuki, K.; Kiyohara, T. Influence of water stress on the development of pine wilting disease caused by *Bursaphelenchus lignicolus*. Eur. J. For. Path. 8:97-107; 1978.

Takashita, K.; Hagihara, Y.; Ogawa, S. Environment analysis to pine damage in Western Japan. Bulletin Fukuoka-ken For. Exp. Sta. 24:1-45; 1975.

Tokushige, Y.; Kiyohara, T. *Bursaphelenchus* sp. in the wood of dead pine trees. J. Jap. For. Soc. 51:193-195; 1969.

PHAEOCRYPTOPUS GAEUMANNII ON DOUGLAS FIR IN NEW ZEALAND

Ian Hood

ABSTRACT: Phaeocryptopus gaeumannii (Rohde) Petrak was first found in Douglas fir stands in New Zealand in 1959, and has since been steadily expanding its distribution. It appears to be responsible for a decline in health and growth of Douglas fir in stands older than 30 years in parts of the country. Artificial inoculation has resulted in reduced levels of needle retention and photosynthetic rates of foliage on potted seedlings. Natural infection of new foliage on seedlings and small trees can be controlled by thorough applications of suitable protectant fungicides in spring and early summer. However, aerial spraying has been largely ineffective in controlling infection in larger trees. Early, pre-commercial thinning does not reduce infection or increase needle retention in the central North Island of New Zealand. However, early thinning may reduce subsequent growth decline, to some extent, by deepening the green crown of individual trees. Trials have been established to test this, and to develop a revised silvicultural regime.

INTRODUCTION

Planted forests (state and private) in New Zealand currently cover an areaof 860 thousand hectares, and are dominated by Pinus radiata which makes up 90% of the total area[1]. Douglas fir, which is the second most abundant species, occupies a total area of 45 thousand hectares (112 thousand acres). This Douglas fir resource comprises a wide range of age classes (planting waves climaxed in the 1930's and 1970's) and represents an investment large enough to arouse concern over any threat to its well being. Total, gross, stem production on favourable sites is approximately half that of P. radiata at age 24 years, but at 420 m^3/ha (6,000 ft^3/acre) compares favourably with that of Douglas fir grown elsewhere in the world (Beekhuis, 1978; Duff, 1956; Spurr, 1963; Bruce, 1972; Warrack, 1979[2]).

It is the aim of this paper to outline results of studies of a Douglas fir needle parasite native to western North America, in a situation well removed from the natural distribution range of it and its host. The topic is relevant, also, because of the association of this parasite with a needle-cast disease in Christmas tree plantations growing within the natural range, here in western North America.

DISTRIBUTION AND ASSOCIATED EFFECTS

Phaeocryptopus gaeumannii (Rohde) Petrak was first found in central North Island in 1959, and has been spreading gradually through the Douglas fir stands in the country ever since (Fig. 1; Gilmour, 1966; Hood and Kershaw, 1975).

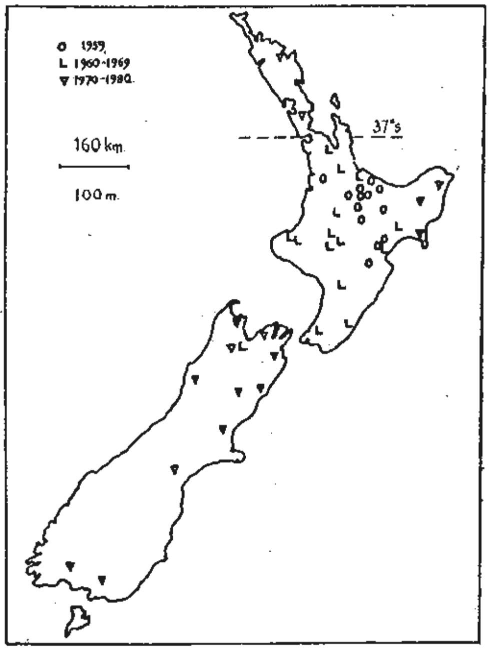


Figure 1.--Occurrence of Phaeocryptopus gaeumannii in New Zealand (simplified).

Ian Hood is a forest pathologist from the Forest Research Institute, Rotorua, New Zealand, currently working under a one-year N.Z. National Research Advisory Council Fellowship at the Pacific Forest Research Centre, Victoria.

[1] N.Z.F.S. National Forestry Planning Model (Predicted area for 1981, as at 5/7/79).

[2] Warrack (1979) unpub.: "Successive thinnings in a natural stand of Douglas fir over a 50-year period." B.C.F.S. Res. Note 87.

Distribution is not yet complete. Earliest reports of chlorosis and needle loss date back to 1962.[3] General symptoms of crown thinning were observed in a private, 30-40 year old forest in the North Island about 1967.* Routine monitoring of growth plots in 40-50 year old stands in Kaingaroa State Forest (central North Island) in 1973 indicated a decline in expected growth increment dating back to the late 1960's. Additional measurements subsequently reinforced this conclusion (Beekhuis, 1978, McGreevy, 1978; Wooff, 1978). The reduced growth rate has necessitated a re-evaluation of long term management options available for Douglas fir in the central North Island.[4] Apart from extensive chlorosis in one east coast forest, younger stands generally appear healthy looking, even when heavily infected, and as yet there is no evidence of growth loss in such stands (McGreevy, 1978).

LIFE CYCLE AND INFECTION PERIOD

In New Zealand mature ascospores first appear in pseudothecia of *P. gaeumannii* at the beginning of September (Hood and Kershaw, 1975). Peak production occurs in October-November, at the time of Douglas fir spring flush, and declines into January. Maximum infection occurs within the first 4-6 weeks of flush, and tails off during December and January. These results are similar to those found elsewhere. Older foliage can also become infected, but at much reduced levels.

THE ROLE OF THE FUNGUS

P. gaeumannii is considered to be the cause of needle cast and/or growth loss, to some degree at least, in Britain and other European countries (e.g. Peace, 1962; Merkle, 1951; Nüsslein, 1970). It is also associated with a needle cast of Christmas trees in eastern and central lake states of the United States (e.g. McCormick, 1939; Boyce, 1940; Morton and Patton, 1970). Nevertheless, few critical pathogenicity studies have been undertaken, possibly because *P. gaeumannii* does not produce spores in culture. Table 1 summarizes glasshouse inoculation experiments carried out in New Zealand, using as inoculum suspensions of macerated mycelium in water (cf. Lyr, 1955). Control seedlings were treated with autoclaved inocula (Hood, 1977). In nearly all experiments, inoculation of new foliage resulted in a reduced level of needle retention, although this did not become apparent until the second year. Nevertheless, measurements of CO_2 gaseous exchange (Table 2) have indicated that infected foliage appears to undergo reduced carbon assimilation even in its first year. This work supports the assumption that *P. gaeumannii* is implicated in the Douglas fir growth decline at Kaingaroa.

Table 1--Results of six inoculation experiments with potted seedlings, summarized.[1]

Seedlot		Group Means		Significance
		Inoculated Plants	Control Plants	of Mean Diff.[2]
I	INF	94	<0.5	-
	RET	1.8	6.4	***
II	INF	84	<0.5	-
	RET	2.9	5.2	**
III	INF	-	-	-
	RET	1.9	3.5	***
	INF	95	1	-
	RET	3.1	7.5	**
	INF	-	-	-
	RET	0.8	2.1	NS
	INF	97	<0.5	-
	RET	2.7	8.3	**

UNITS: INF: Percentage current needles infected approx. 0.5-1 year from treatment.
RET: Retention (as % total plant dry weight) of same foliage approx. 1 year later.

1. No. plants per experiment: 13-37.
2. From t tests; probability of means not being different: *** $\leq$ 0.001
** $\leq$ 0.01
* $\leq$ 0.05
NS $\geq$ 0.05

Table 2--Photosynthesis results from two potted seedling experiments, summarized.[1]

Infection Method		Group Means		Significance
		Infected Plants	Control Plants	of Mean Diff.[2]
Natural infection (with fungicide[3] treated controls).	INF	90	1	-
	PS.	3.6	4.8	**
Inoculated	INF	95	1	-
	PS.	6.0	7.5	*

UNITS: INF: Percentage current needles infected.
PS: Gas exchange, current foliage (mg CO_2/g dry weight/hour) in light.[4]

1. No. plants per experiment, 20, 37, respectively.
2. From t tests; coded as in table 1.
3. Triforine.
4. At 100-145 watts/m^2 and 22-27°C; dark CO_2 exchange was not significant.

---

* Also associated with growth decline.

[3] Unpublished FRI file data, N.Z.F.S.; cf. Gilmour, 1966.

[4] C.J. Mountfort, unpublished report.

CONTROL

1. Alternative Seed Sources

Provenance trial studies[5] failed to reveal any permanent indication of resistance to infection by Douglas fir under New Zealand conditions. Once P. gaeumannii is established all provenances become very heavily infected. A different result has emerged from a study of a trial in the Lake Cowichan area of southern Vancouver Island, where the overall infection level is not as great as in New Zealand (Fig. 2). In this trial certain provenances were clearly more resistant to infection than others. However, infected provenances in New Zealand do vary in degree of needle cast.[5,6]. (Fig. 3). A similar variation was also found in the Vancouver Island trial (Fig. 4). Comparison of the behaviour of a mixed, New Zealand provenance planted on the same sites has indicated that some improvement in needle retention could be achieved in future New Zealand stands. However, any subsequent choice of new seedlots is likely to be governed by several factors in addition to level of needle retention, and largely by growth rate.

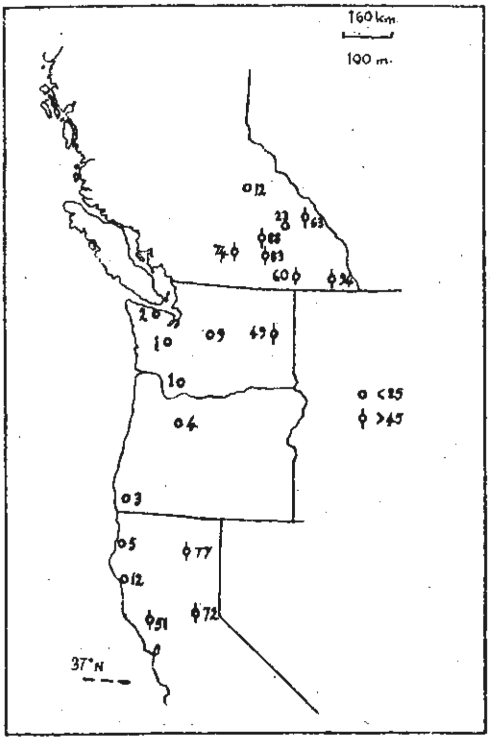


Figure 2.--Provenance means, percentage 3-4 year old needles infected, Mesachie Lake experimental area (B.C.F.S.). A value in one group differs significantly from any in the other (5% Duncans).

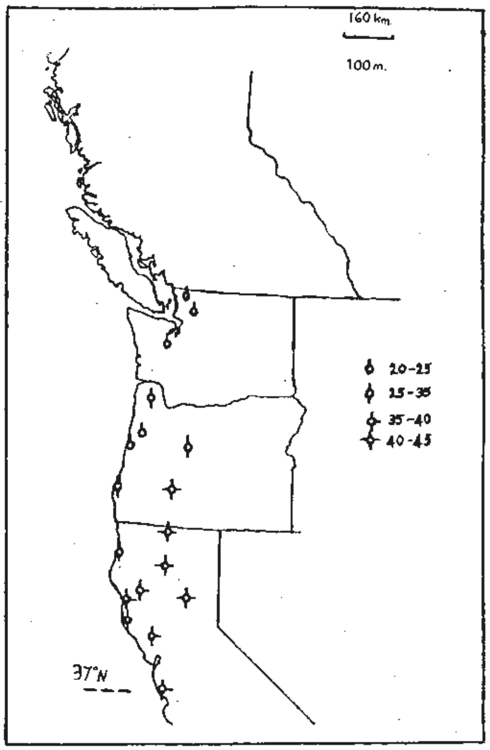


Figure 3.--Provenance means, needle cast and chlorosis, Gwavas State Forest, N.Z., by groups. Larger values on combined assessment scale indicate increasing ill health. All four groups significantly different (1% Scheffé).

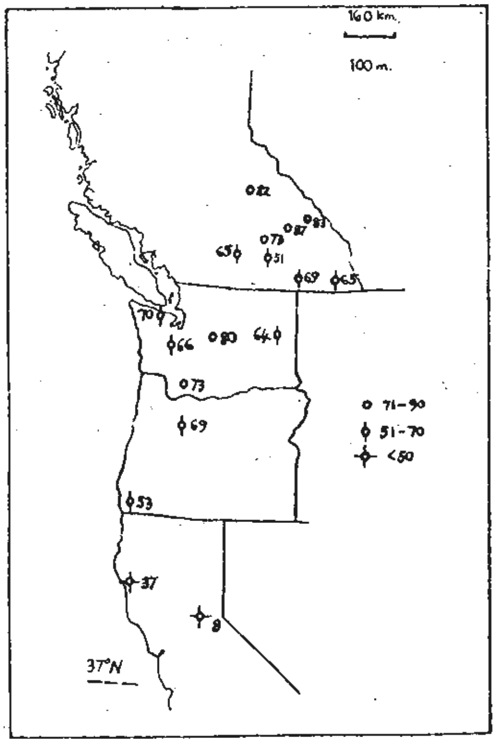


Figure 4.--Provenance means, percentage 4-5 year old needles retained, Mesachie Lake experimental area (B.C.F.S.). A value in the highest group differs significantly from any in the lowest (5% Duncans).

---

[5] Hood, I.A., & M.D. Wilcox (1971, unpubl). N.Z.F.S., F.R.I. For. Path. Rep. No. 32.
[6] Wilcox, M.D. (1974, unpubl.): N.Z.F.S., F.R.I. Gen. & Tree Improv. Rept. No. 69.

2. Fungicidal Spraying

Use of alternative seed stock cannot improve the health of the current Douglas fir crop. With the success of aerial spraying as a control for Dothistroma pini in Pinus radiata, it was natural to consider the use of fungicides as a means of reducing infection of P. gaeumannii.

The earliest record of an attempt to control P. gaeumannii by using fungicides is a reference to an unsuccessful application of bordeaux (Merkle, 1951). Since then, successful control has been achieved in New Zealand and in the U.S. (in the lake states area (Morton, 1975; Morton & Miller, 1976) and in the Pacific Northwest[7], in unhealthy Christmas tree stands). Reports indicate that best control is achieved by a series of two or more protectant spplications, commencing shortly after bud burst. In New Zealand triforine (Cela W524), benlate, and copper based fungicides were effective (Hood, 1973, 1976; Vanner and Hood, 1974), although in subsequent experiments phytotoxicity developed in particularly unhealthy plants treated with the copper fungicides[8]. Use of surfactants was necessary, particularly for success with copper fungicides, and care was always taken to achieve good coverage of new foliage.

The ultimate aim of these experiments with potted seedlings was to develop a suitable schedule for aerial application to stands. Initial attempts, using water suspensions of copper fungicides or triforine at volumes up to 225 l/ha in single or double applications, failed to control P. gaeumannii effectively in trees[9]. Subsequent high volume helicopter applications of up to 2240 l/ha were also unsuccessful, even though simultaneous handspraying with even greater volumes of the same fungicide concentrations did reduce crown infection from 100 to less than 42% needles infected (Hood and van der Pas, 1979). It is still possible that control might be achieved by increasing the quantities of active ingredients per hectare, by testing alternative spray technology in order to improve foliage coverage, or by a choice of alternative fungicides. However, in the New Zealand situation, use of aerial apraying as a control now appears unlikely. It would be impossible to completely eradicate P. gaeumannii from a stand, even with effective applications, and studies in one North Island forest[10] indicate that infection would return to saturation levels in less than 4-5 years from spraying. It is questionable whether the cost of re-spraying at this frequency throughout the life of the stand could be justified.

3. Silvicultural Management

In New Zealand, Douglas fir has been established at planting spacings ranging from 1.8 x 1.8 m to 2.4 x 2.4 m. Until recently, it was general policy to leave Douglas fir untended during the first 40 years, after which a commercial thinning would be carried out once trees were large enough to make it economical to do so (Fenton, 1967). It was considered that close stocking held knot size to a minimum, and the practice did not appear to result in excessive mortality, or affect health or growth rates of final crop trees detrimentally. At the 1974 symposium on Douglas fir[11] it was vigorously argued that early thinning-to-waste was now required to offset the growth decline that had recently developed in Kaingaroa Forest subsequent to the advent of P. gaeumannii[12]. A study had indicated that controlled early thinning would not adversely affect timber quality or increase knot size excessively (James and Revel, 1978). Thinning trials have been established in order to develop a revised silvicultural programme, and to determine the effect of different thinning treatments on growth increment[13]. A recent survey has established that thinning does not reduce the high infection levels in stands under 25 years in Kaingaroa Forest (Hood and Sandberg, 1979). However, thinning has been advocated in Europe as a means of inproving the health of trees infected by P. gaeumannii (eg. Murray, 1955, and others). Early thinning is now being practised in all Douglas fir stands in Golden Downs State Forest on an operational basis, but has not yet been introduced on a wide scale in other Douglas fir forests in New Zealand.

THE FUTURE

In addition to its health problems, Douglas fir is not as versatile, in New Zealand, as radiata pine, and is less economic to grow[14].
Fenton (1978) has challenged the value of Douglas fir as "insurance cover" against any potential catastrophe involving the radiata pine resource. Establishment of Douglas fir will probably continue, but as a reduced component of the total area planted each year. Douglas fir will continue to occupy a place in New Zealand forestry for some time to come. Although heavily infected by P. gaeumannii it should be possible

---

[7] B.A. Fatuga; K. Russell; J. Hadfield; R.S. Byther & G. Chastagner.

[8] cf. B.A. Fatuga (1978 unpubl.): M.Sc. Thesis, Univ. of Wash.

[9] Hood (1973, unpubl.): N.Z.F.S., FRI For. Pathol. Rept. No. 38; J.W. Ray pers. com.

[10] Unpublished data.

[11] A review of Douglas fir in New Zealand. N.Z.F.S., F.R.I. Symposium No. 15; 455 pp. (R.N. James & E.H. Bunn, eds.).

[12] eg. R.J. Cameron; in this context "early thinning" means pre-commercial thinning, or "spacing".

[13] C.J. Mountfort.

[14] "What's new in forest research?" N.Z.F.S., F.R.I., No. 19, Nov. 1974.

to maintain stands in a healthy state by suitable silvicultural management. In the very long term it appears that Douglas fir will be relegated to a place along side other minor species in New Zealand exotic forestry[11].

ACKNOWLEDGEMENTS

The author wishes to thank the many people who have helped to make his stay in North America very worthwhile. In particular, thanks are expressed to staff in the Forest Pathology section at the Pacific Forest Research Centre, Victoria, who have assisted in many ways. P.F.R.C. has also generously supplied travel funds, while in B.C., and the visit to North America was made possible by a fellowship from the N.Z. National Research Advisory Council.

REFERENCES

Beekhuis, J. In "A review of Douglas fir in New Zealand". FRI Symp. No. 15. (James, Bunn, eds.). N.Z.F.S. 455 pp.; 1978.

Boyce, J.S. A needle-cast of Douglas fir associated with Adelopus gaeumannii. Phytopathol. 30 (8), 649-59; 1940.

Bruce, D. In: "Managing young forests in the Douglas-fir region". Symp. held at Oregon State Univ. A.B. Berg, ed.; 1972.

Duff, G. Yield of unthinned Douglas fir, Corsican pine and ponderosa pine in New Zealand. N.Z.F.S., FRI Res. Note No. 5.; 1956.

Fenton, R.T. The role of Douglas fir in Australasian forestry. NZJ For. 12: 4-41; 1967.

__________. In "A review of Douglas fir in New Zealand". FRI Sympos. No. 15 (James, Bunn, eds.) NZFS. 455 pp.; 1978.

Gilmour, J.S. The pathology of forest trees in New Zealand. N.Z.F.S. Tech. Paper No. 48 (82 pp).; 1966.

Hood, I.A. Fungicide and Nematicide Tests 29 (235).; 1973.

__________. Investigations into the fungicidal effect of cuprous oxide against Phaeocryptopus gaeumannii on Douglas fir seedlings. NZJ For. 21: 141-5.; 1976.

__________. Inoculation experiments with Phaeocryptopus gaeumannii on Douglas fir seedlings. N.Z.J. For. Sci. 7(1), 77-82; 1977.

Hood, I.A. and Kershaw, D.J. Distribution and infection period of Phaeocryptopus gaeumannii in New Zealand. N.Z.J. For. Sci. 5(2): 201-8; 1975.

Hood, I.A. and J.B. van der Pas. Fungicidal control of Phaeocryptopus gaeumannii in a 19-year-old Douglas fir stand. NZJ For. Sci. 9(3), 272-83; 1979.

Hood, I.A. and Sandberg, C.J. Changes within tree crowns following thinning of young Douglas fir infected by Phaeocryptopus gaeumannii. NZJ For. Sci. 9(2): 177-84; 1979.

James, R.N. and Revell, D. In "A review of Douglas fir in New Zealand". FRI Sympos. No. 15 (James, Bunn, eds.) NZFS 455 pp.; 1978.

McCormick, F.A. Phaeocryptopus gaeumannii on Douglas fir in Connecticut. Pl. Dis. Reptr. 23: 368-9; 1939.

McGreevy, M. In "A review of Douglas fir in New Zealand". FRI Sympos. No. 15. (James, Bunn, eds.) NZFS, 455 pp.; 1978.

Merkle, R. Über die Douglasien-Vorkommen und die Ausbreitung der Adelopus-Nadelschütte in Württemberg-Hohenzollern. Allgemeine Forst - und Jagdzeitung, Frankfurt-am-Main, 122, 161-91; 1951.

Morton, H.L. Biology and control of Swiss needle cast. Amer. Phytopathol. Soc. 2 (21); 1975.

Morton, H.L. and Patton, R.F. Swiss needle cast of Douglas fir in the Lake States. Pl. Dis. Reptr. 54(7), 612-6; 1970.

Morton, H.L. and Miller, R. Control of Swiss needle cast on Douglas fir. Amer. Phytopathol. Soc. 3(45); 1976.

Murray, J.S. Forest Pathology in Eire. J. For. Comm. 4(23): 25-8; 1955?.

Nüsslein, H. [Growing Douglas fir in the Spessart]. In German. Mitt. St Forstverw. Bayerns No. 38: 5-126; 1970.

Peace, T.F. "Pathology of trees and shrubs". Oxford, 753 pp.; 1962.

Spurr, S.H. Growth of Douglas fir in New Zealand. NZFS, FRI Tech. Paper No. 43; 1963.

Vanner, A.L. and Hood, I.A. Fungicide and Nematicide Tests 30 (235); 1974.

Wooff, W.G. In "A review of Douglas fir in New Zealand". FRI Sympos. No. 15. (James, Bunn, eds.) NZFS. 455 pp.; 1978.

THYRONECTRIA CANKER OF HONEYLOCUST

William R. Jacobi[1]

In recent years honeylocusts (Gleditsia triacanthos) have become popular shade and ornamental trees in Colorado. Honeylocusts account for an estimated 25-50 percent of the urban trees currently planted in Colorado. Honeylocusts have been considered relatively disease free until a canker disease was reported in 1976 (Hudler and Oshima, 1976). At that time, the causal fungus was identified as Thyronectria austro-americana, a close relative of Nectria. The genera differ taxonomically because Thyronectria has muriform ascospores (Seeler, 1940). The disease apparently is becoming more prevalent, or we are more aware of it, since this year workers in Colorado, Kansas and Illinois reported considerable losses to urban and windbreak trees.

The disease is usually first noticed when part of a tree begins to die back. A basal or branch crotch canker is usually found and death occurs by girdling of the cambium. Death occurs in one-two years after initial symptom expression. Commonly a Nectria-like fungus, that apparently helps with the tree's rapid death, is found in the cankered area. The fungus profusely forms pycnidia and occasionally perithecia that push through lenticels. No experimental evidence exists to indicate how and when the fungus is disseminated or the avenues by which the fungus enters a host. Environmental stresses such as drought, oxygen starvation of roots, and insect attacks may predispose the trees to infection by Thyronectria but no pattern has been established.

CURRENT RESEARCH ACTIVITIES

Research on this disease was initiated this spring and summer at Colorado State University. Various aspects of the disease are being studied in a limited manner.

Twenty-five diseased honeylocusts have been detected in Denver and Fort Collins so far this year. Due to reliance solely on private and public cooperators to detect diseased honeylocusts, these findings may be 15-25 percent of the actual number of diseased trees. Of the diseased trees, 50 percent were killed or infected by T. austro-americana. The remaining trees were infected by a Nectria-like fungus or were dead too long to determine exact cause of death. This survey of diseased trees did not reveal any factors such as site conditions or wounds that were consistently related with incidence. Most trees involved range from 12-20 years old which is when the trees are 20-30 feet tall and 6-12 inches dbh. Honeylocusts appear to be killed by two types of cankers or combinations of the two. Isolations from several trees indicated a Nectria-like fungus to be a common companion to Thyronectria on the cankered area. Thyronectria appears to initiate the canker process and then Nectria may attack and help girdle the tree. Either fungus can infect and girdle the tree without help from the other. The extent either fungus grows radially or tangentially in infected trees has not been determined at this time.

Temperature and nutrient requirements of the fungus for optimum growth and pycnidium production in culture are being assessed this fall.

Studies on humidity and temperature effects on spore production from pycnidia have revealed a requirement for 100 percent humidity for sporulation. The time required for spore production varies depending on whether the pycnidium was wetted initially or allowed to absorb moisture from the air. Studies of the time of year that artificial inoculations can be made and how long wounds are suitable infection courts are currently underway.

Cultivars or varieties of honeylocust may vary in their susceptibility to this disease. A test planting of four cultivars (Imperial, Skyline, Sunburst and a thornless selection) has been established at Fort Collins to assess any differences in susceptibility among these cultivars. Test inoculations will not take place for several years until the trees become established.

Research is currently underway to further understand the etiology of this disease and to develop prevention tactics.

LITERATURE CITED

1. Hudler, G. W., Oshima, N. 1976. The occurrence and distribution of Thyronectria austro-americana on honeylocust in Colorado. Plant Dis. Reptr. 60:920-922.
2. Seeler, E. V., Jr. 1940. Two diseases of Gleditsia caused by a species of Thyronectria. J. Arnold Arbor. Harv. Univ. 21:405-427.

---

[1] William R. Jacobi, Assistant Professor, Colorado State University, Fort Collins, CO 80523.

COMANDRA BLISTER RUST OF LODGEPOLE PINE IN THE ROCKY MOUNTAIN REGION

Brian W. Geils

ABSTRACT: Six studies were initiated to measure the influence of comandra blister rust on the growth and survival of lodgepole pine in Colorado and Wyoming.

INTRODUCTION

Hosts

Cronartium comandrae Pk. is a macrocyclic, heterocious rust which parasitizes at least 18 species of hard pines. In western North America the most important hosts are Pinus ponderosa Laws. and P. contorta Dougl. The alternate host in the central Rocky Mountains is Comandra umbellata (L.) Nutt. subsp. pallida (A.DC.) Piehl, the pale bastard toadflax.

Damage

Young infections on pine are indicated by abundant aecial fruiting on a swollen branch. After the fungus invades the bole, the appearance of this branch, continued spore production and copious resin flow on a wide perennial canker identify the disease. Red squirrels remove large areas of infected tissue just prior to spore discharge. Within several years the canker girdles the stem and the tree becomes spike-topped. Advance of the canker down the bole may be slow enough to permit a lower branch to assume dominance as a new leader. Eventually, the canker kills this fork and a "stag" tree of undesirable form develops.

Distribution and Incidence

Since the report by Hedgecock and Long (1915) of the widespread distribution of comandra rust in the northern Applachians, Lake States, and western North America, the fungus was introduced into the Ozark and Cumberland Plateaus. Increased concern over this disease developed as a result of Mielke's (1957) research note that comandra rust is a serious threat to lodgepole of Idaho, Utah and Wyoming. Peterson (1962) and Krebill (1965) found the Rocky Mountain epidemic consisted of infections which dated between 1915 and 1945. The present incidence of comandra rust in Colorado and Wyoming east of the divide was documented by Fuller and Hostetler (1980). Comandra rust occurred in 25% of the region's lodgepole pine type. More significantly, however, over 70% of the stands on the Shoshone and Bighorn National Forests were infected.

Current Studies

To continue the effort at improving the management of these rust infected stands, Colorado State University, Shoshone National Forest, Rocky Mountain Research Station and Region 2 Forest Pest Management have begun a three year project. This study expands upon the work reported by Brown (1977). The goal of this project is to provide resource managers with decision models and guidelines for identifying stands with a high risk of rust caused damage and for evaluating alternative silvicultural treatments.

The first field season of this project has been completed. One long-term study was established at Pingree Park in northern Colorado, and other studies were started on the Wind River District of the Shoshone National Forest.

Branch Canker Study

In 1973 Brown established a series of plots on the Wind River District to follow the development of branch cankers in young lodgepole. Johnson (1979) summarized the first five year's results. He found active branch infections decreased by 56%. In 1981, many of the infections, including some previously classified as inactive had become bole infections. Monitoring of these cankered trees will continue to determine growth and mortality rates.

Stand Growth Plots

Brown had also measured average stand growth on a number of rust-infected plots. This information can be used to adapt the RMYLD program (Edminster 1978) for comandra-diseased lodgepole stands. We established additional plots and remeasured several stands first visited in 1975. From this data we hope to develop yield tables for even-aged stands subjected to a variety of silvicultural treatments.

Incidence Survey and Reconnaisance

An incidence survey was conducted to estimate the proportion of trees and area on the district which is rust infected. Information was also collected on the severity of the problem. Twenty sample stands were selected at random from an area-weighted list of 1014 commercial stands on the Wind River District. These selected stands were a 5% sample. Stand and disease data was obtained on a timber cruise.

The Wind River District had a forest structure and disease intensity which makes comandra rust a serious management consideration. On 96% of the area, lodgepole pine could occur as a major

---

Brian W. Geils, Graduate Research Assistant, Botany and Plant Pathology, Colorado State University, Fort Collins, CO 80523.

seral or persistent species. Mature climax stands with a minor amount of lodgepole occupied 36% of the type. Most of the few lodgepole in this segment were spike-topped by comandra rust. This disease may have a role increasing the rate of succession. An additional 47% of the type was in young, understocked stands. These trees have only been exposed to rust infection for a few years and comandra rust was rarely found in these stands. The remaining 17% was stocked with mature and overmature lodgepole pine. Most areas were infected; from 10 to 70% of the trees were damaged by comandra blister rust.

Along with the survey, a reconnaisance of other stands and the adjacent steppe was completed. Comandra was found as a rhizomatous clone associated with sagebrush on dry open sites at lower elevations. Infected comandra is distributed throughout the district such that no pine stands are more than several miles from an inoculum source. A second rust, Periderium betheli is frequently found in dwarf mistletoe infected stands. Although the number of infected trees is probably not large, the presence of this fungus may be a matter of concern. This fungus occurs in association with dwarf mistletoe on lodgepole pine. Usually many infections are found on a tree or small group of trees, suggesting this fungus may be autoecious.

Tree Growth Plots

At five locations a number of infected and healthy lodgepole pine were destructively sampled to measure individual tree growth and form. Disks were cut from the bole at frequent intervals along the whole length, including a disk at the canker bottom, center and top. Data from these disks will be examined by stem analysis (Herman 1975) and Duff and Nolan (1953).

Rodent-Rust Interaction Study

The final study is being conducted at Pingree Park, Colorado. Measurements will be made of the annual expansion of comandra cankers in older trees and the effect of red squirrel feeding. The plot includes 22 comandra cankers and 20 artificial cankers made by mechanically removing a bark patch to simulate a rust-rodent caused canker. Half of the cankers in each group were completely caged to exclude future squirrel feeding. These cankers will be measured each year for at least the projects' duration.

CONCLUSION

Analysis of these six studies, supplemented by more plots in other locations should reveal useful information on where and how much the growth of stands and trees are affected by comandra blister rust.

LITERATURE CITED

Brown, D.H.; Management guidelines for lodgepole pine stands infected with comandra blister rust and dwarf mistletoe. USDA For. Serv. Tech. Rep. R3-9. Lakewood, CO: Rocky Mt. Reg.; 1977.

Duff, G. H.; Nolan, N.J. Growth and morphogenesis in the Canadian forest species: I. the controls of cambial and apical activity in Pinus resinosa Ait. Can. J. Bot. 31:471-513.

Edminster, C.B. RMYLD: computation of yield tables for even-aged and two storied stands. USDA For. Serv. Res. Pap. RM-199. Fort Collins, CO: Rocky Mt. For. and Range Exp. Stn.; 1978.

Fuller, L.R.; Hostetler, B.B. Annual report for 1979. USDA For. Serv. Lakewood, CO: Rocky Mt. Reg.; 1980.

Hedgecock, G.G.; Long, W.H. A disease of pines by Cronartium pyriforme. USDA Agric. Bull. 247; 1915.

Herman, F.R.; DeMars, D.J.: Woollard, R.F. Field and computer techniques for stem analysis of coniferous forest trees. USDA For. Serv. Res. Pap. PNN-194. Portland, OR; Pac. Northwest For. and Range Exp. Stn.; 1975.

Johnson, D.W. Growth and development of comandra rust cankers on young lodgepole pine. Plant Dis. Reptr., 63:916-918; 1979.

Krebill, R.G. Comandra rust outbreaks in lodgepole pine. J. Forest. 63:519-522; 1965.

Mielke, J.L. The comandra blister rust in lodgepole pine. USDA For. Serv. Res. Note 46. Ogden, UT: Intermountain For. and Range Exp. Stn.; 1957.

Peterson, R.S. Comandra blister rust in the Central Rocky Mountains. USDA For. Serv. Res. Note 79. Fort Collins, CO: Rocky Mt. For. and Range Exp. Stn.: 1962.

THE EFFECTS OF OZONE ON COLORADO FRONT RANGE PONDEROSA PINE

William M. Aitken

INTRODUCTION

The large metropolitan areas of Colorado are recognized as locations with photochemical oxidant air pollution problems. High levels of solar radiation combined with extensive automobile emissions create a situation where the production of photochemical air pollutants is the result. This pollution may subsequently be transported out of the cities and into forest and agricultural areas.

In the San Bernardino Mountains generated oxidants, especially ozone, are found at phytotoxic concentrations (Miller, et al. 1963). The San Bernardino Mountains are 70 miles to the east of Los Angeles, providing a good example of oxidant air pollutants being transported considerable distances. Thus, there is extensive damage and death from successive defoliations to west coast ponderosa pine (Pinus ponderosa var. ponderosa Laws.) in the San Bernardino Mountains. It has been proven that ozone is the major oxidant responsible for this chlorotic decline (Miller, et al. 1963). The average daily peak oxidant concentration is 0.09 ppm in these declining ponderosa pine stands. Ozone concentration in Denver has been recorded as high as 0.375 ppm. Because oxidant concentrations are often found in higher concentrations away from the source, the possibility of ozone damage to Rocky Mountain ponderosa pine (Pinus ponderosa var. scopulorum) exists. To date, no information exists on the effects of ozone on Front Range ponderosa pine.

A research project was initiated in an attempt to determine: (a) the symptomatic response of Rocky Mountain ponderosa pine seedlings to ozone fumigation, (b) those combinations of ozone concentration and exposure duration required to produce initial symptoms.

MATERIALS AND METHODS

Ponderosa pine seedlings were gown in a greenhouse from seeds donated by the Arapahoe-Roosevelt and Pike San Isabel National Forests. Ozone fumigations were conducted in a greenhouse in two identical chambers made of clear plastic fitted with exhaust vents. Ozone was generated using an OREC Model V-510 Ozonator and monitored continuously with a Dasibi Model 1003 AH ozone monitor connected to a strip-chart recorder. Temperature and relative humidity were also monitored.

Initial fumigations were conducted for 24 hours/day on 5 one-year-old seedlings at 1, 0.75, 0.5 and 0.25 ppm ozone until a rough estimate could be made of the sensitivity of the seedlings. Using these results, fumigation was carried out at 0.5 and 0.4 ppm on 20 seedlings for 10 hrs/day (8 a.m.-6 p.m.) for 21 days.

RESULTS

Ozone fumigation at 1 ppm for 24 hours resulted in a chlorotic mottle on all five seedlings. No mottling symptoms were observed on seedlings in the control chamber. A more extensive chlorotic mottle was found after 48 hours. After 72 hours four of the five seedlings exhibited ozone injury which included needle tip dieback in addition to entire needle mottling. At 0.75 ppm ozone, two of five seedlings showed chlorotic mottle after 24 hours. After 54 hours, all seedlings showed varying degrees of tip dieback and mottle. At 0.5 ppm, mottle symptoms were expressed on all seedlings after 8 days of continuous fumigation. One seedling had tip dieback injury after 8 days. No seedlings were symptomatic at 0.25 ppm of ozone after 21 days of continuous fumigation. The 0.5 ppm fumigation for 10 hrs/day from 8 a.m. to 6 p.m. caused a mottle after 2 days on 2 seedlings with 19 of 20 seedlings showing varying degrees of mottle, chlorosis and flecking after 21 days.

The 0.4 ppm fumigation produced results similar to the 0.5 ppm fumigation in that symptom expression was found on 5 seedlings after 2 days and all 20 seedlings showed some form of response after 21 days.

DISCUSSION

Rocky Mountain ponderosa pine seedlings are sensitive to ozone at concentrations as low as 0.4 ppm, exhibiting symptoms of mottling, flecking and chlorosis. Additional research is underway to determine if seedlings will be sensitive to 0.3 ppm ozone.

Because it has been shown that the loss of chlorophyll in bean leaves treated with ozone was a good measure of the impairment of leaf function (Todd, et al. 1961) chlorophyll extractions will be made on the 0.5, 0.4, and 0.3 ppm fumigation seedlings to confirm visual observations of chlorotic mottle and chlorosis.

Ozone monitoring data for the Colorado Front Range is only available for the Denver Metropolitan Area. This study will also attempt to determine if ozone generated in the Denver area is found in phytotoxic concentrations in the mountains where ponderosa pine is found. This wll aid in determining the regional nature of

---

William M. Aitken, Graduate Research Assistant, Botany and Plant Pathology, Colorado State University, Fort Collins, CO 80523.

ozone distribution along the Front Range, and whether this distribution is sufficient to be causing oxidant damage to ponderosa pine to the extent that growth is being affected.

Additional programs utilizing open-top chambers should be developed to aid in determining the effects of ozone on Front Range ponderosa pine in the field. Other studies should be conducted utilizing SO_2 and PAN in conjunction with ozone to determine the combined effect of air pollutants on ponderosa pine. Only in this way can the current and future impacts of air pollutants be understood, anticipated and minimized.

REFERENCES

Miller, P.R.; Parmeter, J.R.; Taylor, O.C.; Cardiff, E.A.. Ozone Injury to the Foliage of Pinus ponderosa. Phytopathology 53: 1072-1076; 1963.

Todd, G.W.; Arnold, W.N. Evaluation of the Methods Used to Determine Injury to Plant Leaves by Air Pollutants. Botan. Gaz. 123: 151-154; 1961.

THE ANATOMY OF DROOPING ASPEN

Valerie J. Scarpa

INTRODUCTION

During the past ten years quaking aspen (Populus tremuloides Michx.) have been observed in the Rocky Mountain region which exhibit a "drooping" symptom. These observations have been made in a variety of habitats including campgrounds, along roadsides and in residential and urban areas.

Morphologically, drooping aspen are characterized by pendulous branches. The total amount of foliage is reduced and those leaves produced are greatly enlarged and borne terminally. The branches of the affected aspen are so rubbery and elastic that they can actually be tied into knots. Nodes are swollen and breakage occurs readily at the nodal region when branches are only slightly pulled. A high mortality rate has been found to be associated with the drooping syndrome.

The flexuous, pendulous condition of the limbs resembles the symptoms associated with a disease of apple known as rubbery wood. This disease of apple which is induced by a mycoplasm is also characterized by spongy, non-rigid wood giving the trees a rambling, vine-like appearance (Beakbane, et al., 1971). Early investigators of apple rubbery wood described a condition resembling tension wood in the branches and stems of infected apple trees (Beakbane and Thompson, 1945; Scurfield and Bland, 1963). Tension wood, a condition of reduced lignification in bent dicotyledonous trees, is recognizable by the enhanced lateral growth on the upper side of the affected limb and by the presence of non-lignified fibers known as gelatinous fibers. Concurrent with these observations a similar drooping symptom has been observed throughout Salicaceae.

In 1979 Livingston, et al. published their findings on several studies on drooping aspen. Because of the similarity of symptoms of drooping aspen to those of apple rubbery wood, a search for a viral or mycoplasmal causal agent was undertaken. Mechanical transmission and grafting of affected aspen tissues to appropriate indicator host plants and apparently healthy aspen as well as electron microscopic examinations of affected aspen tissue, failed to establish the presence of an etiological agent. The possibility of environmental stress resulting in endogenous ethylene generation initiating the drooping symptoms while acting as a growth regulator was also studied with negative results. It was then determined that an anatomical study of both affected and unaffected wood should be made to observe any differences of similarities.

MATERIALS AND METHODS

In September of 1980, four aspen trees in Aspen, Colorado, two drooping and two non-drooping were selected for study. These trees were all growing within ten feet of each other. The close proximity of these trees to one another reduced any variation in environment which might interfere with data interpretation. Two branches were taken from each tree and histological sections were made at specific locations along each. Macerates were also prepared from the wood of each branch.

Branch cross-sections were used to determine vessel element and fiber number, as well as vessel diameter. Fiber and vessel element lengths were determined from macerates. This data is still being accumulated.

RESULTS

From the measurements taken from cross-sections of drooping treewood, there seems to be a great deal of variability in the quantity and quality of cell type observed. However, the growth rings of drooping wood appear to be consistently narrower than those of non-droopers. The wood of unaffected trees has an orderly appearance with most of the cells occurring in files separated frequently by uniseriate rays. This organization is lacking in drooping aspen wood which exhibits a reduction of summer wood and a proliferation and disorganization of ray parenchyma. The affected wood also has a distinct reduction in the number of fibers.

DISCUSSION

Drooping aspen wood exhibits a typical tension wood anatomy. The affected tree grows asymetrically with more tissue material deposited on the adaxial portion of the branch than on the abaxial. Gelatinous fibers are present and occur equally in both drooping and non-drooping wood. Because the presence of this fiber is not an adequate indication of the degree of lignification, a series of chemical tests will be made to quantify the lignin, cellulose, and other cell wall constituents. In addition to the ongoing anatomical studies, a ratio of xylem to phloem to periderm will be formulated in order to determine the location where most photosynthates are being allocated.

The lack of organization of wood cells indicate that the vascular cambium activity is affected. Since this is an area of meristematic activity, it seems reasonable to expect any physiological stress such as nutrition, drought, and growth regulator imbalance to cause some effect. Also, the fact that other Salicaecae have been observed

---

Valerie J. Scarpa, Graduate Research Assistant, Botany and Plant Pathology, Colorado State University, Fort Collins, CO 80523.

exhibiting this drooping symptom, seems to corroborate the idea that this is an abnormal physiology expressed by the entire family.

REFERENCES

Beakbane, A.B.; E.C. Thompson. Abnormal lignification in the wood of some apple trees. Nature 156:145-146; 1945.

Beakbane, A.B.; M.D. Mishra, A.F. Posnette; C.H.W. Slater. Mycoplasma-like organisms associated with chat fruit and rubbery wood diseases of apple, Malus domestica Borkh., compared with those in strawberry with green petal disease. J. Gen. Microbiol. 50:55-62; 1971.

Livingston, C.H.; T.E. Hinds; C.E. Seliskar; R.E. Klein. A "drooping" malady of Western Aspen. Plant Dis. Reptr. 63:923-927; 1979.

Scurfield, G; D.E. Bland. The anatomy and chemistry of "rubbery" wood in apple var. Lord Lambourne. J. Hort. Sci. 38:297-306; 1963.

Workshop Notes

SUMMARY

Tuesday evening a spirited group discussed Christmas tree and nursery problems that might be of mutual interest.

Keith Brownell led a discussion of the pros and cons of solarization in nurseries and showed slides of his California work. He found a minimum 3-week treatment was necessary to get temperatures up to at least 40°C which successfully killed nematodes, weeds, and Fusarium spp. to depths of 25 cm. The combination of heat and moisture is critical although not well understood. (Highlights appear below.)

John Schwandt presented a brief description of the damage caused by Sirococcus tip blight in northern Idaho nurseries and the measures implemented to try to control it.

Christmas tree problems of interest were the outbreak of Lophodermium on Scotch pine in Idaho and Swiss needle cast on Douglas-fir. Several chemicals are being evaluated for control, and Jim Hadfield reported that 100-percent protection was provided by Bravo-500 applied at 3.2 pints per acre. Dithane M-45 achieved 98-percent protection and actually reduced further discharge of spores. (Highlights of Swiss needle cast presentation appear below.)

FUSARIUM

Keith Brownell
University of California-Berkeley

The variety of conifer nursery diseases caused by Fusarium oxysporum was discussed, and some evidence for host specialization within the conifers was presented. Also brought up for discussion was the possibility that conifers are so susceptible to diseases caused by Fusarium oxysporum because this fungus is normally absent from forest soils and, therefore, no selection pressure for resistance to it has developed.

The first slides covered the basic etiology of Fusarium hypocotyl rot and its impact on California nurseries (presented in more detail as a special paper at Pingree Park; see 1980 WIFDWC Proceedings).

Control Strategies

Seed pelleting with four fungicides showed promise with Benomyl providing the best control despite its lack of effectiveness as a soil drench.

Continued early planting trials have shown excellent results; for example, unstratified sugar pine seed planted in January experienced very few losses and developed an excellent stand.

Soil tarping or solarization trials presently underway provided much interest and discussion. It may prove to be a valuable tool in forest nurseries, commonly fallow for the summer months before replanting. It could provide an alternative to fumigation for control of soilborne diseases and weeds. An excellent review on solarization is available by J. Katan in Ann. Review of Phytopathology 19: 211-236; 1981.

SWISS NEEDLE CAST IN PACIFIC NORTHWEST DOUGLAS-FIR CHRISTMAS TREE PLANTATIONS

Gary A. Chastagner, Assistant Plant Pathologist
Ralph S. Byther, Extension Plant Pathologist
Ellen M. Michaels, Assistant Plant Pathologist
Washington State University-Puyallup

Swiss needle cast, caused by the fungus Phaeocryptopus gaeumannii, has become a major problem for Douglas-fir Christmas tree growers throughout the western parts of Oregon and Washington. Premature needle loss associated with this disease results in trees at harvest which retain only 1- to 2-year's compliment of needles. During 1981, this disease was found in 48 of the 53 production areas examined in Oregon and Washington. Efforts are underway to determine what the economic threshold is for this disease.

In order to determine what is the best time to apply fungicides, fungicides were applied on a monthly basis from April 1980 to March 1981. A single application of benomyl plus mancozeb on June 24, 1980, by conventional backpack sprayer provided effective control of this disease on newly emerged needles. However, these applications of fungicides had no influence on the retention during 1981 of the already infected 1979 needles.

Studies on the production of ascospores by pseudothecia during 1981 have shown that ascospores were rapidly released upon moistening pseudothecia. Nearly 75 percent of the total number of ascospores released were released within 1 hour of moistening pseudothecia. Pseudothecia had the potential to produce high numbers of ascospores upon moistening throughout the summer. However, this potential declined rapidly during late August and early September.

Work is currently in progress to determine if aerial applications of fungicides are as effective as ground applications in controlling this disease. We are also determining if the presence of this disease influences needle retention on harvested trees.

Field Trip Notes

September 17, 1981

8:30 am Depart from Vernon Lodge parking lot.

Stop 1 Atropellis piniphila on lodgepole pine: John Hopkins

Stop 2 Armillaria mellea on Douglas-fir, balsam, and spruce: Duncan Morrison

Lunch

Stop 3 Verticicladiella wagenerii on lodgepole pine: Rich Hunt

Stop 4 Phellinus weirii control operation
- Biology: Gordon Wallis
- Rationale behind operation: Gerry Wellburn, CZ
- Consequences of operation: Dick Smith, Ed Wass

Stop 5 Arceuthobium douglasii: Dick Smith

Rich Hunt

DWARF MISTLETOE COMMITTEE HIGHLIGHTS OF 1981--RESEARCH AND MANAGEMENT

John G. Laut, Chairman

I. Taxonomy, Hosts, and Distribution

a. Studies on the Arceuthobium campylopodum-occidentale complex are continuing. The test hosts are being checked periodically for new infection and the development of existing infections is being recorded. Flowering and fruit producing shoots have been collected for careful morphological comparison. (R. F. Scharpf, PSW; W. Mark, Cal. Poly; F. G. Hawksworth, RM).

b. Mountain hemlock has been confirmed as a host for A. tsugense in Alaska, although a very reluctant one. The sparsity of shoots and shape of the swellings indicate an incompatible host relationship. Several individual infections were located in one area near Homeshore, Alaska, where mountain hemlock mixes with western hemlock that is heavily infected with dwarf mistletoe. In this area, however, one pole-sized mountain hemlock was growing adjacent to a similar sized western hemlock with several hundred mistletoe infections. Even though the crows of the two trees overlapped, not a single confirmed mistletoe infection was found on that mountain hemlock. In other areas of SE Alaska cursory observations on mountain hemlock have failed to reveal any other instances of infection.

The only other report of A. tsugense on mountain hemlock in Alaska is a 1913 collection recorded as from "near Sitka." That collection has only a single host needle present and it is thus difficult to confirm that mountain hemlock was the host. That collection differs from the majority of the infections found at Homeshore in that the mistletoe shoots were well developed in the 1913 collection. (T. Shaw, PNW, Alaska.)

c. Knutson, D. and R. Tinnin. 1981. Aarceuthobium cyanocarpum in Oregon. Plant Diseases 65:445. (Portland State University)

II. Physiology and Anatomy

a. Cytokinins were extracted and bioassayed from aerial shoots of Arceuthobium vaginatum subsp. cryptopodum, ponderosa pine (Pinus ponderosa var. scopulorum) wood and bark tissues infected with the parasite, and healthy ponderosa pine wood and bark tissues. The dwarf mistletoe aerial shoots exhibited five peaks of cytokinin activity with zeatin-riboside and zeatin present in the highest concentrations. Ponderosa pine tissue infected with A. vaginatum showed similar pearks of cytokinin activity, however, these cytokinins were observed in much lower concentrations than those in the aerial shoots of the dwarf mistletoe. Healthy ponderosa pine exhibited no detectable cytokinin activity. (Bruce Schaffer, S. D. Wullschleger, and C. P. P. Reid, Colorado State Univ., F. G. Hawskworth, RM)

b. Cytokinins were extracted and bioassayed from aerial shoots of Arceuthobium occidentale parasitizing digger pine (Pinus sabiniana). Aerial shoots of this dwarf mistletoe species exhibited three peaks of cytokinin activity. Except for zeatin, cytokinins observed in A. occidentale shoots appeared to be different from those observed in aerial shoots of A. vaginatum subsp. cryptopodum. (Bruce Schaffer, S. D. Wullschelger, and C. P. P. Reid, Colorado State Univ., and F. G. Hawskworth, RM)

c. Nancy Broshot is studying starch reserves in the needles and twigs of Pinus contorta free of and infected with Arceuthobium americanum (Portland State Univ.)

d. A study of the isoymes of the dwarf mistletoes was started. Techniques to determine several isozyme systems in germinating seeds have been developed. For 1981, concentration will be on the western U.S. taxa of Arceuthobium and in 1982, it is planned to sample several populatins of A. pusillum on various hosts in Canada and the U.S. It will be determined whether isozyme studies will yield information relating to population or taxonomic significance. (D. Nickrent, Miami University, Ohio; F. G. Hawksworth, RM).

III. Life Cycle Studies

a. Manuscripts on seed dispersal by *A. pusillum* on black spruce and on pollination ecology are in preparation. (F. Baker, D. W. French, Univ. Minn.)

b. A manuscript is in press entitled "Population dynamics of dwarf mistletoe on young true firs in the central Sierra Nevada." (R. F. Scharpf, PSW; J. R. Parmeter, Jr., U.C.-Berkeley)

c. Page 97 of last year's proceedings described our life cycle studies with seeds of *A. tsugense* on western hemlock. Several of the 1977 and 1978 inoculations have produced shoots, but no seeds as yet. (T. Shaw, PNW-Alaska.)

IV. Host-parasite Relations

a. The levels of Cytospora canker (*Cytospora abietis*) in dwarf mistletoe infested thinned and unthinned stands of white firs are being monitored yearly. Objectives are to determine: (1) Fluctuations in Cytospora attack and/or branch flagging for several years. (2) Loss of live crown from cytospora over time, and (3) Growth loss or mortality as related to crown loss from cytospora. (R. F. Scharpf, PSW)

b. Paper submitted: Tinnin, R., F. Hawksworth, and D. Knutson. Witches' broom formation in conifers infected by *Arceuthobium* spp.: an example of parasitic impact upon community dynamics. Amer. Midl. Natur. (Portland State Univ.)

V. Effects on Host

a. Studies are continuing on the effects of dwarf mistletoe (*Arceuthobium americanum*) on cone and seed production of lodgepole pine. Lodgepole pine trees in the Roosevelt National Forest were given mistletoe rating based on Hawksworth's 6-class rating system. The trees were also measured for height, d.b.h., length of live crown, vigor, and density. Trees were felled and cones were collected and measured. Seeds were extracted from the cones, measured and given germination tests. Cone and seed production, cone and seed size, and seed viability of trees in each infection class are being statistically compared. (Bruce Schaffer, Colorado State University; F. G. Hawksworth, RM, J. G. Laut, Colorado State Forest Service; W. R. Jacobi, Colorado State University; D. W. Johnson, USFS-Denver)

b. Eight plots were established in jack pine stands infested with *A. americanum* in Manitoba, Canada in order to quantify infection, mortality, and spread rates, and growth loss. Preliminary estimates will be used to develop a simulator for projecting disease losses. (F. Baker, D. W. French, Univ. Minn.)

c. Approximately 50 lodgepole pine stands infested by *Arceuthobium americanum* in central Oregon are being surveyed to quantify impact. Data from the survey will be used to modify RMYLD to fit the central Oregon situation. (C. L. Schmitt, FPM-Portland)

d. Plots have been established in several *Arceuthobium abietinum* f. sp. *concoloris* infested white fir stands on the Deschutes National Forest in central Oregon. The objective is to measure the effects of mistletoe on growth of trees released by overstory removal. There is a high incidence of branch-killing canker fungi associated with dwarf mistletoe infections. Trees with severe dwarf mistletoe infections are growing at much slower rates than those that are lightly infected or disease free. (G. M. Filip, FPM-Portland)

e. Ten long-term plots have been established to study the development of dwarf mistletoe after precommercial thinning western hemlock regenerated beneath infected residual trees. The infected residual was girdled at thinning. All hemlock crop trees within 30 feet of the infected residual were thoroughly examined for dwarf mistletoe infections. All infections were marked and recorded by size, sex and crown location. Plots will be periodically revisited to check infection development.

A manuscript has been drafted on, "Hemlock dwarf mistletoe in southeast Alaska--its development in western hemlock regenerated beneath infected residual trees." During the summers of 1978, '79, and '80, over 3,400 western hemlock regenerated beneath old-growth hemlock severely infected with dwarf mistletoe and left standing on cut-over sites in southeast Alaska were felled and examined for infection. The percentage of understory trees infected averaged 9, 7, 5, and 17, respectively, in 17-, 19-, 35-, and 43-year-old stands. At a comparable age, young stands of hemlock in Alaska are less severely affected by dwarf mistletoe than similar stands in Washington, Oregon, and British Columbia. Disease control strategies will require modification to meet local conditions. (T. Shaw, PNW-Alaska)

Dwarf mistletoe-related mortality and infection severity of ponderosa and Jeffrey pines were followed for 8 years in five campgrounds in California and Nevada. A report summarizing the results will be completed by September, 1981. (D. R. Vogler, FPM-Region 5; R. F. Scharpf, PSW)

f. Field work for the study to develop a yield simulation program for mixed conifers in the Southwest should be completed by December 1981. We expect to have data on about 220 plots (over 30,000 trees) from the Apache-Sitgreaves and Kaibab National Forests in Arizona and the Crson, Santa Fe, and Lincoln National Forests in New Mexico. Model building should take most of 1982. (R. Mathiasen, Univ. of Arizona; E. Wood, Region 3, Albuquerque; C. B. Edminster and F. G. Hawksworth RM)

VI. Ecology

a. A Ph. D. project on fire ecology and prescribed burning to control lodgepole pine dwarf mistletoe was begun. Various phases will be studied: (1) distribution of dwarf mistletoes in relation to fire history in lodgepole pine forests, (2) prescribed burning to control dwarf mistletoe in unmerchantable lodgepole pine pole stands on the Gunnison National Forest, Colorado, and (3) effects of smoke on germination of seeds of several species of dwarf mistletoes. (T. Zimmerman, Colorado State Univ., F. G. Kawksworth, RM)

b. Studies have begun to compare the incidence and distribution of Arceuthobium vaginatum and Arceuthobium douglasii to the understory vegetation of ponderosa pine and Douglas fir, respectively. This data was gathered in accordance with a roadside reconnaissance survey in both forest types, and with merchantable cubic-foot volume loss information due to these mistletoes. Approximately 1,400 miles of roads were travelled throughout several National Forests in Colorado. An estimated 350 plots were established at 3-mile intervals along the roadside survey, and were classified into predetermined habitat types of the region. (L. M. Merrill; F. G. Hawksworth, RM)

c. Lee Kirkpatrick is studying the water budget of infected and healthy Pseudotsuga menziesii. Bob Tinnin is studying the productivity and biomass characteristics of infected and uninfected Pinus contorta. (Portland State Univ.)

VII. Control - Chemical

No reports

VIII. Control - Biological

No reports

IX. Control - Silvicultural

a. Treated over 2,400 acres of A. americanum infested lodgepole pine stands on the Arapaho and Roosevelt, Grand Mesa, Uncompahgre and Gunnison, Shoshone and Medicine Bow National Forests and state-owned sections in Wyoming. (D. W. Johnson, USFS, Region 2)

b. Work is underway to develop procedures to measure the economic efficiency of dwarf mistletoe management practices in commercial forest stands. (J. S. Hadfield, M. Wiitala, FPM-Portland)

c. Two projects to control A. campylopodum on ponderosa and Jeffrey pines were initiated in Region 5 campgrounds on the Sierra and San Bernardino National Forests. Techniques to be used include removing heavily infected overstory trees, thinning, pruning, and establishing buffer strips; 326 trees are scheduled for treatment. A third control project involving witches broom pruning of 165 Jeffrey pines was completed in the Crystal Lakes Recreation Area, Angeles National Forest. (J. Pronos and G. A. DeNitto, FPM-Region 5)

d. Sawtooth National Forest - 280 acres - Douglas-fir and Ponderosa pine Targhee National Forest - 2,000 acres - lodgepole pine overstory gridled Wasatch National Forest - 460 acres - lodgepole pine BLM - Idaho Falls - 200 acres - lodgepole pine sanitized (Jim Hoffman, Region 4-Boise)

e. The Pingree Park lodgepole - dwarf mistletoe management demonstration area was completed with a signed self-guiding trail through the various treatments. A handout brochure is being prepared (J. Laut, Colorado State Forest Service; F. G. Hawksworth, RM; D. W. Johnson, Region 2)

f. The Region 5-PSW cooperative project to test the efficacy of controlling dwarf mistletoe in true firs by precommercial thinning was continued in 1981. All thinning has been done, and all pre- and post-thinning data will be taken by the end of September. The data will be analysed and decisions made on when the plot trees will be remeasured. (R. F. Scharpf, PSW; R. S. Smith and Det Vogler, Region 5).

g. The plots for a study of silvicultural control of lodgepole pine dwarf mistletoe in the Routt National Forest were reexamined in 1981. The 37-1/2 acre plots were sanitized for mistletoe in 1965-66, sanitized again and thinned in 1970, and reexamined in 1975. A 16-year progress report will be prepared. (T. E. Hinds; F. G. Hawksworth, RM; and D. Johnson, FPM-Denver)

h. A manuscript is in preparation summarizing eradication procedures used in dwarf mistletoe-infested black spruce stands. (F. Baker, D. W. French, Univ. Minn.)

i. The Manitoba Provincial Parks have begun efforts to eradicate A. pusillum from white spruce in the Sprucewoods Provincial Park. (The name was recently changed to Baldhead Hills Provincial Park, partially because of the elimination of white spruce). Overtory trees were killed by poisoning so they would remain standing and provide shade for seedlings. Containerized seedlings were planted because these sites are very difficult to regenerate due to dry, sandy soil. (F. Baker, D. W. French, Univ. Minn.)

X. Surveys

a. Presuppression surveys for A. americanum were conducted on 19,000 acres on the Arapaho and Roosevelt, Grand Mesa, Uncompahgre and Gunnison, and White River National Forests and state-owned sections in Wyoming. Silvicultural prescriptions were prepared for 275 stands based on RMYLD (Rocky Mountain Yield) projections of the survey data. Five-year action plans for suppression projects are currently being developed in cooperation with district personnel. (D. W. Johnson, Region 2)

b. Dwarf mistletoe loss assessment survery-ponderosa pine and Douglas-fir-Colorado National Forests. As part of a continuing effort to assess growth loss and mortality caused by Arceuthobium species in the Rocky Mountain Region, a road-plot survey was initiated during the 1981 field season. A report will be issued this winter. (D. W. Johnson, Region 2)

c. A survey of black spruce stands in six townships for dwarf mistletoe is under way in cooperation with the Minnesota Department of Natural Resources. DMLOSS will be used to project future impact of this parasite. (F. Baker, P. Scherman, Univ. Minn.)

XI. Miscellaneous

a. A revised Region 4 Forest Service Manual Supplement was completed. It described dwarf mistletoe management policies and funding procedures. (Jim Hoffman, Region 3, Boise)

b. Lynn Larsen has completed her Master's degree. The title of the thesis is: "Variation in branch growth characteristics of Pinus contorta infected with Arceuthobium americanum." (Portland State Univ.)

c. A study was begun at the Institute of Forest Genetics, Placerville, California, in 1980 to tet the resistance of several geographic selections of Jeffrey pine to dwarf mistletoe infection. The test hosts were plantation trees also being studied for growth, form, and other characteristics. Fifty trees, each from three geographic locations were inoculated with 60 dwarf mistletoe seeds each for a total of 9,000 inoculations. The trees will be examined periodically for seed germination, infection, and mistletoe development. (R. F. Scharpf, Bro Kinloch, and Jim Jenkinson, PSW)

d. Fred Baker completed his Ph. D. thesis entitled "Biology and Control of the Eastern Dwarf Mistletoe." (Univ. Minn.)

e. A package for a laboratory exercise on black spruce dwarf mistletoe using DMLOSS is expected to be completed by November 1981. This exercise will illustrate the long-term spread and impact of this disease, and will demonstrate the economic feasibility of management activities. The package will include a deck of cards, sample exercise, aerial photographs, and instructions; it will be available at X cost from the Department of Plant Pathology. (F. Baker, Univ. Minn.)

f. Arceuthobium americanum is a serious problem on jack pine in the residential and recreational forests along the southeast shores of Lake Winnipeg in Manitoba. A project has begun to evaluate pruning as a control measure. (F. Baker, D. W. French, Univ. Minn.)

ROOT DISEASE COMMITTEE
HIGHLIGHTS OF THE 1981 MEETING

Greg Filip, Chairman

The following summaries of work concerning root diseases were submitted:

1. Phytophthora Root Rot

   Phytophthora root rot of Port-Orford-cedar was surveyed on Federal, State, and private lands in northern California. (Kliejunas, FPM-Region 5; Adams, CSDF)

2. Black Stain Root Disease

   a. Black stain root disease is often found in association with Armillaria root rot in Montana and Idaho. (Byler, James, and Dubreuil, FPM-Region 1)

   b. Various control measures for black stain root disease will be evaluated at Mesa Verde, Colorado. (Fuller, FPM-Region 2)

3. Armillaria Root Rot

   a. Complexes between mountain pine beetle/Armillaria and western balsam bark beetle/Armillaria are under evaluation in Colorado and Wyoming. (Fuller, FPM-Region 2)

   b. Permanent plots were established around 31 infected trees to monitor their rate of decline and effects of selective logging on rate of spread to nearby healthy trees. (Schwandt, IDL)

4. Annosus Root Rot

   a. Fomes annosus is causing considerable mortality of ponderosa pine and Douglas-fir on drier sites in southern Idaho. (Williams, FPM-Region 4)

   b. A regionwide survey of California fir stands showed that 4 percent of 453 green trees and 15 percent of the 240 dead trees had F. annosus. (Parmeter, Schultz, Slaughter, Macedo, and Mihail, Univ. Calif.)

   c. Evaluation of borax treatments of fir stumps showed that of 481 treated stumps, 14 percent yielded F. annosus. (Parmeter, Schultz, Slaughter, Macedo, and Mihail, Univ. Calif.)

   d. Fomes annosus has been found causing substantial mortality in stands of white fir on the Fremont National Forest in southern Oregon. (Goheen, FPM-Region)

5. Red-Brown Butt Rot (Polyporus schweinitzii)

   a. Polyporus schweinitzii has been found in Douglas-fir occasionally in association with F. annosus and P. tomentosus in southern Idaho. (Williams, FPM-Region 4)

   b. Phaeolus schweinitzii appears to be more significant than previously thought in Montana and Idaho. (Byler, James, and Dubreuil, FPM-Region 1)

6. Laminated Root Rot (Phellinus weirii)

   a. A total of 32 permanent plots were established around infected trees in three root rot centers to monitor rate of decline in infected trees and rate symptom development in nearby non-symptomatic (uninfected?) trees. (Schwandt, IDL)

   b. A total of 29 permanent plots were established around infected trees in three large root rot pockets which will undergo a variety of logging treatments to control spread and reduce losses in regeneration. (Schwandt, IDL)

7. Mortality of Alaska Yellow-Cedar in Southeast Alaska

   A brief slide presentation was presented at WIFDWC to acquaint members with this situation. Alaska yellow-cedar is dying over several thousand acres from an unknown cause. Investigations were initiated in the summer of 1981 and a root problem (disease?) is suspected. Root system excavation on 27 trees revealed that dying trees frequently have deep brown stains in the inner phloem tissues that extend up the stem from dead and dying roots. Three or four fungi were rather consistently isolated from such stained tissue, but no identifications have been made. Four permanent plots were established to follow the progression of symptoms on individual trees. (T. Shaw, PNW-Alaska)

DISEASE CONTROL COMMITTEE
HIGHLIGHTS OF 1981 CONTROL INVESTIGATIONS

Kenelm Russell, Chairman

I. Seedling Diseases

A. Gray Mold
Host: Lodgepole pine and western larch
Causal Organisms: Botrytis cinerea
Control: Chemical
Development Stage: Pilot Operational

Test the efficiency of several fungicides against this persistent problem in containerized stock. Test designed to obtain data for basis of registration. Results not yet complete (R. L. James and J. Y. Woo, USFS, R-1, Missoula).

B. Damping-off Fungi
Host: Bareroot Conifer Seedlings
Causal Organisms: Fusarium sp. and Pythium sp.
Control: Biological
Development Stage: Field Trial

Testing clear plastic to raise the soil temperature enough to significantly reduce pathogenic soil fungi (L. R. Fuller, USFS, FPM R-2, Denver).

C. Seed-borne Pathogens
Host: Ponderosa, Lodgepole pine and spruce seeds
Causal Organisms: Fusarium spp. and Pythium sp.
Control: Chemical
Development Stage: Full Operational

D. Soil-borne Pests
Host: Ponderosa pine
Causal Organisms: Soil pathogenic fungi, rematodes, weeds
Control: Silvicultural
Development Stage: Field Trial

Solar tarping ("solarization") compared to fumigation and no treatment of nursery soil. Treatments made 8/81-9/81. Fungi and nematode populations to be determined before and after treatments. Seedling survival and weed population monitored spring 1982. No results yet. (Sally Cooley, USFS, FPM, Portland.)

E. Nursery Root Diseases
Host: Various conifers and herbaceous shrubs
Causal Organisms: Pythiaceous and Monilioceous fungi
Control: Chemical
Development Stage: Field Trial

Maintenance of MC 67-33 at 350-360 lbs/acre, tarped, on a field rotation of 3 years (D. Thatcher, D. Wermlinger, USFS, R-4, Lucky Peak Nursery).

F. Fusarium Root Rot
Host: True fir, sugar pine (bareroot)
Causal Organisms: Fusarium oxysporum f.s. pini
Control: Biological
Development Stage: Field Trial

Solar pasteurization of soil with 1 mil clear plastic tarp. First year data not yet compiled (D. Adams, K. Brownell, W. Krelle, California Dept. Forestry, U.C. Berkeley).

G. Root & Stem Rot
Host: Conifers
Causal Organisms: Fusarium oxysporum
Control: Chemical, Biological & Silvicultural
Development Stage: Field Trial

Beginning Rhizobacteria and solarization studies (R. Bega, A. McCain, USFS, U. of California, Berkeley).

H. Fusarium Root Rot
Host: Sugar pine, bareroot 1-0
Causal Organisms: Fusarium spp.
Control: Chemical
Development Stage: Field Trial

Two different rates and three different application times tested for fungicide Banrot: 41 lb/ac; sowing, 20 days after sowing, and 40 days after sowing. No significant differences in seedling survival found among treatments (including checks). (Salley Cooley, USFS, FPM, Portland.)

I. Phytopthora Root Rot
Host: Douglas-fir, bareroot 2-0
Causal Organisms: Phytopthora spp.
Control: Chemical
Development Stage: Field Trial

"Subdue" (metalaxyl) applied by tractor-mounted sprayer to infested area of nursery, 8/81. No results yet (Salley Cooley, USFS, FPM, Portland).

J. Gray Mold
Host: Spruce
Causal Organisms: Botrytis cinerea
Control: Chemical
Development Stage: Full Operational

Good progress! (T. Laurent, USFS, R-10, Juneau.)

K. Fusarium Hypocotyl Rot
Host: Sugar pine, red & white fir bareroot seedlings
Causal Organisms: Fusarium oxysporum
Control: Chemical
Development Stage: Experimental Field Trials

Fungicides applied as seed coatings. No results yet. (K. Brownell, U. C. Berkeley and D. Adams, C.D.F. Sacramento.)

Kenelm Russell, Chairman, WIFDWC Disease Control Committee

L. *Damping-off*
Host: Ponderosa pine
Causal Organisms: *Fusarium* and *Pythium*
Control: Chemical
Development Stage: Full Operational

Seedling density increases with fumigation. Fusarium and pythium populations decrease (big deal!). Therefore, we will continue to fumigate. (E. Wood, USDA-FS, R-3.)

M. *Sirococcus tip blight*
Host: 1 and 2-year-old bareroot ponderosa pine seedlings
Causal Organisms: *Sirococcus strobilinus*
Control: Chemical
Development Stage: Full Operational

Detected in two north Idaho nurseries Sept. 1980. One-year-old seed beds were hand sprayed with Chlorothalonil (Bravo-500) in the fall but reoccurrence this spring has required frequent sprays to help reduce spread. (John Schwandt, IDL)

II. Foliage Diseases

A. *Swiss Needlecast*
Host: Douglas-fir
Causal Organisms: *Phaeocryptopus guamannii*
Control: Chemical
Development Stage: Field Trial

Trials using Chlorothalonil (Bravo 500), Dithane M-45 and Benlate 50wp established that excellent control can be obtained with one application of chlorothalonil (3 pints/acre) or Dithane M-45 (2.5 lbs/acre) applied June 1 to June 15 (J. Hadfield, USFS, Portland, Northwest Christmas Tree Growers Association).

B. *Larch Needlecast*
Host: Western larch, 2-0
Causal Organisms: *Meria laricis*
Control: Chemical
Development Stage: Field Trial

Benlate, Ronilan, Dithane M-22, Ziram and Carbamate applied 3/6/81-7/27/81 as foliar spray every two weeks. Treatment with Benlate and Dithane M-22 resulted in best control of needlecasting (<5%) compared to check plots (>50%). (Salley Cooley, USFS, FPM, Portland).

C. *Lophodermium needlecast*
Host: Scotch pine Christmas trees
Causal Organisms: *Lophodermium seditiosum* and *Naemacyclus* sp.
Control: Chemical
Development Stage: Full Operational

Detected in two Christmas tree plantations near Sandpoint, Idaho, this spring causing severe defoliation. Periodic sprays of Maneb using backpack sprayers were initiated for control. (John Schwandt, IDL)

III. Root Rots

A. *Annosus Root Rot*
Host: White and Subalpine fir
Causal Organisms: *Fomes annosus*
Control: Chemical
Development Stage: Field Trial

Borax stump treatment in hazard tree clean-up of campground areas on the Dixie National Forest, Utah (B. Tkacz, USFS, FPM, R-4, Ogden)

B. *Annosus Root Rot*
Host: Ponderosa pine
Causal Organisms: *Fomes annosus*
Control: Chemical
Development Stage: Field Trial

Initial trial in Intermountain Region of borax and duff stump treatments. (R. Williams, J. Marshall and J. Hoffman, USFS, FPM, R-4, Boise).

C. *Fomes Root Rot*
Host: Western Hemlock
Causal Organisms: *H. annosum*
Control: Chemical and Silvicultural
Development Stage: Field Trial and Laboratory

1. Further testing of chemicals for controlling stump infection by *F. annosus* following tree felling.
2. Studies are underway on determining the period that freshly cut stumps continue to be susceptible to infection by airborne spores of *F. annosus* (C. Driver and R. Edmonds, Univ. of Washington, College of Forest Resources).

D. *Laminated Root Rot*
Host: Northwest Conifers
Causal Organisms: *Phellinus weirii*
Control: Chemical
Development Stage: Field Trial

Fumigants applied to stumps eradicated *P. weirii* from most treated stumps: Chloropicrin, Vapam, Vorlex and Allyl alcohol were all effective. Expanded trials continue (W.G. Thies, E. E. Nelson, USFS, R-6, Corvallis).

E. *Phellinus Root Rot*
Host: Douglas-fir
Causal Organisms: *Phellinus weirii*
Control: Biological
Development Stage: Field Trial

Slow progress is being made on the developing of a program for the detection and improvement of genetically controlled natural resistance of Douglas-fir to infection by *P. weirii*. (C. Driver and R. Edmonds, Univ. of Washington, College of Forest Resources.)

F. Armillaria Root Rot
Host: Douglas-fir, Grand fir
Causal Organisms: Armillaria mellea
Control: Silvicultural
Development Stage: Field Trial

Currently being set up - cut to be completed spring 1982. Testing four cutting systems: 1) salvage, 2) clearcut and plant with ponderosa pine and western larch, 3) seed tree with ponderosa pine and western larch, 4) seed tree with ponderosa pine, western larch and best Douglas-fir in disease center (looking for resistance in Douglas-fir). Also thinning natural Douglas-fir regeneration in an old Douglas-fir mortality center (S. Dubreuil, N. Martin, B. James, J. Byler, USFS, FPM, R-1, Missoula).

G. Armillaria Root Rot
Host: Ponderosa pine, Grand fir
Causal Organisms: Armillaria mellea
Control: Silvicultural
Development Stage: Field Trial

Extensive field trials were conducted in S. Central Washington, testing a vibrating stump puller mounted on a Drott 50 track driven loader. Data show it is very competitive with bulldozer stump removal. Has feasibility for future use pending minor modification. May also be feasible for use on laminated root rot (K. Russell, WDNR, Olympia).

H. Black Stain Root Disease
Host: Douglas-fir
Causal Organisms: Verticicladiella wagenerii
Control: Silvicultural
Development Stage: Pilot Operational

Survey of freshly cut stumps after harvest to estimate level of infection in stand. Training marking crews in symptomotology of disease (D. Adams, California Dept. Forestry).

IV. Rusts

A. Western Gall Rust
Host: Ponderosa Pine
Causal Organisms: Endocronartium harknessii
Control: Biological
Development Stage: Field Trial

Survey of the R-4 progeny test evaluation plantations to determine the impact of gall rust susceptible trees in the tree improvement program. One quarter completed (J. Hoffman, USFS, FPM, R-4, Boise).

B. White Pine Blister Rust
Host: Sugar Pine
Causal Organisms: Cronartium ribicola
Control: Silvicultural (genetic)
Development Stage: Field Trial, Greenhouse

1. Selection: New greenhouse tests result in greatly increased efficiency for screening candidates for major gene resistance. Field tests are showing other independently inherited mechanisms of resistance.
2. Seed for reforestation being collected in limited quantities from identified candidates in natural stands. Seed orchards not yet in production (B. Kinloch, PSW, Berkeley).

V. Wilt Diseases.

A. Dutch Elm Disease
Host: Ulmus spp.
Causal Organisms: Ceratocytis ulmi (Hylurgopinus rufipes, Sclytus multistriatus)
Control: Chemical
Development Stage: Operational

A special local needs label was obtained for use of Dursban 2E insecticide for control of the Native Elm Bark Beetle and the Smaller European Elm Bark Beetle in cut elm logs on centralized elm disposal sites (F. Baker and B. Phillipsen, University of Minnesota).

The summaries presented here are intended to serve you as a catalog of work going on in disease control throughout the west. The committee will serve other purposes when the need arises. At the 1981 meeting you decided by vote to keep a simple listing only. K.R.

Business Meeting Minutes

The business meeting was called to order by Chairman Larry Weir at 4:45 p.m. on September 16. A tape of the meeting recorded by Secretary Terry Shaw, is filed in the WIFDWC archives held by Gordy Wallis in Victoria, B.C. A summary of pertinent points is presented here.

REPORTS

Disease Control Committee.--The committee will continue to serve primarily to gather and catalog information. Committee meetings will be held during the conference at the discretion of its chairman (no formal meeting was held this year). This represents a continuation of the "as is" policy. The committee report, prepared by Chairman Ken Russell, is included in these Proceedings.

Mistletoe Committee.--The committee meeting, conducted by Bob Scharpf in Chairman John Laut's absence, was held during lunch on September 15. The committee report, prepared by John Laut, is included in these Proceedings.

Root Disease Committee.--The committee met at lunch on September 16. The report, prepared by Chairman Greg Filip, is included in these Proceedings.

Interim Program.--Chairman Bill Jacobi had received few suggestions by business meeting time; several suggestions, however, were subsequently gathered. His final report is included in these Proceedings.

Treasurer's Report.--The treasurer's report, presented in these Proceedings, shows a current balance of $946.13. Stewardship of our funds will continue to be entrusted to Ken Russell. Ken will investigate ways to increase the interest yield from our assets. WIFDWC funds can be used to help offset initial costs incurred by Chairman of Local Arrangements. In the future, the funds may also be used to help defray the cost of the Proceedings.

OLD BUSINESS

The minutes of last year's business meeting and Treasurer's report were approved as printed in the Proceedings of the twenty-eighth conference.

Errata.--Proceedings of the 1962 conference will be corrected to reflect that Victoria is in British Columbia, not Alberta.

Mailing List Update.--An updated mailing list is presented in these Proceedings. According to instructions, the Secretary-Treasurer used his discretion in revising the list. A basic guideline provided in the bylaws was followed: anyone other than a life member who has not attended a meeting within the last 3 years can be dropped from the mailing list. A computer file of the list is maintained by Bob Bega and Bob Scharpf In Berkeley. Members should inform them of changes so the list can be kept current and accurate.

Past Proceedings.--Gordy Wallis maintains a file and partial stock of past WIFDWC Proceedings. Members interested in obtaining copies of past Proceedings, or disposing of them, should contact Gordy.

1982 Meeting Place.--Fields Cobb colorfully described the location for our thirtieth annual meeting, the Stanford Sierra Lodge and Camp on Fallen Leaf Lake. The Lodge is near Lake Tahoe in the Sierra Nevada mountains. The conference will begin Sunday, September 12, and will end at noon Thursday, September 16. Daily room and board for the conference will be $50 per delegate, $50 per delegate's spouse, and $30 per student. The rate for students' spouses is being negotiated.) Transportation from the Lake Tahoe airport will be provided on Sunday.

NEW BUSINESS

1983 Meeting Location.--Jim Byler invited us to meet somewhere in northern Idaho, probably Coeur d'Alene. Greg Filip extended an invitation to meet in Bend, Oregon. Members voted to meet in the Coeur d'Alene area.

Cost of Proceedings: Is It Worth It?--A spirited discussion on budget problems and the value of the Proceedings was held. The Secretary-Treasurer is responsible for producing the Proceedings. Historically, financial responsibilities for the production have been met primarily by the Secretary-Treasurer's employer. Future difficulties may arise under this policy relative to our "nonpublication" disclaimer if the employer is the USDA Forest Service. A consenses suggests that the Proceedings provide a valuable mechanism for informal communication between members as well as a record of our activities. The disclaimer is important to protect the informal nature of the material presented. The membership seemed agreeable to provide additional funds if necessary in the future to support continued production of the Proceedings in their present form. Further discussion was tabled until the Tahoe meeting.

Dictionary of Common Names.--Gordy Wallis suggested that a dictionary of common names for forest tree diseases was needed. Art McCain indicated a committee of the American Phytopathological Society had addressed a similar need for other crops. Further discussion was tabled until the Tahoe meeting.

Election of Officers.--The local train for the WD&S Railroad (Wallis, Drummond, and Scarpa) was running on time. They recommended Bill Bloomberg for Chairman and Bill Jacobi for Secretary-Treasurer. Spared any further nominations from the floor, their recommendations were unanimously accepted. The "Bill Boys" will engineer the Tahoe Special. Subsequent to the conference, Chairman Bloomberg appointed Everett Hansen Program Chairman.

Everett Hansen
1982 Program Chairman

Treasurer's Report

Balance on hand following twenty-eighth meeting		$ 690.00
Interest paid July 1, 1980, through June 30, 1981		36.23
Total		$ 726.33
Twenty-ninth WIFDWC meeting:		
Receipts: Registration (89 people)	$2,691.79	
Deposit	90.00	
	1/$2,781.79	
Expenses	1/ 2,561.99	
Balance		$ 219.80
Balance September 30, 1981		$ 946.13

Deposit held: Washington State Employees Credit Union
P.O. Box WSECU
Olympia, WA 98507
Account No. 936258

Thanks to Ken Russell for maintaining the continuous WIFDWC account at the Washington State Employees Credit Union.

Note: Ken has secured papers for establishing us as a nonprofit organization with the IRS. He will investigate possibilities of investing our funds in a money market certificate. The purpose is to help defray the cost of the Proceedings, if necessary. Details will be presented at the business meeting of the Thirtieth WIFDWC.

1/Adjusted for exchange rate between U.S. and Canadian dollars.

Banquet Speaker(s)

John Corner presented a formal, indepth review of Native Indian pictographs in British Columbia. The excellent slides and commentary covered the various types, ages, and locations of pictographs in the Province. This preparation provided many WIFDWCers their first exposure to this ancient form of communication in art.

A more informal, "special paper," was also delivered, somewhat as a surprise, by Valerie Scarpa; the paper represented the effort of the CSU delegation. The paper, "The Occurrence and Etiology of *Spirgaella deformans* on Colombian Hardwoods" is summarized below to the best of Secretary Shaw's ability(?), memory, and embellishment.

Apparently, both natural stands and plantations of Colombian hardwoods on steep hillsides and valley floors are heavily damaged by this typical wilt-inducing ascomycete. Most recent surveys estimate that mortality is scattered over some 600 245.5 ha ± 200.15.

The disease cycle starts with arthrosporic microconidia of *S. deformans* germinating in primary leaf stomates and quickly moving into the functional xylem within which they are translocated to and concentrated at the tree base. This results in basal exudation of a yellow ooze with a fetid odor, technically called "YUKA-ICKA" by Colombian natives. Loosely transliterated, this represents "Butt-Pus" in English and Canadian. The Colombian timber beetle, *Hyloplylis foulishmalodorous*, copiously feeds on this exudate. Its precise role in disease development or spread, however, is unknown and not under study.

The perfect stage of *S. deformans* develops near the infection court high in the tree crown, resulting in giant pseudothecia that contain 251 spirohelical ascospores per each bitunicate ascus. Hyline at first ascospores melanize and suberize at maturity to a deep red.

An intensive survey of losses in three southern Columbian plantations was made between 1973-80. The prodigious quantities of data were functionally analyzed using stage 2 of Nelson and Fuller's curvilinear V-5 model. Although every angle was tried, no significant differences ($P<0.261$) were located.

Scientists at the C.R.A.P. Institute for higher biology in Frito, Colombia, have devoted 7 years of grueling labor to a large-scale breeding program that has culminated in the imminent release of a completely susceptible line of resistant trees.

Initial control efforts were directed at the unknown, but suspected vector. Hundreds of YCC students were armed with PVC flyswatters and were dropped off for a summer's work at several remote locations. Results over three continuous field seasons were fruitless as well as utterly useless. On one 10.1-ha experimental block, 3,000 cases of flyswatters were employed in a control effort that resulted in a positive cost/benefit ratio of +0.00005.

It was thus apparent that host elimination was the only remaining control option feasible for this disease. This control was implemented using decrepit D-4's on semipermanent loan from the Washington State Department of Unnatural Resources. Each machine was equipped with either a double stinger or a brush blade and reverse vibro-puller. Cleared land has been converted to successful plantations of *Cannabis pseudo-illusionious* much to the joy and profit of flyswatting YCCers and Colombian natives.

In conclusion, the Colombian Government would like to present the Canadian Government, through WIFDWC, the remaining 5,000 cases of PVC flyswatters.

Publications

Andrews, M. W. Studies of discoloration and decay in American elm (Ulmus americana L.) resulting from systemic injections for the control of Dutch elm disease. St. Paul, MN: University of Minnesota; 1981. 78 p. Thesis.

Andrews, M. W.; Blanchette, R. A.; French, D. W. Effects of benzimidazole compounds for Dutch elm disease control on wood surrounding elm injection sites. Plant Dis. [In press].

Andrews, M. W.; Blanchette, R. A.; French, D. W. Internal injury associated with systemic injections of elms for the control of Dutch elm disease. Phytopathology. 71: 857; 1981.

Baker, F. A.; French, D. W. Spread of Arceuthobium pusillum, and rates of infection and mortality in black spruce stands. Plant Dis. 64: 1074-1076; 1981.

Baker, F. A.; French, D. W.; Hudler, G. W. Development of Arceuthobium pusillum on inoculated black spruce. For. Sci. 27: 203-205; 1981.

Baker, F. A.; Scherman, P. J. A microcomputer based system for evaluation of dwarf mistletoe impact in black spruce stands. Phytopathology. 71: 858; 1981.

Blanchette, R. A. Biological decay of forest residues. Pullman, WA: Washington State University; 1979. 75 p. Dissertation.

Blanchette, R. A. A new technique to measure tree defect using an image analyzer. Plant Dis. [In press].

Blanchette, R. A. Phellinus (Fomes) pini decay associated with sweetfern rust in jack pine. Can. J. For. Res. [In press].

Blanchette, R. A. Wood decay: a submicroscopic view. J. For. 12: 734-737; 1980.

Blanchette, R. A.; Sutherland, J. B.; Crawford, D. L. Actinomycetes in discolored wood of living silver maple. Can. J. Bot. 59: 1-7; 1981.

Blanchette, R. H. Wood decomposition by Phellinus (Fomes) pini: a scanning electron microscopy study. Can. J. Bot. 58: 1497-1503; 1980.

Bloomberg, W. J. A case for structured, modular, simulation models in plant pathology research. Prot. Ecol. 2: 209-213; 1980.

Bloomberg, W. J. Disease assessment models. Phytopathology. 71: 103; 1981.

Bloomberg, W. J.; Cumberbirch, P. M.; Wallis, G. W. A ground survey method for estimating loss caused by Phellinus weirii root rot: I. Development of survey design. BC-R-3. Victoria, BC: Department of Environment, Canadian Forestry Service, Pacific Forest Research Centre; 1980.

Bloomberg, W. J.; Cumberbirch, P. M.; Wallis, G. W. A ground survey method for estimating loss caused by Phellinus weirii root rot: II. Survey procedures and data analysis. BC-R-4. Victoria, BC: Department of Environment, Canadian Forestry Service, Pacific Forest Research Centre; 1980.

Bloomberg, W. J.; Smith, R. B.; Van Der Wereld, A. A model of spread and intensification of dwarf mistletoe infection in young western hemlock stands. Can. J. For. Res. 10(1): 42-45; 1980.

Beard, T. H.; Martin, N. E. Sites characteristic of lodgepole pine and stalactiform blister rust. Tech. Rep. 13. Moscow, ID: University of Idaho; Forest, Wildlife and Range Experiment Station; 1981. 19 p.

Boutz, G. E.; Lynch, K. D.; James, R. L. Cankers of cottonwood cuttings in Kansas State and Extension Forestry Nursery rooting beds: fungal associates and control evaluations. R2-80-5. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1980. 10 p.

Chacko, R.; Rogers, J. D. Cultural characteristics of some species of Xylaria. Mycologia. 73: 415-428; 1981.

DeMars, Donald J. Estimates of the occurrence of dwarf mistletoe on the Deschutes National Forest. Res. Note PNW-364. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 11 p.

Dooling, O. J. Evaluation of dwarf mistletoe control projects, Garnet Resource Area, Bureau of Land Management. FPM 81-3. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 5 p.

Dooling, O. J. Evaluation of dwarf mistletoe control projects, Sula and Darby Ranger Districts, Bitterroot National Forest. FPM 81-5. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 5 p.

Dooling, O. J.; Eder, R. G. An assessment of dwarf mistletoes in Montana. FPM 81-12. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 17 p.

Dooling, O. J.; Eder, R. G. Dwarf mistletoe loss assessment on the Flathead and Kootenai National Forests, Montana. FPM 81-2. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 4 p.

Dooling, O. J.; Haglund, S. Evaluation of proposed dwarf mistletoe treatments for fiscal years 1981-1985, Flathead Indian Reservation, Montana. FIDM 80-19. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1980. 4 p.

Florance, E. R.; Noble, E. L.; Shaw, C. G., III. Comparison of *Fomes annosus* basidiospore structure to other species of *Fomes* and related genera of the Polyporaceae: a light and scanning electron microscope study. Phytopathology. 71: 362; 1981. [Abstract].

French, D. W.; Baker, F. A.; Laut, J. Dwarf mistletoe on white spruce in Sprucewoods Provincial Park, Manitoba. Can. J. For. Res. 11: 187-189; 1981.

Fuller, L. R. Dwarf mistletoe surveys, Bow River Section Wyoming State Forestry Division. R2-80-10. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1980. 18 p.

Fuller, L. R.; Gillman, L. S.; Hildebrand, D. M. Production of pathogenic soil fungi at Mt. Sopris Tree Nursery and Big Sioux Conifer Nursery using Dowfume MC-33. R2-80-1. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1980. 13 p.

Fuller, L. R.; Hostetler, B. B. Annual report, Forest Insect and Disease Management, Rocky Mountain Region, 1979. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1980. 51 p.

Funk, A. "Buboes canker" of aspen in British Columbia. Bi-Mon. Res. Notes. Canadian Forestry Service; 1980; 36(6): 31-32.

Funk, A. A description of *Verrucaria plumbaria* Stizenb. on Douglas-fir. Mycologia. 72(2): 422-425; 1980.

Funk, A. *Pseudophacidium garmanii* n. sp., on interior spruce in British Columbia. Can. J. Bot. 58(23): 2447-2449; 1980.

Funk, A. The sclerophomas associated with dieback of Douglas-fir. Eur. J. For. Path. 10, Heft 1, 5, 53-57; 1980.

Funk, A. New *Therrya* species parasitic on western conifers. Can. J. Bot. 58(11): 1291-1294; 1980.

Funk, A.; Kuijt, Job. *Mycocalicium viscicola* n. sp. (Caliceaceae) on mistletoe viscin in South America. Can. J. Bot. [In press].

Funk, A.; Smith, R. B. Potebniamyces *gallicola* n. sp., from dwarf mistletoe infections in western hemlock. Can. J. Bot. 59: 1610-1612.

Goheen, D. J.; Cobb, F. W., Jr. Infestation of Ceratocystic wageneri-infected ponderosa pines by bark beetles (Copeoptera: Scolytidae) in the central Sierra Nevada. Can. Entomol. 112: 725-730; 1980.

Goheen, D. J.; Filip, G. M. Root pathogen complexes in Pacific Northwest forests. Plant Dis. 64: 793-794; 1980.

Goheen, D. J.; Filip, G. M.; Schmitt, C. L.; Gregg, T. F. Losses from decay in 40- to 120-year-old Oregon and Washington western hemlock stands. R6-FPM-045-1980. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1980. 19 p.

Harrington, T. C. Release of airborne basidiospores from the Pouch Fungus, *Cryptoporus volvatus*. Mycologia 72: 926-936; 1980.

Harrington, T. C.; Blanchette, R. A.; C. G. Shaw. In vitro chlamydospore formation by *Cryptoporus volvatus*. Mycologia 72: 1026-1030; 1980.

Harrington, T. C.; Furniss, M. M.; Shaw, C. G. Dissemination of Hymenomycetes by *Dendroctonus pseudotsugae* (Coleoptera: Scolytidae). Phytopathology. 71: 552-554.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. Forest management implications of improved residue utilization: biological implications in forest ecosystems. In: Harvesting and utilization opportunities for forest residues in the northern Rocky Mountains: Proceedings of a symposium; 1979 November 28-30; Missoula, MT. Gen. Tech. Rep. INT-110. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981: 259-267.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. The forest soil environment. In: Effects of fire on flora, a state-of-knowledge review: Proceedings, National Fire Effects Workshop; 1978 April 10-14; Denver, CO. Gen. Tech. Rep. WO-16. Washington, DC: U.S. Department of Agriculture, Forest Service; 1981: 52-55.

Harvey, A. E.; Larsen, M. J.; Jurgensen, M. F. Partial cut harvesting and ectomycorrhizae: early effects in Douglas-fir/larch forests of western Montana. Can. J. For. Res. 10(3): 436-440; 1981.

Harvey, A. E.; Jurgensen, M. F.; Larsen, M. J. Clearcut harvesting and ectomycorrhizae: survival of activity on residual roots and influence on a bordering forest stand in western Montana. Can. J. For. Res. 10(3): 300-303; 1981.

Hawksworth, Frank G. Los muerdagos enanos (*Arceuthobium*) y su importancia en la silvicultura de Mexico. In: Memoria del primer simposio de parasitologia forestal; 1980 February 18-19; Uruapan, Michoacan, Mexico. Champingo, Mexico: Universidad Autonoma de Champingo, Departmento de Bosques; 1980.

Hawksworth, Frank G. Modeling and prediction of losses caused by dwarf mistletoes. In: Crop loss assessment: Proceedings of the E. C. Stakman Commemorative Symposium; 1980 August 20-22; St. Paul, MN. Misc. Publ. 7. St. Paul, MN: University of Minnesota; 1980: 23-28.

Hawksworth, Frank G.; Bailey, D. K. Bristlecone pine. In: Eyre, F. H., ed. Forest cover types of the United States and Canada. Washington, DC: Society of American Foresters; 1980: 89-90.

Hawksworth, Frank G.; Edminster, Carleton B. Carlos Bates' mistletoe resistant ponderosa pines: a postscript after half a century. Res. Note RM-412. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 6 p.

Hawksworth, Frank G.; Laut, J. G. Scots pine is susceptible to Southwestern dwarf mistletoe. Plant Dis. 65: 263; 1981.

Hawksworth, Frank G.; Scharpf, Robert F. Phoradendron on conifers. For. Insect and Dis. Leafl. 16 (rev.). Washington, DC: U.S. Department of Agriculture, Forest Service; 1981.

Hopkins, J. C. Future challenges in forest disease control. In: Proceedings, Canadian Phytopathology Society. [In press].

Hopkins, J. C. Storage moulding. In: Proceedings, Western Forestry Conference; Victoria, BC; 1980.

Hunt, R. S. Rhytisimataceae on salal leaves. Mycotaxon. 11(1): 233-240; 1980.

Hunt, R. S. Variation in *Verticicladiella wagenerii*. Am. Phytopathol. Soc.; 1980. Abstract 122.

Hunt, R. S. White pine management. In: Proceedings, Western Forestry and Conservation Association; 1980. Abstract.

Hunt, R. S. Pine needle casts and blights in the Pacific Region. FPL-43. Victoria, BC: Department of Environment, Canadian Forestry Service, Pacific Forest Research Centre; 1981.

Hunt, R. S. *Trisetacus* (Acarina: Eriophyoidea) on *Pinus contorta* in British Columbia: distribution, symptoms and provenance effects. Can. J. For. Res. 11: 651-653; 1981.

Hutchins, Anita Stiebrs. In vitro inhibition of root-rot pathogens *Phellinus weirii*, *Armillariella mellea*, *Fomes annosus*, and *Phytophthora cinnamomi* by a newly isolated Bacillus sp. Microb. Ecol. 6: 253-259; 1980.

James, R. L. Engelmann spruce needle and twig blight at the Coeur d'Alene Nursery, Idaho. 80-21. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1980. 5 p.

James, R. L.; Cobb, F. W., Jr.; Wilcox, W. W.; Rowney, D. L. Effects of photochemical oxidant injury of ponderosa and Jeffrey pines on susceptibility of sapwood and freshly cut stumps to Fomes annosus. Phytopathology. 70: 704-708; 1980.

James, R. L.; Dewey, J. E. Summary of forest insect and disease conditions in the Northern Region--1980. 81-1. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 23 p.

James, R. L.; Goheen, D. J. Conifer mortality associated with root disease and insects in Colorado. Plant Dis. 65: 506-507; 1981.

James, R. L.; Staley, J. M. Photochemical air pollution damage survey of ponderosa pine within and adjacent to Denver, Colorado: a preliminary report. R2-80-6. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1980. 21 p.

James, R. L.; Stewart, C. L. Root disease survey on the Nezperce National Forest. 81-6. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 12 p.

Johnson, David W.; Hawksworth, Frank G.; Drummond, David B. Yield loss of lodgepole pine stands to dwarf mistletoe in Colorado and Wyoming National Forests. Plant Dis. 65(5): 437-438; 1981.

Johnson, D. W.; Hawksworth, F. G.; Drummond, D. B. 1979 dwarf mistletoe loss assessment survey on National Forest lands in Colorado. MAG 80-6. Davis, CA: U.S. Department of Agriculture, Forest Service, Forest Pest Management Methods Application Group; 1980. 18 p.

Johnson, D. W.; Lister, C. K.; Fuller, L. R. Winter drying injury on conifers, Pikes Peak Ranger District, Pike and San Isabel National Forests. R2-80-7. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1980. 13 p.

Johnson, D. W.; Peterson, G. W.; Telfer, W. G. Diplodia tip blight of ponderosa pine in the Black Hills, South Dakota. R2-81-1. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1981. 18 p.

Jurgensen, M. F.; Harvey, A. E.; Larsen, M. J. Effects of prescribed fire on soil nitrogen levels in a cutover Douglas-fir/western larch forest. Res. Pap. INT-275. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 6 p.

Kohler, S.; Dewey, J. E.; James, R. L.; Gibson, K. E.; Stipe, L. E. Forest insect and disease conditions in Montana--1980. 81-9. Missoula, MT: U.S. Department of Agriculture, Forest Service, Northern Region; 1981. 33 p.

Knutson, Donald M.; Hutchins, Anita Stiebrs; Cromack, Kermit, Jr. The association of calcium oxalate-utilizing *Streptomyces* with conifer ectomycorrhizae. Antonie van Leewenhoek; J. Microbiol. Serol. 46: 611-619; 1980.

Knutson, Donald M.; Tinnin, Robert. Dwarf mistletoe and host tree interactions in managed forests of the Pacific Northwest. Gen. Tech. Rep. PNW-111. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 19 p.

Livingston, W. H.; Wingfield, M. J. *Verticicladiella procera* on white pine in Minnesota. Plant Dis. [In press].

McCauley, Kevin J.; Cook, S. A. *Phellinus weirii* infestation of two mountain hemlock forests in the Oregon Cascades. For. Sci. 26(1): 23-29; 1980.

MacKenzie, Martin. The role of nitrogen-fixing bacteria in wood decay. Pullman, WA: Washington State University; 1981. 109 p. Dissertation.

Mark, Walter R.; Hawksworth, F. G. Taxonomic implications of branching patterns in the dwarf mistletoes (*Arceuthobium*). Phytologia. 47: 441-444; 1981.

Mathiasen, Robert L.; Hawksworth, Frank G. Taxonomy and effects of dwarf mistletoe on bristlecone pine on the San Francisco Peaks, Arizona. Res. Pap. RM-224. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1980. 10 p.

Morrison, D. J. *Armillaria mellea* root disease: a guide to disease detection, development and management in British Columbia. BC-X-203. Victoria, BC: Department of Environment, Canadian Forestry Service, Pacific Forest Research Centre; 1981.

Morrison, D. J. Effects of soil organic matter on rhizomorph growth by *Armillaria mellea*. Trans. Brit. Mycol. Soc. [In press].

Morrison, D. J. Variation among British isolates of *Armillaria mellea*. Trans. Brit. Mycol. Soc. [In press].

Nelson, E. E. Laminated root rot damage in a young Douglas-fir stand. Res. Note PNW-359. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 25 p.

Rogers, J. D. *Xylaria magnoliae* sp. nov. and comments on several other fruit-inhabiting species. Can J. Bot. 57: 941-945; 1979.

Rogers, J. D. The Xylariaceae: systematic, biological, and evolutionary aspect. Mycologia. 71: 1-42; 1979.

Rogers, J. D. *Hypoxylon weldenii* var. *microsporum* and *H. punctidiscum*. Mycologia. 72: 819-832; 1980.

Rogers, J. D. On the types of three putative species of *Eutypa* described by George Massee. Mycologia. 72: 622-625; 1980.

Rogers, J. D. *Sarcoxylon* and *Entonaema* (Xylariaceae). Mycologia. 73: 28-61; 1981.

Rogers, J. D. Two new *Hypoxylon* species from Gabon. Can. J. Bot. 59: 1363-1364; 1981.

Rogers, J. D.; Dumont, K. P. Los hongos de Colombia VI. Two new applanate species of *Hypoxylon*. Mycologia. 72: 807-810; 1979.

Raimo, B. J.; Sharon, E. M. Annual report, Forest Pest Management, Rocky Mountain Region, 1980. Lakewood, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Region; 1981. 22 p.

Roth, L. F.; Shaw, C. G., III; MacKenzie, M.; Crockett, F. H. Early patterns of Armillaria root rot in New Zealand pine plantations converted from indigenous forest--an alternative interpretation. N. Z. J. For. Sci. 9: 316-323; 1979.

Shaw, C. G., III. Characteristics of *Armillaria mellea* on pine roots within expanding infection centers of root rot. Northwest Sci. 54(2): 137-145; 1980.

Shaw, C. G., III; Laurent, T. H.; Israelson, S. Development of Sirococcus shoot blight following thinning in western hemlock regeneration. Res. Note PNW-387. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 6 p.

Shaw, C. G., III; MacKenzie, M.; Toes, E. H. A. Pentachlorophenol fails to protect seedlings of *Pinus radiata* from *Armillaria* root rot. Eur. J. For. Pathol. 10:344-349; 1980.

Shaw, C. G., III; Molina, R. Formation of Ectomycorrhizae following inoculation of containerized Sitka spruce seedlings. Res. Note PNW-351. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 8 p.

Shigo, Alex L.; Hawksworth, Frank G. A dwarf mistletoe on red spruce in New Hampshire. For. Notes 142. Society for Protection of New Hampshire Forests; 1980 Fall: 22-23.

Sigler, L.; Whitney, H. S.; Carmichael, J. W. Chrysosporium filiforme: a new hyphomycete associated with the bark beetle *Dendroctonus ponderosae*. Mycotaxon. 1981.

Smeltzer, D. L. K. Studies of the biology and epidemiology of sweetfern rust (*Cronartium comptoniae* Arth). St. Paul, MN: University of Minnesota; 1980. 38 p. Thesis.

Smeltzer, D. L. K.; French, D. W. Factors affecting spread of *Cronartium comptoniae* on the sweetfern host. Can. J. For. Res. 11: 400-408; 1981.

Smith, R. B.; Funk, A. Assessing *Nectria macrospora* as a biological control agent of hemlock dwarf mistletoe. Bi-Mon. Res. Notes. Department of Environment, Canadian Forestry Service; 36(3): 11-12; 1980.

Smith, R. B.; Wass, E. F. Tree growth on skidroads on steep slopes logged after wildfires in central and southeastern British Columbia. BC-R-6. Victoria, BC: Department of Environment, Canadian Forestry Service, Pacific Forest Research Centre; 1980.

Staley, John; Raymond, Gerry; Harvey, George; Deskins, Robert; Davison, Arlen; Russell, Kenelm. Control of Lophodermium needlecast in Pacific Northwestern Scotch pine. Northwest Lookout; 1981 May: 36-40.

Sutherland, J. R. Time, temperature and moisture effects on incidence of *Caloscypha fulgens*-diseased seeds in Sitka spruce cones. Can. J. For. Res. 11: 727-730; 1980.

Sutherland, J. R. Effects of inland spruce cone rust, *Chrysomyxa pirolata* Wint., on seed yield, weight and germination. CFS Res. Notes. Department of Environment, Canadian Forestry Service; 1(2): 8-9; 1981.

Sutherland, J. R.; Anderson, R. L. Seedling disease and insect problems related to nursery soil conditions in North America. In: Proceedings, North American Forest Tree Soils Workshop; Syracuse University; 1980: 182-190.

Sutherland, J. R.; Lock, W.; Benson, L. E. Disease and insects and their management in container nurseries. In: Proceedings, Canadian Containerized Forest Tree Seedling Symposium; 1981 September 14-16; Toronto, Ontario; 1981.

Sutherland, J. R.; Lock, W.; Farris S. H. *Sirococcus* blight: a seed-borne disease of container-grown spruce seedlings in coastal British Columbia forest nurseries. Can. J. Bot. 59(5): 559-562.

Sutherland, J. R.; Rink, U.; McMullan, E. E.; Woods, T. A. D. Isozyme characteristics of *Caloscypha fulgens*-infested and pathogen-free spruce seed samples and use of alkaline phosphatase activity for qualitative and quantitative disease incidence assays. Can. J. For. Res. 11(2): 200-205; 1981.

Sutherland, J. R.; Van Eerden, E. Diseases and pest insects in British Columbia forest nurseries. Jt. Rep. 12. British Columbia Ministry of Forests; Canadian Forestry Service; 1980.

Thies, Walter G.; Owston, Peyton W.; Hansen, Dian. Effects of four fungicides on survival and growth of containerized Douglas-fir seedlings: greenhouse performance. Can. J. For. Res. 10(3): 423-425; 1980.

Thomson, A. J.; Sutherland, J. R.; Woods, T. A. D.; Moncrieff, S. M. Evaluation of seed disease effects in container nurseries, as illustrated by *Caloscypha fulgens* on Sitka spruce. For. Sci. [In press].

Thomson, A. J.; Moncrieff, S. M. Bud burst in Douglas-fir: estimation of degree-day requirements. Can. J. For. Res. [In press].

Thomson, A. J.; Van Sickle, G. A. Estimation of tree growth losses caused by pest activity. Can. J. For. Res. 10(2): 176-182.

Wallis, G. W.; Bloomberg, W. J. Estimating the total extent of Phellinus weirii root rot centers using above- and below-ground disease indicators. Can. J. For. Res. [In press].

Wallis, G. W.; Morrison, D. J.; Ross, D. W. Tree hazards in recreation sites in British Columbia. Jt. Rep. 13. British Columbia Ministry of Lands, Parks, and Housing; Canadian Forestry Service; 1980.

Whalley, A. J. S.; Rogers, J. D. The geniculate conidial state of Hypoxylon chestersii. Trans. Brit. Mycol. Soc. 74: 439-440; 1980.

Wingfield, M. J.; Blanchette, R. A.; Nicholls, T. H.; Robbins, K. The pine wood nematode: a review of the situation in the United States. Can. J. For. Res. [In press].

Woo, J. Y.; Martin, N. E. Scanning electron microscopy of Cronartium ribicola infecting Ribes leaves. Eur. J. For. Pathol. 11: 7-15; 1981.

New And Modified Projects

A. Forest Disease Surveys--General

71-A-4 Appraisal of damage caused by forest pests in British Columbia. (R. Alfaro and G. Van Sickle).

71-A-5 Forest insect and disease survey (G. Van Sickle).

71-A-7 Disease sampling in Douglas-fir plantations (G. Wallis).

71-A-9 Forest insect and disease survey in the prairie Provinces, Yukon, and Northwest Territories (Y. Hiratsuka and H. Wong).

73-A-4 Forest disease: diagnostic and taxonomic services and research (J. Hopkins and R. Hunt).

74-A-1 Disease (and insect) detection surveys in Colorado forests (J. Laut and M. Schomaker).

74-A-2 *Verticicladiella* in Douglas-fir in Oregon (E. Hansen).

76-A-1 Annual disease and insect detection surveys in Idaho forests (J. Schwandt and R. Livingston).

78-A-1 Evaluation of jack pine mortality in the Nebraska National Forest (E. Sharon).

79-A-1 DISACC: a computerized access and analysis system for forest tree problems (A. Partridge).

79-A-2 Standardizing damage estimation procedures for inventory foresters: a pictorial system (A. Partridge).

80-A-1 Standard damage estimating systems for major disease and insect problems in the inland Northwest (A. Partridge).

81-A-1 Pilot testing in R-3 of the pest damage inventory procedures developed in R-5 to provide estimates on disease losses for FIDIS (E. Wood).

81-A-2 Region-wide surveys to establish impacts of root rots for FIDIS (L. Fuller and D. Johnson).

81-A-3 Appraisal of damage caused by forest pests in the prairie Provinces (B. Moody).

81-A-4 Disease-caused growth impact in southern Utah commercial aspen stands (B. Tkacz).

81-A-5 Evaluation of disease occurrence and conifer family/disease occurrence associations in intermountain tree improvement plantations (J. Hoffman and J. Marshall).

81-A-6 Mortality of *Chamaecyparis nootkatensis* in southeast Alaska (T. Shaw and T. Laurent).

B. Non-Infectious Diseases

68-B-1 Detection of chronic photochemical oxident injury to conifers by remote sensing (P. Miller, R. Bega, and R. Heller).

68-B-2 Physiological impact on ponderosa pine growing under natural conditions of chronic exposure to oxidant air pollution (P. Miller).

71-B-1 Influence of the forest canopy on total oxident concentrations (P. Miller).

71-B-2 The effect of atmospheric effluents on the forest (D. Hocking and S. Malhotra).

72-B-1 Effects of smoke on forest disease fungi (J. Parmeter).

72-B-2 Chronic effect of photochemical oxident air pollution on the composition of the ponderosa pine-sugar pine-fir forest cover type (P. Miller).

78-B-2 Evaluation of air pollution effects on ponderosa pine in the Colorado Front Range (E. Sharon and J. Staley).

80-B-1 Evaluation of ozone susceptibility of forest vegetation in Colorado (W. Aitkin, J. Staley, and W. Jacobi).

80-B-2 Trend of ozone injury to conifers in the southern Sierra Nevada (J. Pronos and D. Vogler).

81-B-2 Determining the sensitivity of Rocky Mountain ponderosa pine seedlings to ozone (W. Aitken, J. Staley, and W. Jacobi).

C. Cone, Seed, and Seedling Diseases

71-C-1 Occurrence of endophytic fungi in conifer seedlings (W. Bloomberg).

76-C-1 Diseases of seeds and cones. PC-14-246 (J. Sutherland).

76-C-2 Simulation of forest nursery diseases. PC-40-157 (W. Bloomberg).

76-C-3 Potential of several species of *Phytophthora* for damage to coniferous forests and forest nurseries (E. Hansen and L. Roth).

77-C-1 Nursery disease problems at the Albuquerque Tree Nursery (E. Wood and J. Riffle).

78-C-2 Greenhouse and nursery pathogenicity and symptomatology of four soil-borne fungi on five commercial species of conifers at various ages of growth (R. Bega).

78-C-3 Chemical and biological control of sugar pine root diseases at the Placerville Nursery, U.S. Forest Service, using seven fungicides and one suppressive soil (R. Bega).

79-C-4 Identification of fungi on Northern Region conifer seed, their detrimental effects, and methods to reduce detrimental effects (J. Woo and R. James).

80-C-1 Fungicide efficacy tests to evaluate control of Botrytis blight at the Coeur d'Alene Nursery, Idaho (R. James and J. Woo).

80-C-2 Sugar pine hypocotyl rot in California forest nurseries. Etiology, inoculum sources, and host-parasite physiology (K. Brownell).

80-C-3 Effects of herbicides on mycorrhizae development of conifer seedlings in Rocky Mountain-Great Basin tree nurseries (A. Harvey and R. Ryker).

80-C-4 Pathogenesis of Fusarium on sugar pine at the Medford Nursery (C. Li, W. Thies, and E. Nelson).

80-C-5 Detection, identification, and quantification of impact of fungi on developing cones and seeds of Douglas-fir and western white pine (S. Cooley).

80-C-7 Parameters to describe normal and disease tree seedlings (A. Partridge).

81-C-1 Seed treatments to reduce mold on white pine seed (J. Schwandt).

81-C-2 *Sirococcus* shoot blight on ponderosa pine seedlings (J. Schwandt).

81-C-3 Seedcoat sterilization of conifer seeds using hydrogen peroxide (L. Fuller).

81-C-4 Mesurol^{R} as a seed treatment to reduce bird predation (L. Fuller).

81-C-5 Reduction of pathogenic soil fungi in a forest nursery using solar radiation (L. Fuller).

81-C-6 Control of Fusarium cortical root in containerized conifers (L. Fuller).

81-C-7 Control of nursery pathogens and weeds by solarization (S. Cooley).

81-C-8 Control of *Meria laricis* on larch seedlings with fungicides (S. Cooley).

81-C-9 Control of Phytophthora root rot of true fir with Subdue (Ridomil) (S. Cooley).

81-C-10 Outplanting success of larch seedlings infected with *Meria laricis* (S. Cooley).

81-C-11 Outplanting success of noble fir seedlings grown in *Phytopthora*-infested soil (S. Cooley).

81-C-12 Benomyl and captan residues and biological activities in forest nursery soils (C. Li and E. Nelson).

81-C-13 Efficacy of inoculating *Pisolithus tinctorius* into conifer seedbeds at Lucky Peak Nursery (J. Marshall).

81-C-14 Survival and growth of seedlings in root disease centers (M. Militante and A. Partridge).

81-C-15 Pathogenicities and modes of infection of some fungi isolated from seeds and symptomatic seedlings of conifers (B. Advincola and A. Partridge).

81-C-16 Influence of pH and temperature on growth of and infection by a *Cylindrocarpon* sp. (B. Advincola and A. Partridge).

81-C-17 Root disease fungi of conifer seedlings not previously reported in the inland northwestern United States (B. Advincola and A. Partridge).

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

66-D-1 Investigations on the occurrence and control of *Fomes annosus* (C. Driver).

66-D-2 Studies on the cytology and genetics of *Fomes annosus* (C. Driver).

66-D-3 Studies on the effects of site treatments (slash burning, fertilization, mechanical soil disturbance, etc.) on limiting the abilities of *Phellinus weirii* to infect the regenerating stand (C. Driver).

69-D-3 Relative species susceptibility to *Phellinus weirii* infection (E. Nelson).

71-D-2 *Phellinus weirii* root rot: biology and control (G. Wallis and D. Morrison).

71-D-3 *Fomes annosus* root and butt rot: biology and control (D. Morrison).

72-D-2 *Armillaria mellea* root disease: development and testing of stand management guidelines (D. Morrison).

72-D-3 Identification, distribution and intensity of root rots in western Montana and northern Idaho (R. James and S. Dubreuil).

73-D-1 Testing native conifer plantings for resistance to *Phellinus weirii* (K. Russell).

73-D-2 Testing red alder plantings to reduce *Phellinus weirii* development (K. Russell).

73-D-3 *Alnus rubra* as a biological control agent for *Phellinus weirii* (E. Hansen, E. Nelson, and J. Trappe).

73-D-4 Taxonomy and distribution of the endomycorrhizal fungi of the family Endogonaceae (J. Trappe).

74-D-2 The role of ectotrophic mycelium in the initiation of *Phellinus weirii* infections (E. Hansen).

74-D-3 Survival infectivity of *Phellinus weirii* in Douglas-fir stumps (E. Hansen).

74-D-4 Changes in severity of *Phellinus weirii* resulting from forest management (E. Hansen).

74-D-5 Cytology and sexuality of *Phellinus weirii* (E. Hansen).

74-D-6 Silvicultural prescriptions for management of stands affected by root diseases (N. Martin, R. James, and S. Dubreuil).

74-D-7 The role of ectomycorrhizas in conversion of nitrogen from inorganic to organic forms (C. Reid and R. France).

74-D-8 Selection and induction of drought resistance in trees from ecotypes of the Colorado Front Range: interaction of tree ecotype with its mycorrhizal symbiant (C. Reid and M. Cline).

76-D-1 An evaluation of *Verticicladiella* in Oregon (E. Hansen).

76-D-4 Simulation of root rot impact in second-growth coastal Douglas-fir stands (W. Bloomberg and G. Wallis).

76-D-5 Fertilization and root disruption to control laminated root rot of Douglas-fir (W. Thies and E. Nelson).

76-D-8 Evaluation of the rate of spread of black stain root disease, *Verticicladiella wagnerii*, in plantations (D. Goheen).

77-D-1 Characterization of zone lines formed on artificial media and in wood by *Phellinus weirii* (C. Li).

77-D-13 Inoculation of ponderosa pine seedlings with *Pisolithus tinctorius* (J. Riffle).

77-D-14 Evaluation of *Pisolithus tinctorius* inoculum produced by Abbott Laboratories for ectomycorrhizal development on pine species in container and bare-root nurseries in the Great Plains (J. Riffle).

78-D-1 Lab, greenhouse, and nursery tests on effect of six mycorrhizal fungi on five species of conifers (R. Bega).

78-D-5 Survival of *Phellinus weirii* in residual roots following stump removal and nitrogen fertilization (W. Thies).

78-D-6 Occurrence of *Phellinus weirii* beyond visible limits of infection (W. Thies).

78-D-7 Growth loss of Douglas-fir infected by *Phellinus weirii* (W. Thies).

78-D-8 Chemical control of *Armillaria* root rot near Glenwood, Washington (K. Russell).

78-D-9 *Fomes annosus* in thinned and chemically treated hemlock stands in Olympic Peninsula, Washington (D. Chavez, C. Driver, R. Edmonds, and K. Russell).

79-D-1 Surveys of root diseases in managed conifer stands in R-2 (R. Fuller and D. Johnson).

79-D-2 *Fomes annosus* on true firs in Colorado: distribution and impact (R. Fuller).

79-D-3 *Verticicladiella wagnerii* on pinyon pine at Mesa Verde National Park: disease spread characteristics and vector relationships (R. Fuller and C. Lister).

79-D-4 Interactions between root diseases and insects on true firs (R. Fuller).

79-D-5 Spread of *Armillaria mellea* disease centers in managed pine stands (R. Fuller).

79-D-9 Evaluation of effects of precommercial thinning in 10- to 20-year-old Douglas-fir plantations infected with *Armillaria* root rot in Oregon and Washington (G. Filip).

79-D-11 Evaluation of timber loss due to root disease in the Wagon Sale area, Sisters Ranger District, Deschutes National Forest, Oregon (G. Filip).

79-D-13 Comparison of root disease incidence in plantations of local versus nonlocal seed source stock (D. Goheen).

79-D-14 Occurrence of airborne spores of *Fomes annosus* at forest sites in southeast Alaska (T. Shaw).

79-D-15 Infection of Sitka spruce and western hemlock thinning stumps by *Fomes annosus* in southeast Alaska (T. Shaw).

79-D-16 Relative abundance of conidia and basidiospores of *Fomes annosus* in airborne inoculum (T. Shaw and E. Florance).

79-D-17 Evaluation of the incidence and impact of *Fomes annosus* in California fir stands (G. Slaughter, J. Mihaill, and J. Parmeter).

79-D-18 Evaluation of borax stump treatment for control of *Fomes annosus* in California fir stands (M. Schultz and J. Parmeter).

79-D-21 Displacement of *Phellinus weirii* from stumps by the antagonist, *Trichoderma viride* (E. Nelson and W. Thies).

79-D-22 Chemical control of *Phellinus weirii* (W. Thies and E. Nelson).

79-D-23 Susceptibility of Pacific Northwest conifers to laminated root rot (W. Thies and E. Nelson).

79-D-24 Conifer culture with roots in nutrient mist (A. Harvey).

79-D-25 Spatial relations of tree species in root disease areas (N. Martin).

79-D-26 Fungi and insects associated with and causing black stain root disease in Idaho (A. Partridge).

79-D-29 Evaluation of selected mycorrhizal fungi for improving the survival and growth of container grown Sitka spruce in southeast Alaska (T. Shaw).

79-D-30 Effect of red alder, cottonwood, and Douglas-fir on nitrogen and microbiological activity in soil (C. Li).

80-D-2 Black stain root disease of western North American conifers. Epidemiology and taxonomy of *Verticicladiella wagnerii* (T. Harrington and F. Cobb).

80-D-3 Distribution and activity of conifer mycorrhizae in Rocky Mountain forest ecosystems: impacts of disturbance, species, and age (A. Harvey).

80-D-4 Effects of fire management and intensive forest utilization on soil nitrogen status in northern Rocky Mountain timber types (M. Jurgensen and A. Harvey).

80-D-5 Evaluation of effects of precommercial thinning in 10- to 20-year-old red fir plantations infected with *Armillaria* root rot in southern Oregon (G. Filip).

80-D-7 Losses caused by black stain root disease in intensively managed Douglas-fir stands, Coos Bay District, BLM (D. Goheen).

80-D-9 Biology and management of *Phellinus weirii* (E. Hansen).

80-D-10 Identification and characterization of high and low laminated root rot hazard sites in the coastal Douglas-fir region (E. Hansen).

80-D-11 Insect-fungus interactions in the development of black stain root disease in Douglas-fir (E. Hansen).

80-D-12 Occurrence of *Phytophthora lateralis* in the forests of California (J. Klienjunes and D. Adams).

80-D-13 Systems of organisms causing black stain in pine roots (A. Partridge).

81-D-1 Black stain root disease: biology and control (R. Hunt and D. Morrison).

81-D-2 Growth loss of Douglas-fir caused by *Phellinus weirii* (W. Bloomberg).

81-D-3 Effects of *Armillaria*/bark beetle complexes on residual stocking (R. Fuller and E. Lessard).

81-D-4 Logging effects on root disease areas (J. Schwandt).

81-D-5 Impacts of root disease control measures by silvicultural means on soil and site productivity (R. Smith and E. Noss).

81-D-6 Evaluation of factors contributing to *Armillaria* root disease risk to conifer regeneration on potential stand conversion sites in the upper peninsula of Michigan (J. Bruhn).

81-D-7 Mortality caused by *Fomes annosus* in 10- to 20-year-old lodgepole pine plantations in central Oregon (C. Schmitt).

81-D-8 Evaluation of the vibro stump puller in *Armillaria*-infected ponderosa pine stands (K. Russell).

81-D-9 Survey for root diseases on the Kootenai National Forest (R. James).

81-D-10 Evaluation of selected silvicultural treatments on root disease development in the Northern Region (S. Dubreuil, N. Martin, and R. James).

81-D-11 *Odontia bicolor* in coniferous root wood (C. Bertagnole and A. Partridge).

81-D-12 *Hylurgops porosus* as a possible carrier of *Verticicladiella* spp. (C. Bertagnole and A. Partridge).

81-D-13 Some conditions affecting the growth of *Perenniporia subacida* in culture and in wood (M. Chang and A. Partridge).

81-D-14 *Phellinus weirii* and *Phellinus furrugineo-fuscus* in wood: penetration and modes of action (E. Militante and A. Partridge).

81-D-15 Insect attractants produced by some *Verticicladiella* spp. and pine hosts (C. Bertagnole and A. Partridge).

81-D-16 Root disease agents associated with subalpine fir mortality in central and southern Utah (B. Tkacz).

81-D-17 Identification of root pathogens and development of root disease management strategies in southern Utah spruce forests (B. Tkacz).

81-D-18 *Fomes annosus*: longevity and rate of spread in a young ponderosa pine plantation (J. Hoffman and J. Marshall).

81-D-19 *Fomes annosus*: evaluation of methods to prevent introduction into and to remove existing inoculum from ponderosa pine stands in southwestern Idaho (R. Williams and J. Marshall).

81-D-20 Infection, development, and survival of *Fomes annosus* in large hemlock stumps created by clearcutting (B. van der Kamp).

E. Foliage Diseases

71-E-1 *Elytroderma deformans*: mortality and growth impact on Jeffrey pine (R. Scharpf and R. Bega).

74-E-1 Inheritance of resistance to *Rhabdocline pseudotsugae* in Douglas-fir (G. McDonald and G. Rehfeldt).

76-E-2 Evaluation of the growth impact of *Rhabdocline pseudotsugae* on sapling Douglas-fir in western Oregon (D. Goheen).

77-E-1 *Dothistroma pini* resistance in ponderosa pine (G. Peterson).

77-E-2 Inheritance of resistance to *Dothistroma pini* in Austrian pine (G. Peterson and D. Van Haverbeke).

77-E-4 Resistance to *Phomopsis juniperovora* in geographic sources of *Juniperus virginiana* and *J. scopulorum* (G. Peterson).

81-E-1 Needle casts on Christmas trees (J. Schwandt).

81-E-2 Impact (growth loss and mortality) of *Hypodermella laricis* and larch casebearer on western larch in northeastern Washington (D. Goheen).

81-E-3 Impact (growth loss and mortality) of *Meria laricis* and larch casebearer on western larch in eastern Oregon (J. Hadfield).

81-E-4 Fungicidal control of Swiss needle cast in Douglas-fir Christmas tree plantations in northwestern Oregon (J. Hadfield).

81-E-5 Registration of Daconil 2787, Dithane M-45, and Benlate for control of Swiss needle cast *Phaeocryptopus gaumannii* in Washington (K. Russell).

81-E-6 Identification of needle fungi associated with the "grey beard" needle disease of pines (R. Williams and J. Staley).

Stem Diseases, Malformations, Witches-Brooms, Dwarf Mistletoes, etc.

62-F-1 Life tables for lodgepole pine and ponderosa pine dwarf mistletoe (F. Hawksworth and T. Hinds).

62-F-2 Ecology of lodgepole and ponderosa pine dwarf mistletoes (F. Hawksworth).

62-F-4 Taxonomy, hosts, and distribution of *Arceuthobium* (F. Hawksworth and D. Wiens).

62-F-5 Silvicultural control of ponderosa pine dwarf mistletoe in the Southwest (F. Hawksworth).

63-F-1 Spread and intensification of dwarf mistletoe in ponderosa and Jeffrey pines in California (R. Scharpf and J. Parmeter).

65-F-1 The effect of dwarf mistletoe on growth of western hemlock (K. Russell).

68-F-4 Spread and intensification of dwarf mistletoe in young unistoried stands of western larch, Douglas-fir, and lodgepole pine with controlled stocking (N. Martin).

71-F-1 Growth impact, associated mortality, and spread and intensification of dwarf mistletoe in stands of Douglas-fir, lodgepole pine, and western larch (O. Dooling and N. Martin).

71-F-2 Dwarf mistletoe control in rural and suburban residential developments (J. Laut and F. Hawksworth).

72-F-1 Simulation of the effects of dwarf mistletoe in ponderosa pine and lodgepole pine stands (F. Hawksworth, T. Hinds, and C. Edminster).

76-F-4 Inoculation studies to determine the host ranges of *Arceuthobium campylopodum* and *A. occidentale* in California (W. Mark, R. Scharpf, F. Hawksworth).

76-F-5 Biology and epidemiology of a *Peridermium* associated with lodgepole pine dwarf mistletoe (F. Hawksworth).

78-F-1 Expanded field plot study (into southwest Oregon) of Douglas-fir dwarf mistletoe development in thinned precommercial stands (D. Knutson).

78-F-2 Control of dwarf mistletoe-caused losses in young true fir stands by thinning (R. Smith, R. Scharpf, and D. Vogler).

78-F-3 Population dynamics of dwarf mistletoe on true firs in California (R. Scharpf and J. Parmeter).

78-F-4 The effect of dwarf mistletoe on mortality and volume loss in released true fir stands (R. Scharpf).

78-F-5 Reduction of dwarf mistletoe-caused mortality of Jeffrey pines by broom pruning (R. Smith and R. Scharpf).

78-F-6 Simulation of hemlock dwarf mistletoe infection and spread (W. Bloomberg, R. Smith, A. Thomson).

79-F-1 Lodgepole pine dwarf mistletoe surveys in the Gunnison National Forest (D. Johnson).

79-F-3 Dwarf mistletoe loss assessment in Douglas-fir, lodgepole pine and western larch in Montana and north Idaho National Forests (O. Dooling).

79-F-4 Dwarf mistletoe infection in young-growth western hemlock beneath infected old-growth residuals in southeast Alaska (T. Shaw).

79-F-5 Genetics of resistance of western hemlock to dwarf mistletoe (B. van der Kamp).

79-F-6 Relationship between spread of dwarf mistletoe and stand development in western hemlock (B. van der Kamp).

79-F-7 Growth loss in managed, even-aged, dwarf mistletoe-infested stands of ponderosa pine in the Pacific Northwest (E. Nelson).

79-F-8 Impact of dwarf mistletoe in the Intermountain Region (J. Hoffman).

79-F-9 Evaluation of dwarf mistletoe effects and development of a yield program for mixed conifer stands in the Southwest (R. Mathiasen, R. Gilbertson, F. Hawksworth, C. Edminister, and R. Wood).

80-F-1 Dwarf mistletoe loss assessment surveys (D. Johnson and F. Hawksworth).

80-F-2 Seed production and viability loss assessment of dwarf mistletoe of lodgepole and ponderosa pines (D. Johnson, F. Hawksworth, J. Laut, and B. Schaffer).

80-F-4 Changes in plant growth regulators in black spruce associated with infection by eastern dwarf mistletoe (W. Livingston, M. Brenner, F. Baker, R. Blanchette, and D. French).

80-F-5 Seed collection, storage, and inoculation of eastern dwarf mistletoe on black spruce and white spruce (W. Livingston, R. Blanchette, and D. French).

80-F-6 Root disease fungi found on black spruce infected with eastern dwarf mistletoe (W. Livingston).

80-F-7 Evaluation of effects of dwarf mistletoe on the growth and release of understory grand fir in central Oregon (G. Filip).

80-F-8 Adaptation of RMYLD to predict yields in dwarf mistletoe-infected lodgepole pine stands in the Pacific Northwest (C. Schmitt).

80-F-9 Evaluation of effects of dwarf mistletoe on seed and cone production in lodgepole pine (B. Schaffer, F. Hawksworth, J. Laut, and D. Johnson).

80-F-10 Evaluation of dwarf mistletoe control projects in southwestern Idaho (J. Schwandt).

81-F-1 Resistance of Jeffrey pine to dwarf mistletoe, *Arceuthobium campylopodium* (R. Scharpf, B. Kinlock, and J. Jenkinson).

81-F-2 Correlation of ponderosa pine and Douglas-fir dwarf mistletoes with ecological factors (L. Merrill and F. Hawksworth).

81-F-3 Interactions of dwarf mistletoe and fire in lodgepole pine forests of the central Rocky Mountains (T. Zimmerman and F. Hawksworth).

81-F-4 Development of hemlock dwarf mistletoe following precommercial thinning of infected young stands in southeast Alaska (T. Shaw and T. Laurent).

G. Stem Diseases: Stains, and Decays

63-G-1 A study of *Ophiostomaceae* wood staining fungi in North America (R. Davidson).

72-G-2 Characterization and development of heartwood stain in *Populus trichocarpa* (A. Gokhele).

73-G-1 Decay associated with logging-damaged conifers in Oregon and Washington (P. Aho).

73-G-2 Tests of wound dressings on artificial injuries on western hemlock and Sitka spruce (P. Aho).

73-G-3 Decay hazard in advanced regeneration of tolerant conifers in Oregon and Washington (P. Aho).

73-G-4 The role of microorganisms in bark beetle epidemiology (H. Whitney).

77-G-1 Survey for *Fomes fraxinophilus* heart rot of green ash in natural stands in Nebraska (J. Riffle and E. Sharon).

79-G-1 Evaluation of decay in released stands of advanced grand and white fir regeneration in eastern Oregon and Washington (G. Filip and P. Aho).

79-G-3 *Phellinus robineae* stem decay of black locust: distribution, damage, and biology (J. Riffle).

79-G-4 Decay associated with logging wounds in young-growth white fir and red fir in northern California (P. Aho, R. Smith, and G. Fiddler).

79-G-5 Decays and cavity-nesting birds in the Pacific Northwest (A. Partridge).

79-G-7 Improved methods for identifying cultures of common wood-inhabiting fungi (A. Partridge).

80-G-1 Decay and height growth losses associated with Douglas-fir and grand fir tops killed by the spruce budworm in the Wenatchee and Okanogan National Forests (P. Aho).

80-G-2 The role of Actinomycetes in the discoloration and decay process of living trees (R. Blanchette).

80-G-3 *Inonotus andersonii* and decay of oaks in Arizona (K. Yohem and R. Gilbertson).

80-G-4 Rate of decay in mature grand fir and western hemlock infected by *Echinodontium tinctorium* in northern Idaho (J. Schwandt).

81-G-1 Identification of *Hiericium abietis* in old-growth silver fir stands in the Olympic Peninsula. Determination of decay indicators from this fungus for scalers (K. Russell).

H. Stem Diseases: Rusts and Cankers

53-H-1 Testing progeny of resistant pines for susceptibility to white pine blister rust in the Inland Empire (R. Bingham).

61-H-1 Streamlining pollination and progeny test methods in breeding for blister rust resistance in western white pine (R. Bingham).

61-H-2 Breeding and selection for climatic adaption in interspecies hybrids, toward accumulation of a pool of rust-resistance genes from other white pines of the world (R. Bingham).

66-H-1 Comparative physiology of varieties of western white pine with respect to their reaction to the blister rust fungus (R. Hoff).

66-H-4 Numbers and kinds of resistance genes and their relation to rust symptomatology (G. McDonald and R. Hoff).

66-H-5 Precise estimates of heritability and combining ability of rust resistance (G. McDonald).

66-H-6 Development and pathogenicity of *Hypoxylon fuscum* on northwestern species of alder (J. Rogers).

67-H-1 Etiology of aspen cankers (T. Hinds).

67-H-2 Field level of blister rust infection in early generation, partially resistant, western white pine stock (R. Hoff).

69-H-1 Thinning and pruning western white pine to control the blister rust disease (J. Byler and N. Martin).

71-H-3 Forest tree rusts of western North America (Y. Hiratsuka).

71-H-4 Computer simulation of white pine blister rust disease (G. McDonald and R. Hoff).

74-H-1 Rust fungi of Cupressaceae and Taxadeae: taxonomy and life histories (R. Peterson).

74-H-4 Biology, development, and systematics of *Hypoxylon* and its allies (J. Rogers).

74-H-6 Seed production areas for obtaining western white pine that is genetically improved for resistance to blister rust (R. Hoff and G. McDonald).

77-H-1 Characterization of Champion Mine race of *Cronartium ribicola* (G. McDonald and E. Hansen).

77-H-2 White pine blister rust (R. Hunt).

79-H-1 Diplodia tip blight in the Black Hills of South Dakota (G. Peterson and D. Johnson).

79-H-4 Ecological studies of spruce rust diseases in subarctic taiga forests. Coop with USFS and Univ. Alaska (J. McBeath).

80-H-1 Evaluation of aspen harvesting practices in Colorado and New Mexico (D. Johnson, T. Hinds, and J. Walters).

80-H-2 A survey of the incidence and impact of stem rusts and *Atropellis* canker on immature lodgepole pine in British Columbia (B. van der Kamp).

80-H-4 Genetic variation of gall frequency in lodgepole and ponderosa pine seedlings inoculated with western gall rust (R. Hoff).

80-H-5 Inheritance of horizontal resistance mechanisms (R. Hoff).

80-H-6 Verification of white pine blister rust simulation (G. McDonald).

81-H-1 Biology, cytology, and systematics of *Xylaria* (J. Rogers).

81-H-2 The effects of comandra blister rust on lodgepole pine: predicting the consequences of silvicultural treatments in rust-infected stands (B. Geils and W. Jacobi).

81-H-3 The etiology of Thyronectria canker on Colorado honeylocusts (W. Jacobi).

81-H-4 Mode of penetration and tissue invasion by *Endocronartium harknessii* (M. Chang and A. Partridge).

81-H-5 Biology and control of stem rusts of hard pines (R. Blanchette and D. French).

81-H-6 Wood deterioration by canker-rot fungi (R. Blanchette).

I. Wilt and Blight Disease

71-I-1 Dutch elm disease detection surveys in all municipalities in Colorado (J. Laut).

74-I-1 Control of Dutch elm disease using vector pheromones. Coop with USFS, NEFES, and CSFS. (C. Helburg, D. Leatherman, and J. Laut).

77-I-1 Distribution of Dutch elm disease and its principal vector, the smaller European elm bark beetle, in Montana urban areas (O. Dooling and S. Kohler).

77-I-3 *Diplodia pinea* tip blight on pines: etiology of stem infections (G. Peterson).

77-I-4 *Herpobasidium deformans* blight of honeysuckle: infection and control (J. Riffle).

79-I-1 Dutch elm disease control demonstration project in Colorado (D. Johnson and J. Laut).

79-I-2 Resistance to *Cerospora sequoiae* var. *juniperi* in geographic sources of *Juniperus virginiana* and *J. scopulorum* (G. Peterson).

80-I-1 Microbial antagonists as a biological control for Dutch elm disease (R. Blanchette).

80-I-2 Methyl bromide fumigation of oak wilt-infected oak logs (D. French).

81-I-1 Diplodia tip blight in the Black Hills of South Dakota (D. Johnson and G. Peterson).

J. Defects and Decays of Forest Products

58-J-1 Deterioration of beetle-killed Engelmann spruce in Colorado T. Hinds).

68-J-2 Role of heartwood microflora in the breakdown of thujaplicin in western redcedar heartwood (B. van der Kamp).

71-J-1 Evaluation of potential wood preservatives: Thiram and Thiram-Oxathiin mixtures (R. Smith and C. Johansen).

71-J-2 Analysis of aspen chip deterioration during outside storage R. Smith and C. Johansen).

72-J-1 Decay and shock resistance of western redcedar transmission poles in service (J. Roff and W. McGowan).

72-J-2 Utilization of decayed wood in pulp manufacture (K. Hunt).

72-J-3 Degradation and preservative treatments of western redcedar shingles and shakes (A. Cserjesi, R. Smith, and T. Littleford).

73-J-1 Interaction of fungi and chemicals--pentachloraphenol (A. Cserjesi).

76-J-1 Microdistribution and efficacy of preservatives in treated wood and their effects on microorganisms (W. Wilcox).

79-J-1 Diagnosis of wood decay (W. Wilcox).

K. Miscellaneous Studies

71-K-4 Species of *Mycospaerella* on Salicaceae in western interior of Canada (H. Zalasky).

71-K-5 Winter injury in poplar: a histological study (H. Zalasky).

71-K-6 Prevention of winter injury to conifers and other hardwoods (H. Zalasky).

72-K-1 The pathology of Ohia decline in Hawaii (C. Hodges).

73-K-2 Forest disease simulation model (W. Bloomberg).

73-K-3 Fungi of Washington State (J. Rogers).

76-K-2 Determination of cause of "drooping malady" in Colorado aspen (V. Scarpa, T. Hinds, and C. Livingston).

77-K-5 Development of operational use of biological control of forest pests in British Columbia. PC-45 (H. Whitney).

78-K-1 Effect of thinning on the incidence and impact of cytospora canker, fir engraver beetle, and *Fomes annosus* in white fir stands on the east-side Sierra Nevada (G. Ferrell, R. Scharpf, and J. Parmeter).

78-K-2 Reduction in stem volume of grand fir defoliated by western spruce budworm outbreaks in the Payette National Forest, Idaho (G. Ferrell and R. Scharpf).

79-K-1 Use of the Shigometer for assessment of tree vigor and growth in 25- to 100-year-old Sitka spruce and western hemlock (T. Shaw).

79-K-2 Mortality of Douglas-fir: biotic systems and impacts (A. Partridge).

79-K-3 Management alternatives in forests with Douglas-fir mortality centers (A. Partridge).

79-K-4 Revision and update of "Keys to major disease and insects..." in color (A. Partridge).

80-K-1 Evaluation of hazardous trees in forested recreation sites and ski areas (D. Johnson and E. Sharon).

80-K-2 Evaluation of diseases and their impact on Minnesota's shade trees (R. Blanchette).

80-K-3 Interactions among the pine wilt nematode, fungi, and bark beetles in the Midwest (M. Wingfield and R. Blanchette).

80-K-4 Evaluation of the Mount St. Helens eruptions on insect and disease activity in the blast area (J. Hadfield).

80-K-6 Computer programs to analyze street tree inventory data in urban areas of Idaho (J. Schwandt).

81-K-1 Comparative roles for saprophytic and pathogenic decays in Rocky Mountain forest soils: impacts of disturbance on regeneration and growth (A. Harvey and M. Larsen).

81-K-2 Life histories and anamorphs of lignicolous Pyrenomycetes (J. Rogers).

81-K-3 Hazard tree program for Washington's recreation area managers and homeowners (K. Russell and L. Mills).

81-K-4 Reestablishment of vegetation on Mount St. Helens-created debris flow: an unusual "pathological" event (K. Russell).

Interim Program Chairman's Report

William R. Jacobi

The following topics for discussion on an activity were suggested for the 1982 meeting:

1. Insect-disease relationships. Local entomologists should be encouraged to attend and participate in discussions on this topic. Actual IPM programs, joint loss assessment projects. How do IPM programs become a reality?
2. An entire day should be spent with discussions and workshops on black stain root disease. Display materials on the fungus and diseased trees should be included.
3. A field trip to observe Elytroderma in the Tahoe Basin area.
4. A clinic-workshop of foliage diseases found in the Tahoe Basin area.
5. The initiation of a weird pointer competition.
6. The initiation of a T-shirt competition.
7. Urban forest pathology. Is "research" supporting urban problems at an amount appropriate to the value of the resource? Who is responsible for urban forest pathology? Are we doing a good job in urban forest pathology research and extension?
8. Taxonomy: Genera revisions--why? What are the latest?, etc.
9. Extension: Who should be doing extension work? Can the reward system be modified so extension is as valuable as research? Do we need to educate the public about diseases and ourselves?
10. Loss assessment: Where is the West going in the area of loss assessment? Is it part of our goal? Or is it a subject we hope will go away? Are government edicts reasonable?
11. Invite foresters to attend and comment on our activities.
12. As part of the field trip, a workshop-look at highway salt damage to trees around Tahoe.

Procedural suggestions:

1. Each organization should explain what they are doing on each of their on-going projects in more detail than presently given. Thirty minutes for each group may be appropriate.
2. Encourage participants to bring copies of recent publications and display them.
3. Encourage participants to bring displays of work.
4. Change the title of "New, Modified, and Terminated Projects" to (1) Progress Reports on Research Projects, and (2) New Techniques.
5. Consider holding the meeting in August.