PROCEEDINGS OF THE 35th ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

Nanaimo, British Columbia
September 1987

Proceedings of the 35th Annual Western International Forest Disease Work Conference

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Compiled by:
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Proceedings of the Thirty-Fifth Western International Forest Disease Work Conference
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MINUTES AND REPORTS

IN MEMORIAM - OSCAR J. DOOLING

Oscar passed away on June 19, 1987 at Bellingham, Washington. He and Harriette had just completed a move from Missoula about a month previously. Oscar retired as forest pathologist with the Northern Region of the U. S. Forest Service in Missoula, Montana in January, 1986. Oscar was born in Galena, Missouri on January 7, 1931, and grew up in Jefferson City. During 1950-1954, he served in the Air Force. He did both his undergraduate work (BS in Forestry) and graduate work (MS in forest pathology) at the University of Missouri. He began his forestry career with a brief stint as forester at the USFS Regional Office in Altanta in 1962. Oscar then served as forest pathologist for the Forest Insect and Disease Management unit at Alexandria, Louisiana for 5 years and transferred to Missoula in 1967.

Oscar's strong desire to help on-the-ground foresters with forest pest problems was widely known throughout the Northern Region. Foresters all over the area have expressed their strong appreciation for his willingness to explain pest problems and to help managers to decide what to do about them. Oscar was renowned throughout the Inland Empire for his down-to-earth philosophy of forest pest control. His vast knowledge on forest pests in the Northern Region, particularly the dwarf mistletoes, was willingly shared with forest managers, homeowners, and researchers alike.

In spite of a number of severe heart problems over the years, Oscar will be remembered for his positive outlook on life and for his great sense of humor. He could always be counted on to liven up a conversation by dipping into his vast repertoire of jokes, usually of the North Dakota variety.

Oscar married Harriette Hoffman in 1970, and she was his constant companion and supporter. They are said to have met as Oscar visited Harriette's pharmacy to obtain wax for his legendary handle-bar moustache. Oscar and Harriette attended practically all the WIFDWC meetings over the last two decades and enjoyed the companionship that these meetings provided, both professionally and personally. Oscar was a active supporter of WIFDWC and served as Local Arrangements Chairman of the 1975 meeting in Missoula and Secretary-Treasurer of the 1980 meeting in Pingree Park, Colorado. He will be sorely missed.

Frank Hawksworth and Jim Byler.

These Proceedings are dedicated to the memory of Oscar Dooling.

CHAIRMAN'S WELCOME

John Muir

Honorary members, guests, forest pathologists, ladies and gentlemen:

Welcome to the 35th Western International Forest Disease Work Conference (WIFDWC). I am pleased to see that you are able to attend and support this organization.

The purpose of WIFDWC is, as you know, a session for informal discussions on mutual concerns about pathogens and forest diseases in Western North America - Canada, United States of America, and Mexico. The emphasis in this workshop is on informality and lively discussion.

WIFDWC runs on voluntary efforts of individuals who are sponsored by their employer organizations. This session was organized by your local arrangements committee headed by Janna Kumi, MacMillan Bloedel, and several members from other organizations including U.S. Forest Service, B.C. Forest Service, and Canadian Forestry Service. The program was organized by Jerry Beatty, and notices were prepared and sent by your secretary Gregg DeNitto.

We also thank Dr. Al Funk, and the Canadian Forestry Service, Pacific Forestry Centre, for hosting and organizing the workshop on identification of canker-causing fungi in Victoria, on Monday. This type of workshop where members can share their expertise and experience is extremely valuable and appreciated by all of us.

It is also appropriate at this time to acknowledge the contribution of former members of WIFDWC. Several honorary members are here today. We were very sorry to hear of the recent death of Oscar Dooling. Oscar was a longtime enthusiastic supporter of WIFDWC, and we will miss him. I ask you to join me in a moment of silence in memory of his contributions.

As Chairman, I also have the opportunity of talking about where we are going with WIFDWC. How can we in WIFDWC respond to some of the recent challenges facing forest pathology? For example, we are concerned with decreasing support for forest pathology research and services. Several members of WIFDWC are working on these and other issues, and it might be appropriate to consider a motion or resolution of support for these efforts at our business meeting on Friday.

We might also consider forming one or more committees to pursue further work on these topics between our annual meetings. A recent example of positive action of WIFDWC was the publication on common names of tree diseases by Frank Hawksworth, Bob Gilbertson, and Gordon Wallis. The B.C. Forest Service, and the Canadian Forestry Service, Pacific Forestry Centre, now recognize these names as the standard for British Columbia which is very helpful to our organizations in these days of changing scientific names.

I feel that the continued success and support for WIFDWC must depend not only upon the informal workshops and the benefits we gain by these discussions, but also on specific projects or achievements that will be of benefit to our employers.

Finally, as I have mentioned several times, WIFDWC is based on the efforts of individuals. WIFDWC is what we want it to be, and what we make it to be. Your participation is vital and very much appreciated.

WESTERN GALL RUST IN BRITISH COLUMBIA

Bart J. van der Kamp

ABSTRACT: The current status of a major project dealing with the inheritance of resistance of lodgepole pine to western gall rust is described. The distribution of the rust within and between trees, an inoculation technique, and symptom development are discussed. There is considerable variation in resistance between trees and half-sib families, but evidence for major genes for resistance or local variation in virulence of the rust has not so far been uncovered.

INTRODUCTION

Western gall rust (Endocronartium harknessii Hirat.) is a common pathogen of lodgepole pine in British Columbia. The rust is also found on other hard pines in the province, both native and introduced. The work on gall rust reported here started in 1981 and has involved a number of students. Currently Harrison Kojwang, Maureen Curran, and Jun Wang are in various stages of their thesis research dealing with this rust. Catherine Bealle, Margo Spence and Stephan Zeglen have completed substantial projects dealing with the disease. Hadrian Merler and Tom Hsiang were involved in some of the early field work, and Carolyn Scagel spent a hot summer working with the disease at the UBC nursery. Most of the field work has been done in one experimental area just SE of Prince George, B.C. and at the UBC forest nursery on the campus.

The project, funded by NSERC Canada, consists of several major parts, and I can only mention some highlights here. The initial work consisted of describing the disease as it is found in natural stands and plantations, dealing with such aspects as spatial distribution of infection within trees and stands, damage, and effects of juvenile spacing on infection. It soon became evident that genetics played a major role, and a set of experiments were established to determine how resistance was inherited. In order to conduct these it was necessary to develop a reliable inoculation technique and to describe in some detail the various symptoms (early and late) associated with resistant and susceptible reactions. The main thrust of the genetic work consists of determining the extent to which resistance is conditioned by major genes, and to look for variation in virulence and aggressiveness in the parasite. If all goes according to schedule, we will have some well supported answers within a few years.

DISTRIBUTION OF GALL RUST IN THE FIELD

Marked variation in infection levels between trees is the rule. Figure 1 shows the distribution of galls in a typical but rather lightly infected stand. The number of trees free of infection, as well as the number that are heavily infected is much larger than expected if all trees had an equal probability of infection. Figure 2 shows the relationship between the percent of trees infected and the average number of infections per tree in 20 blocks of a spacing plantation near Prince George. Even in the most heavily infected stands (we have observed up to a mean of 50 infections per tree), between 10 and 20

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percent of the trees remain uninfected. Part of the variation might be due to unequal distribution of inoculum arising when the first galls to be established in the stand begin to produce spores. To test whether this effect is likely to be important, we have mapped the location and degree of infection of all trees in the 20 replicates of the spacing trial mentioned above. In each block we selected the most heavily infected trees, and then divided the other trees into two groups, those immediately adjacent to a heavily infected tree and the remainder. We then compared the average number of infections in the two groups. Over the trial as a whole, the adjacent trees had a slightly but significantly lower level of infection than the trees farther removed from heavily infected trees. This result suggests that local variation in spore concentration does not play a major role in infection levels.

We also looked at the distribution of infections within the crown. The major conclusions were that 1. the rate of infection (galls per meter of branch length) decreases rapidly with height, such that the rate at one and two meters was more than ten times that at eight meters. This was true for both branch and stem infections; 2. infection rates were the same for all branching orders; and 3. infection rates were the same on all sides of the crown.

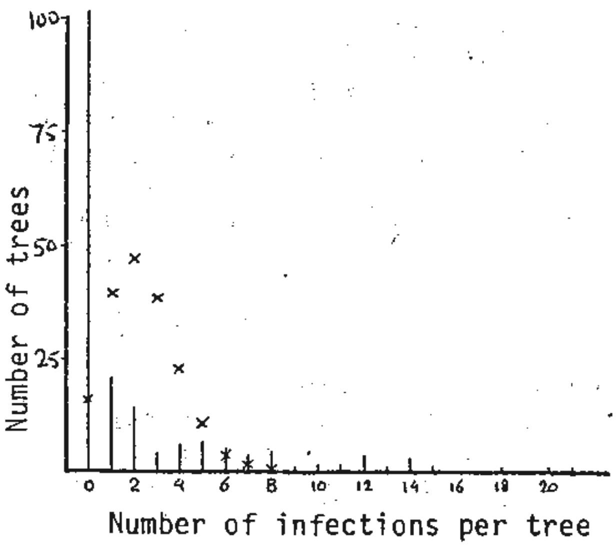

Figure 1--Distribution of number of infections per tree in an experimental 7 X 7 ft. spacing trial. Mean: 2.40 X-Poisson expectation if all trees are equally susceptible.

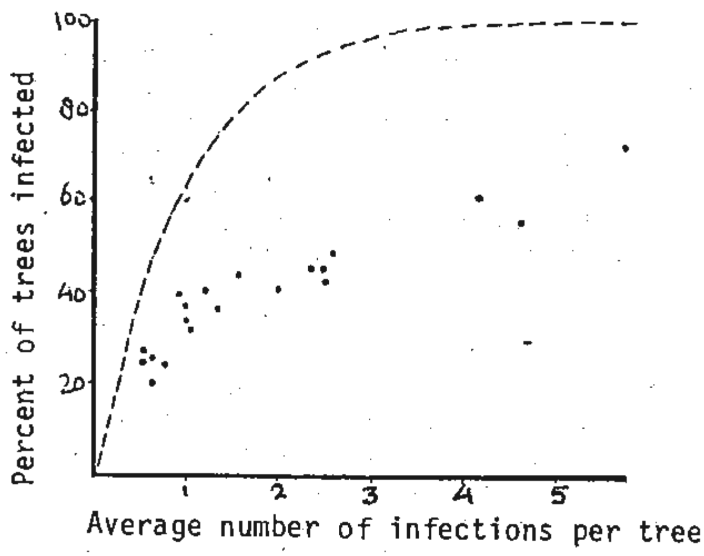

Figure 2--Percent of trees infected as a function of the average number of infections per tree in 20 blocks of a spacing trial. ---- Poisson expectation if all trees are equally susceptible.

Operational juvenile spacing usually leaves increased infection levels. The larger leave trees are on average also more heavily infected, no doubt as a result of their larger crown size. Following spacing, gall rust infection continues, and at rates similar to those found in unspaced controls. In four replicated and remeasured installations, 81% of the trees remained free of visible stalactiform (Cronartium coleosporioides Arth.), comandra (C. comandrae Peck) and gall rust stem infections and Atropellis canker two years after spacing and 60 % five years later. In the unspaced controls, the infection levels (as percentage of trees with stem infections) was about half that of the treated area. Infection by stalactiform rust increased markedly in the spaced areas; the other two rusts did not respond strongly to spacing.

We measured the incidence of gall rust and stalactiform rust in a large provenance trial (54 inland provenances of lodgepole pine, each represented by 15 half-sib families of 6 trees replicated in 3 blocks) at Prince George. There were highly significant differences between provenances and between families within the provenances. In general the provenances from areas in which infection is low (presumably because of climate) were most heavily infected at Prince George. This result is of some concern because it appears that productivity can be increased by moving provenances one to two degrees north. Such movement could at times result in substantial losses to the two rusts. One interesting feature of this study was that resistance to the two rusts was not related. This lack of relationship was evident at the provenance, the family and the individual tree level. Presumably the main resistance mechanisms to the two diseases are independently controlled.

INOCULATION TECHNIQUE.

In order to start work on inheritance of resistance it was first necessary to develop a reliable inoculation technique. After a number of false starts we settled on a dry spore technique in which a mixture of spore and fine silica is placed in a flask in a chamber together with the seedlings to be inoculated. The chamber is then partially evacuated and air admitted into the flask. After the spores have settled (10 minutes) the seedlings are taken out, sprayed to runoff with distilled water, and placed in a chamber at 18°C for 48 hours. After that seedlings are kept outside. All our inoculations are done in the spring using fresh spores and actively growing seedlings. The first symptoms show after two weeks (red staining of the epidermis). More develop in the course of the summer (necrosis, bark roughening, resinosis, and development of lateral shoots from primary needle axes in the infected area) and the first galls are evident by late August. More galls develop the next spring, and the final assessment is made 14 months after inoculation.

We use both eight week and one year old seedlings. The younger seedlings exhibit indeterminate growth and a section of the stem about one cm long and one cm below the growing tip is susceptible with occasional infection at the cotyledons. This apparently arises because the epidermis on the young stem is shed about six weeks after formation, and at that point the stems are no longer susceptible. It is therefore not possible to rate the degree of infection on such seedlings. We suspect that in most cases there are several separate successful penetrations within the short segment of susceptible stem tissue, but since they develop into a single large gall, it is not possible to determine how many.

One year old seedlings are inoculated when shoot elongation is about 70 % complete and the new needles are just beginning to emerge from their fascicles. The whole length of the new stem is susceptible, and up to 30 separate galls can be counted one year later. One year old seedlings also commonly have several shoots, each of which can be assessed separately. It follows that one year old seedlings allow assessment of the degree of susceptibility as expressed by the average number of galls per seedling or per shoot. This measure is not available when using eight week seedlings.

SYMPTOM DEVELOPMENT

Although several early symptoms can be observed, they do not appear to be related to the eventual appearance of galls. Red staining of the epidermis shortly following infection occurs on both eight week and one year old seedlings. There are also distinct differences in the frequency of red staining between half-sib families. Nevertheless the proportion of red stained seedlings eventually developing galls is not significantly different from that of non-stained seedlings. This is true both when using mass spore collections and using single gall spore sources. Other early symptoms behave similarly, with one exception. Lateral shoot development at the point of infection in young seedlings, which is evident about ten weeks after inoculation is always followed by gall formation. However, less than half of the seedlings that eventually develop galls exhibit lateral shoots.

We now believe that the most critical event in the process is the invasion of the vascular cambium by the fungal mycelium. This probably happens between eight and 12 weeks after inoculation. Something happens to the cambium at this time. Both xylem and phloem tissues produced by the infected cambium differ from normal tissues. Prolific hyphal development appears to be restricted to tissues produced by the infected cambium. Moreover the stem below the gall also shows excessive diameter growth (Bill Libby pointed this out to me), so that, by 14 weeks after inoculation, infected seedlings are decidedly stiffer than healthy seedlings. Once the cambium has been infected, and a gall begins to form, there appear to be no further major resistance mechanisms. All such galls eventually produce spores.

INHERITANCE OF RESISTANCE AND VIRULENCE.

Using these inoculation and assessment techniques, we have some preliminary results to report.

1. There are marked differences between half-sib families, both in percent seedlings infected and number of galls per infected seedling. Infection generally varies between 25 and 85 percent. We have reproduced results in successive years from successive seed and spore crops.

2. The parent-offspring correlations (Fig. 3) are very poor and never significant. In several experiments we observed that the poor correlation arises because some trees free of infection in the field yield very susceptible offspring. Such trees do not appear to be escapes. Some were selected such that their crowns were intermingled with heavily infected and spore producing crowns of neighbouring trees. We are now checking grafts to confirm this observation. Possibly, the resistance of some trees may be an epistatic effect. We have not seen the opposite phenomenon of heavily infected trees giving rise to relatively resistant offspring. If the phenomenon turns out to be common, it may be important in epidemiology: such trees could have a significant spore diluting effect in the pathosystem. One can also speculate about the use of such trees in clones. If resistance is not based on major genes, than perhaps it cannot be easily overcome by mutations in the pathogen. Of course another explanation of the phenomenon is that the resistance of such trees is based on a major but recessive and relatively rare gene in the pine population.

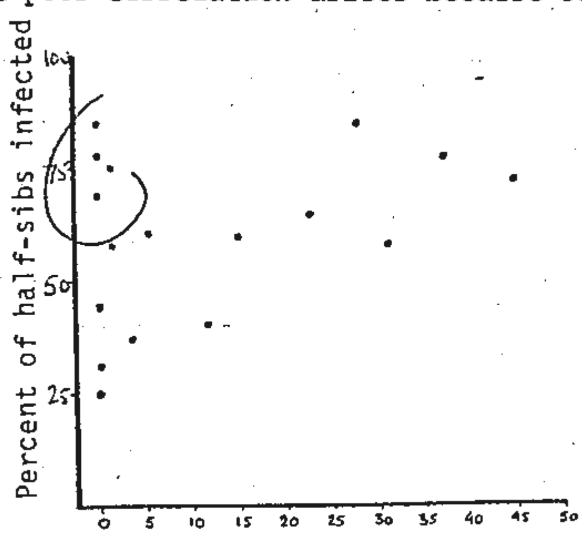

Figure 3--Parent-offspring (half-sib family) relationship. Circled points may indicate epistatic resistance in the female parents.

3. The percent of seedlings infected and the number of galls per infected seedling (in half-sib families) are not related. Various interpretations are possible, including qualitative and quantitative effects, but all need further

testing, and none have been confirmed to date.

4. In two trial involving scots pine, we have found that scots pine always shows a much lower percent of seedlings infected, but that infected seedlings have almost as many galls as lodgepole pine (table 1). There are no differences between spore ;lots collected from scots, lodgepole, and in one case, mugo pine.

Table 1--Relative susceptibility of lodgepole (Pl) and scots (Ps) pine to western gall rust.

Host	Spore source	% seedling infected	galls/ infected seedling
Pl	Pl	93.2	18.8
Pl	Ps	91.9	16.5
Ps	Pl	18.7	14.7
Ps	Ps	18.8	12.1

n=250 1-yr. old trees per treatment

5. The only clear indication to date of variation in pathogenicity of the rust comes form a provenance trial of seven pine provenances from Saskatchewan, Alberta, and the coast and interior of B.C., inoculated by four rust provenanaces, three from the B.C. interior and one from the coast (table 2). Coastal provenances are much more resistant to interior than to coastal spore sources. On the other hand, non-coastal pine provenances were more or or less equally susceptible to all spore sources. The one seedling provenance from the Cypress Hills, an isolated lodgepole pine population straddling the Alberta Saskatchewan border just north of the 49th parallel proved to be relatively resistant to all rust provenanaces. Gall rust was common in that pine population. Some day I'll manage to collect some spores there

Table 2--Percentage of eight week old seedlings infected for seven seedling by four pathogen provenances.

Pathogen provenance	Seedling provenance						
	-Sask.-	Alta.	B.C. Interior			B.C. Coast	
	Cypress Hills	Banff	Blue Lake	Silver Lake	Manning Park	Burns Bog	Lighthouse Park
Burns Bog	23	86	89	81	95	57	64
Silver Lake	31	81	82	80	88	6	20
Blue Lake	24	91	69	86	90	7	35
Vanderhoof	17	64	57	63	61	5	22
Means	24	80	74	77	83	19	35

n=45 seedlings per cell.

Our current work aims largely at detecting variation and interaction between host and pathogen within stands (the multiline hypothesis). We are in the process of developing clones and we have several large diallel crosses recently inoculated. Our first attempt, consisting of inoculating some 90 three year old seedlings in 18 half-sib families by five single gall spores (two replicates per tree) (Maureen Curran's MSc thesis) did not find any interaction between spore sources and trees or families. On the basis of the evidence available to date the pine-gall rust pathosystem appears to be wholly horizontal. However, it is still early days; work now underway may yet lead to different conclusions. Failure to find a vertical resistance in a relatively small trial does not necessarily mean that it isn't present in this natural pathosystem; continued failure will mean that even if major genes are present in the population, they probably play only a minor role in the epidemiology of the pathosystem.

SUMMARY OF WESTERN GALL RUST RESEARCH AT THE UNIVERSITY OF ALBERTA

P.V. Blenis

ABSTRACT

Gall rust research at the University of Alberta has two main components: epidemiology and disease resistance. Epidemiological studies have focussed on spore release, dispersal, survival and germination. On dry days, most spores were released during the daylight hours. One explanation for this observation is that the majority of spores are produced during the evening, when relative humidity is high, and then passively released during the subsequent day, as wind speed and temperature increase, and relative humidity decreases. Spore release during rainy days occurred over a somewhat longer time period than was the case on dry days. Spore survival in the dark was greater at 40% RH than at 98% RH, and decreased with increasing temperature from 6°C to 24°C. Spore survival declined rather quickly out of doors. Rotorod spore samplers were used to trap spores at distances of 2 to 80 m from a heavily infected stand. Although the spore dispersal gradient was quite steep, over 10% of the seedlings in 75 m^2 plots, located 120 m from the stand edge, were infected. Germination of eight lots of spores stored in liquid nitrogen was initially slower than that of seven lots of fresh spores, even though the germination was ultimately the same for both groups.

One of the first goals in our resistance program was to develop a reliable inoculation technique. An apparatus that produced a uniform cloud of spore/talc mixture was developed. Inoculation methods using talc or water as diluents were better than a method using mineral oil. Inoculum doses of 7-20 mg of spores/tray of 120 seedlings were best for maximizing differences in percentage infection between seedlots from heavily galled and lightly galled trees. Studies are currently underway to correlate initial infection symptoms with the subsequent development, or lack of development, of galls. The fungus has been grown in axenic culture.

Peter V. Blenis is an Assistant Professor at the University of Alberta.

ISOZYME ANALYSIS OF *PERIDERMIUM HARKNESSII*

Detlev R. Vogler

ABSTRACT: Electrophoretic analysis of enzymes in spores of the western gall rust fungus from several pine hosts in California, Oregon, Idaho, and Montana revealed remarkably little variation. Most single-gall isolates were monomorphic for each of the 19 enzymes tested. Near Lake Tahoe, California and at two locations in Idaho, we found isolates with variant patterns that were identical for seven of the 19 enzyme loci; the variant bands were characteristic of heterokaryons. Analysis of bands in 6-phosphogluconate dehydronenase (6-PGD) isozymes did not support independent segregation of alleles, suggesting that this fungus propagates clonally.

I am working on a research project to determine whether the western gall rust (*Peridermium harknessii*)/Monterey pine (*Pinus radiata*) pathosystem is controlled by specific, gene-for-gene interactions, or by non-specific, additive inheritance. The principal investigators are Bohun B. Kinloch (PSW Station, Berkeley), William J. Libby (Dept. of Forestry, UC Berkeley), and Fields W. Cobb, Jr. (Dept. of Plant Pathology, UC Berkeley). As part of the overall project, we are trying to measure the amount of variability inherent in this host-parasite interaction. Common-garden experiments over the last two decades have revealed consistent differences in susceptibility within and among populations of *P. radiata* from native stands along the Pacific Coast. The extent of genetic variability within the pathogen, however, is still unclear.

Isozyme analysis is one way to explore variability in fungal pathogens. Soluble extracts of ground aeciospores from single galls are subjected to electrophoresis in starch gels, and the differing mobilities of functionally identical enzymes are used as genetic markers. To date, we have screened 35 enzyme staining systems, and have identified 19 enzyme loci that resolve adequately for interpretation. In addition, we have analysed 255 aeciospore isolates from several pine hosts (predominantly *P. radiata* and *P. muricata* along the California coast, and *P. contorta* inland). Isolates were collected from throughout central and northern California, and from several sites in Oregon, Idaho, and Montana.

Results are displayed in table 1. Almost 90% of the isolates were monomorphic, showing no differences in enzyme mobility. All banding patterns were characteristic of homokaryons; in other words, the two nuclei in each aeciospore were identical. A small number of isolates were polymorphic for one or another enzyme locus, but the frequency of any one variant was low in all cases. In the remaining isolates, seven of the 19 enzymes tested had different mobilities from the typical pattern. At and near Lake Tahoe, CA, all 16 isolates had this same variant pattern; at two sites in Idaho, two of 16 isolates exhibited the variant pattern, while the remaining 14 isolates were enzymically identical to those from the Pacific Coast.

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In all cases, the grouped variant patterns were characteristic of heterokaryons, in which two genetically different nuclei reside within the same aeciospore. This was confirmed by analysis of banding patterns in 6-phosphogluconate dehydrogenase (6-PGD), a dimeric enzyme. The triple-banded pattern seen in the 6-PGD variants represented two homodimers (a fast and a slow allozyme) and a heterodimer (an intermediate, hybrid band); these are the expected gene products of dissimilar nuclei. Among the 93% of all isolates that were homokaryons, however, only the fast-migrating allozyme of 6-PGD was detected; isolates homokaryotic for the slow allozyme were not observed. This genetic structure departs sharply from the Hardy-Weinberg equilibrium, indicating that random mating does not occur in *P. harknessii*.

Although more data remain to be analysed, our results so far suggest that western gall rust propagates clonally and has remarkably little genetic variation. Heterokaryons have been detected, but there is no evidence for independent segregation of alleles. Sex appears to be absent in this rust fungus.

Table 1. Frequency, host origin, and geographic distribution of monomorphic and polymorphic isolates of aeciospores from single galls of *Peridermium harknessii*.

No Variation	Grouped Variants	One-Locus Variants
226/255	18/255	11/255
88.6%	7.1%	4.3%
All pine hosts.	*P. contorta* only.	*P. contorta, P. attenuata, P. jeffreyi X P. coulteri.*
CA, OR, ID, & MT.	CA: Nr. Lake Tahoe; ID: Two sites.	CA, OR, ID, & MT.

Using Computer Graphics to Assess the Visual Impact of Limb Rust in Ponderosa Pine

F.A. Baker and D.Rabin.

ABSTRACT: Computer graphics systems provide an opportunity to measure pest impact while holding all other variables constant. Using one computer graphics system, we have shown that viewers find increasing severity of limb rust correspondingly less desirable.

INTRODUCTION

The use of our forests for recreation has increased steadily for many years. A recent study by Hof and Kaiser (1983) predicted that recreation use will continue to increase well into the 21st century. Given this profusion of recreation-oriented forest visitors, it is clear that the visual quality of our forests is an important resource.

In response to the public's concern for the aesthetic qualities of our forests, Congress has enacted legislation mandating management of visual and other amenity resources. The Multiple Sustained Yield Act of 1960 and The National Environmental Policy Act of 1969 required land managers to show concern for intangible forest resources including aesthetics, wilderness, non-consumptive uses of wildlife and recreation. The Federal Land Policy and Management Act of 1976 strengthened those earlier laws by compelling land managers to consider scenic resources equally with other resources in management decisions involving public lands.

The management of any resource requires a method of measuring the impact of changes in an environment on that resource. The management of visual resources is no exception. However, unlike water, timber or other resources for which techniques of measuring impacts are well established, impacts on visual quality are more difficult to quantify.

Most attempts to assess visual impacts on forests and other wildlands have involved predicting changes to the visual character of a landscape resulting from proposed timber harvests, roads, dams, powerlines or other man-caused alterations or developments. To aid in this process, a wide range of graphic techniques have been developed to simulate proposed landscape changes. These include freehand sketching, special-effect photography, 3-D modeling and computer-modified imagery (U.S.D.I. Bureau of Land Management, 1980b; Orland, 1986a, 1986b). Time requirements, need for artistic skills, expense, and realism of the images produced vary greatly for these different techniques (Orland, 1986b).

F.A. Baker is Assistant Professor, and D.R. Rabin is graduate student, Department of Forest Resources, Utah State University, Logan, UT 84322-5215.

While these simulation techniques have been applied almost exclusively to planned or proposed changes to landscapes, not all impacts on visual resources are a direct result of man's intentions. Natural forces often change the appearance of forest landscapes dramatically.

In forest environments, insects and diseases occur naturally, killing, deforming, defoliating, or in other ways altering the appearance of trees. In some situations forest pests impact tens or even hundreds of acres. In other instances only a few trees in a forest stand are affected. In either case, it is reasonable to assume that some degree of visual impact occurs as a result of the presence of forest pests.

Without a functional method of measuring visual impacts caused by forest pests, land managers are hampered in their efforts to consider visual quality when making management decisions in pest-infested forests. They must rely on intuition, their perception of public sentiment, or best professional judgement (in cases where trained landscape managers such as landscape architects are involved) if visual resources are to be considered at all. In visually sensitive areas such as along road corridors or trails, in parks, campgrounds or other areas where the public is likely to travel, a more reliable method of assessing impacts to the visual resource resulting from pest infestation is necessary.

Many variables affect the scenic value of an area. To hold these constant while varying the paramater of interest - pest infestation - is very difficult to do when using slides of representative areas or best professional judgement. Artist sketches may be used, but they often lack the detail needed to show pest impact, and are very expensive when doing factorial experiments. Recent developments have made computer graphic systems available at relatively low cost. These systems can produce and manipulate very detailed images, and be useful in visual assessment of pest impacts.

We evaluated several graphics systems to find one with the features necessary for altering images. We were looking specifically for a system which would allow us to "grab" pieces of images and store them in a file for later recall, in order to replace one part of an image with part of another The first system we used, designed by Wasatch Computer Graphics in Salt Lake City, was limited in its ability to perform this "cut-and-paste" function. Creating images with this system was also very slow (> 8 hours), expensive, and did not produce acceptable results. After evaluating several other systems, we selected the Artronics PC 2000 system Version 3.1 manufactured by Artronics, Inc. of South Plainfield, N.J. This system is slow (at least on our computer) in its ability to convert images from the video camera to a computer image (this is called "grabbing" the image), but its flexibility in working with the images offset other deficiencies.

METHODS

A preliminary experiment was done to determine levels of visual impact of limb rust resulting from different "types of infection" and also to examine the relationship between visual impact ratings and the proposed 6-class limb rust rating system (Baker et al. 1986). Of special interest was the question of whether trees appearing differently but rated equally for limb rust would also be rated equally for visual impact. For example, a tree may be assigned a rust rating of 4 when less than 30% of the upper third of the crown is infected (3 for position + 1 for % crown infected), or when 30-60% of the crown is infected at midcrown (2 for position + 2 for % crown infected). Twelve computer images representing all possible visual manifestations of the 6-class rating system (from uninfected to class six trees) were shown in a paired comparison test to two groups of student observers. Each student was asked to select the least attractive slide of each pair. All possible pairs of slides were shown enabling a ranking of the images. The visual rankings derived form this test were generally consistent with the 6-class rating system at the extremes of the scale. However, in the middle rust rating classes, the visual ratings did not correlate as strongly (fig. 1).

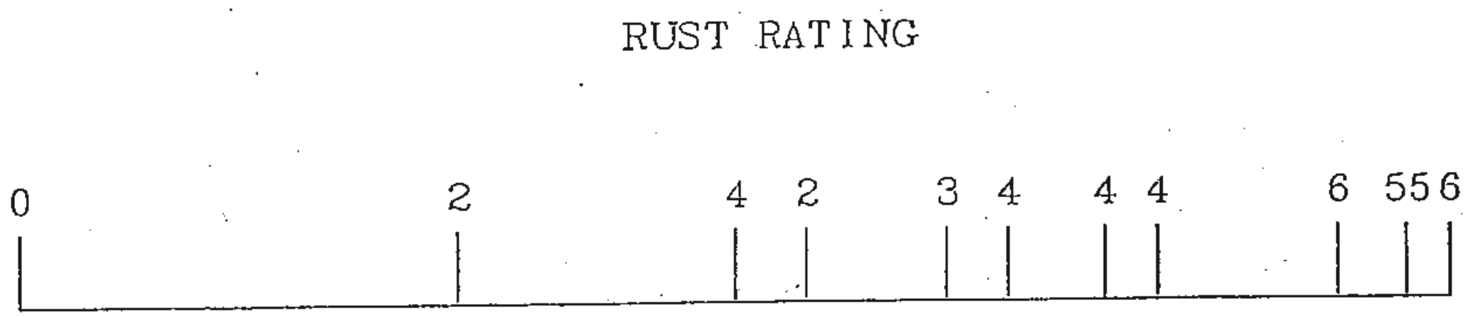

Figure 1. Linear ranking of viewer preference of limb rust infected ponderosa pines. The distance between lines reflects the degree of difference in viewer preference.

Since there was no obvious, easily applied means of restructuring the rating system to correspond with visual rankings, images for the visual assessment experiment were selected to represent different levels of visual impact rather than different rust rating classes (although the images selected represent rust rating of 0, 2, 4, and 6). The objective of this experiment is to measure the viewers response to different levels of incidence and severity (percent infection and extent of infection) in near view ponderosa pine scenes. Four scenes were selected, and two trees removed from each scene to become infected. These trees are then added back to the scene with varying amounts of rust. A total of 10 separate images per scene were tested, representing the combinations of rust ratings. Thirty-seven viewers were instructed to rate each scene for scenic beauty on a scale from 1 to 10, and no mention of limb rust was made.

Because viewers used the scale differently, their scores were transformed using the Z distribution (Snedecor and Cochran 1974). From these Z-scores, the variance for each viewer from the mean for a particular slide was computed. The 4 viewers with the largest variance were dropped from the study. The Z-scores for the 4 scenes with the same incidence and severity of limb rust were then averaged. Means were multiplied by 100, and the value of the lowest mean added to all scores to make all values positive. One way analysis of variance and contrasts were used to determine statistical differences between means. Kendall's Tau was used to test the hypothesis that viewer's ratings of scenes decreased progressively with increasing disease (Kendall 1955).

RESULTS AND DISCUSSION

Viewers ratings decreased with increasing incidence and severity of limb rust determined by summing the rust ratings for each scene (Figure 2). Kendall's Tau value was 0.876, indicating a probability of 0.000058 that a higher value of Kendall's Tau could occur by chance alone. In Figure 2, it appears that there are three or more levels of visual impact. If one is willing to accept probabilities of 0.15, the three groups can be separated. (Total rust scores of 0 and 2 are separate from those of 4 and 6 at $p= 0.13$; scores of 4 and 6 separate from scores of 8 or more at $p = 0.11$).

What does all this mean? To a manager? Unfortunately, not much. We have told - or will tell when these results are published - that John Q. Public sees limb rust in near view scenes typical of those surrounding Bryce Canyon National Park and Zion National Park in southern Utah. But what should he do about it? Maybe people would rather have the dead trees than have them removed. Perhaps the perception that diseased trees are bad can be changed by educating viewers that dead trees provide habitat for birds and other wildlife. We intend to carry this visual assessment one step farther by evaluating these hypotheses. We are now "cutting" the diseased trees on the computer, and will ask another group of viewers to rate the slides with the diseased trees removed, as well as few diseased slides for reference. Another group will be asked to rate the same slides, but after an introduction to the value of dead trees for wildlife. The results of this later study will help the managers to make intelligent decisions concerning management of visual resources.

ACKNOWLEDGEMENTS

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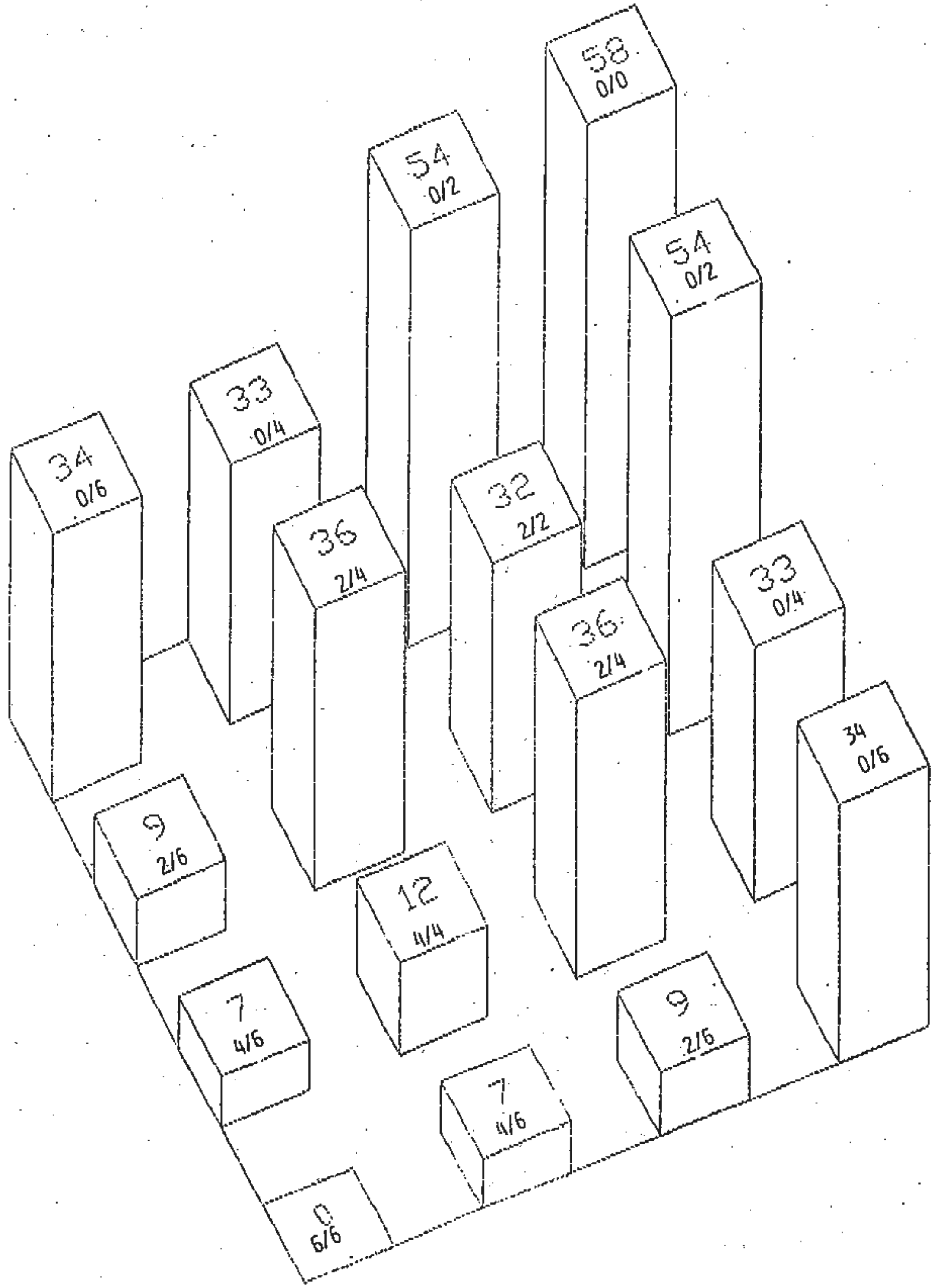

Figure 2. Relative viewer preference for near view ponderosa pine scenes with varying incidence and severity of limb rust. Upper number on the bars is the standardized viewer preference for the specific combination of incidence and severity indicated by the numbers below. Lower numbers refer to the limb rust ratings of each of the two trees in a scene.

COMANDRA RUST RISK-RATING RESEARCH

W.R. Jacobi and J.E. Boyd

INTRODUCTION

Our project, funded by the Rocky Mountain Forest and Range Experiment Station, on comandra rust has changed drastically since last year. During the 1986 field season we found there were too few infested lodgepole pine stands in the 40-60 year age range to make the establishment of more permanent plots feasible. Thus, we then established new areas of research to complete in 1987.

The overall objective of this project is to develop a risk rating scheme for comandra blister rust in lodgepole pine.

Subojectives:

1. Determine the incidence of weather conditions related to rust infection of pine.
2. Validate growth and mortality equations.
3. Determine the effects of different disease scenarios on forest productivity.
4. Test a risk rating hypothesis on the Laramie District of the Medicine Bow National Forest.
5. Demonstrate our findings on a National Forest District.

METHODS AND MATERIALS

1. Weather Conditions Related to Rust Infection:

   The defining of weather conditions related to rust infection will involve three studies related to historical weather data: a) pinpointing potential infection periods; b) relating historical weather data to on site weather data; and c) relating identified infection periods to known infection occurrences.

2. Validation of Growth and Mortality Equations

   Additional data are needed to improve and validate existing equations relating growth of lodgepole pine after girdling by comandra rust. Currently we have data from cankers near the top and near the bottom of the crown but very few in mid crown (40-60%). Thus, an attempt will be made to collect growth data from girdled trees from Wyoming or Montana that will fill the gap in our data. Trees will be cut adjacent to existing permanent plots and disks removed at DBH, canker center and at

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the last live branch. Additional trees will be selected from nearby stands if they appear appropriate. We should be able to collect data from at least 25-30 trees.

Mortality data can be collected from permanent plots established five years ago. Revisiting these plots will be a cooperative activity of the Forest Service and University.

3. Disease Scenarios

RMYLD and Prognosis programs will be utilized to determine what the results of rust infestations are on stand productivity. Several factors will be varied to see what effect these changes will have on productivity. The factors will include stand age at infection, number of infection periods/rotation, incidence of rust, stand density, site index and average canker height. An overriding purpose will be to demonstrate to forest managers what conditions cause economically serious losses.

4. Testing the Risk Rating Hypothesis

From previous research and observation of rust incidence throughout Wyoming and Montana, we have developed a hypothesis that describes why some lodgepole pine areas differ in their risks of high incidences of rust. The hypothesis is that rust will occur at high incidences 0-8 miles from large concentrations of the alternate host when the host is downwind from the pine, and that the level of rust incidence will decrease as the distance from the alternate host increases. Wind direction during the periods of optimum humidity and temperature for pine infection is a major factor in our hypothesis.

We will survey the Laramie District of the Medicine Bow National Forest to test this hypothesis in a preliminary manner. The Laramie District has a high incidence of rust on the eastern half of the district and a low incidence on the western half.

Lodgepole pine will be sampled using a system of sample plots divided into cluster plots. There will be 4-5 cluster plots per sample plot to get a total of approximately 100 trees.

Comandra location and population densities will be mapped on the edges of the forest. Locations will be recorded via maps in mile blocks at areas of 1/4 square miles. In each 1/4 square mile area, two transects will be walked. Square meter plots will be located at known intervals along each transect. In each square meter plot, the number of comandra plants will be recorded.

Rust incidence will be related to distance between comandra and lodgepole and comandra population densities. One would assume either there are no comandra populations on the western side of the district or, if there are populations, the wind rarely blows from the west during infection periods.

The WINDS model will be run under several scenarios before the field sampling begins. The sampling procedure used will be based on the outputs of this model and worked out with the help of atmospheric scientists and statisticians.

This study will be preliminary and will only represent a coarse overview of one site so application of any results will be limited.

5. Demonstration of Findings

Time-permitting, we will demonstrate what we have learned about infection periods and growth and mortality impact by projecting impacts on a National Forest District. We will run various scenarios of RMYLD or Prognosis on a district-wide basis based on predicted locational occurrence of rust, subjectively selected average infection amounts (incidence) and severity (girdling/or not). Incidence of rust is not known on a stand by stand basis for any district so this demonstration is similar to section III. Other inputs will be current stand parameters. Hopefully, part of this can be done in conjunction with the Regional Office since they have access to the stand information. This demonstration could be quite a massive undertaking so the exact procedures undertaken will be clarified by future discussions with Experiment Station personnel.

RESULTS

We have just completed the survey of the Laramie district for the distance relationship study and thus we don't have any specific results to report. We have found a gradient of decreasing rust incidence away from the alternate host but the data will need some analysis before we can report definitive results.

The analysis of weather conditions conducive to infection of lodgepole pine will be completed this fall. Jane Boyd will report during this meeting on preliminary findings using one rust-infested location.

DISCUSSION

We are inching closer to expressing the risk of rust to particular areas and the impact of the rust to the resource. Unfortunately, unless we can find funds for a follow-up study, time restrictions and project termination will restrict a complete explanation of why many areas escape the rust.

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INCIDENCE AND EFFECTS OF WHITE PINE BLISTER RUST IN PLANTATIONS WITH SUGAR PINE IN THE NORTHERN AND CENTRAL SIERRA NEVADA, CALIFORNIA

Gregg A. DeNitto

ABSTRACT: Twenty-nine plantations in the northern and central Sierra Nevada were surveyed for blister rust incidence. One plantation was uninfested, whereas other stands, 4 to 26 years of age, possessed infection levels ranging from 44 to 93% with an average of 64%. Rust has reduced stocking to below acceptable levels in one stand (28% of total) and is projected to reduce stocking in four more plantations (41% of total). In three other plantations some sugar pine must survive or stocking levels will not be acceptable. No relationship between blister rust incidence and estimated site hazard was found. Adequately stocked stands can best be assured by not relying on survival of sugar pine, or by planting resistant sugar pine.

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INTRODUCTION

White pine blister rust has been spreading throughout the range of sugar pine in northern California. Surveys in 1982 and 1983 on the Sierra and Sequoia National Forests extended the southern limit of the disease and found increasing incidence and intensification in natural stands.

Since these surveys, the disease has been observed with increasing frequency. Blister rust has been identified in new infection centers and has increased in intensity where already present. The importance of this increase is being recognized on Forests in the central and southern Sierra Nevada where sugar pine has been a significant species for regeneration. Also, the disease is being found and recognized as a potential management constraint on what were once considered low hazard sites in the central and northern Sierra Nevada.

Forest Pest Management initiated a survey of plantations with sugar pine to evaluate the future viability of the species in intensively managed stands. The objectives of the survey were:

1) To determine the proportion of sugar pines infected by blister rust in a sample of 5- to 25-year-old plantations on the Plumas, Tahoe, Eldorado, and Stanislaus National Forests.

2) To determine the proportion of trees lethally infected by blister rust in each of the plantations.

3) To determine our ability to predict site hazard using existing information.

METHODS

Districts on each of the four National Forests were asked for information on plantations with sugar pine. Potential candidates were to be 5 to 25 years of age, have at least 10 percent sugar pine stocking, and preferably be on low hazard sites. Low hazard sites were defined as being ridge tops and upper slopes with southerly aspects.

Plantations submitted were screened and plantation age was expanded to 4 to 26 years to broaden the distribution. Plantations were randomly selected independently from each Forest's submission to ensure an adequate north-south distribution. The number of plantations selected for each Forest varied depending on the size of the sample submitted.

Prior to initiating the survey of each plantation, observations of surrounding stands were made to detect the presence of blister rust. Impressions of the site's rust hazard potential were noted. The plantation was then systematically sampled starting at a randomly selected point on the boundary. The direction of the transect was predetermined and attempted to have the transect cross any topographic gradient. The sampling unit was a 1/2-chain wide strip centered on the transect line. Total transect length for the plantation was measured to determine area sampled. Blister rust infection data were collected on each sugar pine in the sampling unit. Each sugar pine received one of the following five infection rating classes: healthy with no infections; non-lethal infections, being those 24 or more inches from the bole; lethal infections, being bole infections or within 24 inches of the bole; dead from blister rust; and dead from other causes. If more than one rating was possible, then the most severe rating was given.

At 10 chain intervals along the transect, a plot 1/2-chain on a side was established. In addition to the above information, the following data were collected: number of trees by species, number of Ribes plants up to 4 per plot, and the site hazard rating. Hazard ratings were based on vegetation and site information that were developed during the blister rust control work of the 1960s and perceptions on biological and ecological requirements of the fungus.

When the transect reached the boundary of the plantation, the return transect was begun 3 to 10 chains along the boundary. The distance between transects was determined by the size of the plantation. Transects were continued until either the plantation was completely surveyed, 300 sugar pines were tallyed, or 20 plots were recorded.

RESULTS

A total of 29 plantations and 4323 sugar pines were sampled on the four National Forests. Most of the sites were south or west facing and on the upper slope or on ridge tops. Slopes were minimal to moderate.

Of the 29 plantations surveyed, all but one were infested by blister rust. Infection levels in the 28 plantations with blister rust ranged from 44 to 93%. A north to south gradient of infection was not observed. Average infection levels for each Forest were: Plumas - 61%; Tahoe - 72%; Eldorado - 71%; and Stanislaus - 72% (Figure 1). The majority of infected trees had lethal infections (Figure 2). All dead trees had been killed by blister rust. The proportion of trees in each infection rating class varied with plantation age (Figure 3). Younger plantations generally had more trees that had either been killed or were uninfected. With increasing plantation age, the proportion of trees that had died decreased, as did the number of uninfected trees. The proportion of living infected trees increased, although the proportion of non-lethal infections was still a minor component.

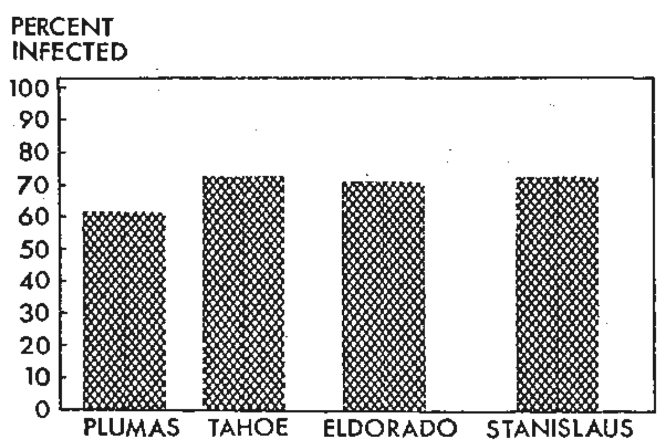

Figure 1. Average Forest-wide infection levels of blister rust on sugar pine in plantations.

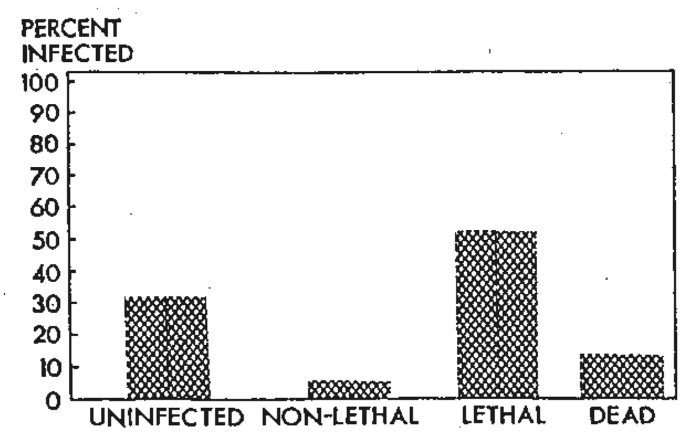

Figure 2. Average infection levels, by infection rating class, of blister rust on sugar pine in plantations.

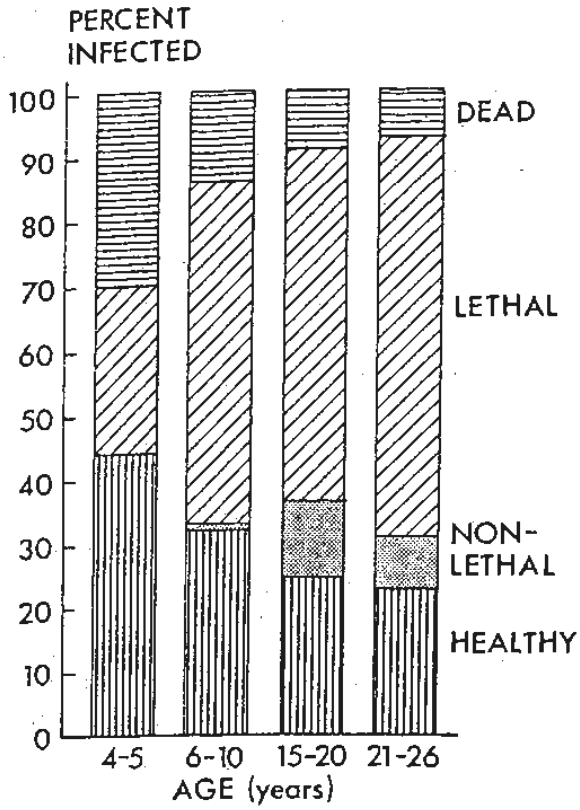

Figure 3. Infection levels (%) of blister rust in plantations with sugar pine by tree age and infection rating class.

Stocking levels were highly variable, with 7 plantations (25%) not reaching the Regional standard of 150 trees/acre. Sugar pine ranged from a minor component to the sole species in a plantation. The amount of Ribes varied between plantations. Even though Ribes plants may not have been in the survey plots in some plantations, they were observed in most plantations. No association between site hazard rating and rust infection was found.

The effect of blister rust on each plantation was examined by determining the stocking reduction due to the disease. It was assumed that all lethally infected trees would die before reaching a merchantable size. Future infections that might occur and further reduce stocking were not considered. Of the 29 plantations, 4 will have their stocking level reduced below minimum acceptable levels by the disease. An additional 7 plantations will have their currently unacceptable stocking reduced even further by the disease.

Each plantation was rated for blister rust site hazard based on site and vegetation characteristics. Many of the sites were classified moderate in hazard primarily because of the species of vegetation on the site. The vegetation commonly encountered included whitethorn, green leaf manzanita, and bitter cherry. These species are common associates with Ribes on disturbed sites.

DISCUSSION

White pine blister rust is a major limiting factor in the growing of sugar pine in the northern and central Sierra Nevada. With average infection levels of 60 to 70%, sugar pine will not be a significant component in future plantations unless management direction is changed.

Until the late 1960s, it was believed that blister rust would be of minor importance in the central and southern Sierra. Surveys in 1968 rejected that hypothesis and showed that the rust could become established and intensify in the southern Sierra Nevada. However, the rate of introduction and intensification would be slow and most infections were expected to be limited to streamsides. Many initial infections occurred after these surveys were completed. Intensification of the disease has taken place since then.

Surveys of natural mixed conifer stands on the Plumas, Tahoe, and Eldorado National Forests in 1969 and 1970 found Forest-wide infection levels of 18%, 7%, and 10%, respectively. Although this survey is not directly comparable, it does suggest a large increase in infection over a 15 year period. It does not appear that the rate of infection has stabilized in most areas and further increases can be expected.

Although some existing older plantations may not be exposed to additional lethal infections, present incidences of 40 to 50% in very young plantations suggest that their infection levels may increase considerably. With 10 to 15 years of susceptibility remaining, trees in these plantations will experience several additional infection periods. Most infections will be lethal in trees of this small size. Also, since blister rust is established in these areas, sufficient inoculum will be available for infection to occur regularly even without the influence of "wave years" of infection.

Sugar pine has a very limited future as a component of plantations in California without the use of rust resistant stock. Although some survival of wild sugar pine can be expected, the amount will vary between locations, and in almost all plantations the proportion of sugar pine stems at harvest will be small.

As a result of observations over the past several years, recent policy changes have been made on the regeneration of sugar pine in the National Forests of California. The general direction is to build a seed bank inventory of rust resistant seed as rapidly as possible. In the meantime, non-rust resistant seed in the seed bank will be used with certain constraints to fulfill sugar pine regeneration needs. Specifically, if sugar pine is to be planted, rust resistant seed will be used when available. If none is available, then non-resistant sugar pine will be planted at no more than 10 percent of the stocking and will be well distributed throughout the plantation. Increased efforts are being made at collecting and screening seeds from trees in natural stands for rust resistance. Trees identified as resistant are being protected and used for seed trees for reforestation efforts.

IS THERE A BIOLOGICAL RISK OF WESTERN WHITE PINE PROVENANCES TO ROOT DISEASES?

R.S. Hunt

INTRODUCTION

Idaho populations and two populations from the Olympia peninsula of western white pine (Pinus monticola Dougl.) do not show provenance effects in Idaho (Steinhoff 1981; Rehfeldt et al. 1984). Also, western white pine from Idaho grows well on Vancouver Island (Bower 1987; Hunt et al. 1987).

Terpenes and isoenzymes studies indicate that there is variation within individual populations but no apparent differentiation among Pacific Northwest populations of western white pine (Steinhoff et al. 1983; Hunt et al. 1985). If this species is as plastic as these observations suggest, it would mean that there could be an exchange of blister-rust (Cronartium ribicola J.C. Fisch, ex Rabehn.) -resistant materials among all the resistant programs (B.C. coast, B.C. interior, Idaho and Oregon) and thus the genetic base of each program could be enlarged more economically than through the costly and time-consuming inoculation methods employed to identify a large number of trees for each region.

Field observations and unpublished research (Wallis 1976) indicate that western white pine is resistant to Phellinus weirii (Murr.) Gilbertson leading to a demand for blister-rust-resistant stock for planting in P. weirii infection centers. However, the geographic range of western white pine (Fowells 1965) is greater, particularly to the south, than the range of P. weirii (Anonymous 1960); therefore, it is possible that the lack of selection pressure from P. weirii in allopatric populations of western white pine may make them more vulnerable to attack by P. weirii than pine sympatric with the root rot. This has been found true when selection pressure is lacking in other pine-pathogen relationships (Hunt and Van Sickle 1984).

Western white pine could be used as an alternative species for sites infested with Armillaria, Fomes and Polyporus root diseases, for it seems more tolerant to Armillaria obscura (Pers.) Herink than Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco] (Koot and Vallentgoed 1987). Only the non-pine strain of Heterobasidion annosum (Fr.) Bref. is common in B.C. (Morrison, pers. comm.) and western white pine does not seem to be a documented host for Inonotus tomentosus (Fr.) Gilbertson (Shaw 1973; Lowe 1977). Inonotus tomentosus which is most important in spruce (Whitney 1977), largely occurs north of the geographic range of western white pine in B.C. (Wood 1986). However, western white pine, like lodgepole pine (P. contorta Dougl.), perhaps has recently moved northward after the last glaciation (McDonald and Cwynar 1985) and perhaps, also like lodgepole pine, can be moved northward 4-5° latitude without suffering adverse environmental effects (Ying et al. 1985). The approximate 2° warming expected within 50 years from the CO_2 effect (Justus 1984; Titus and

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Barth 1984) and the general plasticity within western white pine all suggest that in the future western white pine may be used considerably north of its native range.

It is imperative that forest pathologists devise experiments to test the hypothesis that western white pine is resistant to root pathogens. When testing this hypothesis it is important to consider the effects of population source on resistance. Although environmental parameters (Rehfeldt 1984) suggest that the seed transferability of western white pine is extremely broad, the biological risk of such transfers needs further evaluation.

In B.C. we are setting up one testing experiment of which others should be aware before embarking on a similar expensive adventure. The goal was to establish one white pine plantation of diverse origins in each B.C. Forest Service Regional jurisdiction of the province, providing the that there would be enough "grass-roots" support so that no special funds would be needed for the project, particularly including the support of the Regional Pathologist or equivalent.

METHODS

Through the kind support of Jerry Beatty, Ray Hoff, Mike Srago and Ray Steinhoff we managed to obtain seed of 14 provenances from throughout the range of western white pine and one collection of P. strobiformis Engelmann (fig. 1; table 1). Each provenance was to be derived from a minimum of five trees and 40 individuals were to be planted in 10, 4-tree reps per plantation. We did not have enough seedlings from all sources for all plantations, and

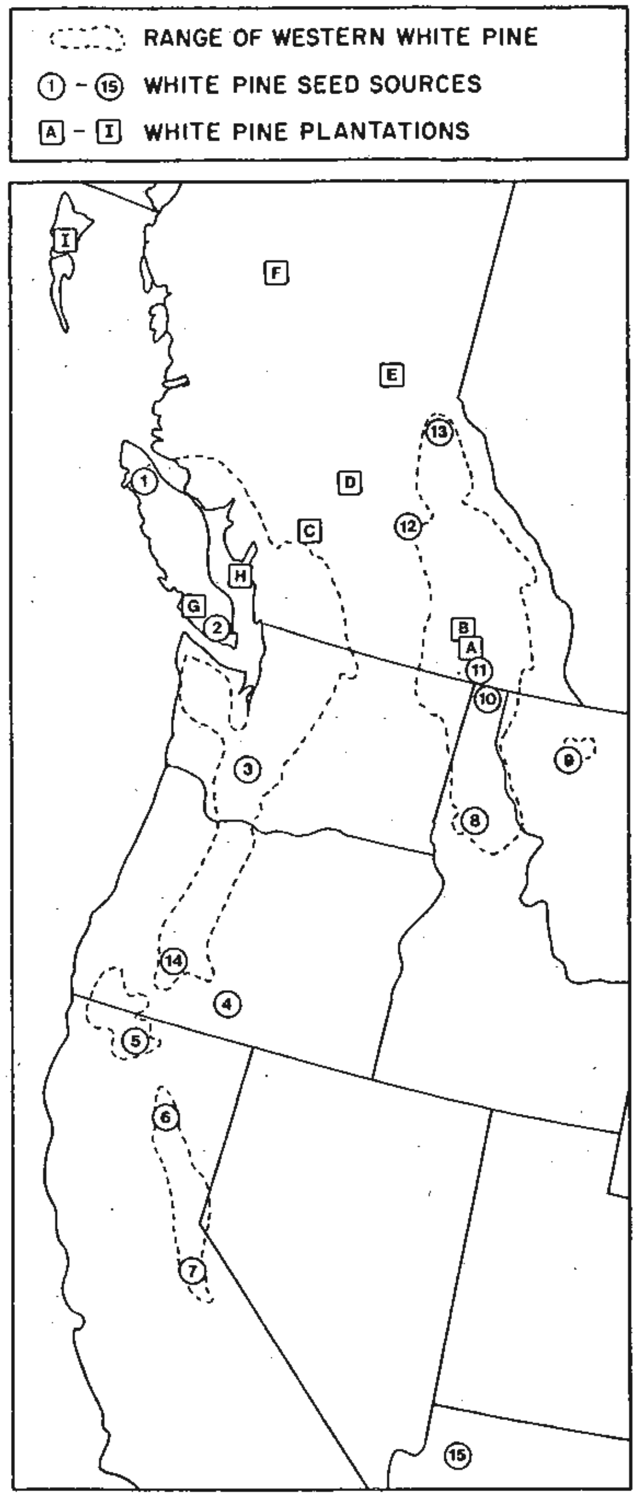

Figure 1.

in others we had too many. For some inadequate seed sources we managed to obtain seedlings from adjacent stands which had been grown for other purposes. The extra seedlings went into additional plantations.

Root-disease sites were selected in 1986 (fig. 1; table 2), in most cases prior to logging, but the IWA strike delayed harvesting of coastal sites, thus they are not yet planted. All six interior sites were planted as 1-0 plugs in the spring of 1987. Forty appropriate control seedlings (Table 2) were planted at each location. The Smallwood Creek (plantation A) site was an unusual configuration but was planted in a pattern as similar to the other sites as possible, which was 20 rows of 32 trees or 8 provenances each, at 3 m spacings. A provenance sequence pattern was obtained by randomly assigning each provenance to a position within the first two rows. One provenance was drawn at random to start the rest of the odd numbered rows, with the rest of the provenances following in the same sequence as in the first two rows. This uniform planting pattern should make it easy to check a particular provenance within any plantation over future years.

Plantations will be monitored by BCFS Regional Pathologists, FIDS staff and CFS white pine staff. Geographic sources from Gifford Pinchot NF, Warner Mt., Mogollon Rim and Dorena are expected to be highly resistant, and from Hoomak, Davie, Deerholme, 19 Mile Creek and Butchart Lake moderately resistant to blister rust. Blister rust will be minimized on the sites by roguing Ribes spp., and pruning white pine (Hunt 1982) as necessary. Dead and dying trees will be sampled for root disease, although species and geographic trends are not expected for at least 12 years.

ACKNOWLEDGEMENTS

All provincial forest pathologists, John Muir, Jeff Beale, Don Norris, Hadrian Merler, Kathy Lewis, Wayne Martin and Don Doidge have provided excellent coordination with Regional staff and most contributed physically to installation of plantations. Special thanks should go to McMillan-Bloedel, Northwood and Evans forest companies who did some special cleaning up of the root disease sites under their management, and to the Pacific Forestry Centre crew of Hugh Craig, Don Craigdallie and Richard Lenz, who planted most of the sites.

Table 1. White pine root disease seed sources

No.	Place Name	°N Lat.	°W Long.	elevation (m)	Plantations used
1.	Northern Vancouver Island	50	128	--	--
	1-1 Mt. Cain			760	A-H
	1-2 Hoomak			20	H-I
	1-3 Davie			250	I
2.	Southern Vancouver Island	48	124	--	--
	2-1 Bamberton			20	A-H
	2-2 Deerholme			490	I
	2-3 19 Mile Cr.			300	I
	2-4 Butchart Lk.			550	H-I
3.	Gifford Pinchot NF	47	122	120	A-I
4.	Warner Mt. Fremont NF	42	120	2000	A-I
5.	Klamath NF	41	123	1750	A,E, F&I
6.	Plumas NF	40	121	2200	A,E, F&I
7.	Sequoia NF	37	118	2500	A-I
8.	Palouse	46	116	850	A-I
9.	Hungry Horse	48	112	1100	A-I
10.	MacDonald	49	117	960	A-I
11.	South Kootenays	49	117		
	10-1 Buckworth			1200	A-G
	10-2 Arrow			665	H-I
12.	N. Barriere	51	120	675	A-I
13.	Upper Canoe	53	120	900	A-I
14.	Dorena[1]	42-44	123	1370	A-I
15.	Mogollon Rim[2]	34	111	2380	A-H

[1]seed orchard trees originating from throughout southern Oregon.

[2]*Pinus strobiformis*

Table 2. White pine root disease plantations

No.	Place Name	Elevation (m)	Cooperator	Root Disease	Control species
A[1]	Nelson-Smallwood Cr.	1050	BCFS	*Phellinus weirii*	interior Douglas-fir
B[1]	Nelson-Busk Cr.	1200	BCFS	*Armillaria obscura*	lodgepole pine
C[1]	Lillooet	1200	Evans Forest Products & BCFS	*Phellinus weirii*	interior Douglas-fir
D[1]	Cariboo-Horsefly Tisdall L.	850	BCFS	*Armillaria obscura*	interior spruce & lodgepole pine
E[1]	Prince George	760	Northwood & BCFS	*Inonotus tomentosus*	interior spruce
F[1]	Bulkley-Sharpe Cr.	365	BCFS	*Inonotus tomentosus*	*P. sitchensis* x *glauca*
G[2]	Alberni-Bainbridge Lk.	65	M&B	*Phellinus weirii*	coastal Douglas-fir
H[2]	Sechelt	20	BCFS	*Phellinus weirii*	coastal Douglas-fir
I[2]	Queen Charlotte Is.		BCFS	*Heterobasidion annosum*	western hemlock

[1] Planted spring 1987 as 1-0 plugs.

[2] Proposed planting 1988 as 2-0 plugs.

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FOREST PATHOLOGY AND QUARANTINES

Sarah Sheffield and John Muir

ABSTRACT: Organizations involved with quarantine issues, recent examples of important new or unusual pests, processes or elements involved with dealing with a quarantine issue, and features of diseases that make them difficult to deal with were briefly outlined and discussed.

INTRODUCTION

Several new or unusual occurrences of pests have threatened Pacific Northwestern forests or forest product exports. These occurrences demand rapid, coordinated, and concerted action by industry and by regulatory, management, and research agencies. Recent examples have been gypsy moth, pinewood nematode, bark beetles and Colletotrichum blight of western hemlock seedlings. Management agencies such as provincial and state governments do not have direct responsibility for international regulations and negotiations for pests. However, these agencies have a vital interest in maintaining the productivity of their forest lands and fostering a vigorous forest industry. Management agencies often play a major role in conducting detection surveys, damage appraisals and pest suppression programs or control treatments for new pests.

The purpose of this workshop is to outline some of the organizations and procedures involved with quarantine issues, and to describe the steps in a quarantine issue that should be considered while dealing with pathogens.

THE PHYTOSANITARY SYSTEM

An international phytosanitary (plant health) framework, the International Plant Protection Convention, was developed after World War II, under the Food and Agriculture Organization of the United Nations. The aims of the IPPC are:

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1. To prevent spread of plant pests through international trade.
2. To report outbreaks of significant plant pests in countries subscribing to the convention.
3. To provide a phytosanitary certification system for plant exports.
4. To facilitate the development of sound import and export controls in subscribing countries.
5. To ensure controls are biologically sound and do not restrict trade unnecessarily.

Over 80 countries, including Canada and the United States, have signed the IPPC. The primary document controlling the international movement of plants and plant materials is the phytosanitary certificate, issued by the exporting country. Almost all countries require that imported plants be accompanied by a phytosanitary certificate. Plant products and other items may also require a phytosanitary certificate. Requirements vary widely among countries and commodities. Many countries, including Canada, also require that importers of plants and some plant products obtain an import permit in advance.

In Canada, the Plant Health Division of Agriculture Canada regulates the movement of plants and plant materials into, within, or from Canada. Those with specific import or export concerns or requests may contact one of the offices listed below:

B.C. Regional Office	(604)	666 0593
Burnaby District Office		666 3317
Vancouver (Airport Office)		270 1928
Vancouver (Dock Office)		666 3837
Victoria		388 3421
Prince Rupert		627 8818
Summerland District Office		494 7711
Kelowna		762 2458
Vernon		549 5171
Osoyoos		495 6574
Creston		482 2522
Prince George		963 9632

Arrangements for phytosanitary certificates can be made with above offices. Import permits are issued from Ottawa, but permit application forms may be obtained from any district office. Allow several weeks for processing of the application.

NORTH AMERICA PLANT PROTECTION ORGANIZATION (NAPPO)

In 1976 NAPPO was formed by Canada, the United States and Mexico to strengthen cooperation among the three countries in plant quarantine and plant protection matters. It is a consultative rather than a regulatory body. It functions as a system of permanent and ad hoc committees, whose members are generally affiliated with the official plant protection agencies of their own countries.

Various other regional plant protection organizations with a similar function, such as the European and Mediterranean Plant Protection Organization (EPPO), are also in existence.

Wilson and Graham (1983) described the objectives and functions of these and other organizations involved in plant quarantine issues.

Locally, several councils or committees have been formed to help deal with quarantine issues. These include pest action councils of the Western Forestry and Conservation Association, and the B.C. Plant Protection Advisory Council.

Canadian NAPPO Contacts

Principal Liaison Officer: Dr. Bruce Hopper,
Associate Director, Biological Support Section
Plant Health Division, Agriculture Canada

Others: Mr. Wayne Morris,
Director, Plant Health Division, Agriculture Canada

Mr. Dave Gray
Associate Director, Import Section
Plant Health Division, Agriculture Canada

The above may be reached at: K. W. Neatby Building
Central Experimental Farm,
Ottawa, Ontario
K1A 0C6

Phone: (613) 995-7900

B.C. Plant Protection Advisory Council Executive

Mr. Allan Oliver, Chairman (604)666-6513
Agricultural Inspection Directorate, Agriculture Canada

Dr. B. DeBoo (604)387-5965
B.C. Ministry of Forests and Lands

Dr. B. Frazer (604)224-4355
Research Branch, Agriculture Canada

Mr. T. Kluge (604)356-1681
B.C. Ministry of Agriculture & Fisheries

Mr. G. Miller (604)388-0600
Canadian Forest Service

Mr. Gordon Powell (604)666-0593
Agricultural Inspection Directorate, Agriculture Canada

ACTION ON QUARANTINE ISSUES

Plant quarantine issues concerning diseases often are very complex, indefinite or uncertain, and deliberations and action are usually protracted or prolonged. To achieve relatively quick and effective results, and to minimize frustration and counter-productive actions, the activities of the agencies and organizations concerned with a particular issue must be coordinated, and preferably, integrated in a cooperative fashion. We recommend that a local committee or action group be organized to deal with each issue. In B.C., the Plant Protection Advisory Council is the major group to sponsor this type of committee.

Any action program should encompass most or all of the following steps that also are common to most pest management activities:

1) Detection. These can be activities to prevent exotic pest introductions or to determine the occurrence or extent of indigenous pests. Depending on the situation, diseases or pathogens or vectors or preferably all three can be sought.

   It is important to remember that fungal behavior is extremely variable. A fungus which is a virulent pathogen in one area can be an innocuous saprophyte in another. Also, there might be several strains of a pathogen that vary greatly in virulency.

2) Identification. A recognized authority must identify a representative and well-documented specimen. In Canada the Canadian Forestry Service, Forest Insect and Disease Survey provide this service.

   Further requirements include determination of particular subspecies, forms or strains of the pathogen, and pathogenicity usually has to be demonstrated by fulfilling Koch's postulates or similar requirements. These are generally research activities, and complete identification sometimes might take several months or even years.

3) Assessment. Initially, and subsequently at frequent intervals, the status of the pest has to be assessed and (or) decided upon, usually by consensus of the organization involved. Survey and damage appraisal data, although essential, often are lacking or insufficient. However, some initial assessment of the status of the pest has to be made in order to activate research activities and control actions. Here again, the role of a coordinating committee is essential to recommend needed surveys and damage appraisals.

4) Control actions. These activities range widely in scope from limited, one-time treatments to eradicate limited infestations; to continuing or extensive treatments to control widespread infestations; and even to international negotiations to avert or reduce restrictions to forest product exports. The roles and efforts of the various agencies ideally should be coordinated by a national or more local action committee. Further research also might be required to test or develop new control treatments.

5) Information. Data, background, literature, reports, and records of decisions and recommendations, are of paramount importance - both for resolving quarantine issues and for managing the affected land or forests. A major function of a coordinating committee is to ensure that all concerned organizations are informed of essential information and recent progress. Another major role not discussed here is to keep the news media informed, particularly for any emergency actions.

WIFDWC has several potential roles or functions on quarantine issues. It can be a source of expert opinion and support, particularly for regulatory agencies that often lack knowledge or expertise about specific diseases. It could be a useful coordinating or communicating body for resolving international quarantine issues. It also could foster or facilitate preventative action to deal with new or potentially threatening pests for the region. Anyone interested in participating on a WIFDWC informal working group for quarantine issues is asked to contact John Muir.

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PITCH CANKER IN CALIFORNIA

Arthur H. McCain

Pitch canker caused by Fusarium subglutinans (Wollew. & Reinking) (Nelson, Toussoun and Marasas 1983) was recognized for the first time in California in August 1986. The disease had been misidentified by several people and attributed to insects. Surveys by the California Department of Forestry, the California Department of Food and Agriculture, and others determined the extent of the disease. Several thousand Monterey pines (Pinus radiata D. Don.) are infected in Santa Cruz County. Smaller infections centers occur in Alameda, Monterey, Santa Clara, and San Mateo Counties. Several Bishop pines (P. muricata D. Don.), one aleppo pine (P. halepensis Mill.), and one Italian stone pine (P. pinea L.) were found naturally infected. All pines inoculated in the Plant Pathology greenhouse trials at Berkeley were susceptible. Pines tested and found susceptible include: P. attenuata Lemmon, P. canariensis Sweet ex K. Spreng., P. coulteri D. Don., P. eldarica Medvedev., P. halepensis, P. jeffreyi Grev. & Balf., P. lambertiana Dougl., P. muricata, P. pinea, P. ponderosa Dougls. ex P. Laws. & C. Laws., P. radiata X attenuata, P. sabiniana Dougl. ex D. Don., and P. sylvestris L.

To date the disease has been found only in landscape plantings and in one retail nursery. However there are native stands of Monterey pine within 10 miles of infected trees. There is a recent report of an infected tree within 3 miles of the Swanton native stand of Monterey pine.

Based on symptoms such as bare branches and bole cankers, the disease has been present for several years and probably longer in the Santa Cruz area. However pitch canker likely is not a native disease for several reasons. There are many competent plant pathologists who encounter Monterey pines and other pines in their work and they would have noticed and reported the disease. It is not listed as occurring in California in Diseases of Pacific Coast Conifers (Bega 1978), or in Diseases of America (Offord 1964). Offord was aware of the disease and lists it in his appendix of fungi associated with Pinus radiata outside of Western North America. Byler (1970) studied non-rust fungi associated with galls caused by Peridermium harknessi Moore. Among those found was Gibberella lateritium (Nees.) Snyd. & Hans. (anamorph F. lateritium Nees. amend. Snyd. & Hans.), which was "significantly less pathogenic than F. lateritium f. pini, the cause of pitch canker in the southeastern United States". His isolate of F. lateritium f. sp. pini Hepting was from North Carolina. Byler (1972) also states "Gall inoculations indicated that isolates of G. lateritium from galls differ greatly in pathogenicity from F. lateritium f. pini, but differ little from G. lateritium isolates from nonpine hosts".

Seeds from cones collected from infected Monterey pines can be contaminated with the fungus. If contaminated seeds were used to produce seedlings, it is likely that some seedlings would become infected and thus the disease could be introduced

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into new areas. This apparently has not happened as yet in California with Monterey pine. The disease has not been reported from other countries such as New Zealand where Monterey pines are an important timber species. My conclusion is that the pitch canker fungus is a relatively recent arrival to California and poses a threat to native and exotic pines in natural stands, landscape plantings and Christmas tree plantings.

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Impacts of Jack Pine Dwarf Mistletoe in Manitoba

F.A. Baker, K.Knowles, Y. Beaubien, T. Meyer, and D.W.French

ABSTRACT: In Manitoba and the prairie provinces, Arceuthobium americanum, causes large witches' brooms and rapid mortality in jack pine stands. The mortality and subsequent pulp and timber volume lost has been a primary concern of forest managers. Impacts such as loss of productive forest land, reduced and deferred volume when sites are converted, increased fire hazard, and loss of valuable shade trees must be considered.

The lodgepole pine dwarf mistletoe *Arceuthobium americanum* Nutt. *ex.* Engelm. causes extensive growth loss and mortality in stands of the lodgepole pine (*Pinus contorta* Dougl.) in the western United States and Canada. In the Northern and Rocky Mountain regions of the western United States, this parasite causes an annual loss of 57 million cubic feet of volume growth (Anonymous 1986). In British Columbia, the annual loss is estimated at 3 million cubic meters per year (Anonymous 1985). These losses are primarily attributed to reduced growth of infected trees. This dwarf mistletoe is believed to have recently spread onto jack pine (*P. banksiana* Lamb.) in Alberta, where it grows on lodgepole pine, jack pine and their hybrids, and then spread eastward on jack pine in Saskatchewan, Manitoba and Ontario (Hawksworth and Wiens 1972). The magnitude of the losses in jack pine stands is unknown, but is probably much more important, as more jack pine is harvested in these provinces, and mortality is much greater in jack pine than in lodgepole pine. Jack pine is very important to the economy of the Saskatchewan and Manitoba. Along with black spruce, jack pine is the most important softwood timber specie in these provinces. In Manitoba, 31% of the volume harvested from provincial forests is jack pine. In this paper we discuss some of the impacts of this parasite in jack pine forests.

On lodgepole pine, *A. americanum* causes branch swellings and occasionally small witches' brooms. Trees are killed, but only after being infected for many years. In contrast, jack pines frequently form large witches' brooms and seem to be killed rapidly. In preliminary studies, we found that 3.5% of infected trees died each year. This mortality rate is much greater than commonly observed in infested stands of lodgepole pine.

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Mortality is the major component of volume loss in infested jack pine stands. Mortality is evident on aerial photographs, appearing as large openings in the crown canopy. Muir and Robins (1973) were able to use these openings to detect the dwarf mistletoe on aerial photographs. They found that the openings enlarged an average 3.2-4.2 feet per year, increasing in area by 260% in 20 years.

Although aerial photographs provide some indication of the impact of the dwarf mistletoe, the financial impact may be more impressive. On an aerial photograph of a 150 ha dwarf mistletoe infested stand near Moose Lake, Manitoba, areas where the crown density was reduced to class 2 or less were delineated. The volume on the 10.3 ha of density class 2 was reduced to 30 m^3 /ha, a 5.4% volume loss. Uninfested portions of the stand had a net merchantable volume of 138 m^3/ha. On an aerial photograph taken 15 years later, 26.4 ha were designated with crown density class 2 or less. Volume loss at this time was 13.8%, an increase in volume loss of 8.4% in the 15 years. Without this volume loss, the area could have produced 20,841 m^3, but it only produced 17,970 m^3. Forestry contributes $200 million to the Manitoba Gross Provincial Product, with an annual harvest of 1.7 million m^3. Thus, each m^3 of harvested timber is worth $117.65, and the loss in this 150 ha stand alone is $337,773. Since this loss will be experienced in 20 years when the stand is scheduled for harvest, this loss should be discounted, at 5% for 20 years, the present value of the loss is $121,086. This is an underestimate of losses, as reduction in stand density to class 3 was not considered, nor was an allowance made for any increase in the area of mortality during the 20 years until harvest. While this is not a definitive estimate of the impact of this parasite in Manitoba forests, this estimate caused enough concern to prompt the province to initiate a a 5-year, $750,000 research project to develop impact estimates and control procedures.

Recognizing the losses caused by this parasite, and the potential for long distance spread, the University of Minnesota and the USDA Forest Service initiated a cooperative project with the Manitoba Department of Natural Resources. The objectives of this project are to determine the current distribution of the parasite in Manitoba, to develop management practices to halt the spread and intensification of the parasite, and to evaluate effects of A. americanum in jack pine stands. There was another motive for the USDA Forest Service to be involved in Canada: by assisting the Manitoba Department of Natural Resources with efforts to understand and manage the dwarf mistletoe, the parasite would also be kept out of jack pine stands in the Lake States.

To develop an estimate of the impact of A. americanum in jack pine forests of Manitoba, we are attempting to build a simulation model. This approach is justified by the idea that even if we knew how much volume was lost in current stands, losses will increase until the stand is harvested or the mistletoe is reduced. A simulation model can provide estimates of current losses, as well as an estimate of losses occurring in the future. We are currently in the third year of the project, and a skeleton model has been built.

	Number of Trees						
	Uninfected		Infected				
Tree Diameter	Vigorous		Vigorous		Declining		Dead
	1980	1986	1980	1986	1980	1986	1986
0-4"	4	4	6	2	26	10	20
6"	1	3	17	9	26	8	24
8"	0	0	11	2	7	5	11
10"	0	0	1	1	1	0	1
Totals	5	7	35	14	60	23	56

Another impact that has become a concern only recently occurs when a jack pine stand is converted to a species which is not a host for A. americanum. Jack pine is the species of choice on these deep, sandy soils. Planting other species creates new pest problems, or the new species grows more slowly. In 1980, A. americanum was not considered a problem, because

Table 1. Condition of 100 jack pines in front yards of cottages in the Lester Beach development along Lake Winnipeg.

the stands would be regenerated with red pine. In 1982 however, red pines in a young plantation began dying after being attacked by Armillaria spp. Volunteer jack pines on the site are less susceptible, and generally outperform the uninfected red pines. The mortality has continued, and Armillaria will greatly reduce the volume of red pine on the site. This is not just a problem of young plantations, as Armillaria has caused mortality in stands of red pine up to 40 years old. Conversions to Scotch pine have had a similar fate, except that the pest on this species is the pine root collar weevil. Conversion to white spruce has been unsuccessful, as white spruce grow very slowly on jack pine sites. In many cases, volunteer jack pines dominate, and will be the major specie harvested from the site. To manage these sites for any species other than jack pine is likely a mistake.

A potential impact, if these sites could be converted, would be the loss of recreational activity and/or food gathering activity associated with collecting the mushrooms produced by fungi mycorrhizal with jack pine. Mushroom gathering is a major activity of several ethnic groups which travel more than 40 miles from Winnipeg. We have already heard at this meeting that commercial mushroom pickers are required to have a license in Washington, in part because of pressure brought about by recreational pickers. It would be difficult to quantify this impact, but nonetheless, there is an impact.

The lodgepole pine dwarf mistletoe is not only a problem of forests, but it is a serious concern in residential/recreational areas. In 1980 a population of 100 jack pines in the front yards of cottages in Lester Beach, Manitoba were mapped, , their condition rated according as vigorous, or declining, and the presence or absence of dwarf mistletoe was noted. Each year thereafter the trees were relocated and examined. During the 5 growing seasons we have observed this population of jack pines, 66 trees have died (Table 1). Two trees have become free of infection due to pruning by homeowners. Of 35 infected trees originally considered vigorous, only 14 are still rated as vigorous, and, of the original sixty declining trees, only 23 are now considered declining, the rest were killed.

From this survey it is evident that infected trees will ultimately die. Sixty percent of the population was declining in 1980. Just 6 years later, 56 trees are dead, and an additional 23 are declining. If no planting is done, there will be no jack pines in these subdivisions. Perhaps even more important, the dead brooms and trees provide fuel for fires. With a major influence of man on this area, this is particularly dangerous. A fire burned near one of the developments in 1981. The dwarf mistletoe brooms served as a fire ladder and allowed the fire to burn in the tree crowns. Had the wind come from a different direction, the fire would have burned into one of the developments and caused major damage.

Timber volume lost is a relatively easy impact to quantify, and many of our efforts end there. Concern for wildlife habitat, fuel management, visual resources and other non-timber outputs is having increasingly greater effects on management decisions. Even though these impacts are difficult to quantify, we can no longer ignore them. We must consider them, as in the future they will often be of greater importance than the loss of wood volume.

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SOME EFFECTS OF DWARF MISTLETOE AND WESTERN SPRUCE BUDWORM ON DOUGLAS-FIR IN THE BLUE MOUNTAINS OF OREGON

Catherine A. Parks and Gregory M. Filip

ABSTRACT: Branches with douglas-fir dwarf mistletoe (DM) and without were examined in stands defoliated by western spruce budworm. No difference was found in the percent of buds with budworm feeding between mistletoe infected and uninfected branches. Trees within all DM infection classes were equally debilitated by budworm.

INTRODUCTION

Dwarf mistletoe (Arceuthobium douglasii Engelm.) is one of the most destructive pathogens of interior Douglas-fir (Pseudotsuga menziesii var. glauca (Beissn.) Franco), annually causing a loss of 1.3 million m^3 of timber in Oregon and Washington (Childs and Shea 1967). The western spruce budworm (Choristoneura occidentalis Freeman) is one of the most destructive forest defoliators in western North America, especially of Douglas-fir (Williams 1967). Some outbreaks in the Rocky Mountains have been in progress more than 20 years (Furniss and Carolin 1977). Dwarf mistletoe infection and western spruce budworm infestation in Douglas-fir have been quantified many times, but their interaction has not. Objectives of our study were to test two hypotheses: (1) Douglas-fir branches with dwarf mistletoe are more defoliated by western spruce budworm than branches without dwarf mistletoe and (2) defoliation decreases growth of Douglas-fir more in trees with severe dwarf mistletoe infections than in trees with light infections in the Blue Mountains of Oregon.

METHODS

100 Douglas-firs with dwarf mistletoe infections and evidence of defoliation by western spruce budworm were selected at random from five stands on the Wallowa-Whitman National Forest in Oregon. From each tree, two primary branches in the lower crown were selected from the same whorl, one branch infected with dwarf mistletoe (plants visible) and one without. Infected branches were within witches'-brooms, and noninfected branches were not. In September 1985, the distal 45 cm of each branch was removed, and the total number of new shoots and buds, with and without budworm feeding, were recorded. Each tree was rated for degree of dwarf mistletoe infection on a scale of 1 to 6 (low to high infection according to Hawksworth 1977). Two increment cores were removed at breast height on opposite sides of each tree to obtain radial growth data for the last 5 years (during the outbreak), 10 years (previous 5 years or preoutbreak), 15 years (third 5 years or no outbreak), and 20 years. Cores were measured in the field to the nearest millimeter with the aid of a hand lens. The same radial growth data were collected from five randomly selected pondersosa pine (Pinus ponderosa Dougl.:Laws) per stand.

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The following data were analyzed for significant (P<.05) differences with paired-T statistics: (1) total number of new shoots and buds on branches infected by dwarf mistletoe vs. noninfected branches, (2) percentage of new shoots and buds with budworm feeding on infected vs. noninfected branches, and (3) radial growth during the last 5-year period (during outbreak) vs. the previous 6-10 year period (preoutbreak) for Douglas-fir and ponderosa pine. One-way analysis of variance was used to determine significant (P<0.05) differences between total number of buds on dwarf mistletoe-infected and noninfected branches, percentage of buds with budworm feeding on infected and noninfected branches, and the last 5-year and previous 5-year radial growth. Means that were significantly different were compared by Fisher's least significant difference test.

RESULTS AND DISCUSSION

Paired dwarf mistletoe-infected and noninfected branches from 100 Douglas-firs were examined in five stands. The total number of buds on branches not infected with dwarf mistletoe (table 1) were significantly different among the five stands. The total number of new shoots and buds on infected branches was significantly less than the number on noninfected branches of the same length (table 1), which is consistent with observations of Tinnin and Knutson (1980).

TABLE 1

Stand Number	Total New Shoots and Buds DM-	Total New Shoots and Buds DM+	New Shoots and Buds with Budworm DM-	New Shoots and Buds with Budworm DM+
	Number		Percent	
1	23.0	22.6	97.2	97.8
2	22.4	19.3	100.	100.
3	22.5	15.3	99.1	98.7
4	37.7	22.0	99.7	100.
5	24.1	17.1	98.1	100.
Mean	25.9	19.3	98.8	99.3
T-Value	-5.47**		-1.23ns	

No significant difference was found between infected and noninfected branches in the percentage of new shoots and buds with budworm feeding. During intense outbreaks such as the current one in the Blue Mountains, the western spruce budworm apparently has no preference for infected or noninfected branches. Whether there is a preference when budworm population are low is not known.

Radial growth of host trees was significantly less during the current outbreak than before it (table 2). As others reported, significantly more radial growth on nonhosts compensated for this (Carlson and McCaughey 1982, Carlson and others 1985). Losses in radial growth caused by budworm on Douglas-fir often are difficult to detect, especially in lower boles (Williams 1967, Brubaker and Greene 1978). Apparently, the current budworm outbreak in the Blue Mountains is severe enough to cause significant reduction in radial growth in trees also infected by dwarf mistletoe. During (last 5 years) or before (previous 5 years) the budworm outbreak, radial-growth rates between trees with low and high degrees of infection were significantly different (table 3). The additional growth loss apparently caused by budworm occurred both at a low degree of dwarf mistletoe infection (12 percent reduction) and at a high degree of infection (18 percent reduction), but these differences were not significant (T-values: -2.33 vs. 2.67, table 4). The additional growth loss during the last 5 years also apparently was caused by budworm and not by increase in dwarf mistletoe in the 10-year period.Comparisons between two preoutbreak periods (previous 5 years and third 5 years) showed no significant differences in radial growth at either low or high degree of infection (table 4).

TABLE 2

	Radial Growth			
	Douglas-fir		Ponderosa pine	
Stand Number	During Outbreak	Before Outbreak	During Outbreak	Before Outbreak
	-----mm-----			
1	9.0	11.2	10.4	9.4
2	8.6	9.1	11.0	10.5
3	7.4	8.0	5.1	3.9
4	8.5	8.8	13.8	11.7
5	7.4	7.5	4.8	4.2
Mean	8.2	8.9	9.0	7.9
T-Value	3.89**		3.09**	

TABLE 3

	During Outbreak		Before Outbreak	
	Low DMR	High DMR	Low DMR	High DMR
	Mean 5-Year Radial Growth (mm)			
	9.4	4.5	10.7	5.5
T-VALUE	-3.93**		-3.54**	

TABLE 4

	Low DMR			High DMR		
	During 5 YR.	Before 5 YR.	Third 5 YR.	During 5 YR.	Before 5 YR.	Third 5 YR.
	----Mean 5-Year Growth----					
	9.4	10.7	10.7	4.5	5.5	5.6
T-Value	-2.33*	0.01ns		2.67*	0.33ns	

Simple regression analysis indicated that 5-year radial growth of Douglas-fir was most affected by degree of dwarf mistletoe infection. This analysis predicted 5-year reductions in radial growth of 17, 40, and 63 percent during the budworm outbreak and 16, 38, and 60 percent before the outbreak in trees with low (1,2), medium (3,4) and high (5,6) degrees of dwarf mistletoe infection, respectively. These figures are comparable to data from Montana where 10-year basal area growth reductions of 14, 41, and 69 percent for low, medium, and high infection were reported (Pierce 1960), (table 5).

TABLE 5

	Percentage Reduction in Radial Growth (5 Yrs.)		
PM Level	During Outbreak	Before Outbreak	Pierce (1960)
Low	17	16	14
Medium	40	38	41
High	63	60	69

The intent of this study was to explore some of the complex associations between two ubiquitous and damaging pests in the interior Douglas-fir type. Budworm showed no preference for foliage on branches infected by dwarf mistletoe or on noninfected branches during the outbreak. The additional growth reduction caused by budworm does not differ significantly among dwarf mistletoe severity classes. Further studies are needed to quantify losses in tree growth resulting from infestation by both dwarf mistleoe and western spruce budworm, especially when budworm populations are high.

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Resistance of Jeffrey pine to dwarf mistletoe

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Abstract: Progeny of Jeffrey pine (*Pinus jeffreyi*) from several different geographic locations in northern California were planted in 1940 at the USDA Forest Service Institute of Forest Genetics in Placerville, California. Since then, many of the trees have been exposed to infection by dwarf mistletoe (*Arceuthobium campylopodium*). Of the four different seed sources of Jeffrey pine exposed to dwarf mistletoe, one is highly resistant to infection. Both numbers of trees infected and intensity of infection are much lower than found for the other seed sources. Further research is underway to identify the mechanisms of resistance, and to develop a rapid method of screening pines for resistance to dwarf mistletoe.

Introduction: The host specificity of dwarf mistletoes (*Arceuthobium*) and variation in resistance among different conifer species to dwarf mistletoes is well known (Hawksworth and Wiens 1972; Scharpf 1984). Much less is known about the intraspecific variation in resistance of conifers to a dwarf mistletoe species. One of the first known tests of resistance to dwarf mistletoe in North America was established by Bates in 1932 based on observations by Roeser (1926) and Bates (1927). Their observations indicated that some individual ponderosa pines (*Pinus ponderosa* var. *scopulorum* Engelm.) were apparently resistant to dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum* [Engelm.] Hawksw. & Wiens). Several hundred progeny from susceptible and resistant trees were planted in an infested stand and examined at intervals for nearly 50 years. By 1959 some of the surviving trees were only lightly to moderately infected and were possibly resistant. However, in 1979 Hawksworth and Edminster (1981) found no significant difference in survival rate, percentage of trees infected, and average rated level of infection between "resistant" and "susceptible" trees.

In Western North America, Roth (1966) observed an unusual morphological characteristic of ponderosa pine that he considered to impart a measurable level of resistance to western dwarf mistletoe (A. campylopodum Engelm.). On some ponderosa pines, needles droop rather than grow erect. Roth considered these pines to be more resistant because dwarf mistletoe seeds would slide off the needles rather than down to an infection site on a branch. However, he found that scions with drooping needles grafted to small trees lost the drooping growth habit when outplanted on test sites (Roth 1974).

Roth (1974) grafted seedlings with scions from what he considered to be "genetically or physiologically resistant" ponderosa pines in Oregon, and then planted these seedlings in stands naturally infested with western dwarf mistletoe. In addition, he inoculated the seedlings with dwarf mistletoe seeds each year for 5 years. After 14 years he reported grafted seedlings from 1 resistant candidate tree to be uninfected and apparently immune, and seedlings grafted with scions from 3 of 7 resistant candidates to be highly resistant. No further testing or propagation of these "resistant" candidate trees has been undertaken.

In 1961, at the USDA Forest Service's Institute of Forest Genetics in California, Scharpf and Parmeter (1967) noticed in a progeny test plantation of Jeffrey pine (P. jeffreyi Grev. & Balf.) that trees from some geographic locations were more heavily infected by western dwarf mistletoe than others. They considered these differences to result from inherent host resistance rather than disease escape.

This paper presents results of further studies made in the plantation of Jeffrey pine at the Institute of Forest Genetics, and reports on additional studies in progress on resistance of Jeffrey pines to western dwarf mistletoe.

Methods: A plantation of Jeffrey pine established in 1940 at about 825 m elevation was used as the test site. The plantation was initially established to study growth characteristics of families of Jeffrey pines from different trees from four sources in California and Nevada (Mirov and others 1952) (figure 1, table 1). At the time of plantation establishment, the presence of western dwarf mistletoe in the seed collection areas or in the native ponderosa pines adjacent to the plantation was not recognized. In 1965, the adjacent infected ponderosa pines were removed, and the plantation thinned without regard for dwarf mistletoe infection. Since 1961 we have continued to study additional spread, intensification, and resistance among individual trees and families within the Jeffrey pine plantation. Data recorded periodically for all trees since the initial

Table 1. Sources of Jeffrey pine seed used in plantation establishment, Institute of Forest Genetics, Placerville, California, 1940.

Seed Source	Elevation (m)	Notes
1. Alpine County	2510	High-elevation pines growing along the Carson River on eastern slope of the Sierra Nevada near Markleeville; dwarf mistletoe not present on seed collection site, but within a few km on Jeffrey pines.
2. El Dorado County	1920	Pines growing in mixture with ponderosa pines in Lake Tahoe Basin, near Richardson Bay on the eastern slope of the Sierra Nevada; both ponderosa and Jeffrey pines heavily infected with dwarf mistletoe in area of seed collection.
3. Ormsby County	1925	Pines growing along Clear Creek about 5 km east of Lake Tahoe, on the eastern slope of the Sierra Nevada; dwarf mistletoe not present on the seed collection site but is within a few km on Jeffrey pines.
4. Placer County	1125	Low elevation pines growing in isolated stand of only 1000-2000 ha on western slope of the Sierra Nevada near Foresthill; Low levels of dwarf mistletoe present on some trees in seed collection area.

study by Scharpf and Parmeter (1967) include tree mortality, height to the nearest foot (0.3 m), number of infections per tree, vertical spread of the parasite within tree crowns, and the dwarf mistletoe rating [DMR] (Hawksworth 1977), (figure 2).

Results: The proportion of trees infected by dwarf mistletoe, and the mean number of infections per tree increased markedly from 1961 to 1982 for trees from some seed sources, but increased less from others (table 2, figure 3).

The most striking result was a high level of resistance among the progeny from several families of Jeffrey pines from the Placer seed source. Not only were a much lower proportion of trees infected than any other seed source,

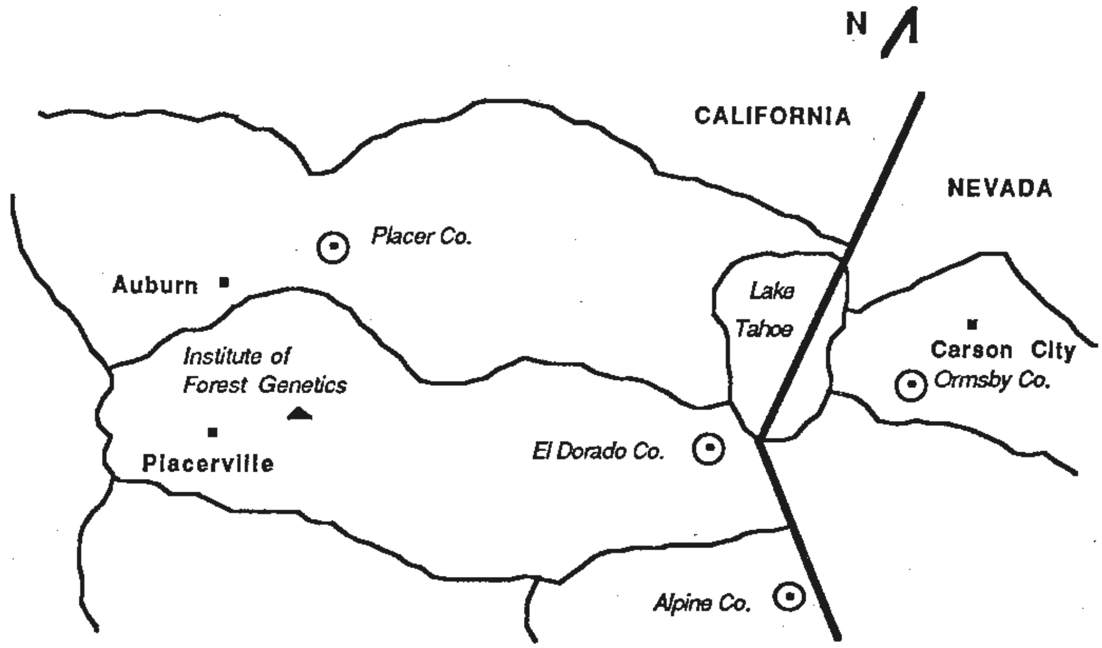


Figure 1. Jeffrey pine seed was collected at four sites in California and Nevada for establishment of the 1940 plantation, Institute of Forest Genetics, Placerville, California.

but on the average the number of infections per tree remained very low from 1961 to 1982. One less tree was infected in 1982 than in 1976, probably because little spread occurred during this period. Also, lower branches bearing older infections naturally pruned out. Careful examination of these trees in the field failed to show any noticeable morphological features or growth characteristics that could be responsible for this high level of resistance. It was difficult to determine the level of resistance in progeny among families from the El Dorado and Ormsby sources, however. Some trees were uninfected or bore few infections, whereas others were heavily infected with dwarf mistletoe in 1982. Only two trees from the Alpine source remained after thinning, but both were heavily infected with dwarf mistletoe by 1976.

Resistance to dwarf mistletoe was also determined by using the"Hawksworth" dwarf mistletoe rating system (DMR),(Hawksworth 1977;figure 2). This system rates the relative intensity of the parasite and seriousness of the disease in individual trees and groups of trees.

The mean DMR for all seed sources in 1961 was low and not appreciably different from one another (table 3). However, by 1982 marked differences were seen in mean DMR among the sources. Mean DMR for the Placer seed source was much lower than that for any other seed source and much below the rated level of dwarf mistletoe that is considered to have any noticeable affect on either trees or stands.

Table 2. Number of Jeffrey pines from different seed sources in California and Nevada and percentage infected by western dwarf mistletoe; 1961-1982.

Year	Alpine		El Dorado[1]		Ormsby		Placer	
	No.	pct	No.	pct	No.	pct	No.	pct
1961	40	38	136	25	14	36	69	11
1969	2	100	68	46	10	40	29	7
1972	2	100	68	51	10	40	29	7
1976	2	100	66	62	10	40	29	21
1982	2	100	64	86	10	50	29	17

[1] Four El Dorado trees died between 1961 and 1982.

Although mean DMR rating for the Ormsby trees was five times greater than that for the Placer source,the Ormsby trees were still considered lightly infected. Trees on the El Dorado ranged from lightly to heavily infected, with a mean DMR of moderate. Both Alpine trees were rated very heavily infected. Thus, the increase in percentage of trees infected, the intensification in numbers of infections per tree, and the Hawksworth dwarf mistletoe rating system can all be used as measures of resistance to dwarf mistletoe in Jeffrey pines.

None of the trees from the different geographic locations grew well in height from 1969 to 1982 (table 4). During this 13-year period, the mean height growth for the most rapidly growing trees (El Dorado) was 1.8 m, whereas all others showed an overall mean height growth of only about 0.3 m. Some broken tops were responsible for the low, mean growth rates, however. Because of slow growth, dwarf mistletoe could spread vertically into the upper crowns of many of the trees.

One way dwarf mistletoe can perpetuate itself in the absence of adjacent larger infected trees is by spreading vertically within the crown as the tree grows taller. Dwarf mistletoe that does not spread vertically often dies as lower infected branches naturally prune out. Another measure of a trees susceptibility to dwarf mistletoe is based on how rapidly the parasite can spread vertically and become established within the newly developing crown.

If we look at the mean height of the infections in the crowns of the Jeffrey pines infected in 1969, we see that except for the Placer seed source the highest infection was about half way from the top of the tree (table 4). Infections in Placer trees were limited to the lowest branches in the crown. Until 1961, most of the infections in the plantation trees arose from seed produced by dwarf mistletoe plants in the taller surrounding overstory. However, since 1965, when the overstory trees were removed and the plantation thinned,

Table 3. Mean dwarf mistletoe rating (DMR) of Jeffrey pines from different seed sources in California and Nevada: 1969 - 1982.

	DMR							
Seed Source	Alpine		El Dorado		Ormsby		Placer	
	N	DMR	N	DMR	N	DMR	N	DMR
1969	2	1.5	68	0.8	10	0.5	29	0.07
1972	2	2.0	68	1.2	10	0.7	29	0.07
1979	2	4.0	66	1.8	10	0.7	29	0.3
1982	2	6.0	64	2.8	10	1.6	29	0.3

nearly all spread and buildup of the parasite has been within tree crowns. Even for the most resistant trees (Placer), vertical spread of the parasite was more rapid than tree height growth. The mean height growth from 1969 to 1982 was 1.46 m or 11 cm per year whereas mean vertical spread of dwarf mistletoe was 3.15 m or 24 cm per year.

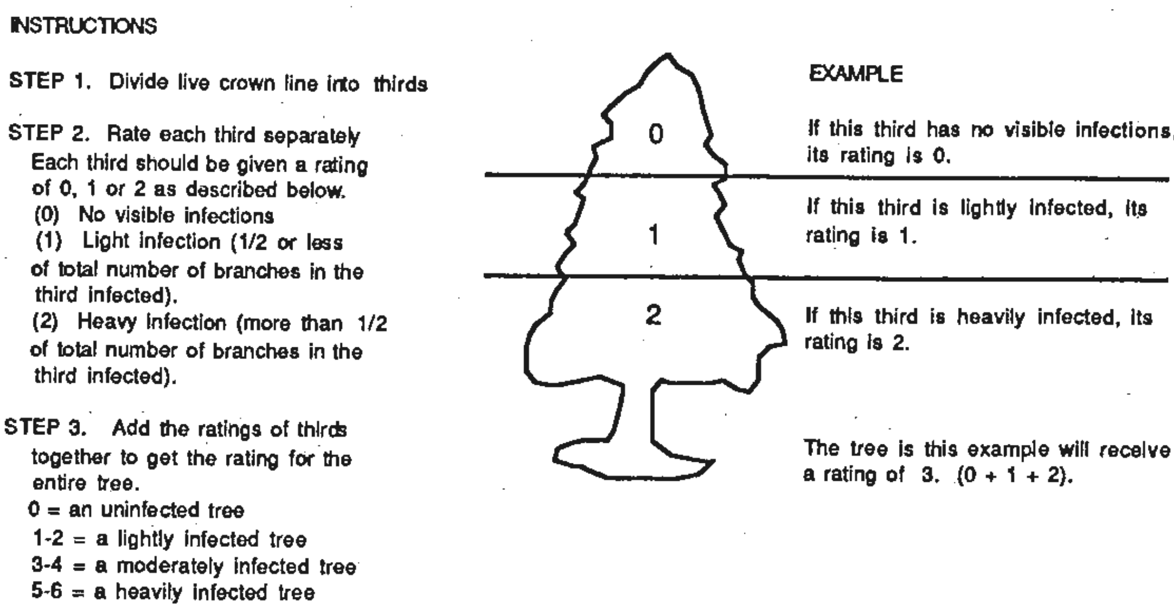
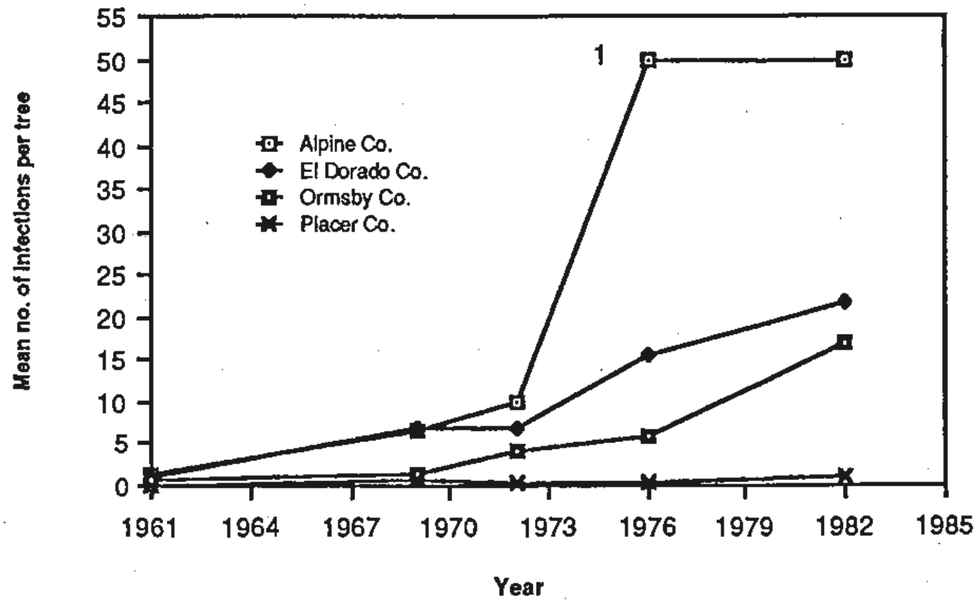


FIGURE 2. The 6-class mistletoe rating system (from Hawksworth 1977)



1. This number represents a mean of 50 or more infections

Figure 3. Infection of different seed sources of Jeffrey pine by dwarf mistletoe at the Institute of Forest Genetics, Placerville, California

Table 4. Mean tree height and mean height of the highest infection in Jeffrey pines from different seed sources in 1969 and 1982.

	mean tree ht. (m)		mean infection ht. (m)	
Source	1969	1982	1969	1982
Alpine	9.8	9.8	4.3	8.8
El Dorado	9.5	11.3	5.2	7.6
Ormsby	7.9	8.2	3.0	8.2
Placer	9.5	10.7	1.5	5.5

Discussion & Conclusions: The various seed sources of Jeffrey pines used in this study have been exposed to dwarf mistletoe for more than 45 years. Unlike the results of the long term study by Bates of ponderosa pine (Hawksworth and Edminster 1981), results of this study indicate that there is a high level of resistance to dwarf mistletoe in at least one seed source of Jeffrey pine. Also, resistance appears to be based on inherent physiological differences among trees rather than any recognizable morphological characteristics (Roth 1966,1974).

Only four trees have died since the beginning of the study in 1961; three were heavily infected. In trees that did not die, heavy infection probably reduced growth rate and vigor somewhat. Therefore, early death, diminished vigor, and suppressed growth from dwarf mistletoe should be mitigated somewhat through the use of resistant Jeffrey pines.

Mean annual vertical spread of about 24 centimeters was more than twice that of the spread reported for _A. campylopodum_ on ponderosa pine in the Pacific Northwest and for _A. vaginatum_ ssp. _cryptopodum_ in the Southwest (Hawksworth and Geils 1985).

In the near future, the main use for dwarf mistletoe-resistant trees will be for planting in high value, intensively managed areas such as parks,campgrounds, and other recreational sites where the disease occurs. Resistant trees should grow faster, live longer, present less hazard from failure, and require less maintenance than their seriously diseased counterparts.

Because of the interest in dwarf mistletoe resistant-trees by forest managers, and because little is known about the inheritance and mechanisms of resistance to dwarf mistletoe, the following research and testing are planned or in progress in California:

1. Jeffrey pines have been artifically inoculated and are being screened in lath houses and in plantations to determine more precisely the variability and levels of resistance among progeny from various seed sources. Resistant selections are also being planted in infected stands to determine resistance under varying field conditions.
2. Histological and anatomical studies are in progress to determine what tissue or cellular reactions are involved with resistance.
3. Enzyme studies will be undertaken using gel electrophoresis to determine differences in host enzyme patterns that may be related to resistance.
4. Studies using host tissue in culture are in progress to determine if callus tissue, when inoculated, can be used as a rapid method of screening for resistance in Jeffrey pines. Studies are also underway to determine if dwarf mistletoe can infect and grow in susceptible callus tissue in culture.

With the increased interest in resistance of trees to plant pests,and with the rapid progress in the field of biotechnology and genetic engineering, the prospects of developing not only dwarf mistletoe resistance but other disease resistance in forest trees shows promise. Efforts should be made to identify, catalog, and preserve forest trees known to be resistant to deseases.

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DWARF MISTLETOE CONTROL IN EASTERN WASHINGTON PONDEROSA PINE AND DOUGLAS-FIR STANDS SEVENTEEN YEARS AFTER TREATMENT

Kenelm Russell [1]

ABSTRACT: Dwarf mistletoe control-precommercial thinning was evaluated 17 years after treatment. Ring width approximately doubled over pre-treatment rates and reinfection and intensification of dwarf mistletoe was low. Eighty-eight percent of the measured trees were within allowable limits of original sanitation rules. It was generally concluded that one early treatment would be sufficient to minimize dwarf mistletoe impact on growth until commercial harvest.

INTRODUCTION

During the late 1960's, the Department of Natural Resources embarked on a large precommercial thinning program in the fast growing young forests of Western Washington. Thinning funds were not allocated for the slower growing eastside forests because they yielded a lower rate of return on timber stand improvement investments.

Fortunately, new dwarf mistletoe (DM) sanitation techniques were emerging, and with some hard selling to executive management, limited funds were secured for precommercial-sanitation thinning of young eastside conifer stands infested with dwarf mistletoe. In addition, the Forest Service agreed to cost share, at first 25 percent and later 50 percent of the control efforts. From 1969 to 1974, 7714 acres were treated at costs ranging from $22 to $32 per acre, or averaging about $25 per acre (Russell 1979). The bulk of the control was done in ponderosa pine infested with western dwarf mistletoe, *Arceuthobium campylopodum* and a smaller amount was done in Douglas-fir infested with *A. douglasii*. Results presented in this paper pertain to both ponderosa pine and Douglas-fir.

CONTROL PROCEDURE

Pre-1965 dwarf mistletoe control trials attempted to eradicate the parasite, proving both costly and impractical. Control concepts gradually evolved into deciding how much dwarf mistletoe could remain in stands without losing appreciable growth. The department based criteria for selecting crop trees on the Hawksworth Dwarf Mistletoe (DMR) Rating System.

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Under this six point system described below, "1" is lightly infected and "6" is severe. A tree rating of three loses about ten percent of its growth due to the mistletoe. [1]

First, the tree was rated at a glance for DM severity.

STEP 1: Divide live crown into thirds

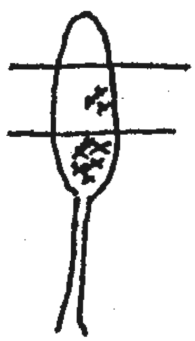
STEP 2: Rate each **third** separately and assign either 0, 1, or 2

- **0**-No visible Infection
- **1**-Light-**Less** than **half** of branches with DM plants
- **2**-Heavy-**More** than **half** of branches with DM plants and/or brooms

STEP 3: Add ratings of thirds for total tree DMR

Then the estimated diameter class determined cut/leave status.

FOR THIS DBH CLASS (inches)	THIS IS THE MAXIMUM DMR
0 - 2.4	0
2.5 - 4.4	1
4.5 - 6.4	2
6.5+	3



The drawing shows a DMR of 3.

We allowed trees rating 3 or below to remain in the stand as long as they were larger than 6.5 inches dbh. Smaller trees were allowed progressively less DM, because they would remain longer and dwarf mistletoe would gradually increase enough to cause stagnation and eventual death. This method, in theory, would allow only a small proportion of trees in treated stands at maturity with DM ratings greater than 4.

The infection rating and cut/leave status information above were printed on wallet-sized cards and given to each tree cutter. When cutters encountered DM infestation pockets, they used the two step rating rule to decide cut trees. With practice, this evaluation was done at a glance. When DM was absent, tree cutters mechanically spaced crop trees 12 to 14 feet apart.

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[1] Hawksworth, F. G. 1974. Personal communication. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

This method of sanitation created final stands with regularly spaced trees in mistletoe-free areas and small openings and somewhat irregular spacing where DM was present.

Treatment was done in moderate to lightly infested stands in order to keep costs down and retain adequate stocking. Heavily infested stands needed complete destruction followed by regeneration and were not included in this project.

Treatment unit boundaries used barriers such as roads, streams, small meadows, and other natural openings to minimize reinfection from adjoining infected stands. Occasionally, tree free barriers were created where needed on some unit boundaries but were eventually dropped because of cost.

WHAT DID WE MEASURE?

In 1974 we evaluated dwarf mistletoe infection and effects on tree growth on five-year old DM sanitation units throughout eastern Washington. We originally measured 832 trees on thirty-four 1/10 acre permanent plots. The plots were grouped in three subregions of north central, northeast, and south central eastern Washington, often considered three distinct tree growing areas. Fourteen plots are near Glenwood, 11 are north of Spokane and 9 are west of Omak. The plots were remeasured in 1979 and 1986, 10 and 17 years after treatment. Two plots were destroyed by fire, reducing to 768 the original number of measured trees.

In order to track reinfection, plots were purposely placed where there was known pre-treatment dwarf mistletoe infestation. We noted: host tree species, diameter, height, thickness of last 5 annual rings, crown class, vigor, dwarf mistletoe rating, presence of trunk canker, overstory-understory description, and cut or leave status. In this last category we evaluated whether the tree should have been cut or left.

WHAT DID WE FIND?

Seventeen years after treatment, visual inspection showed that growth had improved on crop trees and reinfection by dwarf mistletoe was low. Radial ring width almost always doubled after treatment, provided trees had been adequately released. The appearance of treated stands was a definite plus, both aesthetically and silviculturally. Previous infection centers which had been almost clearcut were often stocked with conifer regeneration.

Remember that the main objective of these plots was to evaluate reinfection by dwarf mistletoe during a period from early treatment to at least a commercial harvest. Also keep in mind that short term tree growth improvement resulted primarily from the removal of competing trees, both infected and uninfected, not from the removal of the disease. Eventually, the reduction of dwarf mistletoe in a treated stand would have an added positive effect on growth.

There were a few plots where dwarf mistletoe blossomed and spread substantially, probably because some trees were too severely infected prior to treatment.

In the 12 year period since plot establishment, tree height increased 32 percent and diameter (b.h.) increased 22 percent. The 1986 remeasurement showed the first significant mortality and ingrowth. Mortality reduced the measured trees by 4.7 percent and ingrowth seedlings increased them by 4.6 percent.

The sampled stands are characterized in figure 1 and average growth parameters are given in table 1. Height and diameter growth slowed appreciably when trees had DMR's greater than 5 and took an even greater plunge at DMR 6 (fig.1). The 1986 remeasurement values were substantially lower than in 1979. The shape of the overall graphs in figure 1 indicates that the tree selection rules are doing the job of keeping dwarf mistletoe infection from making a serious impact on growth.

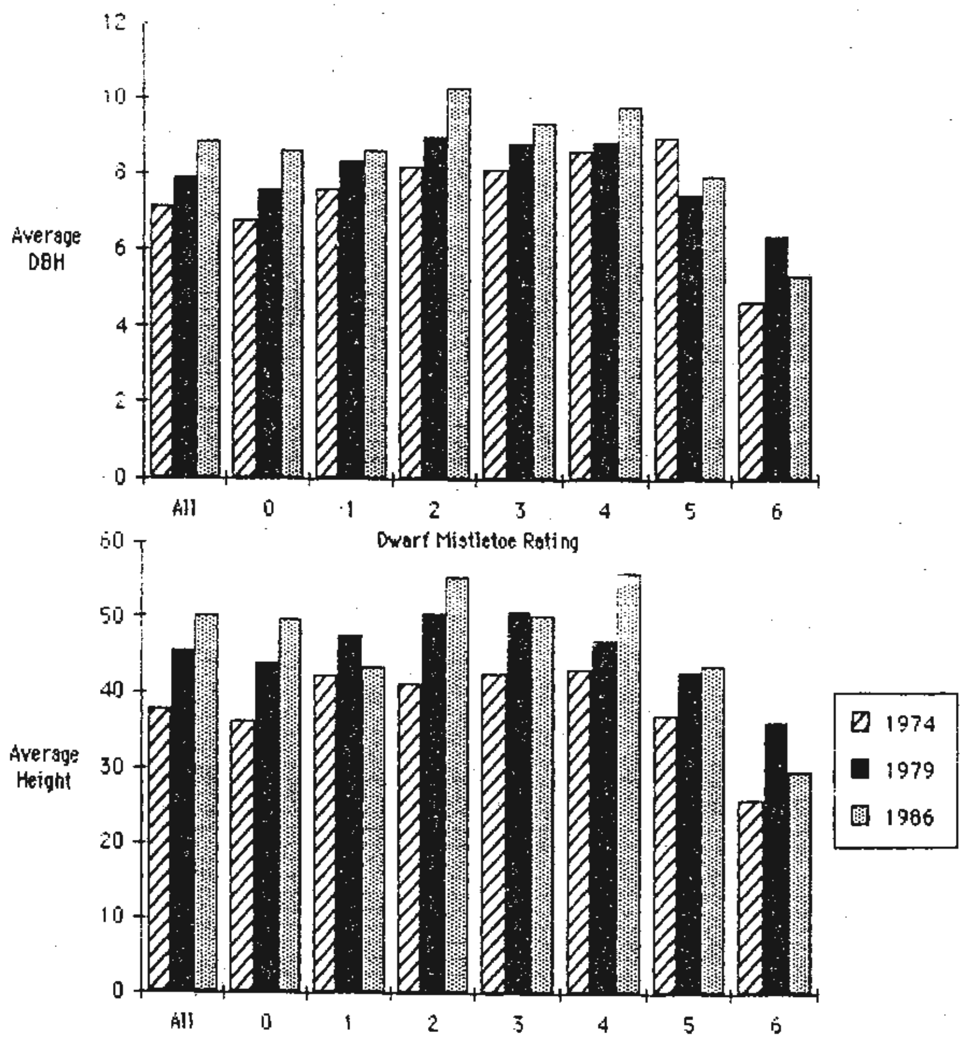

Figure 1--Average height and diameter (b.h.) in feet and inches by dwarf mistletoe rating characterizes the sampled treated stands at each of the three remeasurements. Note the dwarf mistletoe influence on tree growth when DMR's become 5 or greater.

Table 1--Average growth parameters for crop trees for the 12 year period since plot establishment

	Years Since Treatment		
	5	10	17
Diameter (in)	7.2	7.8	8.8
Height (ft)	38	46	50
Dwarf Mistletoe Rating	0.76	0.82	1.00
Mortality (number of trees)	0	1	35
Ingrowth "	0	0	35
Number of trees	768	767	767

Table 2--Percent of trees, including ingrowth, in each diameter class 5, 10, and 17 years after treatment

Years Since Treatment	Diameter Class (inches)			
	6.5+	4.5-6.4	2.5-4.4	2.4-
5	61	21	8	9
10	70	16	7	7
17	75	11	7	7

Increase in average dwarf mistletoe rating was low, changing overall from 0.76 to 1.00 (table 1). After treatment, the percent of trees in the 6.5 inch and larger diameter class rose from 61 percent at five years to 75 percent at 17 years. Detail of diameter class distribution and the changes since treatment are shown in table 2.

Five years after treatment, 69 percent of the crop trees were free of dwarf mistletoe. After 17 years, 58 percent were still disease free (table 3). In the ten year assessment report, I had noted that the six percent drop in DM free trees (69-63 percent) was insignificant.

At 17 years, the change increased another five percent, still insignificant, but changing at a slightly flatter rate (table 3). It appears that this trend will continue as the trees approach harvest size.

We observed a number of trees where DM ratings 17 years after treatment were lower than at the first evaluation. These trees grew sufficiently fast to gradually escape old lower crown infections. Density and above average

Table 3--Percent of trees, including ingrowth, in each dwarf mistletoe rating class 5, 10, and 17 years after treatment indicates small changes in infection ratings

Years Since Treatment	Dwarf Mistletoe Rating 0	1	2	3	4	5	6
5	69	10	8	8	3	1	1
10	63	15	9	7	3	3	1
17	58	14	11	8	5	3	1
Period	**Change**						
1974-79	-6.0	4.5	0.9	-1.1	-0.7	1.2	0.1
1979-86	-4.7	-0.8	2.1	1.2	2.7	0.4	0.4
1974-86	-10.7	3.7	3.0	0.1	2.0	1.6	0.3

site contributed to their ability to outgrow the dwarf mistletoe. This situation was not the rule and could only be expected in the best sites.

Overall, DM infection increased at a steady, but slow upward rate across all of the DM rating classes. The most rapid changes in infection ratings were in the smaller trees, particularly those below the 4.4 inch diameter class. Rapid change occurred when trees went from zero infection to DMR 1, the lowest rating class (table 4). Undesirable trees in the five year columns to the right of the stepped line in table 4 were either missed by thinners or moved into this category since treatment because of increases in mistletoe. The changes in percentages between the five and 17 year columns, particularly in the DMR 1 class, probably reflect true movement of trees into undesirable crop tree status from increases in dwarf mistletoe.

Five years after treatment, we found that 91.3 percent of the measured trees fell within the allowable DM ratings. After 10 and 17 years, 90.4 and 88.0 percent of the trees were still within the allowable infection ratings. Crop trees with DM infections moved into undesirable infection rating classes at an average rate of 0.25 percent per year.

The high proportion of trees remaining in below allowable infection ratings over the 17 year post treatment period assures that the treated stands will make it to harvest with little growth impact from dwarf mistletoe.

In the 10 year report noted earlier, I stated that precommercial DM sanitation was just the first step and follow-up actions might be necessary. At that time we had only scant knowledge about how long it would take for Pacific Northwest dwarf mistletoes to intensify enough to again slow stand growth.

Table 4--Percent of trees in each diameter (b.h.) class by dwarf mistletoe rating 5 and 17 years after treatment; stepped line separates desired crop trees (left) from undesirable crop trees exceeding the Rating Rule (right)

	Dwarf Mistletoe Rating													
	0		1		2		3		4		5		6	
Diameter Class	Years Since Treatment													
	5	17	5	17	5	17	5	17	5	17	5	17	5	17
6.5+	60	58	13.8	13.0	10.1	12.0	9.9	8.7	3.7	5.9	1.7	2.0	0.4	0
4.5-6.4	79	55	4.8	13.0	5.9	12.0	5.9	6.1	3.7	3.7	0.5	9.0	0.5	1.0
2.5-4.4	77	64	5.5	20.0	5.5	2.0	6.8	6.0	2.7	4.0	2.7	4.0	0	0
0.0-2.4	88	65	6.8	16.0	1.1	3.5	2.3	5.3	0	1.8	0	3.5	2.3	5.3

After seeing only small increases in DMR's 17 years after treatment, I have concluded that, in most cases, follow-up control could be delayed until early treated stands become merchantable. The dwarf mistletoe does not usually become severe enough in the interim to warrant further action. This assumption is made, provided that the early infection was not too great and that the degree of control was good.

Whenever eastside conifer stand entries are made, it is important to make sure dwarf mistletoe sanitation principles are followed when crop trees are again selected. As long as infested stands are managed on an uneven-aged basis, the dwarf mistletoe presence must drive the method of tree selection. The parasite can exist in the managed forest at low to even moderate levels depending on time to harvest.

In conclusion, "If dwarf mistletoe is readily visible in a young stand, it is probably losing growth and is a candidate for control. If you have to look twice to see the mistletoe, don't worry about it. **But, don't let latent or casual infestations get the upper hand over the long haul."** As I noted at the end of the ten year report, "Dwarf mistletoe control works!" The 17 year assessment reinforced this statement.

LITERATURE CITED

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ROOT DISEASES IN WESTERN NORTH AMERICA: A GEOGRAPHICAL PERSPECTIVE

Panel Moderator: Gregory M. Filip

Panel Members: John Muir, Paul Hennon, Paul Hessburg, John Kliejunas, Sue Hagle, Borys Tkacz, and Dave Johnson

The purpose of this panel is to compare and contrast major forest root diseases in seven principal areas in western North America: 1) Alaska, 2) British Columbia, 3) Oregon-Washington, 4) California, 5) Montana-No. Idaho, 6) So. Idaho-Utah-Nevada, and 7) Colorado-Wyoming-Arizona-New Mexico. Seven speakers will present such topics as major pathogens, tree species affected, major impact, stand/site conditions, and controls and use. Their names and information presented are shown in tabular form below.

It is interesting to compare these topics across western North America. For instance, Armillaria and F. annosus are major problems in all areas, and blackstain is absent only in Alaska. Compare this with Port-Orford-cedar root disease, a major problem on Port-Orford-cedar, which occurs only in So. Oregon and No. California. Some root pathogens, such as P. schweinitzii and I. tomentosus, probably occur in all regions but are not reported to be major problems.

With respect to major impact, Armillaria, annosus, Phellinus, and blackstain cause primarily mortality in all regions whereas schweinitzii and tomentosus cause primarily cull. In Alaska, however, damage from all root pathogens including Armillaria, annosus, tomentosus, and schweinitzii is primarily cull. This may be because in Alaska these pathogens are found in virgin stands. Whereas in stands that are disturbed through thinning or harvesting, Armillaria and annosus cause mortality as seen in every region.

Where root disease control is practiced, species conversion is the most commonly used method of control for Armillaria, annosus, Phellinus, and blackstain. It is being experimentally used in B.C. and Utah-Nevada for tomentosus. Stump removal is used occassionally in BC for Phellinus. Stumping is experimentally used in OR-WA for Phellinus, Armillaria, and annosus, in BC for Armillaria and tomentosus, and in Utah for tomentosus.

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Alaska
Paul Hennon

Major Pathogens	Species Affected	Major Impact	Stand/Site Conditions	Controls
P. weirii	WRC	Cull	Virgin	None in use
H. annosum	WH	Cull	Virgin	None in use
H. annosum	WH,SS	Unknown	Young-growth	Alter thinning and harvest schedules?
Armillaria	WH,SS	Cull	Virgin	None in use
Armillaria	All	Secondary killer	Virgin	None in use
I. tomentosus	WS,LS	Cull, mortality?	Virgin	None in use
P. schweinitzii	SS	Cull	Virgin	None in use

California
John Kliejunas

Major Pathogens	Species Affected	Major Impact	Stand/Site Conditions	Controls
F. annosus	Pines	Mortality	Second growth stands	Borax stump treatment
	True fir	Growth loss, Cull, Mortality	Old growth/ second growth	Avoid wounding, species conversion
C. wageneri	Pines, DF	Mortality	Disturbed sites	Species conversion, thinning
Armillaria sp.	Pines Hardwoods True fir	Mortality	Oak stands converted to pines	Avoid planting near oak stumps

Tree Species

WRC = western redcedar	TF = true fir	PP = ponderosa pine
WH = western hemlock	DF = Douglas-fir	WP = white pine
SS = Sitka spruce	AF = subalpine fir	MH = mountain hemlock
WS = white spruce	LP = lodgepole pine	WF = white fir
LS = Lutz spruce	POC = Port-Orford cedar	ES = Engelmann spruce
JP = Juniper	BS = blue spruce	GS = grand fir

British Columbia

John Muir

	Disease[1]	Species Inf.	Major Impact	Stands	Controls[2]	Use[3]
1)	laminated	DF,GF	Mortality	second growth	SPP D-S	R O
2)	armillaria	DF	Mortality	disturbed stands, plantations, Christmas trees	SPP D-S (FT?)	O E E
3)	tomentosus	Spruce	butt rot	second growth	SPP D-S?	E E
4)	annosus	WH,AF,SS	butt rot	second growth thinned	N C?	 E
5)	blackstain	DF,LP	Mortality	plantations	N	

1 In decreasing order of importance.

2 Controls are: SPP - less susceptible tree species; D-S - de-stumping; FT - fertilizing; N - nothing; C - chemical stump treatment

3 Uses are: R - routine; O - occasional; E - experimental

Oregon and Washington

Paul Hessburg

Area	Major Pathogen	Species Affected	Major Impact	Stand/Site Conditions	Controls and Use	
So. OR No. CA	P. lateralis	POC	Mortality	Cool, wet soils	Res. species, pathogen exclusion	UO UO
OR + WA	O. wageneri	DF,PP,LP WH, WP, MH	Mortality	Cool, moist soils, disturbed sites	Res. species, avoid site dist., time, thinnings	UR UR UE
OR + WA	P. weirii	MH,WF,DF	Mortality	All	Res. species, stump treat.	UR UE
OR + WA	A. ostoyae	All	Mortality	All conditions and stressed trees	Res. species, stump treat., host vigor	UR UE UR
OR + WA	F. annosus	Hemlock True fir Pines	Mortality Cull	Entered stands, rec. sites	Short rotation, wound prevention, borax, res. species, stump removal	UR UR UO UO UE

UO = Used occasionally
UR = Used routines
UE = Used experimentally

Utah, Nevada, So. Idaho
Borys Tkacz

Area	Major Pathogens	Species Affected	Major Impact	Stand/Site Conditions	Controls and Use	
UT,NV	1) F. annosus	AF,WF,PP	Mortality, cull, predis. to beetles	Harvested or disturbed stands, dev. rec. sites	Res. species, wound prev., borax (dev. rec)	UO UR UO
SoID	F. annosus	Ditto some DF	Ditto	Generally Ditto. Also common in old growth fir.	Ditto	
UT,NV	2) A. obscura	AF,WF,LP PP,ES,BS	Mortality windthrow, predis. to beetles	Harvested or disturbed stands, thinned LP stands	Res. species	UO
SoID	Arm. sp.??	AF,WF,PP ES, (?DF)	Predis. to beetles??, infreq. mort	Old growth, occ. second growth	Ditto plus maximizing stand vigor	UO
UT,NV	3) I. tomentosus	ES,BS	Mortality, cull, predis. to beetles?	Stands regen. after beetle	Res. species, stump removal, buffer cuts	EX EX EX
SoID	I. tomentosus (w/P. schweinitzii)	DF,ES AF	Cull, predis. to beetles, blowdown	Early mature to old growth trees	Shorten rotation length	UR
UT,NV	4) V. wagenerii	Pinyon	Mortality	Dev. rec. sites	Res. species, barrier cuts	UO EX
SoID	V. wagenerii	Pinyon, (occ. DF and LP)	Mortality, predis. to other root pathogens and beetles	Rangeland, mature stands	None required for Pinyon, otherwise too infrequent to worry about	
SoID	5) P. schweinitzii (w/I. tomentosus)	DF	Predis. to other root pathogens, beetles and ? defoliators	Mature and overmature trees	Shorten rotation length, wound prev.	UR UR

Montana and Northern Idaho

Sue Hagle

Spp. affected:	Impact	Stand/Site	Controls	Agency	Use
Armillaria (obscura?)					
Location: N. ID, W. MT, Lewis & Clark N.F.					
DF(1), GF(2), AF(2)	Mortality	All ages, esp. disturbed	Spp. conv.	FS, PVT ID,MT BIA	UR UO EX
			Red. entry	FS,MT,ID BIA,PVT	UR UO
PP(3),WWP(3), LP(3), WH(4), WRC(4)	Mortality	Second growth, regen. 30 yrs., off-site plant	Delay thin, avoid stumps	FS FS,PVT,MT	EX UO
WRC	Butt rot	Old growth, mature 2nd gr.	None		
Phellinus weirii					
Location: N. ID, Cabinet R.D. of Kootenai, scattered in W. MT on true fir types					
DF(1), GF(2), AF(3)	Mortality	All ages, esp. 40 yrs.	Spp. conv.	FS,PVT,ID PVT	UR UO
		esp. disturbed	Red. entry	FS,ID,PVT PVT	UR UO
WRC(1)	Butt rot	Esp. old growth	90-100 yr rotations	all	UR
Fomes annosus					
Location: Nez Perce NF, Clearwater NF, Lolo NF, Flathead NF, probably many other areas					
DF(1)	Mortality	All ages esp. disturbed	Spp. conv.	FS	UO
GF(2),SAF (2)	Mortality Butt rot	All ages esp. disturbed	Spp. conv.	FS	UO
PP(2)	Mortality	Thinned	None		
Phaeolus schweinitzii					
Location: Range of Df in Mt, N. ID					
DF(1)	Butt rot, root rot	Mature or old	Clearcut reg.	FS, MT	UR
PP(2),WL (2),WP (2),GF(2) AF,WH, WRC,LP, ES(3)	Butt rot	Mature or old	Clearcut reg.	FS, MT	UR
DF	Mortality	Eastside MT 30+ years old	Clearcut reg. Spp. conv.	FS FS	UR UO

Verticicladiella wageneri
Location: One location of V. wageneri has been confirmed on the Flathead Indian Reservation. Other verticicladiella species have been found associated with black "staining" in roots; Clearwater, Nez Perce, Idaho Panhandle, and Helena National Forests, and the Flathead Indian Reservation.

PP(1)	Mortality	All ages	None
DF(1)	Mortality	All ages	None

esp. disturbed = especially stands with any cutting history including selective harvest, thinning, and all regeneration harvests

spp. conv. = species conversion to disease tolerant by seedtree, planting and/or precommercial thinning to favor disease tolerant species

red. entry = reduce number of stand entries

avoid stumps = avoid planting near stumps

clearcut reg. = clearcut method of regeneration (with or without planting)

PVT = private companies with large ownerships, ID & MT = state land.

Colorado, Wyoming, Kansas, Nebraska, So. Dakota

Dave Johnson

Area	Major Pathogens	Species Affected	Major Impact	Stand/Site Conditions	Controls and Use	
CO, WY	1) Armillaria	LP,PP, AF,Aspen	Mortality	Nat. regen. stands	None	
KS, NB	2) V. wagenerii	Pinyon pine	Mortality	Nat. regen. all west of Continental Divide	Chemical physical barriers	EX
SD	31) F. annosus	WF,JP	Mortality, cull	Plantations (jack pine), harvested stands	Stump treatment w/ borax (jack pine)	UR

Arizona, New Mexico

Area	Major pathogens	Species affected	Major impact	Stand/site conditions	Controls and use
AZ,NM	1)Armillaria	PP,TF,DF	Mortality	Nat. regen. stands, planted PP stands, associated with bark beetels	None
AZ,NM	2)F.annosus	PP,TF,DF, Spruce	Mortality, but decay	Natural stands	None
AZ,NM	3)C.wageneri	Pinyon, PP	Mortality	Scattered, not of significance in commercial timber	None
AZ,NM	P.schweinitzii	DF,TF	Cull, butt rot	Natural stands	None
AZ,NM	I.tomentosus	PP,Spruce	Cull, butt rot	Natural stands	None

PATHOGEN DISTRIBUTION

	AK	BC	OR-WA	CA	MT-ID	SO.ID UT-NV	CO-WY AZ-NM
ARMILLARIA	x	x	x	x	x	x	x
ANNOSUS	x	x	x	x	x	x	x
PHELLINUS	x	x	x		x		
TOMENTOSUS	x	x	x			x	x
BLACKSTAIN		x	x	x	x	x	x
SCHWEINITZII	x		x		x	x	x
LATERALIS			x	x			

x = present and causing damage

MAJOR IMPACT

	AK	BC	OR-WA	CA	MT-ID	SO.ID UT-NV	CO-WY AZ-NM
ARMILLARIA	cull	mort	mort	mort	mort	mort	mort
ANNOSUS	cull	cull	both	both	both	both	both
PHELLINUS	-	mort	both	-	both	-	-
TOMENTOSUS	both?	cull	-	-	-	both	cull
BLACKSTAIN	-	mort	mort	mort	mort	mort	mort
SCHWEINITZII	cull	-	-	-	-	predis	cull

AK = Alaska
BC = British Columbia

OR-WA = Oregon - Washington

CA = California

MI-ID = Montana - No. Idaho
SO.ID/UT-NV = Southern Idaho, Utah, Nevada
CO-WY/AZ-NM = Colorado, Wyoming, Arizona, New Mexico

STAND/SITE CONDITIONS

	AK	BC	OR-WA	CA	MT-ID	SO.ID UT-NV	CO-WY AZ-NM
ARMILLARIA	virg	dist	dist, plant	oak	all ages esp dist	dist	nat reg
ANNOSUS	virg, 2nd	thin, 2nd	dist	2nd, old	all ages esp dist	dist	dist, plant
PHELLINUS	virg	2nd	all	-	all ages esp dist	-	-
TOMENTOSUS	virg	2nd	-	-	-	old	nat reg
BLACKSTAIN	-	plant	dist, plant	dist	all ages	dev rec	nat reg
SCHWEINITZII	virg	-	-	-	-	old	nat reg

CONTROL-ROUTINE OR OCCASIONAL

	AK	BC	OR-WA	CA	MT-ID	SO.ID UT-NV	CO-WY AZ-NM
ARMILLARIA	none	spec	spec, entry	oak	spec, entry	spec	none
ANNOSUS	short	none	spec, short, entry borax, wound	spec, borax, wound	spec	spec, borax, wound	borax
PHELLINUS	none	spec, stump	spec, entry	-	spec, entry	-	-
TOMENTOSUS	none	none	none	-	-	short	none
BLACKSTAIN	-	none	spec, dist	spec	none	spec	none
SCHWEINITZII	none	-	short	-	short wound	short	none

mort. = mortality
predis. = predisposition to other pests
virg. = virgin (unentered) stands
dist. = disturbed (entered) stands
2nd = second growth stands
plant. = plantations
old = old growth
dev. rec. = developed recreation stands

CONTROL-EXPERIMENTAL

	AK	BC	OR-WA	CA	MT-ID	SO.ID UT-NV	CO-WY AZ-NM
ARMILLARIA	none	stump, fert	stump	none	delay thin	none	none
ANNOSUS	none	borax	stump	none	none	none	none
PHELLINUS	none	none	stump	-	none	-	-
TOMENTOSUS	none	spec, stump	none	-	-	spec, stump, buffers	none
BLACKSTAIN	-	none	time thin	none	none	barrier cuts	chem/phys barriers
SCHWEINITZII	none	-	none	-	none	none	none

spec. = species manipulation
oak = oak stands converted to pines
entry = limited stand entries
wound = wound prevention
short = short rotations
stump = stump removal
fert. = fertilization
time thin = restricted thinning season

VIRUSLIKE PARTICLES IN ARMILLARIA[1/]

Jimmy L. Reaves, Thomas C. Allen, Charles G. Shaw, III,
William V. Dashek, and John E. Mayfield

ABSTRACT: Mycelial pellets from sixteen isolates of Armillaria (nine haploid and seven diploid) were examined for viruslike particles using transmission electron microscopy. Viruslike particle aggregates were observed within cells of haploid and diploid isolates. When pellets were treated with active pronase for 3 hr, there was a reduction in the distribution of the particle aggregates and a further diminution when the pellets were treated for 6 hr. Elongated viruslike particles were observed in pellet extracts of two haploid and five diploid isolates of Armillaria including several highly pathogenic isolates of A. ostoyae. These particles dissappeared after a 24 hr exposure to RNase, but remained after exposure to DNase up to 48 hr.

INTRODUCTION

Viruses or viruslike particles (VLP) occur in several fungi (Dunkel 1974; Lemke 1976, Ghabrail 1980, Rawlinson et al. 1977). Fungal viruses are typically isometric particles that range from 25 to 48 nm in diameter; most are from 35 to 45 nm in diameter (Bozarth 1979). Anisometric types of fungal VLP also have been reported in fungi, including bacilliform particles (Hollings 1972), elongated VLP (Dieleman-van Zaayen et al. 1970), and herpes-type VLP (Kazama and Schorstein 1972). These anisometric VLP were characterized primarily by electron microscopy (Bozarth 1979).

This paper reports the occurrence of viruslike particle aggregates (VLPA) and VLP in various isolates of Armillaria, a fungus that causes root disease on conifers and hardwoods throughout the world (Wargo and Shaw, 1985).

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[1/]This study formed portions of a dissertation submitted by the senior author to the Faculty of Biology, Atlanta University, May 1985, in partial fullfillment of the requirements for the degree of Doctor of Philosophy (Ph.D.).

distilled water. Mycelial pellets were grown in a modified liquid medium (SRM) of Shaw and Roth (1976) which consisted of 20 g dextrose, 30 g malt extract, 5 g bacto-peptone, in 1,000 ml of distilled water.

MATERIALS AND METHODS

Fungi and Media

Origins of the Armillaria isolates appear in Table 1. All isolates were grown on water agar medium (WAM) that consisted of 20 g agar per liter of distilled water. Mycelial pellets were grown in a modified liquid medium (SRM) of Shaw and Roth (1976) which consisted of 20 g dextrose, 30 g malt extract, 5 g bacto-peptone, in 1,000 ml of distilled water.

To obtain mycelial pellets, all isolates of Armillaria were grown on WAM in plastic petri dishes (90 mm x 15 mm) for 15 to 20 days. The original mycelial plug and the oldest portion of each colony was asceptically removed from the center of a 15 to 20 day-old colony and the remaining portion of the colony was placed into a sterilized Waring[2/] blender containing 100 ml of sterile distilled water and blended for 12 seconds. One-ml aliquots of this mycelial suspension was added to 500-ml Erlenmeyer flasks that contained 100 ml of SRM. Flasks were wrapped in aluminum foil and incubated on an Eberbach gyratory shaker at 150 rpm for 21 days at ambient room temperature. After incubation, flasks were removed from the shaker and mycelial pellets harvested by vacuum-filtration through Whatman's No. 1 qualitative filter paper (Fig. 1).

Transmission Electron Microscopy

Non-treated whole pellets.--Pellets were fixed for 10-15 min at 25 °C and then at 4 °C for 10-15 min in 3% glutaraldehyde in 0.05 M sodium cacodylate buffer, pH 7.4 and postfixed for 2 hr at 4 °C in 2% OsO_4 in the same buffer. Samples were then stained in 0.5% uranyl acetate for 12 hr and dehydrated through an ethanol series (50, 75, 95%) and two changes of 100% absolute acetone. The samples were infiltrated for 24 hr in a 1:1 mixture of acetone and low-viscosity embedding medium (Spurr 1969) and embedded in the same medium. Thin sections (200 to 500 Angstroms) were cut on a LKB Bromma-ultramicrotome with a glass knife and were collected on 100-mesh, acid-washed copper grids. Sections were counterstained with 0.5% uranyl acetate and lead citrate (Reynolds 1963) for 5 and 15 min, respectively, and were viewed with a RCA-EMU 4 (TEM) at an accelerating voltage of 50 kv.

Pronase treated whole pellets.--Pellets of A. ostoyae (Romangn.) Herink from isolates H-I and D-1 were obtained from liquid culture as previously described. Residual medium was removed by washing the pellets twice in 0.1 M Tris buffer (pH 8.1) and fixing the pellets in 0.1 M Tris-buffered 3% glutaraldehyde (pH 8.1). After fixation, pellets were washed twice in the same

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[2/] The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement of approval by the U. S. Department of Agriculture or any product or service to the exclusion of others that may be suitable.

Table 1. The origin of *Armillaria* isolates

Isolates[1/]	Host	Substrate	Location/ date collected
Diploid			
D-1	ponderosa pine (*Pinus ponderosa* Laws.)	mycelial fan at root collar	Oregon, 1981
D-2	western hemlock (*Tsuga heterophylla* (Raf.) Sarg.	butt rotted stem tissue	Oregon, 1981
D-3	grand fir (*Abies grandis* Dougl. Lindl.)	root tissue	Washington, 1986
D-4	Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco)	root tissue	Oregon, 1986
D-5	white fir (*Abies concolor* Gord. and Glend.)	basidiocarp at base of stem	California, 1986
D-6	red alder (*Alnus rubra* Bong.)	basidiocarp at base of stem	Oregon, 1986
D-7	Oregon white oak (*Quercus garayana* Dougl.)	basidiocarp at base of stem	Oregon, 1986
Haploid[2/]			
H-I thru H-X			

[1/] Isolates D-1-5 were identified as *Armillaria ostoyae* as described by Morrison et al. (1985).

[2/] Haploid isolates were obtained from Dr. James B. Anderson, University of Toronto, Mississauga, Ontario, Canada and correspond to nine biological species of *Armillaria* (Anderson and Ullrich, 1979).

Table 2. The occurrence of elongated viruslike particles in isolates of Armillaria

Armillaria Isolates	Occurrence of elongated viruslike particles[2]
Haploid[1]	
H-I	++
H-II	-
H-IV	-
H-V	-
H-VI	-
H-VII	+
H-VIII	-
H-IX	-
H-X	-
Diploid[3]	
D-1 (ponderosa pine)	+++
D-2 (hemlock)	++
D-3 (white fir)	+
D-4 (grand fir)	++
D-5 (Douglas-fir)	++
D-6 (red alder)	-
D-7 (white oak)	-

1/ Isolates designated as "H" correspond by Roman numeral with the biological species of Armillaria from North America (Anderson and Ullrich, 1979).

2/ + = present, ++ = moderately abundant, +++ = abundant, and - = absent.

3/ Dipoid isolates D-1 thru 5 have been identified as *A. ostoyae* by methods of Morrison et al. (1985). The biological species of isolates D-6 and D-7 are unknown but they were not *A. ostoyae*. Isolates obtained from hardwoods within the west have limited pathogenicity on conifers (Shaw, 1977).

buffer and incubated with 10 mg/ml Streptomyces griesus pronase (B grade, Calbiochem, LaJolla, CA) (a broad spectrum protease) dissolved in 0.1 M Tris buffer (pH 8.1) (Dashek et al. 1971). Similarly prepared pellets treated with boiled pronase served as the control. Pellets within flasks were incubated in a gyratory water bath at 37 °C for either 3 or 6 hr, were washed 3 times in 0.1 M Tris buffer (pH 7.5) for 5 min, and were prepared for TEM as previously described. To determine if the enzyme was active, pronase was tested against bovine serum albumin (BSA). Diminution of BSA was quantified colorimetrically with Coomassie blue at 595 nm (Bradford 1979).

Non-treated pellet extracts.--To obtain free VLP, a portion of pellets of each Armillaria isolate was macerated with a razor blade in a drop of 2% sodium phosphotungstate (PTA) negative stain (pH 7.0). A grid (300 mesh) coated with Formvar was floated onto the dilute macerated solution. Excess stain was removed from the grid with filter paper. The grid was allowed to dry and was then viewed with a EM-300 Philips TEM at 60 kv.

RNase and DNase treated pellet extracts.--To observe stability of VLP when exposed to RNase and DNase, a fresh pellet of isolates H-I and D-1 (Table 1) were maserated in 1 ml of RNase (50 ug/ml RNase in sterile distilled water) and DNase (50 ug/ml DNase in 5 mM $MgCl_2$). Sterile distilled water and $MgCl_2$ served as controls. Formvar-coated electron microscope grids were briefly floated on the liquid surface after 15 min, 45 min, 3 hr, 24, hr, and 48 hr treatments at room temperature. Each preparation was washed and stained with three drops of 2% PTA (pH 7.0). Two grids were used for each treatment and the experiment was performed in triplicate. Grids were viewed with an EM 300 Philips TEM at 60 kv.

RESULTS

Transmission Electron Microscopy

Non-treated whole pellets.--Mitochondria, endoplasmic reticulum (ER), and nuclei were present within most nontreated pellet cells (i.e., not exposed to active or to boiled pronase) (Fig. 2). Viruslike particle aggregates (VLPA) were also prevalent in most cells but were not associated with any subcellular organelle (Fig. 2). The VLPA ranged from a few particles (Fig. 3), to dense units of particles in regular arrays, which in some cases, filled the entire cell (Fig. 4).

Pronase treated whole pellets.--The pellets incubated with boiled pronase (control) had VLPA dispersed throughout the cells (Fig. 5). When pellets were treated with active pronase for 3 hr, there was a reduction in the distribution of VLPA, and the VLPA were less distinct than those in boiled pronase treatments (Fig. 6). All other cellular organelles were similar to those of the controls. When compared to the control (Fig. 7), pellets treated with active pronase for 6 hr showed a further diminution in the distribution of VLPA (Fig. 8).

Non-treated pellet extracts.--The presence and number of VLP in pellet extracts varied in haploid and diploid pellets (Figs. 9 and 10). There were abundant elongated VLP in isolate H-I, only a few in isolate H-VII, and none observed in all other haploid isolates (Table 2). The VLP were present in diploid isolates

D-1, D-2, D-3, D-4, and D-5 but absent in isolates D-6 and D-7. The VLP were variable in length.

RNase and DNase treated pellet extracts.--Since their pellets contained numerous VLP, isolates H-I and D-1 of A. ostoyae were chosen for DNase and RNase treatments. Elongated particles were still present when these two isolates were treated with DNase or $MgCl_2$ for up to 48 hr (Figs. 11 and 12). In contrast, the particles began to break-up after 3 hr of treatment with RNase (Fig. 13) and were completely degraded after 24 hr of RNase treatment. The particles were still present in water (control for RNase treatment) at 48 hr (Fig. 14).

DISCUSSION

Aggregates of viruslike particle were observed in various isolates of A. ostoyae. These structures are proteinaceous as shown by their degradation by a protease. Lawson and Hearon (1976) reported similar reductions in virus inclusion bodies of the carnation etched ring virus of Sapronaria vaccaria L. with protease VIII. To our knowledge, this is the first report of VLPA observed within cells of A. ostoyae. Bacteria and rickettiae-like particles have however, been observed in hyphae from rhizomorphs of Armillaria mellea Quelet (Welvaert and Samyn 1986) and elongated (bacilliform) particles resembling virions in the fruiting bodies of Armillaria mellea (Vahl ex Fr.) Karst (Blattny et al. 1973) .

Further examination of extracts from haploid and diploid isolates revealed elongated VLP. We believe the VLPA are the same as the elongated VLP but are rather different in arrangement and configuration. These VLP are similar in appearance to those reported by Lyons and Allen (1963) in Lilium longiflorum Thunb. and those reported by Ushiyama (1979) in Lentinus edodes (Berk.) Sing.). Subsequent treatment of these elongated particles with RNase revealed that these particles were degraded, suggesting that they contained ribonucleic acid. Consequently, the elongated VLP resemble viruses biochemically as well as structurally.

Moreover, it is interesting that these elongated VLP were found mostly in haploid and diploid isolates of A. ostoyae--a well known pathogen of conifers (Wargo and Shaw 1985) whereas they were absent in isolates from hardwood species presumed to have limited pathogenic capabilities (Shaw, 1977).

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THE WESTERN ROOT DISEASE MODEL: A STATUS REPORT

Bov B. Eav and Charles G. Shaw

ABSTRACT: The western root disease model, recently developed through joint efforts by research scientists, forest pest management specialists, and modelers in the USA and Canada, can be used to predict effects of either Phellinus weirii or pathogenic Armillaria spp. on forest stands under various management regimes. A keyword system allows users to input root disease inventory data, remove stumps, modify pathogen behaviors, and activate windthrow or bark beetle attacks. At present, the model is attached to the northern Idaho/western Montana and south central Oregon/northeast California variants of Prognosis which reside at the Fort Collins Computer Center. Validation testing, sensitivity analysis, development of a user interface program, and adaptation of the model to other western areas of the United States are in progress.

BACKGROUND AND STATUS

In 1985 Shaw and others made a presentation to WIFDWC on the effort that the USDA Forest Service is making to model root diseases in Western coniferous forests (Shaw et al. 1985). The objectives of this effort have been to develop a computer simulation of root disease dynamics so that a model of disease behavior and expression could be merged with various growth and yield models, and to identify inadequacies in the collective understanding of root disease biology and responses to management treatments (McNamee et al. 1987).

This on-going effort has been coordinated by Al Stage of the Intermountain Station and Terry Shaw of the Rocky Mountain Station and has been primarily conducted by a contractor team and a core group. The contractor team (Adaptive Environmental Assessments, Inc.) facilitated workshops designed to gather knowledge on the biology and management of root diseases and then used this knowledge to develop a simulation model. This integrated process of workshops and model development is further described by Brookes (1985). The core group, composed of scientists and practitioners familiar with root diseases, forest stands, and growth and yield models in the West, provided knowledge about root disease biology, stand/disease interactions, and management strategies. They also offered guidance to the contractors in model development.

The core group and contractors met in September 1984 to clarify model needs and to put reasonable bounds on the modeling process. Since that first gathering, a series of workshops, core group meetings, and contractor toil led to the development of the model and its eventual transfer in April 1987 to the USDA Forest Service Methods Applications Group (MAG). MAG is now responsible for establishing and maintaining the model as a working entity at the Fort Collins Computer Center (FCCC).

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To provide interested users with access to the model, MAG and the core group hosted a training session for key individuals from each of the Western Regions of the Forest Service in May 1987. Since then, the model has been used by some who attended that meeting from their home locations. The model is functioning and available for use by those with access to the FCCC. Even while the model is available for use, MAG and others are continually trying to improve it through a series of sensitivity analyses, validation testing, code checking, and other exercises.

To date, the western root disease model has been integrated with the Inland Empire and southern California/northeast Oregon variants of the Prognosis (Stage 1978) growth and yield model (Fig. 1). The initial intent had been to allow the root disease model to "stand alone" so that it could be integrated with various growth and yield models; however, in the process of development it has become usable only as an extension to Prognosis variants. Whether this attribute can be changed or not remains to be seen.

MODEL OVERVIEW

The western root disease model consists of three major components (McNamee et al. 1987): 1) stand interface subroutines; 2) root disease subroutines; and 3) other agents' subroutines. These subroutines interact with the Prognosis growth and yield model to compute effects of either Phellinus weirii or pathogenic Armillaria spp. on forest stands. At present, the western root disease model does not address Fomes annosus, nor can the functions for Armillaria spp. and P. weirii be used concurrently. A brief description of each component follows:

1) The stand interface subroutines integrate effects of root disease, other agents, and management actions on stand growth, yield, and regeneration. These subroutines: A) maintain a dead tree/stump list; B) predict radial extend of tree roots; C) reconcile mortality predicted by the stand model with that predicted by the root disease and other agents subroutines; D) simulate growth loss due to root disease; and E) initialize stand and root disease conditions inside root disease centers.

2) The root disease subroutines provide a dynamic representation of the spatial epidemiology of P. weirii or pathogenic Armillaria spp. within an affected stand. These subroutines assume that the distribution of root disease in a forest stand can be characterized by a number of spreading root disease centers, each of which contains both infected and uninfected trees and, possibly, other inoculum sources as well (i.e. infected stumps). The disease centers may be precisely defined by their field-measured locations in the stand (coordinates) and their sizes (radii), or these centers can be randomly or otherwise assigned various locations and sizes. This flexible structure allows for representation of various root disease situations. For example, a stand with several discrete centers of infection which may or may not overlap, a stand with scattered mortality throughout, or a young stand with inoculum from disease centers present in the previous stand. These subroutines also calculate and model the expansion rate of spreading centers and simulate the dynamics of infection and inoculum inside root disease centers. The carry-over of root disease from a stand that has been clearcut into a new stand is also handled by these subroutines.

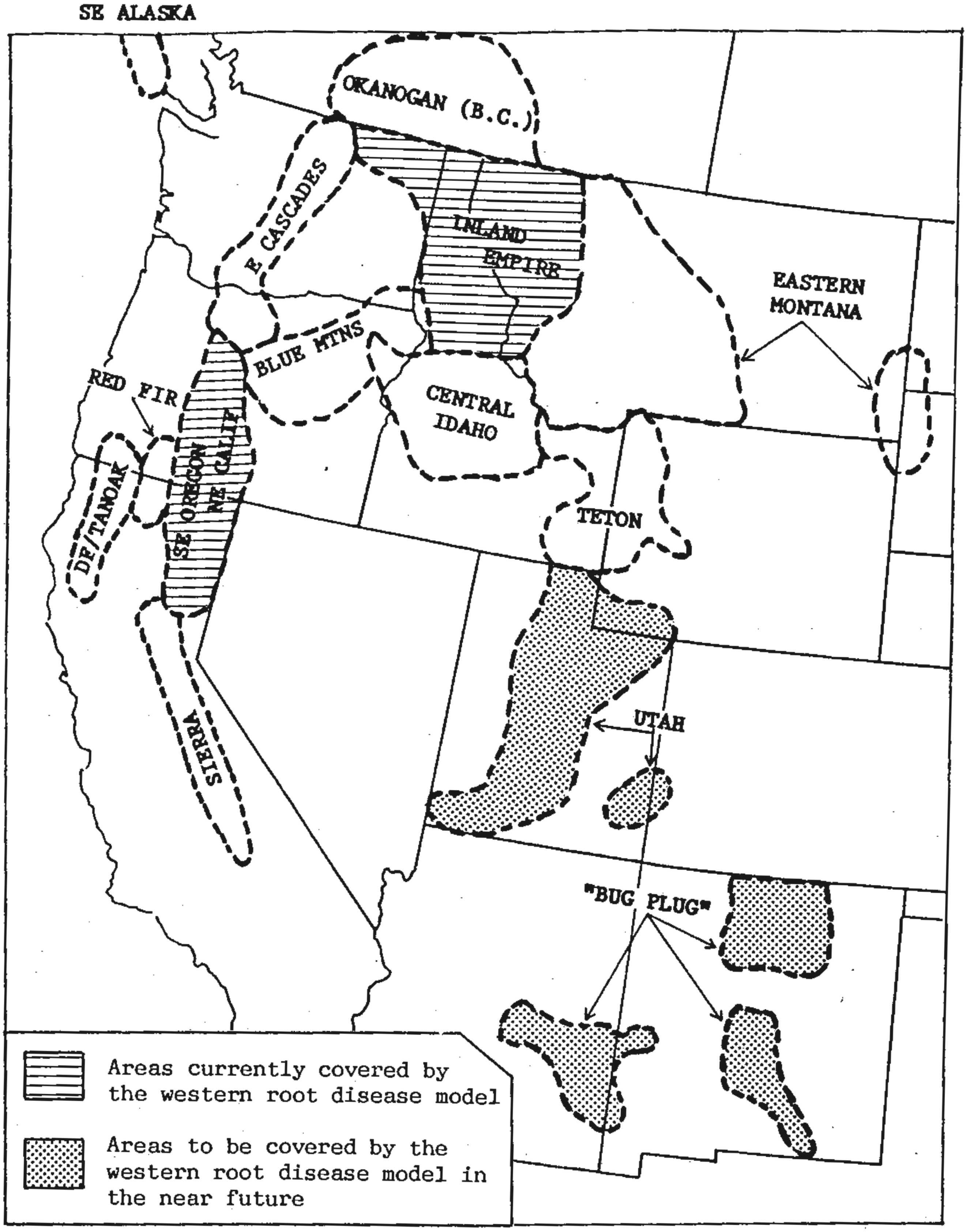

Figure 1--Approximate geographic range for variants of Prognosis and Prognosis-root disease models in the inland west as of September 1987 (some variants are under development)

3) The other agents' subroutines simulate the influence of several physical and biological agents on root disease and stand dynamics. These subroutines compute mortality in infected and uninfected trees inside root disease centers and all trees outside root disease centers. These mortalities are used by the stand interface subroutines to calculate the actual levels of mortality for infected and noninfected trees. These subroutines currently simulate windthrow and three functional types of bark beetles, as shown in table 1.

Table 1--Functional types of bark beetles simulated by the other agents component of the root disease model

FUNCTIONAL TYPE	BEETLE SPECIES	TREE SPECIES
I	Mountain pine beetle	Lodgepole pine
I	Mountain pine beetle	Ponderosa pine
I	Western pine beetle	Ponderosa pine
II	Douglas-fir beetle	Douglas-fir
III	Mountain pine beetle	White pine
III	Fir engraver	Grand fir

RUNNING THE WESTERN ROOT DISEASE MODEL

The western root disease model is controlled by the use of keywords structured in the same format as Prognosis keywords (Wykoff et al. 1982). A detail discussion and guide to the use of the five sets of keywords that control operation of the model, and their default values, appear in Sutherland and McNamee (1987), which is available from us on request. Functions of these five sets of keywords are:

1) Program execution keywords control initiation of the western root disease model and the type of outputs.

2) Inventory keywords provide information about the extent, pattern, and intensity of root disease. Model users can specify the type of disease (Armillaria or P. weirii), size and location of centers, number of infected and uninfected trees in these centers, proportion of root systems colonized by the pathogen, list of stumps containing inoculum, and stand size.

3) A single management keyword allows users to request stump removal operations. Prognosis keywords for stand management (Wykoff et al. 1982) such as thinning, site preparation, and stand establishment may also be used for desired silvicultural prescriptions.

4) Model modification keywords allow users to specify how root disease spreads, (dynamic or static), and how it carries over from an old stand to new one. The model reflects, through programmed default values, our current understanding of the epidemiology of Armillaria or P. weirii in the Inland Empire region of the western United States (Fig. 1). If users are confident that they have additional knowledge to indicate that disease behavior and stand conditions in their locale differ from these default values, then parameters can be adjusted to more accurately reflect these particular local conditions. Such changes, however, should be made only after consulting with MAG to ensure that the user is aware of the full ramifications of any changes. Infection levels that kill trees, their time-to-death, probability of infection upon root contact, minimum lifespan of inocula, and extent to which Armillaria expands outward after cutting in and around root disease centers, can be controlled by using these keywords. A random number generator is used in the dynamic simulation of spread rate and infection inside root disease patches. The number used to initiate the random number generator can also be changed.

5) Other agents' keywords permit other agents to act when stand conditions are favorable. Windthrow and the various bark beetle outbreaks described above are the only items currently governed by these keywords.

MODEL OUTPUTS

Outputs of the root disease model consist mainly of two tables: (1) a table displaying summary statistics for root disease areas, and (2) a detailed output table describing species-specific consequences of root disease infection on growth and mortality. Sutherland and McNamee (1987) provide the description and guidance for interpretation of outputs of the root disease model. Table 2 is an example of the summary table produced by the root disease model.

Effects of root disease on the entire stand appear in Prognosis output tables that summarize stand conditions during the period covered by the projection. Wykoff et al. (1982) provide a guide to interpret these Prognosis outputs. The most familiar output from Prognosis is the summary table (table 3) in which each line details a particular stand condition at the end of each prediction cycle. These lines contain: calendar year (initial year is set by the inventory year), stand age, number of trees, basal area, crown competition factor, dominant height, mean tree diameter, total cubic foot volume, merchantable cubic foot and board foot volumes, number of trees and volume removed, cubic foot volumes due to accretion and mortality.

FUTURE PLANS

User Interface

To facilitate access to the combined Prognosis-root disease model by users who are familiar with the growth and yield submittal system, MAG plans to develop a user interface program which ties into the growth and yield submittal system maintained by the Washington Office Timber Management group at FCCC. The user will choose the root disease model as an extention to Prognosis.

Table 2--Sample root disease summary output table (from Sutherland and McNamee 1987)

ROOT DISEASE MODEL VERSION 1.0															
SUMMARY STATISTICS FOR ROOT DISEASE AREAS															
		DISEASE STATISTICS			DEAD TREE CHARACTERISTICS				LIVE TREE CHARACTERISTICS						
					STUMPS		LOSSES FROM DISEASE		UNINF	INFECTED		OVERALL			
YEAR	AGE	NO. OF CENTS	DISEASE AREA ACRES	SPREAD RATE FT/YR	TOTAL /ACRE	BA/ ACRE SQFT	NO. OF TREES KILLED	VOLUME LOSSES CU FT /ACRE	NO. OF TREES /ACRE	NO. OF TREES /ACRE	AVE %ROOTS INFECTED	MERCH CU FT /ACRE	BA/ ACRE SQFT	IDENTIFIERS STAND ID	MGMT ID
1980	90	11	1.61	0.00	63	31	0	0	381	381	30.0	9554	240	37111001	42C2
1985	95	11	2.17	1.91	54	29	311	1	228	135	33.9	10056	244	37111001	42C2
1990	100	11	2.48	0.91	66	36	81	213	179	103	49.0	10278	237	37111001	42C2
1995	105	11	2.74	0.80	101	73	83	1622	139	64	54.4	9113	200	37111001	42C2
2000	110	11	2.91	0.54	73	93	59	2287	108	39	55.9	7357	158	37111001	42C2
2005	5	11	5.09	0.00	60	90	0	0	0	0	0.0	0	0	37111001	42C2
2010	10	11	5.09	0.00	40	70	0	0	1207	0	0.0	0	2	37111001	42C2
2015	15	11	5.09	0.01	26	49	19	0	1388	0	0.0	72	11	37111001	42C2
2020	20	92	2.10	0.02	12	30	17	1	1328	1	39.4	252	28	37111001	42C2
2025	25	92	2.51	0.07	7	13	14	3	494	5	38.5	587	48	37111001	42C2
2030	30	92	2.54	0.09	4	4	5	8	1384	3	56.8	1089	76	37111001	42C2
2035	35	92	2.57	0.13	3	0	10	8	1321	2	44.2	1691	102	37111001	42C2
2040	40	21	1.80	0.14	4	0	12	11	1254	4	28.5	2366	128	37111001	42C2
2045	45	21	1.86	0.33	0	0	18	3	1130	11	36.1	3026	148	37111001	42C2
2050	50	21	1.91	0.23	5	1	18	35	1018	10	30.2	3659	164	37111001	42C2
2055	55	21	2.04	0.37	0	0	48	25	880	18	33.0	4308	178	37111001	42C2
2060	60	21	2.20	0.33	10	1	50	28	742	38	31.4	4891	188	37111001	42C2
2065	65	21	2.31	0.26	16	3	62	122	614	46	28.6	5352	191	37111001	42C2
2070	70	21	2.40	0.46	13	5	30	142	539	39	29.2	5764	192	37111001	42C2
2075	75	21	2.55	0.37	23	8	43	128	450	47	32.0	6178	194	37111001	42C2
2080	80	21	2.75	0.41	16	8	42	150	374	53	33.6	6562	195	37111001	42C2
2085	85	21	2.89	0.51	21	13	49	326	300	54	30.7	6774	190	37111001	42C2
2090	90	21	3.00	0.34	22	18	30	368	256	47	31.6	6926	184	37111001	42C2
2095	95	21	3.23	0.46	23	20	32	298	215	47	34.0	7153	182	37111001	42C2
2100	100	21	3.38	0.45	30	24	24	336	181	45	33.5	7306	177	37111001	42C2
2105	105	21	3.56	0.38	22	25	20	404	158	41	34.0	7422	172	37111001	42C2

Table 3--Sample Prognosis summary output table (from Sutherland and McNamee 1987)

STAND GROWTH PROGNOSIS SYSTEM VERSION 5.1 -- INLAND EMPIRE

SUMMARY STATISTICS (BASED ON TOTAL STAND AREA)

		VOLUME PER ACRE				REMOVALS PER ACRE				GROWTH							IDENTIFIERS	
YEAR	AGE	TREES /ACRE	TOTAL CU FT	MERCH CU FT	MERCH BD FT	TREES /ACRE	TOTAL CU FT	MERCH CU FT	MERCH BD FT	BA/ ACRE SQFT	CCF	TOP HT FT	PRD YRS	ACC CUFT	MOR /YR	STAND SAMPLE WEIGHT	STAND	MGMT
1980	90	762	9554	9227	47261	0	0	0	0	240	242	121	5	177	76	5	37111001	42C2
1985	95	534	10056	9734	50251	0	0	0	0	244	243	124	5	167	100	5	37111001	42C2
1990	100	463	10393	10084	52458	0	0	0	0	243	239	126	5	151	164	5	37111001	42C2
1995	105	398	10330	10041	52599	0	0	0	0	234	226	129	5	153	194	5	37111001	42C2
2000	0	345	10126	9857	51952	345	10126	9857	51952	0	0	0	5	0	0	5	37111001	42C2
2005	5	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5	37111001	42C2
2010	10	1207	0	0	0	0	0	0	0	2	3	19	5	15	0	5	37111001	42C2
2015	15	1398	73	0	0	0	0	0	0	11	15	29	5	36	0	5	37111001	42C2
2020	20	1351	253	0	0	813	0	0	0	26	29	36	5	70	1	5	37111001	42C2
2025	25	515	591	135	520	0	0	0	0	49	52	45	5	105	2	5	37111001	42C2
2030	30	1405	1105	474	1939	0	0	0	0	77	79	54	5	128	4	5	37111001	42C2
2035	35	1348	1726	1092	4516	0	0	0	0	104	105	61	5	147	9	5	37111001	42C2
2040	40	1288	2413	1783	7502	0	0	0	0	131	127	68	5	150	16	5	37111001	42C2
2045	45	1181	3086	2318	9958	0	0	0	0	152	144	73	5	161	27	5	37111001	42C2
2050	50	1076	3756	3173	13612	0	0	0	0	169	157	78	5	170	36	5	37111001	42C2
2055	55	973	4429	3838	16597	0	0	0	0	184	166	83	5	164	44	5	37111001	42C2
2060	60	877	5030	4495	19503	0	0	0	0	195	173	87	5	169	62	5	37111001	42C2
2065	65	785	5564	5018	21934	0	0	0	0	201	175	91	5	172	72	5	37111001	42C2
2070	70	705	6063	5536	25096	0	0	0	0	206	176	95	5	175	80	5	37111001	42C2
2075	75	630	6536	6028	28082	0	0	0	0	209	175	98	5	176	89	5	37111001	42C2
2080	80	562	6973	6512	30960	0	0	0	0	211	174	102	5	177	101	5	37111001	42C2
2085	85	497	7350	6938	33460	0	0	0	0	211	171	106	5	177	108	5	37111001	42C2
2090	90	444	7695	7297	35608	0	0	0	0	210	167	111	5	177	111	5	37111001	42C2
2095	95	394	8026	7648	37797	0	0	0	0	209	164	115	5	175	116	5	37111001	42C2
2100	100	351	8325	7959	39667	0	0	0	0	208	160	120	5	176	121	5	37111001	42C2
2105	105	314	8600	8243	41684	0	0	0	0	206	156	124	0	0	0	5	37111001	42C2

NOTE: PREVIOUS 26 LINES HAVE BEEN WRITTEN TO THE FILE REFERENCED BY LOGICAL UNIT 4

Expansion of Areas Covered

Because of requests from the user community and research scientists, MAG will link the root disease model to the "Bug Plug" variant of Prognosis that covers areas in Arizona and New Mexico. The Utah variant of Prognosis is another variant which will be attached to the root disease model in the near future. User requests through FPM regional offices will dictate which additional variants of Prognosis will be attached to the western root disease model.

Research Needs

The modeling process has identified an array of research needs. Studies to address some of these needs are now in progress; hopefully more will start soon. Some of the identified research needs are :

- Inoculum dynamics in dead trees and stumps, particularly minimum lifespan of inoculum and saprophytic colonization of dead, noninfected material

- The dynamics of carryover, and how the level of carryover is influenced by the nature of the original stand and tree resistance to root disease in the new stand

- Interactions between other agents and root disease

- Better estimates of probability of infection and time to death, and an assessment of how these parameters vary with host species, seed source, habitat, and stand management history

- The relationship between crown symptoms and level of root infection and how this may vary by pathogen

- The levels of scattered isolated infection and mortality in stands, and the dynamics of scattered root disease

- The relationship between the actual extent of root disease centers and the observed extent

- The relationship between the actual number of infected trees and the observed number

- Root extent

- Reconciliation of mortality between Prognosis and the root disease model

- The degree to which root disease expansion occurs when a stand is clearcut

- How use of the static option of the root disease model affects projections of disease development.

Model Validation

Several scientists are collecting data to use in the ongoing process of testing the validity of the model. Results of these tests are expected within the next two years. MAG is performing a sensitivity analysis of the model to examine model keywords in order to identify those most influential in the spread of the disease. In cooperation with the Pacific Northwest Forest Research Station, MAG is also evaluating the rate of spread in actual stands as compared to model outputs.

Problems and concerns

Even though the model is a functioning entity with interested users, several items require some attention. These include: publication of the model; revision of keywords and the user's manual; training sessions; testing and refinement of inventory procedures; development of graphic displays for output; access for non Forest Service users; extension to other root disease types and multiple types in the same stand; use on microcomputers; interactions with other pest models; use in forest planning; adaptation to other growth and yield modeling systems; and an evaluation of the accuracy of its reflections on the real world.

The length of this needs list ensures that WIFDWC will again be updated on the status of this ongoing, cooperative effort to provide managers with a tool to use for understanding the dynamics and dealing with the damage caused by root diseases in western coniferous forests.

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VARIATION IN VIRULENCE WITHIN HOST SPECIFIC VARIANTS OF LEPTOGRAPHIUM WAGENERI

William J. Otrosina, Fields W. Cobb, Jr., and Tina L. Popenuck

ABSTRACT: No information exists on the variability in virulence among isolates of L. wageneri. Such information is important in evaluation and identification of resistance in host tree species. Preliminary data suggests there is variation among isolates of a given host specific variant of the fungus as measured by mortality, symptom expression, and disease development. Further analysis of data is continuing.

INTRODUCTION

Leptographium wageneri (=Verticicladiella wageneri) is a serious pathogen of hard pines, Douglas-fir, and pinyons in the western US. Recent isozyme studies (Otrosina and Cobb, 1987) have indicated L. wageneri is a genetically uniform fungus with less than 25% of the isozyme loci analyzed being polymorphic. Generally, lack of variability in isozyme phenotypes in plant pathogenic fungi do not necesssarily indicate a corresponding reduced amount of virulence. There are indications, however, that in asexually reproducing populations of some plant pathogenic fungi, isozyme variability may be associated with variability in virulence (Burdon and Roelfs, 1985). There are also some indications that sexual recombination in L. wageneri may not be common, at least in the ponderosa pine variant (Otrosina and Cobb, unpublished).

While studies by Harrington and Cobb (1984) have demonstrated pathogenicity and host specificity relationships among the variants of this fungus, very little is known about virulence differences among isolates within each variant. Obtaining such information is important to the development of disease control strategies involving screening for resistant genotypes within host tree species. This study was undertaken to determine the variability in virulence among isolates of the hard pine and Douglas-fir variants of L. wageneri.

METHODS

Two-year-old bare root nursery grown seedlings of ponderosa pine and Douglas-fir were potted into plastic coated, one quart milk containers with standard UC Berkeley soil mix. Seedlings of both tree species originated from seed collections comprised of less than 4 parent trees. Seedlings were allowed to acclimatize in the greenhouse for one month before inoculation with L. wageneri isolates.

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Twelve representative isolates of each L. wageneri variant were selected from different geographic areas. The Douglas-fir isolates represented collections from the northern California coastal areas, the central Sierras, and New Mexico. Hard pine isolates ranged from the northern to central Sierra.

Inoculum was in the form of infested 1cm X 3cm branch segments of ponderosa pine and Douglas-fir which were initially prepared by boiling the segments in 2% malt extract for 20 minutes. After boiling, the segments were placed in 2 layers in 60 ml screw cap specimen jars, autoclaved, and inoculated with the appropriate cultures of the 12 L. wageneri variants. The inoculated branch segments were incubated at 18 C for 8 weeks prior to seedling inoculation.

Eleven hundred seedlings of each tree species were inoculated with the 12 isolates of each variant. The inoculation of test seedlings was performed by removing a small amount of soil from the seedling root collar area sufficient to cover the inoculum block. Infested branch segments were then placed next to the root collar after gently scraping the region to be inoculated with a sterile metal spoon. Treatments (L. wageneri variants), were randomly assigned within each of 5 blocks for each tree species. Within a block, there were 18 seedlings per treatment, along with a control treatment where the seedlings were treated identically except inoculation was performed using non-infested branch segments.

Seedlings were removed from the container after death. Dissections and isolations were then made to confirm infection. Besides percent mortality, data on the timing of onset and progression of symptoms, length of stain above and below point of inoculation, and total length of shoot and root were obtained. All seedlings were checked twice per week after the initial onset of symptoms. At the time of termination of this study, all seedlings without symptoms were also dissected and examined for presence of stain.

PRELIMINARY RESULTS

The percent mortality for all isolates and tree species 26 weeks after inoculation are presented in table 1. Control seedlings of both species were asymptomatic and only two Douglas-fir died during the course of the experiment. No evidence of black stain root disease was present in those seedlings.

In general, pine tended incur less mortality overall than did the Douglas-fir. Symptom expression also differed between the two tree species. Stain tended to travel further up the stem of pine whereas the Douglas-fir tended to have limited staining in the stem. Also, the major onset of symptoms did not occur on pine seedlings until 3-4 weeks after bud break and shoot elongation. Douglas-fir seedlings tended not to break bud before symptom development. Also, symptoms (wilting, chlorosis) developed approximately 3 weeks earlier in Douglas-fir than in the pine. At termination of the study when the remaining seedlings were dissected, the Douglas-fir tended to have more stain in the residual, asymptomatic seedlings than the ponderosa pine (table 2).

Table 1--Percent mortality by Leptographium wageneri isolate in Douglas-fir and ponderosa pine seedlings

Douglas-Fir

Isolate # 1	5	27	30	32	40	55	56	57	F	X	NMD
71	82	71	62	77	77	61	8	9	67	61	36

Ponderosa Pine

Isolate # 3	4	19	36	37	39	A	E	G	V	W	L
57	51	60	38	40	51	73	40	57	58	39	52

Table 2--Number of trees and %( ) remaining of Douglas-fir and ponderosa pine seedlings having stain but showing no symptoms at termination of study 26 weeks after inoculation

Douglas-Fir

Isolate # 1	5	27	30	32	40	55	56	57	F	X	NMD
9(35)	6(38)	7(27)	3(9)	6(29)	4(19)	6(17)	0(0)	0(0)	8(27)	7(20)	21(36)

Ponderosa Pine

Isolate # 3	4	19	36	37	39	A	E	G	V	W	L
3(8)	0(0)	1(3)	1(2)	0(0)	0(0)	1(2)	0(0)	0(0)	1(3)	0(0)	0(0)

DISCUSSION

There appears to be differences in virulence among isolates as measured by total mortality. Douglas-fir isolates tended to be more uniform in their virulence than ponderosa pine isolates relative to total mortality, except for 3 anomalous isolates (# 56, 57, and NMD). The reasons for the apparently lower virulence observed in these isolates are not known. Unfortunately, there is a lack of data regarding effect of geographic source of isolate on genetic variation and relative virulence in L. wageneri. As a speculation regarding the isolate NMD, geographic origin (New Mexico) may be a factor. In a recent study, isozyme differences between the pinyon variant and the Douglas-fir and ponderosa pine variants of L. wageneri were attributed in part to geographic separation of the pinyon host (Otrosina and Cobb, 1987). Although the host of origin of NMD is Douglas-fir, this isolate has a slightly different isozyme phenotype than do other Douglas-fir isolates from differing geographic regions (Otrosina, unpublished data). Isozyme analyses were not performed for isolates 56 and 57.

There are also some indications that duration of asymptomatic presence of the fungus as determined by stain existing in residual seedlings may differ among isolates. In the data for Douglas-fir (table 2), the anomalous isolates mentioned above also deviate from other isolates regarding this parameter. Ponderosa pine isolates apparently had few residual seedlings with asymptomatic staining present, illustrating differences in experssion of symptoms between the tree species. Such characteristics can be important when evaluating resistance, for example. These and other data are being analyzed at this time and firm conclusions regarding these measures of virulence among these isolates await these evaluations.

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THE EFFECT OF SNOW COVER ON THE DEVELOPMENT OF SCLERODERRIS SHOOT BLIGHT--CAN THIS EXPLAIN THE NEW YORK STATE OUTBREAK?

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ABSTRACT: In Wisconsin, Scleroderris shoot blight occurred if cumulative duration of conducive winter conditions (-6 to +5°C or > 30 cm snow) was great enough. In New York, similar temperature conditions (regardless of snow cover) occurred over most 2-yr periods between 1964 and 1985. Hence the New York epidemic in upper crowns of mature trees may have been due to winter conditions rather than differing virulence of pathogen serotypes.

INTRODUCTION

Scleroderris shoot blight, as it occurs in the Lake States, is a problem in red and jack pine plantations. The disease is incited by the fungus *Gremmeniella abietina* (Lagerb.) Morelet (= *Ascocalyx abietina* [Naumov] Schlaepfer-Bernhard). Symptoms include flagging of current-year shoots on the lower branches of these trees. The infection can progress to the main stem and form cankers, which on small trees can lead to tree mortality due to girdling. Mortality of large trees has not been observed in this area.

Scleroderris shoot blight led to serious losses of red and jack pine in the Lake States in the 1960s. By the early 1970s, however, the use of preventative fungicides in nurseries halted distribution of infected planting stock. Disease spread apparently stopped, leading to the belief that the disease was essentially under control.

In the mid-1970s, *G. abietina* caused mortality of mature red and Scots pine at epidemic levels in New York State. The symptoms were similar to those reported for this disease in Europe. The fungus isolated from these trees was determined to be serologically identical to isolates from Europe, but serologically distinct from all isolates of the fungus previously collected in North America. The coincidental appearance of the European (EU) serotype and symptoms similar to those found in parts of Europe led some to believe that the EU and North American (NA) serotypes differ with regard to pathogenic aggressiveness. Alternatively, pathogenic aggressiveness might be similar for the two serotypes, but the disease syndrome may be different due to different environmental conditions. Given the lack of evidence to distinguish between the two hypotheses, serious concern was raised that the EU race of *G. abietina* might spread to the Lake States and begin attacking mature stands of red and jack pine there.

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Since its detection in New York, the EU race of G. abietina has been detected throughout New England in the United States and as far west as eastern Ontario in Canada. The NA race has been found as far west as British Columbia. Although additional outbreaks of Scleroderris shoot blight on mature trees have not occurred, it is still not known what triggered the New York State epidemic, or what might trigger a similar event in the future.

Scleroderris shoot blight has a very unusual disease cycle. Initial penetration by the fungus typically occurs in late spring or early summer, after which proliferation stops and the fungus appears to remain quiescent in bract tissue throughout the summer and fall. Rapid colonization of tissue occurs only in late January or early February (Patton et al. 1984). Initial symptoms, typically red discoloration of needle bases, appear by early spring, approximately one year after initial penetration. Hence, it is likely that environmental conditions conducive to growth of G. abietina during mid-winter are essential for disease development.

Reports in the literature and personal observations suggested certain environmental factors that might play a role in mid-winter tissue colonization. In both Europe and North America, high disease incidence has frequently been associated with preceding winters of high snow cover (Martin 1964, Yokota 1975, Yokota et al. 1974). Snow is capable of moderating temperatures near the ground to near 0°C, even if ambient air temperatures are much lower than 0°C (Alberga et al. 1987, Dorworth 1972). Both northern and southern Wisconsin, where this research was conducted, experience extremely cold winter temperatures. Usually, however, northern Wisconsin, where the disease occurs naturally, has significantly more snowfall than does southern Wisconsin, where the disease does not occur naturally. Since G. abietina is capable of growth at temperatures as low as -6°C (Ettlinger 1945, personal observation), the conditions necessary for disease may be extended periods of temperatures near 0°C.

The details of three experiments designed to test the effect of snow cover on disease development have been reported previously (Marosy and Patton 1988). The concept of a "conducive day" was developed as a quantitative measure of the amount of time a given experimental seedling is completely covered with snow, or exposed to conditions similar to those provided by a snow cover. A conducive day was defined as one in which the ambient air temperature is between -6 and +5°C, or the snow cover is enough to completely cover the experimental trees. The lower temperature limit was chosen as that above which growth of the fungus has been observed. The upper limit was chosen somewhat arbitrarily as a temperature below which physiological activity of the tree is severely reduced (Vegis 1973). Six-month-old containerized red pine seedlings were transplanted to the field or to wooden flats, inoculated with a conidial suspension, and exposed to either (1) natural climatic conditions in a latitudinal gradient from southern Wisconsin to upper Michigan (Local Climate Experiment), (2) artificially manipulated field conditions in northern and southern Wisconsin (Snow Cage Experiment), or (3) completely artificial conditions (Controlled Temperature Experiment). In these experiments, conducted in 1984-85 and repeated with new seedlings in 1985-86, between 43 and 51 conducive days between 1 October and 28 February were necessary for disease to occur.

The objective of the current research was to investigate the effect of snow cover and temperature, as measured by conducive days, on the natural disease situation in the field, both in northern Wisconsin and in New York State.

EXPERIMENTAL PROCEDURES AND RESULTS

Northern Wisconsin

Three 6-yr-old plantation trees in northern Wisconsin were artificially inoculated in the summer of 1984 and reinoculated in the summer of 1985. The tops of two of these trees were pulled to the ground and secured in such a way that they would be covered by winter snowfall. The third tree was left standing throughout the winter. The trees were assessed for symptoms in the spring and summer of 1985 and 1986. In the summer of 1986, the experiment was repeated with three additional trees at each of two nearby locations. One tree at each site was inoculated and pulled to the ground, one was inoculated and left standing, and one was pulled to the ground but not inoculated. These trees were assessed for symptoms in the summer of 1987. Temperature and snow data for the area were compiled (U.S. National Climatic Data Center 1984-87) and the number of conducive days for each year was determined.

No symptoms were observed on the experimental trees in 1985. The number of conducive days during the previous winter, based on 30 cm of snow, was 22, and natural infection in the area was low. In 1986, 16 of 17 inoculated leaders within 1 m of the ground on one tree were infected. On the second tree, all eight inoculated leaders within 1 m of the ground were infected, whereas none of 19 inoculated leaders, greater than 1 m above ground on this tree, developed symptoms. The third tree, not pulled toward the ground, remained free of symptoms. In this year, the roped trees had been exposed to 44 conducive days. Twenty-nine of these days were conducive due to snow cover alone. In 1987, no symptoms were observed on any of the experimental trees. The control tree and branches more than 1 m above ground on the roped trees were exposed to 27 conducive days between 1 October 1985 and 28 February 1986. In 1987, no symptoms were observed on any of the experimental trees. Snowfall during the winter of 1986-87 was unusually light at the site, and only 25 days were conducive. Natural infection in the area was the lowest observed in approximately 20 years.[1] Thus, the NA serotype caused disease in the tops of 2-3 m tall trees, but only if exposed to appropriate winter conditions.

New York State

It was not clear how snow might bear on the 1975 New York State outbreak of Scleroderris shoot blight in the upper crowns of mature trees. In Wisconsin and Michigan the requirement of more than 43 conducive days in a given season was never met by temperature alone. To determine if this was also true in New York, temperature data for Boonville, New York, one of two main centers

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[1]Personal communication with D. D. Skilling, USDA--Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota 55108.

of upper crown infection (Skilling 1977), were compiled for the period from 1964-65 to 1984-85 (U.S. National Climatic Data Center 1964-85). The number of conducive days for each season during this 20-yr period was determined. In no single winter during this period were there more than 43 conducive days at Boonville. The number of conducive days accumulated over two consecutive winters, however, was greater than 43 for all but two periods (1977-79 and 1978-80) (Table 1).

DISCUSSION

The number of conducive days required to allow disease development due to the NA race in the Lake States (44) is similar to the number of conducive days, based on ambient air temperature alone, in Boonville, New York over consecutive 2-yr periods between 1964-65 and 1984-85 (37-69). Those periods at Boonville with fewer than 43 conducive days in a consecutive 2-yr period (1977-79 and 1978-80) coincide with the end of epidemic disease levels and widespread mortality in New York (Skilling 1981). The NA serotype of the fungus has been shown to remain viable in host tissue for almost 2 yr, causing symptom development only after exposure to two consecutive cumulatively conducive winters (Marosy and Patton 1988). These data suggest that (1) the two serotypes of the fungus are responding very similarly to environmental conditions, and (2) the occurrence of Scleroderris shoot blight in the upper crowns of mature trees in New York may have been due to the build-up of inoculum in the upper crowns combined with the frequent occurrence of very restricted environmental conditions. Two non-conducive 2-yr periods, along with the elimination of a large source of inoculum as infected trees were killed, may have contributed to the drop in disease incidence which occurred in 1980 (Skilling 1981). The current increase in disease levels[2] may be an indication of inoculum once again building up in the upper crowns of large trees unaffected by the previous epidemic.

If this proposed explanation of the New York State epidemic is correct, it is very possible that a similar outbreak could occur again, at any time and in any place that the proper environmental conditions occur in the presence of susceptible hosts and sufficient inoculum. Conditions appropriate for the development of Scleroderris shoot blight--heavy snow cover in mountainous regions and moderate winter temperatures in coastal areas--are common in western North America. Many western forest species are susceptible to the pathogen. Lodgepole pine (Pinus contorta Dougl.), sugar pine (P. lambertiana Dougl.), western white pine (P. monticola Dougl.), and ponderosa pine (P. ponderosa Laws.) are all highly susceptible to the NA serotype of G. abietina (Skilling and Riemenschneider 1984), which has already been identified in British Columbia. Host resistance trials conducted during the past five years with over 200,000 ponderosa pine seedlings belonging to 300 seed sources have revealed no resistance to the pathogen.[1] Species other than pine, including western larch (Larix occidentalis Nutt.), Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) and western hemlock (Tsuga heterophylla (Raf.) Sarg.) are highly susceptible to the EU race of the pathogen (Skilling and Riemenschneider 1984). This race has to date been found as far west as eastern Ontario. There is also evidence of possible

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[2]Personal communication with B. Schneider, New York State Department of Environmental Conservation, Lowville, New York 13367.

Table 1. Number of conducive days at Boonville, New York, and Ashland, Wisconsin, for one or two winters ending in year shown, as determined by temperature alone.

	One Winter		Two Winters	
Year	Boonville	Ashland	Boonville	Ashland
1964-65	15	6		
1965-66	41	30	56	36
1966-67	22	16	63	46
1967-68	26	22	48	38
1968-69	33	23	59	45
1969-70	17	15	50	38
1970-71	27	14	44	29
1971-72	27	24	54	38
1972-73	31	30	58	54
1973-74	29	25	60	55
1974-75	39	22	68	47
1975-76	19	17	58	39
1976-77	29	17	48	34
1977-78	18	17	47	34
1978-79	19	9	37	26
1979-80	21	24	40	33
1980-81	25	17	46	41
1981-82	22	20	47	37
1982-83	28	39	50	59
1983-84	40	28	68	67
1984-85	29	14	69	42

mutation from the NA race to the EU race.[3] Should inoculum levels build up, the potential for serious outbreaks of Scleroderris shoot blight would exist. In light of the data and arguments presented here, individuals involved in forest management and pathology in the western United States and Canada should be concerned about the possible threat of Scleroderris shoot blight to western forests and take care to prevent introduction of _G. abietina_ into any areas where it is not currently present.

[3]Oral presentation by H. Gross at the 1986 Central International Forest Pest Conference held at Sault Ste. Marie, Ontario, October 28-29.

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Relationships of Weather Episodes and Occurrence of Comandra Rust

Jane E. Boyd and William R. Jacobi

Comandra blister rust, induced by Cronartium comandrae, is a damaging canker disease of lodgepole pine in the Rocky Mountain West. The effects of the disease include growth loss, deformity and mortality. It is second only to dwarf mistletoe in terms of growth loss and mortality in the Rocky Mountain region (Krebill, 1975).

The infection of the lodgepole pine depends on an intricate interaction of host, pathogen, and weather conditions. This study concentrates on the influence of weather conditions on rust infections.

The overall question in this study is how many times a year are the weather conditions conducive to transporting basidiospores from the alternate host (Comandra umbellata) to the lodgepole pine for potential infection? This study focused on infection of pines and not comandra plants. We feel justified in looking at only one part of the disease cycle because after 6 years of observation it is assumed that the comandra plants are infected most years.

This study was conducted on a site where data was available on the number of new infections on lodgepole pines each year for the last five years. The study site is in a 20 year old naturally seeded lodgepole pine stand on the Dillon District, Beaverhead National Forest which is west of Dillon, Montana and southwest of Butte, Montana. The stand was located about four miles from the nearest known population of the alternate host. The number of new cankers were recorded on 88 trees every year starting in 1981.

Weather data, obtained from the National Oceanic and Atmospheric Administration (NOAA), was used to determine potential infection episodes each year. Weather data was used from a station 20 miles northwest of the study area at Wisdom, Montana and another station 30 miles southeast at Dillon, Montana.

Several criteria were used in selecting potential weather episodes: 1) only July - September data (until hard freeze); 2) >10° F temperature drop from previous day; 3) a diurnal range <25° F; 4) precipitation; and 5) duration of episode. The months of July, August and September were selected for because those are the months basidiospores are being formed and released. Selection was stopped at a hard freeze (<25°F) because spore production is probably inhibited.

Krebill (1968) showed that near 100% relative humidity is necessary for basidiospore survival and germination. However, the NOAA weather data did not contain humidity information. Therefore the following criteria were used to select for days of high humidity. A 10°F drop in the maximum temperature from the previous day was selected because this indicates that a weather system has moved into the area probably resulting in increased moisture. A diurnal range of <25°F was selected because this indicates high humidity is present since cloud cover reduces heat loss and humidity stores heat and keeps night time temperatures warm. The occurrence of precipitation also had to occur because on

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occasions when the relative humidity remains near 100% for 24 hours, in all likelihood, some precipitation would occur. Daily NOAA weather maps were examined for days selected using the other criteria. These maps indicated if the weather system actually stayed in the study area for one or two days or passed through quickly (NOAA, 1981-1985).

There does not appear to be a relationship between the number of new infections and the number of suspected infection episodes (Table 1).

Table 1. Relationship of new comandra rust infections and potential infection episodes

		Infection Episodes[2]	
Year	New Infections/[1] 100 Trees	Wisdom Station	Dillon Station
1981	23	1	1
1982	80	2	2
1983	80	3	4
1984	83	3	3
1985	43	2	3

[1] Based on numbers for 88 trees.
[2] Based on NOAA weather data.

The number of potential infection episodes each year was greater than expected. It was assumed that the number of episodes a year was one or two, with some years having no episodes at all. We do not know if each suspected episode had the appropriate duration of high humidity since this data is not available. Perhaps the number of episodes per year is not important and all infections each year result from just one good weather episode.

This study is a preliminary attempt at determining the relationship between the number of rust infections and suspected weather episodes. This relationship will be studied further in two other forests using weather data and canker age data. We also will have on-site humidity data to correlate with the NOAA data. After completing this study next year more information should be available on the relationships between comandra rust infections and weather conditions.

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EVALUATION OF DOUGLAS-FIR SEED TREE MORTALITY ON THE POWELL RANGER DISTRICT, CLEARWATER NATIONAL FOREST, IDAHO

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ABSTRACT: Effects of fire and root disease on Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seed trees were evaluated on the Powell Ranger District, Clearwater National Forest, Idaho. Thirty trees on an underburned and an unburned site were sampled for total water potential, root disease infection and fine root counts. Fire intensity was moderate to light. Total water potential was significantly higher and fine root counts were significantly lower in the burned stand compared to the unburned stand. Root disease infection, by Phaeolus schweinitzii (Fr.) Pat., was not significantly different between the two sites. The combined effects of fire damage and root disease caused moisture stress and tree mortality.

INTRODUCTION

Use of seed trees is an effective and cost efficient method for regeneration in the inland northwest. They provide seed well suited to the site, shade for seedling survival, and can help maintain the visual quality and other resources of the site. The failure of seed tree systems may require artificial regeneration of the site at an increased cost. Successful application of the seed tree method depends upon survival of selected seed trees by selecting healthy, undamaged, cone producing trees that will survive site preparation.

Seed tree mortality is a persistent problem on Forest Service lands on the Powell Ranger District, Clearwater National Forest, Idaho, in spite of seed trees meeting the selection criteria and precautions taken to protect trees while underburning. Post-fire examination showed most trees to be infected with Phaeolus schweinitzii (Fr.) Pat.. The disease was not previously detected prior to site preparation.

Traditionally, conifer mortality has been primarily examined within individual disciplines of research with little integration. Fire related mortality of trees has been studied in detail but most studies have concentrated on crown scorch and bole damage (Wyant et al. 1986, Peterson 1984, Bevins 1980). Root damage by fire has been associated with the physical effects of duff consumption on the site, and tree stress and secondary insects and diseases have been linked to tree survival (Ryan 1982). The impact of fire on the fine root component and infected tree roots has not been evaluated. In this study, we have evaluated some of the combined effects of fire and root infection on water stress and resulting mortality of the seed trees.

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METHODS

Study Area

Two stands similar in aspect, elevation, slope, soil type, and habitat type were selected for comparison on northern Idaho National Forest land. One stand was underburned in August after harvest under standard operational prescribed burn conditions. Slash was cleared in a 3.5-meter square area around the seed trees prior to burning. Levels of damage to the residual trees were determined to be within acceptable limits (personal communication, Kevin Ryan 1985). Weather conditions were within prescribed limits to ensure minimum intensity and flame length for seed tree survival.

The study trees were 200- to 250-year-old Douglas-fir. Tree characteristics were measured and found to differ slightly between the two stands--trees on the unburned stand were generally smaller in diameter, shorter, and averaged 50 years younger than those on the burned site. Trees on the burned site were selected from the survivors and were in various stages of decline.

Plant Moisture Stress

Plant moisture stress (expressed as positive bars of pressure that represent negative bars of leaf xylem pressure potential) was selected as the variable that best represents the overall vigor of the tree. As a measure of the water potential of the xylem sap, it indicates the amount of water flow through the soil-plant-atmosphere continuum and reflects any relative deficiencies in tree moisture requirements.

The plant moisture stress was measured at midday using pressure chamber measurements on both stands. Stems with 2 years' growth from midcrown samples were used. Midday measurements were used in place of predawn measurements to insure that tree physiological stress was being measured and not soil moisture stress during periods of most active uptake.

Fine Roots

Soil cores were taken in mid-June 1985 to sample the fine roots. Samples were taken with a 10-cm by 30-cm tube driven into the ground. Two soil core samples were taken per tree 1 meter uphill and 1 meter downhill from the root collar. Samples were immediately bagged and kept cool to minimize continued respiration. Samples were seived using a 2-mm screen to separate root material from soil and organic matter. All roots were placed in formalin acetic acid for preservation until counted. Root samples were sorted to separate live Douglas-fir roots from dead or non-Douglas-fir roots. Fine Douglas-fir roots less than 1 mm width and greater than 1 cm length were tallied. Live Douglas-fir roots were oven dried at 70°C for 48 hours and then weighed.

Fire Damage

Fire damage was assessed on the burned site using methods established by Ryan (1982)(Ryan and Noste 1983). These methods involved visual estimates of circular areas around the base of the tree to determine the amount of litter consumption and ground char that occurred. The classifications are unburned, light burn, moderate burn, and deep burn.

Root Disease Infection

Root disease infection was determined for a subsample of the root systems. Seven trees per stand were cut and the stumps were excavated using water gel explosives. The gel explosives loosened the soil around the root system with minimum damage. Excavation was completed using hand tools.

Each root system was ocularly divided into cardinal (longitudinal) quadrants to detect root disease throughout the system. Within each quadrant roots from three zones were subsampled at 1 meter from the root collar, one half meter, and at the root collar. Three diameter classes within each zone were also sampled: <1cm, 1-5 cm, and 5 cm and above. Disease infection was determined based on visual symptoms from cross-sections cut from each sample. Random samples of symptomatic roots were selected for fungus isolation to confirm pathogen identification.

T Test

All samples were averaged and a students t test was performed using SPSS-X to evaluate the data. The groups used for the comparison were burned and unburned.

RESULTS

The average plant moisture stress was significantly higher on the burned site at the 86 percent level of confidence, and the average number of fine roots was significantly lower at the 84 percent level (table 1). However, there was no significant difference between the average level of root disease infection on the burned and unburned sites.

Table 1--Averages and probability levels for burned and unburned sites

	BURNED SITE	UNBURNED SITE	P
PMS	15.6 bars (4.16 std dev)	13.4 bars (1.98 std dev)	0.14
FINE ROOTS	30.8 (21.73 std dev)	52.9 (40.48 std dev)	0.16
DISEASE INFECTION	77% (.09 std dev)	79% (.07 std dev)	1.20

Plant moisture stress was significantly higher on the burned site compared to the unburned site (table 1).

Duff consumption around 5 sample trees was classified as moderate litter consumption with 4 classed as moderate or less ground char. These classifications were determined to be insufficient to cause direct mortality (personal communication - Kevin Ryan 1985). Some root injury was sustained and appeared to affect the fine root production capacity of injured roots.

The level of disease infection was similar on both sites based on the results of the statistical test (table 1) and supported by visual estimates. Within the 2 years since burning the stress imposed by underburning did not cause an increase in the level of infection on the burned site. The infection probably contributed to the decline of the trees on the burned site in conjunction with the effects of burning.

On both sites many large roots were extensively infected by *P. schweinitzii* and rotted off at the one-half or 1 meter length. Roots were commonly stubbed with callous tissue. Incipient decay by *P. schweinitzii* was evident even in small adventitious roots 3 mm in width. The presence of *Armillaria obscura* (Schaeff.:Secr) was marginally greater on the burned site but in both stands it was limited to dead or nearly dead trees (table 2).

Fine roots averaged less per tree core on the burned site than on the unburned site (table 1). We had some difficulty distinguishing the Douglas-fir from the non-Douglas-fir at the beginning of the tally. It is possible this confusion may have affected the results. Hopefully, any affect would be unbiased and the main difference in number of fine roots would be due to the impact of fire.

Table 2--Tree data

TREE #	PMS	ROOT DISEASE	FINE ROOTS/CORE	FIRE EFFECTS
BURNED SITE				
06	dead	.86 (Armillaria)		
08	24		24	Mod. ground char
07	23	.91 (Armillaria)	8	Mod. litter consumn, grd char
13	20	.72	14	Light
01	17		79	Mod. litter & ground char
12	16	.86	32	Light
04	16	.66 (Armillaria)	24	Mod. ground char
15	15	.80 (Armillaria)	18	Light
11	14	.74 (Armillaria)	64	Light
10	14	.69	30	Light
09	14		39	Mod. litter consumption
14	13		53	Light
02	11	.84	2	Light
05	11	.66	7	Mod. litter consumption
03	11		43	Mod. litter consumption
UNBURNED SITE				
29	dead		.86 (Armillaria)	
28	16	.83	33	
26	16	.83	20	
23	15	.70	25	
25	14	.95	59	
30	14	.78	102	
22	14		128	
17	14	.76	8	
20	14		104	
27	13		94	
19	13	.81 (Armillaria)	9	
24	13	.70	56	
16	12	.77	51	
21	10		1	
18	9	.75	50	

DISCUSSION

The overall poor health of the sample trees on both sites is reflected in the low moisture stress readings. The greater levels of water stress are probably due to the influences of the root disease combined with the influence of fire. The significantly higher moisture stress readings ($P < 0.07$) on the burned site reflect the additional impact of fire on the infected root system. The reduced root system size caused reduced water uptake even when soil moisture was not limiting. Teskey et al. (1985) found a decline in xylem pressure potential when half of the root system of Abies amabilis (Dougl.) Forbes was severed. Running (1980) found that water relations in lodgepole pine (Pinus contorta Dougl ex. Loud) were controlled primarily by root and soil resistance. Root systems reduced in overall size would be less likely to compensate for this resistance and produce a favorable flow of water.

The contribution of fire to root system damage is a function of duff consumption and soil moisture (Shearer 1975, 1976). The greater the duff consumption, the more heat flux generated through the mineral soil and to the superficial roots. The low levels of duff consumption and ground char in this study should have resulted in relatively light impact from the fire. However, the combined effects of fire and root disease resulted in high rates of seed tree mortality.

Infection by Phaeolus schweinitzii (Fr.) Pat. alone seldom causes standing mortality except on rocky, dry sites in the northern Rocky mountains.1/ It predisposes host trees to infection by other pathogens such as Armillaria obscura or to bark beetle attack (Hadfield et al 1986). Similar infection rates by P. schweinitzii on both the burned and unburned sites indicates that mortality on the burned site was not attributable to P. schweinitzii infection alone.

As the primary source of absorbed water and nutrients for conifers, the fine root system plays a crucial role in tree survival. Damage to the root systems of trees by fire and disease infection would reduce the overall size of the system with consequences for water uptake. The fine roots (less than a few millimeters in width) are concentrated in the top 20 cm of forest soil (McQueen 1973). This vulnerable location exposes them to temperature changes from fire. In addition, 90-200% of fine roots are replaced annually (Persson 1979) with a spring and fall flush (Vogt et al 1980). Without the recurring root flush in damaged roots, the numbers are drastically reduced along with the absorbing capacity of the root system. Moisture requirements of the tree are not satisfied and water stress can result due to the reduced absorption capacity.

CONCLUSIONS

The high level of water stress, as indicated by the higher PMS readings, reflects the combined impact of fire and root disease infection. The level of

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1/ Unpublished report; on file with S.K. Hagle, USDA Forest Service, P.O. Box 7669, Missoula, MT. 59807.

fire damage on the burned site was judged not to be sufficient to cause death of otherwise healthy seed trees. But the combination of fire damage to subsurface lateral roots and root system reduction by advanced P. schweinitzii infection did result in high moisture stress levels and, in some cases, death. This is probably a result of impaired fine root production which would lead to reduced water absorption.

Future seed tree prescriptions on the District should give ample consideration to possible subtle root disease infection of candidate seed trees.

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THE EFFECT OF ARMILLARIA ATTACK ON THE NUTRIENT STATUS OF INLAND DOUGLAS-FIR

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ABSTRACT: Nutrient status, sapwood basal area (SBA) and sapwood/heartwood basal area ratio (S/H) were measured on second growth Pseudotsuga menziesii [(Mirb) Franco] trees in western Montana. Armillaria infected trees had significantly lower S/H ratios and foliar N content than noninfected trees. Our results indicate a general influence of Armillaria infection on nutrient content and physiological status of P. menziesii trees but these measurements are not a reliable method to determine the extent of infection.

INTRODUCTION

Armillaria root rot is a serious problem in the United States and Canadian forests. Many former pine stands have gradually changed to more disease-susceptible spruce and fir species as the result of an 85-year-old fire suppression policy and past cutting practices (Filip and Goheen, 1984, Byler 1984). Approximately 1% of the total commercial forest land in the northern Rocky Mountains is occupied by large active root disease pockets, and 13% of these areas contain scattered root disease mortality of at least three trees/ha (James et al., 1984).

Both diameter growth reduction (Hrib et al. 1983) and height growth reduction (Singh and Bhure 1974) have been demonstrated to occur for several years preceding death of Armillaria-infected trees. Coastal variety Douglas-fir (Pseudotsuga menziesii var. menziesii) with Armillaria root rot was shown to have decreased in height growth for at least six years prior to death compared to healthy trees (Singh and Bhure 1974). These diseased trees also had differences in foliar nutrient content compared to healthy trees. Singh and Bhure (1974) reported lower concentrations of several macro-nutrients in foliage of Armillaria infected coastal Douglas-fir than in healthy trees. Calcium and three micro-nutrients (Mn, Fe and Zn) were higher in the infected trees. The authors hypothesized that height growth reduction is a result of changes in mineral nutrient uptake by diseased roots.

Our objectives were to find if inland Douglas-fir (P. menziesii var. glauca) with Armillaria root rot experienced similar changes in foliar

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nutrient content to those observed in coastal Douglas-fir; if other physiological parameters of trees were different between diseased and healthy trees, specifically, sapwood:heartwood basal area and diameter growth; and if foliar nutrient and physiological parameter differences are proportional to the extent and duration of root infection.

MATERIALS AND METHODS

Sites

Charity

Charity ridge is located on the Flathead Indian Reservation near Charity peak, Arlee, Montana, T15N R 20W sec. 3 SE quarter, Montana Principal Meridian; Lat 114° 42' N Long 47° 05' W is at 1815 m elevation on a northeast aspect with a 30% slope. Annual snowpack ranges from 1.15 to 3.9 m. Mean annual air temperature is 6.4°C with extremes of -25.9 to 29.4°C. The soil is a loamy mixed skeletal Andic Cryochrept of the Holloway Series (Veseth and Montagne 1980) derived from volcanic ash overlying noncarbonate argillite of the Montana beltrock supergroup. The organic horizon comprises undecomposed P. menziesii needles and lichens (l layer 5-9 cm thick) atop partially decomposed P. menziesii needles (F layer 2 cm thick); the latter overlie humus (H. layer 2 cm thick) the root zone is mostly limited to the ash cap 30-35 cm thick.

The site is classified as a Pseudotsuga menziesii/Linnea borealis habitat type (Pfister et al 1977), and is dominated by 82-year-old P. menziesii 8-9 m high Pinus contorta var. latifolia Engelm). Eight percent of the stand is comprised of 30-60-year-old Larix occidentalis Nutt. which are 3-5 m high. The stand has a basal area of 160 A. The ground vegetation consists of 70% Xerophyllum tenax (Pursh) Nutt., 5% Mahonia repens (Lindl.) G. Don., 10 % Calamagrostis rubescens (Buckl.), 10% Vaccinum gobulare (Rydb.) 5% Spirea betulafolia, and 5% Arnica latifolia (Bong.).

Hellroaring

The Hellroaring Bench site is located on the Flathead Indian Reservation near Polson, Montana T 22N R 19W Sec 4, SE quarter Montana Principal Meridian Lat., 47° 42' North long. 114° 02" W at 1062 m elevation on a southwest aspect with a %5 slope. Annual snowpack depth on this site ranges from 0.76 m to 2.54 m and mean annual air temperature is 7.5°C with extremes of -31.7 to 29.6°C. The soil is a Udic Haplborol Walstad gravelly loam derived from Argillite in the Montana Beltrock supergroup. The organic horizon is comprised of undecomposed P. menziesii needles and lichens (L layer is 2-7 cm thick) atop a partially decomposed P. menziesii needles (F layer 2-5 cm thick); the latter overlie humus (H layer 2 cm thick). The root zone extends to 35cm.

The site is classified as a Pseudotsuga menziesii/Physocarpus malvaceus habitat type (Pfister et al, 1977), is dominated by 54 year-old P. menziesii 9-25 m tall. Basal area of the uniform even-aged P. menziesii is 120. A few large western Larch (Larix occidentallis Nutt.) and Pinus Ponderosa (Dougl.) are also present on the site. The ground vegetation consists of 15% Physocarpus malvaceus, 25% Symphorcarpus albus (L.) Blake, 10% Calamagrostis rubescens (Buckl.), 20% Rosa woodsii Lindl., 20% Spirea betulafolia (Pell.), 5% Smilacina stellata (L.) Desf., and 5% Amelanchier anifolia Nutt.

Gold Creek

The Gold Creek site is located on in the west fork of Gold Creek near Bonner, Montana (T 15 N R 16W Sec 29 NW ¼ Lat 47° 01' N long. 114° 51'W) is at 1630 m elevation on a southwest aspect with a 35% slope. Annual snowpack depth ranges from 1.5-5.1 m. Mean annual air temperature is 3.5°C with extremes of -25.9 to 25.6°C. Soil is a loamy skeletal Andic cryochrept in the Felan series derived from Argillite of the MacNamera formation of the Montana beltrock supergroup. The organic horizon consists of undecomposed P. menziesii needles and lichens (L layer 5-9 cm thick) atop partially decomposed P. menziesii needles (F layer 2 cm thick); the latter overlie humus (H layer 2 cm thick).

The site is classified Pseudotsuga menziesii/Symphorcarpus albus habitat type (Pfister et.al, 1977) is dominated by 50-80 year-old P. menziesii 7-9 m in height. Stocking level of this stand is 120 basal area. A few 60-90 year-old 20-40 m tall Pinus ponderosa (Dougl.) also are on the site. The ground vegetation consisted of 10% (Arctostaphylos uva-ursi L. Spreng.), 5% Balsamrhiza sagittata (Pursh) Nutt., 50% Calamagrostis rubescens (Buckl.), 10% Pachistema myrsinites (Pursh.) Raf., 10% Symphorcarpus albus L. Blake, 5% Smilacina raceumosa, and 5% Mahonia repens (Lindl.) G. Don.

Sampling and Analysis

The study was implemented using a generalized randomized design (Kirk 1982) on second growth P. menziesii trees on the three sites. Six Armillaria infected trees and six paired noninfected trees were chosen on each site. For the purpose of this study Armillaria-infected trees were defined as those having at least one infection on a root within 1 m of the root collar. Armillaria infection was identified by the presence of white mycielium fans (Morrison 1981, Hadfield et al 1986). The extent of infection was determined by uncovering main roots 1 m from the stem of each tree. Noninfected trees were at least 5 m from any infected tree. Age of Armillaria infection was determined by inspecting the base of each tree annually for the last five years. Tree height, diameter at 1.4 m (DBH) radial growth at breast height in the last ten years and heartwood and sapwood basal area was measured. All trees were sampled for foliar nutrient analysis using methods described by (Comerford and Leaf, 1984). Three composite samples of current needle foliage from each tree were dried at 80°C, ground to < 1 mm, and 1.0 g of subsample was ashed at 525 ± 2°C. The ash was taken up in 6 N HCl brought to 40 ml volume and analyzed for Al, B, Ca, Cu, Fe, Mg, Mn, K, P, S, and Zn (Jackson, 1958), and analyzed on an inductively coupled plasma spectrometer. Total N was analyzed by standard microkejeldahl techniques modified for nitrate citation for modification.

Statistics

The data were normally distributed and analyzed using ANOVA and regression procedures with SAS programs (SAS Institute, 1985) for a generalized randomized block design. Individual means were compared with Tukeys Honestly Significantly Difference (HSD) test at the 5% level.

RESULTS

Tree height, diameter, age, and radial growth during the last ten years and sapwood basal area were not different between Armillaria infected and noninfected trees (table 1). However, attack by Armillaria resulted in a large reduction in sapwood:heartwood basal area (S/H) ratio. There was no correlation between the extent or duration of Armillaria infection and the S/H ratio.

Table 1. Height, diameter, age, growth in the last ten years, sapwood basal area and sapwood/heartwood basal area ratio of *Pseudotsuga menziesii* trees.

Treatment	Height (m)	Diameter (cm)	Age	G10 (cm)	SBA (cm^2)	S/H ratio
Noninfected	47A	18.4	50A	2.5A	147A	2.16B
	(± 19)	(± 8.4)	(± 18)	(± 0.7)	(± 134)	(± 1.31)
Infected	51A	18.8	57A	1.9A	243A	0.57A
	(± 20)	(± 8.8)	(± 20)	(± 0.8)	(± 202)	(± 0.24)

[a] Means followed by the same letter are not significantly different as determined by Tukeys Honestly Significant Difference test ($p > 0.05$).

• Standard deviation n=36.

G10 Growth in the last ten years

SBA Sapwood basal area

S/H Sapwood basal area/heartwood basal area at dbh

Table 2. Nutrient concentration of noninfected and *Armillaria* infected *Pseudotsuga menziesii* trees.

Treatment	B	Ca	Fe	K	Mg	Mn	P	S	Zn	Total N
	----	----	----	----	----	μ/g	----	----	----	----
Noninfected										
	19.9 A (±5.1)	7561 A (±5235)	80.2 A (±22.6)	7253 A (±1843)	992 A (±183)	211 A (±84)	2053 A (±417)	847 A (±900)	20.4 A (±4.5)	10639 A (±2970)
Infected with *Armillaria*										
	19.4 A (±4.5)	7273A (±288)	84.4 A (±19.1)	7120 A (±2001)	989 A (±261)	209 A (±62)	1897 A (±469)	767 A (±1071)	20.1 A (±5.1)	5549 B (±1745)

α Values followed by the same letter are not significantly different as determined by Tukeys Honestly Significant Difference Test (P > 0.05).

• Standard deviation.

Foliar N concentration was the only element we measured that was significantly different between *Armillaria* infected and noninfected trees (table 2). There was no correlation between time since *Armillaria* infection was first detected in P. *menziesii* trees and any of the individual elements analyzed. However, a multiple regression of foliar N, P, K, S, Ca, Mg, Mn, Fe, Cu, B, Zn, and Al show a significant correlation with duration of infection ($r^2 = 0.76$) and the extent $r^2 = 0.66$) of the *Armillaria* infection.

DISCUSSION

Our results indicate a general influence of *Armillaria* attack on the nutrient and physiological status of P. *menziesii* trees. *Armillaria* infections in the three areas has caused high rates of mortality, twenty three percent of the Douglas-fir in the Hellroaring stand have died in the past seven years. Twenty one percent of the remaining, live trees have known infections (Hagle & Goheen 1987). Although death is imminent, the nutritional status of infected trees appears surprisingly stable. Decrease in N concentration may be the earliest foliar nutritional effect from *Armillaria* infection. Rykowski (1981b) reported a strong correlation between N in foliage, and *Armillaria* *mellea* (Vahl, Fries) Drummer S. Str. especially during the first stages of infection. Discussion of the nutrient status of trees based on foliar analysis must be hedged with qualifications because the elemental content of the foliage will reflect mineral composition of the soil (Rykowski, 1981b). Rykowski (1981a) reported that fertilization decreased the correlation between foliar N and *Armillaria* disease symptoms. Higher available N in soils resulted in improved appearance of *Pinus* *sylvestris* L. trees, although it did not decrease the number of trees attacked by *Armillaria*. Standard deviations for many nutrients, especially Ca, S, Mn, and Al were very large. We expect different physiological reactions of P. *menziesii* genotypes to *Armillaria* infection. Some genotypes of P. *menziesii* might exhibit a stronger correlation between *Armillaria* infection and foliar nutrients than others. While we detected differences only in total N, Singh and Bhure (1974) found differences in N, P, K, Mg, and Na (decrease) and Ca, Mn, Fe, and Zn (increase) in foliage of Armillaria-infected coastal Douglas-fir. They used young (12-14 yrs) planted trees within a single provenance to test for changes in foliar nutrients. This may have helped to limit variation within the sample allowing them to detect smaller differences in nutrients.

Growth parameters varied sufficiently among the individuals to obscure any differences attributable to *Armillaria* infection. Bloomberg and Wallis (1979) found radial increment at breast height and total height by dbh classes were not sensitive indicators of growth reductions resulting from *Phellinus* *weirii* infections in Douglas-fir. However, an adjusted total height:dbh ratio was found to be a sensitive indicator of growth reduction which was correlated with extent of infection.

Our results suggest that *Armillaria* infection decreases foliar N concentration, and the S/H ratio in Inland Douglas-fir trees, but these changes are not directly proportional to the duration or extent of root infection.

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THE EFFECT OF PHELLINUS WEIRII DISTURBANCE ON MICROBIAL BIOMASS AND NEEDLE DECOMPOSITION IN A TSUGA HETEROPHYLLA FOREST

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ABSTRACT: Microbial biomass and needle decomposition were measured seasonally for one year in a Tsuga heterophylla [Bong (Cass.)] old growth and regrowth forest that was caused by Phellinus weirii [Murr. (Gilbertson)] disturbance. Microbial biomass was higher in the old growth forest than the regrowth forest due to the higher concentration of carbon in this soil. However, needle decomposition was significantly higher in the regrowth forest than in the old growth. Our results suggest that increased organic matter decomposition could increase soil fertility and ultimately lead to improved tree vigor.

INTRODUCTION

Phellinus weirii (Murr) Gilbertson root rot is a serious problem in large areas of the Pacific Northwest forests. Many former pine stands have gradually changed to the more disease susceptible spruce and fir species as the result of an 85 year-old fire suppression policy and past cutting practices (Filip and Goheen 1984). Phellinus weirii has been estimated to cause an annual loss of 32 million cubic feet of timber (Hadifield et al., 1986).

Phellinus weirii becomes established in a host tree and proliferates in its root system, weakening it and causing the tree to die and topple (McCauley and Cook 1984). It then spreads vegetatively through root contacts to adjacent trees, creating rings of infection. The fungus can survive in fallen trunks and large roots and for 50 years (Hansen 1979). However more resistant trees (Filip and Schmitt 1979, Hatfield and Johnson 1977) may not be killed and the forest is reestablished through germination and regeneration. Higher soil nitrogen availability in the regrowth areas may increase the growth and reestablishment of vegetation. Changes in soil biology and nutrient availability caused by root rot disturbance have been difficult to study due to the unpredictability of disturbance in space, time and intensity (Matson and Boone 1984). However, wave-form diebacks in the Oregon Cascades offer an ideal area for

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such studies because tree mortality is predictable (McCauley and Cook 1980, Matson and Boone 1984). We examined three dieback areas near Waldo Lake, Oregon where waves were advancing into 200-250 yr. old mountain hemlock, Tsuga heterophylla [Bong (Carr)] stands at rates of ≅ 34 cm/yr. (McCauley and Cook 1980, Nelson and Hartman 1975). The objective of this study is to determine if microbial biomass and litter decomposition in a high elevation Pacific Northwest forest soil are altered by T. heterophylla dieback caused by P. weirii.

MATERIALS AND METHODS

The Site

The study site is located in the Oakridge Ranger District of the Willamette National Forest, Oregon, 2 km east of Waldo lake. It is the coolest of Western Oregon's forest zones at an elevation of 1,770 m and is relatively wet (1,600-2,800 mm annually) with most precipitation occurring as snow in the winter months (Franklin and Dryness 1973). The site is snowcovered from November until June. The soil is a sandy well-drained entic cryorthod in the Winopee series. The parent material is volcanic pumice and ash deposited by the Mount Mazama eruption ≅ 6,600 years ago. The area was studied by Matson and Boone (1984) and McCauley and Cook (1980). The overstory vegetation on the site includes relatively pure stands of T. heterophylla with a few lodgepole pine (Pinus contorta var. latifolia Engelm.), western white pine (Pinus monticola Dougl.), Pacific silver fir (Abies amabilis [Dougl.] Forbes), and subalpine fir (Abies lasiocarpa [Hook] Nutt.). The understory consists of 30% grouse huckleberry (Vaccinium Scoparium Lieberg) and 20% kinnikinik [Arctostaphylos uva ursi (L.) Sprang]. Fifty percent of the ground area is bare. The regenerating stands consist of relatively few mountain hemlock with lodgepole pine Pinus contorta Var. Latifolia Engelm. assuming increased importance (Matson and Boone 1984).

This study was set up in a generalized randomized block design with three wave fronts as blocks and mature forest and regrowth forest as treatments.

Soil sampling, and analysis

We collected 10 random soil samples per treatment x block from the top 7 cm of soil midmonth in October, June and August 1986 and used these samples to estimate microbial biomass. Samples were then placed in plastic bags that were air and moisture tight and transported to the Oregon State Forest Science Laboratory. Soil pH was determined from a 1:1 paste of soil and water with a digital pH meter. Soil moisture was determined gravimetrically. Samples were held in the laboratory under moisture conditions similar to those found in the field at a temperature of 4°C and prepared for microbial testing the same day; this method does not significantly alter microbial activity (West et al. 1986).

Microbial biomass was determined by Jenkinson and Powlson's (1976) fumigation method. All visible roots were removed from the equivalent of approximately 20 g of dry organic soil. Each 20-g sample was placed in a

230-mL container and those containers put in a 30-cm³ desiccator, along with a beaker of 60 mL of alcohol-free chloroform. Alcohol had been removed from reagent-grade chloroform by shaking 3 times with 5% concentrated H_2SO_4 in a separatory funnel. The chloroform was then washed 5 times with water and distilled in a rotary evaporator; the first 50 mL of distillate were discarded. The alcohol-free chloroform was stored over K_2CO_3 in the dark.

The desiccator was evacuated until the chloroform boiled vigorously. The first two vacuums were held for 10 min; the third vacuum was held for 24 h at 23°C in the dark, after which the desiccator was evacuated 6 times, for 30 min. per vacuum, to remove the chloroform. After chloroform evacuation, the samples were removed and placed in 0.95-L jars, each equipped with a vial containing 20 mL of distilled water to maintain the moisture level and a vial containing 10 mL of 1 M NaOH to trap CO_2. Reinoculation with unchloroformed soil was not necessary (Vorony and Paul 1984). The jars were sealed and incubated at 23°C for 10 days. Samples were removed and oven-dried at 85°C for 24 h so that moisture content could be determined. One milliliter of 0.3 kg/kg $BaCl_2$ and four drops of phenolphthalein were added to the NaOH as a pH indicator, and the solution was titrated with 1 M HCl. Jenkinson and Powlson's (1976) equation calculates biomass as $(X - x)/K$, where X is the CO_2 produced from fumigated samples, x is the CO_2 produced from unfumigated samples, and K is 0.45.

In the fall of 1985, senescent unleached needles from T. heterophylla saplings by shaking them onto a drop cloth. Needles contained 0.32% N and 14.4% lignin; lignin to N ratio was 45:1

Forty decomposition bags containing 5,000 g of the air dry needles were placed on each treatment plot June 1986. Five bags from each treatment x block were recovered in October 1986 and June 1987. Needles were dried at 80°C for 24 h and weighed. Litter decomposition was estimated using the exponential decay model of Olson (1963); $X_t/X_o = e^{-kt}$, where X_o = initial weight of needles and X_t = weight of the needles after time t in years.

Statistical Analysis

Data were subjected to a two way analysis of variance (ANOVA) for a generalized randomized block design (Kirk 1982). SAS programs (SAS Institute, Inc. 1985) were used to calculate the ANOVA's and regressions. Significance was determined at $P<0.05$ with Tukey's Honestly Significant Difference Test.

RESULTS

Microbial biomass was higher in soil of the old growth forest than the regrowth vegetation of the P. weirii dieback zone throughout the sampling period (table 1). Microbial biomass was significantly higher in the spring and fall seasons than the summer season.

Decomposition of T. heterophylla needles was significantly greater in the regrowing vegetation of the P. weirii dieback zone than the old growth forest (table 1).

Table 1. Microbial biomass and needle decomposition in a *Tsuga heterophylla* old growth and regrowth forest.[4]

Treatment	Fall	Summer		Spring	
	Microbial Biomass[1]	Microbial Biomass	Decomposition[2] (k)	Microbial Biomass	Decomposition[2] (k)
Old Growth	573A	349A	0.26A	327A	1.09A
	(±154)[3]	(±127)	(±0.12)	(±67)	(±0.04)
Regrowth	304B	189A	0.26A	206B	1.12B
	(±52)	(±84)	(±0.12)	(±29)	(±0.02)

1) microbial biomass is μg C g^{-1} soil
2) decomposition constant (k)
3) standard deviation
4) In each column values followed by the same letter are not significantly different ($p<0.05$) as determined by Tukey's Honestly Significant Difference Test.

DISCUSSION

Increased microbial biomass in the old growth forest is probably the result of the higher amount of carbon in the forest floor. Soil in regrowing vegetation contained less microbial biomass but resulted in higher *T. heterophylla* needle decomposition rates. Increased needle decomposition is most likely due to the higher concentration of soil N in the regrowing forest. Higher N mineralization of the forest floor and mineral soil doubled following *P. weirii* disturbance on this site (Matson and Boone 1984, Waring et al. 1987). The increased needle decomposition rates resulting increased N uptake by surviving trees in root rot dieback areas improved growing conditions to trees in regenerating this stand (Waring et al. 1987). Oren et al. (1985) also reported an increase in stand sapwood basal area and increased growth of residual trees as a result of thinning by *P. weirii* root rot in an old growth coastal stand of Douglas-fir. The ongoing thinning resulting from pathogen-induced mortality should keep a stable relationship from developing because the canopy would be continually changing (Oren et al. 1985). Harvestable volume lost to *P. weirii* in nonepidemic situations might be equivalent to that from density related mortality (Oren et al. 1985).

Our results show that trees surviving in _P. weirii_ centers will probably be growing on sites with higher concentration of soil N and light intensity than the surrounding forest. Survival of _P. weirii_ in _Alnus rubra_ (Bong) stems was inversely related to the N concentration in soil (Nelson 1976). Increased N concentration in soil may provide a better environment for competing soil microflora which can reduce the amount of _P. weirii_ in root systems (Nelson 1975). Pathologists (Hatfield et al. 1986, Morrison 1982) have suggested planting relatively resistant species such as _Thuja plicata_ Donn. and _Pinus monticola_ Dougl. ex. D. Don. to retard the spread of _P. weirii_ infection areas. Surviving trees in root rot centers should experience improved soil nitrogen which may result in increased growth and tree vigor.

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CLONAL SIZE AND VARIABILITY OF HETEROBASIDION ANNOSUM FROM WESTERN HEMLOCK IN WESTERN WASHINGTON STATE

Tom Hsiang, Robert L. Edmonds and Charles H. Driver

ABSTRACT: Isozyme electrophoresis and cross-plating reactions of Heterobasidion annosum from western hemlock (Tsuga heterophylla) in western Washington demonstrated that genotypes of the pathogen are mostly confined to single trees, and that they belong to the spruce-group sensu Korhonen (1978). Within a single forest stand, the isolates of H. annosum can vary two-fold in linear extension rate and three-fold in biomass production rate.

INTRODUCTION

Heterobasidion annosum (Fr.) Bref. (=Fomes annosus (Fr.) Cke.) causes a severe root and butt decay of western hemlock (Tsuga heterophylla (Raf.) Sarg.) in Washington state. Although many important aspects of disease epidemiology have been elucidated (Rishbeth 1951, Hodges 1969), the basic population structure of this pathogen has been touched upon by relatively few papers (Chase & Ullrich 1983, Stenlid 1985), with none in the Pacific Northwest. Two techniques that can be used to examine population structure of H. annosum are: isozyme electrophoresis and cross-plating reactions.

Isozyme analysis of H. annosum has been done in few previous studies (Ostrosina 1985, Stenlid 1985). Isozymes are enzymes possessing the same enzymatic activity but varying in structure. Isozyme electrophoresis on starch gels separates enzyme proteins on the basis of charge and size. By staining for a particular enzymatic activity on a starch gel after it has been subjected to electrophoresis, the emergence of bands of activity yields characteristic banding patterns for different isolates. Through the use of several enzymes, different individuals can be distinguished from each other.

Cross-plating of H. annosum was first successfully done by Korhonen (1978). Stenlid (1985) also from Scandanavia has had success with this technique. Cross-plating involves placement of inocula on the same media plate one to two cm apart and observing the reactions as the isolates grow toward each other. Mycelia of H. annosum merge when they are genetically identical; if they are different, they form a barrage zone which is a gap between the mycelia devoid of aerial hyphae. There is, in addition, a higher level of mycelial interaction involving somatically incompatible groups of H. annosum. Korhonen (1978) first discovered the existence of these groups of H. annosum which are called the spruce and pine groups based on host preferences. The cross-plating reaction between mycelia of these two groups involves the formation of a thick melanized ridge.

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OBJECTIVES

To determine clonal size, intersterility group, and growth variability of H. annosum from western hemlock in western Washington.

METHODS

Fifty isolates of H. annosum were collected from western hemlock stands throughout western Washington. These were subjected to isozyme electrophoresis and cross-plating experiments. Tester isolates of the spruce and pine groups were obtained from Dr. Kari Korhonen in Finland to test the intersterility group of Washington isolates.

Isozyme electrophoresis followed Conkle et al. (1982) except for the initial collection and extraction steps. Small plugs of H. annosum were placed into bottles containing 75 mL of 2% malt extract. After 2 to 3 weeks of growth, the mycelia were collected by pressure filtration and set into grinding wells for crude enzymes extraction. With a glass rod and acid-washed sand, the mycelia were ground for 1 min while chilled over an ice block. Following the methods of Conkle et al. (1985), twenty-five enzyme systems were assayed: alcohol dehydrogenase, beta-esterase, peroxidase, phosphoglucoisomerase, acid phosphotase, catalase, glucose-6-phosphate dehydrogenase, malate dehydrogenase, phosphogulconate dehydrogenase, *alkaline phosphotase, phosphoglucomutase, glutamate dehydrogenase, glutamate oxaloacetate transferase, *sorbitol dehydrogenase, aldolase, isocitrate dehydrogenase, shikimic acid dehydrogenase, *cytochrome oxidase, *galactose dehydrogenase, *glucose dehydrogenase, *glycerate-2-dehydrogenase, *alpha-glycerophosphate dehydrogenase, *malic enzyme, *polyphenol oxidase, and *xanthine dehydrogenase. Additional recipes (*) are from Cheliak & Pitel (1984). After the initial enzyme assays, only the first ten enzymes in the list were found to be suitable as distinctive genetic markers.

For the cross-plating experiments, cultures were incubated for at least two weeks on 2% malt agar in 9 cm petri dishes, after which the reactions were recorded.

One stand of western hemlock near Hoquiam, Washington was intensively sampled for H. annosum isolates. These isolates from 10 different trees were subjected to growth tests such as linear extension and biomass production.

RESULTS AND DISCUSSION

Cross-plating was found to be a more sensitive indicator of clonal identity than isozyme electrophoresis. However, isozyme electrophoresis always supported the results of cross-plating, where differences in electrophoretic banding patterns always showed up also as barrage (non-self) reactions in cross-plating experiments. Single clones of H. annosum were found to be almost exclusively confined to single trees or even parts of trees which they were sharing the host with other clones. All western Washington isolates of H. annosum were found to belong to the spruce-group of Korhonen (1978).

Although isozyme electrophoresis and cross-plating reactions pointed out isozyme and other genetic differences between isolates, how does this relate to pathological aspects? The 14 non-identical isolates from the Hoquiam stand were found to vary greatly in linear extension (0.54 to 1.11 cm/day at 25 C on 2% malt agar) and biomass production (0.17 to 0.49 mg/day at 25 C on 2% malt extract). The large differences between neighboring isolates of H. annosum gives an indication of the great amount of genetic variability at the population level. Thus within one forest stand of western hemlock, there may be many competing genotypes of H. annosum of different fitnesses and perhaps physiological capabilities.

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Ozone Levels and Fog Chemistry in Forested Areas in Western Washington

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ABSTRACT: Ozone concentrations in forested areas in western Washington during 1985-1987 have exceeded the National Air Quality Standard (120 parts per billion). These elevated ozone levels occurred during the growing season from May to August , and were generally higher than upwind urban areas during the same time period. Fog samples collected from Paradise on Mt. Rainier (1645 m) were consistently more acidic (pH 3.6-4.9) than coastal fog (pH 5.3-6.2) from the northeast Olympic Peninsula. The dominant anions in Mt. Rainier fog and cloud water were nitrate and sulfate, while sulfate and chloride were the dominant anions in coastal fog water on the Olympic Peninsula.

INTRODUCTION

Ozone and acidic fog have recently been considered important causal agents of forest declines in North America and Europe (Roberts 1987, and Woodman 1987). Ambient ozone concentrations have been shown to reduce forest tree growth and cause mortality in field and laboratory studies (Reich and Amundson 1985, Wang et al. 1986, and Woodman 1987).

It is important to consider that elevated tropospheric ozone episodes are weather dependent, and often coincide with periods of drought. Such has been the case in western Washington during the past three growing seasons where ozone concentrations in forested areas have exceeded the national air quality standards of 120 parts per billion. It is likely that these summer droughts may also predispose the Washington forests to other pathogens.

Forests in western Washington have periodically been exposed to ozone concentrations determined to reduce tree growth in the Northeast U.S. (Wang et al. 1986) and cause visible symptoms such as chlorotic mottling (Basabe unpublished).

Compared to rain, clouds and fog are generally ten to several hundred times more efficient in scavenging particulate and gaseous air pollutants, and in some forest ecosystems cloud water may dominate hydrologic inputs during certain portions of the growing season.

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The effects of acid fog on forests has yet to be determined but preliminary investigations (Joslin et al. 1987) have revealed acidic fog causes significant calcium leaching from red spruce foliage via cation exchange with hydrogen ions.There is the potential for acid fog to degrade the wax cuticle of conifer needles prediposing the foliage to frost damage.

When elevated ozone episodes are followed by a fog events, there is potential for formation of hydrogen peroxide which has recently been proposed as regional abiotic pathogen (Roberts 1987).

METHODS

Ozone measurements were conducted at seven forested areas during the growing seasons from 1985 though 1987. The location of the ozone monitoring sites are shown in figure 1. Monitoring stations were operated by the Washington State Department of Ecology and the University of Washington. Ambient ozone was continuously monitored during the growing season using Dasibi ozone monitors which were calibrated against a National Bureau of Standards traceable photometer.

Fog and cloud water were actively collected by a fog water collector recently developed at the University of Washington (Pade et al. 1987). Fog water samples were collected in 1986 and 1987 from the Olympic Peninsula coast, Seattle, and Mt. Rainier (figure 1). For comparison purposes we are only presenting data where fog or cloud events lasted a minimum of four hours and visibility was less than one kilometer. Anion analyses were performed on a Dionex ion chromatograph. Cation analyses were conducted via inductively coupled plasma emission spectroscopy on a Jarrel Ash (ICP), model 955. Ammonium ion analyses were performed via a Technicon Aouto analyser II. Hydrogen ion concentration were determined on a Beckman 1002 digital read out pH meter.

RESULTS AND DISCUSSION

The highest ozone concentrations in 1985 and 1986 were measured at Pack Forest. Monthly ozone profiles during the peak ozone periods are shown in figure 2. Periods when ozone concentrations are highest generally coincide with hot dry periods where air temperature is above 27 degrees celsius, and the winds are fairly calm.

Ozone, like stomatal conductance, is generally diurnal in nature and the uptake of ozone is dependent on stomatal conductance (Reich and Amundson 1985). The diurnal ozone patterns for the ozone concentrations presented in figure 2 are also shown in figure 2. These ozone concentrations are similar to those which have reduced growth in hybrid poplars and eastern white pine (Wang 1986, and Reich and Amundson 1985).

The effects of ozone on native Pacific Northwest forest trees under field conditions is not known, but the possibility of ozone predisposing forest to other pathogen should not be overlooked.

One hundred and twenty-six fog and cloud water samples were collected in western Washington from 1985 to 1987. The cloud water pH of the clean air site (Cheeka Peak), which is characterized by on-shore marine air masses, ranged from 5.3 to 6.2. The pH of radiation fog from the Seattle area ranged from 2.9 to 5.2. The pH of radiation fog and cloud water from Paradise on Mt. Rainier ranged from 3.6 to 4.9. Compared to rain water, cloud and fog water from Paradise contained 40 to 400 times the amount of hydrogen ions sampled during the same general time period. The dominant ionic species from Mt.Rainier cloud water are shown in figure 3.

The dominant ions in fog water that have potential effects on vegetation are hydrogen, ammonium, and nitrates. The nitrogen containing species may act as fertilizer and high concentrations of free hydrogen ion may cause cat ion exchange with foliage upon contact (Joslin et al. 1987). Sulfates in many areas has been considered an anthropogenic tracer of air pollution. In western Washington natural sulfates from the ocean are thought to be the cloud condensation nuclei. These sulfates occur in significant concentrations and are difficult to separate from anthropogenic sulfates. The liquid water content of a cloud or fog event can be highly variable from one event to another. The variability in aqueous concentration of the dominant ionic species is largely due to differences in cloud liquid water content. Equivalent fractions of ionic species is more useful for event comparisons. Event to event comparisons of the mean values of the equivalent fraction of the major anions are shown in figure 4. The nitrate concentration in Mt. Rainier cloud events, in some cases, appear to be more like Seattle fog water than coastal fog water. There is a potential for autumn cloud water rich in nitrates to act as a foliar fertilizer which may negatively affecting vegetation by by delaying winter hardenning. This effect may have direct consequences and or predispose the vegetation to other pathogens during the subsequent growing season.

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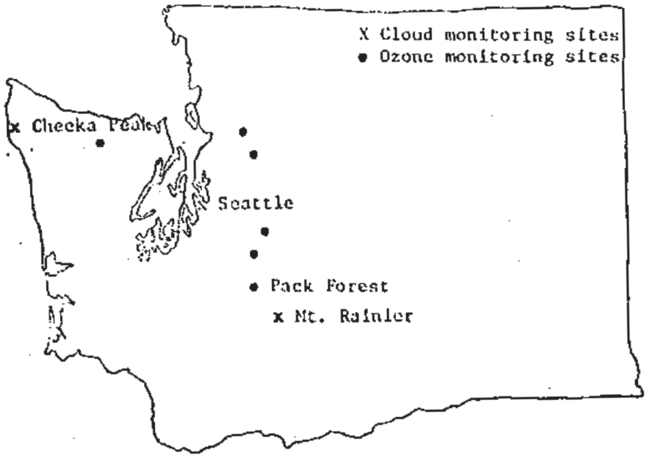

Figure 1. Study site locations.

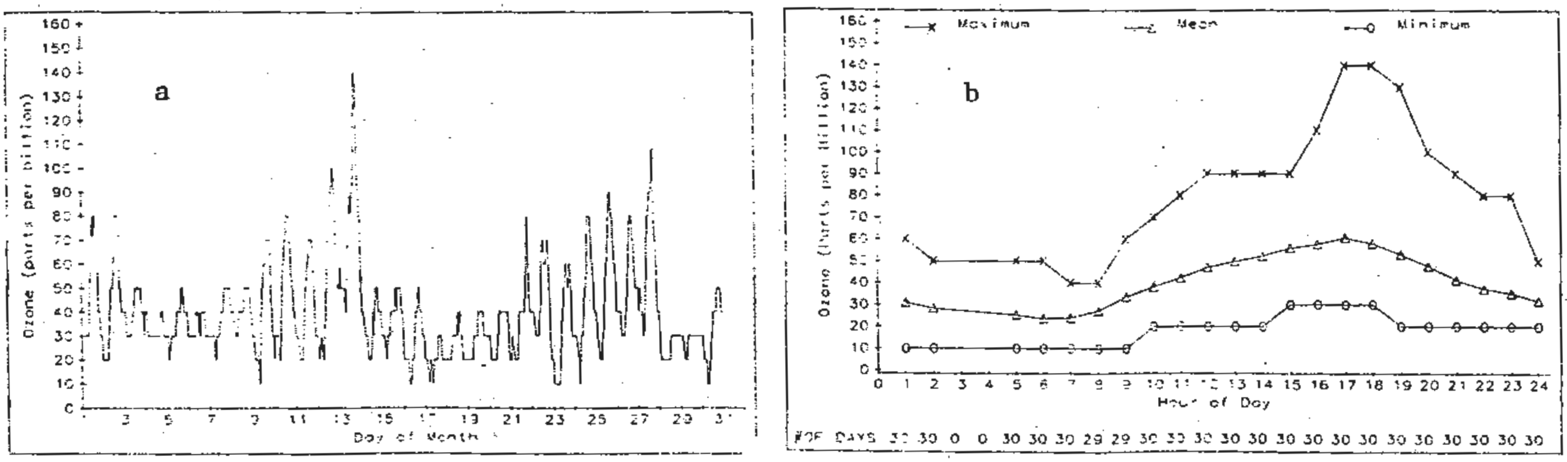

Figure 2. June 1986 ozone concentrations at Pack Forest, WA. a = monthly profile, b = diurnal pattern.

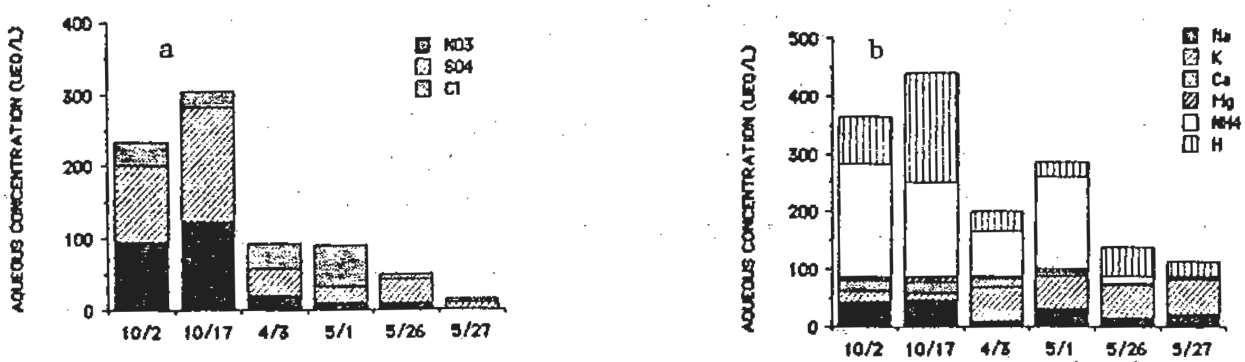

Figure 3. Mean aqueous concentration of the major inorganic ions by event for samples collected at Mt. Rainier, WA. a = anions, b = cations (10/86-5/87).

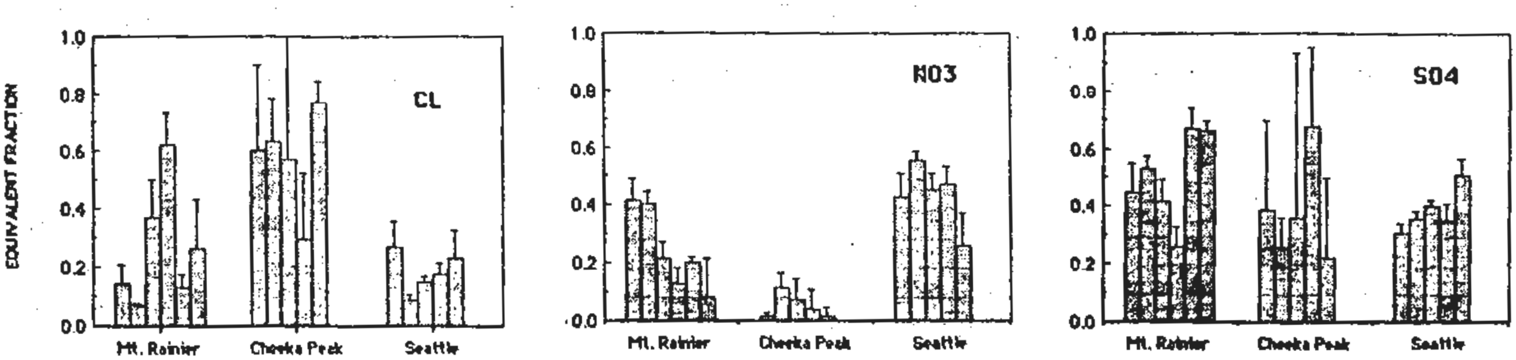

Figure 4. Event comparison of the mean values of the equivalent fractions of the anions for the events collected in western WA. (1985-1987).

Fomes annosus IN WESTERN HEMLOCK AT CLALLAM BAY, WASHINGTON; EVALUATION 20 YEARS AFTER PRECOMMERCIAL THINNING.

David C. Shaw, Robert L. Edmonds and Charles H. Driver

ABSTRACT: Three tenth-acre plots were sampled for occurrence of advanced decay in butts of 35 year old western hemlock. Two plots had been thinned 20 years ago: one had stump treatment with borax, the other had no treatment. The third plot was not thinned. The unthinned plot had 9% of the trees with advanced decay, the thinned, untreated plot had 29% of the trees with advanced decay , while the borax treated site had no trees with advanced decay from *Fomes annosus*. However, 9% of the trees on the borax treated plot had advanced sapwood decay from *Armillaria* sp. rot.

INTRODUCTION

Fomes annosus (Fr.) Karst (=*Heterobasidion annosum* (Fr.) Bref.) causes root and butt rot in mature (Englerth 1942) and young-growth (Wallis and Morrison 1975) western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) in western Oregon, Washington, British Columbia and Alaska. Forest management, particularly thinning, has increased the prevalence of this fungus in Europe (Rishbeth 1950) and in the southeastern United States (Driver and Ginns 1969). Stumps are infected and the fungus moves to remaining trees via root grafts or contacts. Wound infection is also common.

Western hemlock is an intensively managed species in the Pacific northwest and it is suspected that thinning, particularly precommercial thinning, will increase the within stand spread of *F. annosus*. Precommercial thinning is now a standard procedure in coastal western hemlock management. Stump infection is generally over 50% in the west (Driver and Wood 1968, Edmonds 1968, Russell et al. 1973, Morrison and Johnson 1978) and can occur in all months of the year (Reynolds and Wallis 1966, Morrison and Johnson 1970).

Borax has often been applied to stump surfaces to prevent infection (Russell et al. 1973). However, the long term effectiveness of this treatment has not been investigated in coastal western hemlock.

DAVID C. SHAW is a graduate research assistant, ROBERT L. EDMONDS and CHARLES H. DRIVER are professors, College of Forest Resources, University of Washington, Seattle.

The objective of this phase of the study was to determine the abundance of advanced decay in stands precommercially thinned 20 years ago with stumps treated or not treated with borax. In addition, we compared these stands with an unthinned stand.

MATERIALS AND METHODS

The study site is located 2.5 miles southwest of Clallam Bay, Olympic Penninsula, Washington on Washington State Department of Natural Resources land and has been described by Chavez et al. (1980) and Edmonds (1968). Plots were precommercially thinned in 1967 when trees were 15 years old. Several 0.1 acre plots had the stumps treated with borax while several were left untreated. In 1978 Chavez et al. (1980) found no advanced decay but 90% of the trees had incipient decay on two untreated plots.

Up to 35 western hemlock trees were cut per plot and examined for advanced decay. If decay was present, total height and diameter of decay column was determined.

RESULTS

Thirty-five trees were cut on the unthinned plot, three of these, or 9% of the trees, had advanced decay present. Fomes annosus has not been positively identified on one of these infections. Average advanced decay column height was 1.5 feet. One tree with advanced decay had a basal wound.

Thirty-one trees were cut on the chainsaw thinned and untreated plot. Nine of these, or 29% of the trees, had advanced decay. Average advanced decay column height was 2.7 feet. Three of these trees had basal wounds.

Thirty-three trees were cut on the chainsaw thinned and borax treated plot. None of these had advanced decay caused by F. annosus, while three, or 9%, had decay associated with Armillaria sp. infection. Average sapwood decay column height was 6 feet.

DISCUSSION

The borax treatment appears to have been effective in preventing advanced decay caused by F. annosus 20 years after precommercial thinning. It is interesting that Armillaria sp. infection occurred on the borax treated plot and not on the other plots.

In the future we plan to replicate this study again at Clallam Bay and at two other sites in coastal Washington. In addition, we will be quantifying incipient decay for a picture of total stand infection.

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BUSINESS MEETING MINUTES

The business meeting was called to order by John Muir, Chairman, at 11:06 am on August 22, 1987. Special thanks were extended to Janna Kumi and the local arrangements committee for the time and effort they gave to making the 1987 WIFDWC an enjoyable meeting. Appreciation was expressed to Jeff Beale and Bart Van der Kamp for the excellent field trip. Thanks were given to Jerry Beatty for arranging a successful and stimulating program.

OLD BUSINESS

The minutes and treasurer's report fom the 1986 WIFDWC were approved as printed in the 1986 proceedings. Thanks were given to Sally Cooley, 1986 WIFDWC Secretary, for the terrific effort involved in putting out the 1986 proceedings.

Committee Reports. Committee reports were made by John Muir, Mistletoe Committee Chairman; Rich Hunt, Rust Committee Chairman; Greg Filip, Root Disease Committee Chairman; and Ken Russell, Disease Control Committee Chairman. Written reports from committees appear elsewhere in these proceedings as committee reports. Ken Russell expressed a desire to retire from his position and urged any interested parties to speak up during new business.(No one did.)

1988 WIFDWC Information. The 1988 WIFDWC meeting will be held in Park City, Utah, September 19-23. Premeeting excursions in the Flagstaff, Ariz./Southern Utah region are a possibility. Fred Baker will have details.

Honorariums and Awards. No proposals have been made regarding the awarding of honorariums or awards. Terry Shaw volunteered to donate a "sick tree" mug that he owns for use as a revolving award. This suggestion was met with general revulsion.

SAF CE Credits. Jerry Beatty reported that there may be some problems in obtaining Continuing Education credits through the Society of American Foresters for attending WIFDWC. It is apparently not as easy as one would think. This is being investigated further. Jeff Beale reported that the British Columbia Professional Foresters Association has a more casual arrangement for obtaining credit and that interested persons attending WIFDWC should get hold of the BCPFA for more information.

Meeting Format. Meeting format was discussed, particularly the placement of discussion sections dealing with specific detailed information regarding forest pathology problems. A motion was made and carried to continue presenting general topics in the main program format and to provide opportunities to discuss specifics in special meetings at meals or outside the main meeting hours. An effort will be made to announce to WIFDWC attendees when and where such special meetings will take place and for those arranging such gatherings to report back to the general session.

Al Funk's canker workshop, held prior to the general session was an excellent idea and a great success. More "hands-on" workshops such as this are hoped for in the future.

NEW BUSINESS

Honorary Life Members. Dr. John Hopkins retired fom the Pacific Forestry Centre, Victoria, British Columbia.

In Memorium. Oscar Dooling passed away earlier this year. Oscar was a vital member of the WIFDWC group and will be missed. In his honor, Fields Cobb told Oscar's favorite joke.

A motion was made and unanimously carried to dedicate the 1987 proceedings to Oscar's memory.

Reports From Other Meetings

APS. Fields Cobb reported that the Forest Pathology Committee met and discussed the status of Forest Pathology funding. The next APS meeting will be held in San Diego, Ca., in November. One or two field trips are planned, as well as a discussion section on Forest Decline. Fields reported that NAS will be conducting a major study on the Status of Forest Biology which will include forest pathology as well as the broader perspective of forest biology.

CPS. Pritam Singh reported that Forest Pathology was a major topic of discussion at the last meeting. Two sessions on forest pathology were held for the first time in CPS history. CPS has granted space to forest pathology as a subject committee, with R.D.Whitney as Chairman.

W110. The annual meeting of the W110 group will be held in Lakewood, Colorado, September 22 and 23, 1987. Fred Baker has details.

Bob Scharpf reported that dwarf mistletoes were mentioned for the first time at the 4th International Symposium on Parasitic Plants held this past year.

The International Symposium on Biocontrol of Plant Pathogens will be held in Rome,Italy, in March, 1988.

Resolution to the Chief. In light of the recent disclosure of possible reductions in funding for root disease research by the USDA Forest Service, a motion was made and unanimously carried to send the following resolution to the Chief of the Forest Service and the Associate Chief of Research.

> The members of the Western International Forest Disease Work Conference have learned that the USDA Forest Service recently reduced proposed funding for research on root diseases of forest trees. Root diseases account for losses of forest resorces worth millions of dollars annually in western North America. And, it is known that losses from root diseases increase with increasing management. The executive committee of WIFDWC recommends that the USDA Forest Service reinstate the original funding proposal for research on root diseases so that USDA Forest Service Scientists and their cooperators can develop the information that will lead to decreasing losses from these serious tree pathogens in western North America.

Other News. Walt Thies reported that Earl Nelson has been awarded a Fullbright Fellowship and is currently doing research in Australia. Earl is due back to the U.S. in February,1988.

Rich Hunt reports that the Western Forest Genetics Association is interested in holding their annual meeting at the same time and in the same location of a future WIFDWC in order to hold an overlapping/joint session. Rich volunteers to look into the possibility of such a meeting.

1989 Meeting. An invitation was extended by the entomologists to hold a joint meeting in California at a time of our convenience during 1989. Alan Kanaskie, with a slide show of somewhat questionable taste, invited WIFDWC to Central Oregon. After much discussion, a motion was made and carried to have a joint meeting with the entomologists in the near future. A vote was taken to decide whether to hold the meeting in 1989 in Central Oregon or in California with the entomologists. Central Oregon won. An invitation will be extended to the entomologists to join us there.

Jerry Beatty volunteered to look into the possibility of holding a WIFDWC meeting in Hawaii. He will report to the 1988 WIFDWC.

1988 Executive Committee. The 1988 nominating committee (chaired by Fields Cobb) nominated the following candidates for officers: Jim Byler, Chairman and Bart Van der Kamp, Secretary-Treasurer. They were duly railroaded and the meeting was adjourned.

Respectfully submitted for Gregg DeNitto by Ellen Michaels Goheen

INTERIM PROGRAM CHAIRMAN'S REPORT

Don Goheen

Suggestions fell into two general categories: (1) Procedural suggestions and (2) Specific suggestions for next year's program. Names of suggestors will be included with the latter group.

Procedural Suggestions

1. Continue effort to stream-line institution reports (but do not eliminate them). Present mainly new projects, personnel changes, etc. Play down specific results of completed projects. These should be presented elsewhere.

2. Improve name tags. Encourage everyone to wear the infernal things. Perhaps (if possible) develop a list of attendees based on registration to distribute to everyone.

3. Downplay "trendy" subjects in future programs, especially sexuality of fungi, biotechnology, etc. (Note: This may represent only a few people's biases, but it was suggested to me by several individuals).

4. Remind speakers not to use slides with intricate graphs or numerous lines of lettering. The audience is lost.

5. Caution speakers to avoid off-color, sexist, or racially-offensive language.

6. Consider scheduling the business meeting for the morning before the last day (to increase attendance).

7. Resurrect the disease committee luncheons.

8. Continue the distribution of notes from the Honorary WIFDWC members, such as was done in 1985 (Olympia meeting). In the first WIFDWC mailing, ask for an update note from each retired member, duplicate, and make available at the meeting. This is a good way to update the address list.

Specific Suggestions

1. Panel on Forest Tree Seed Diseases - S. J. Frankel

2. Panel on Forest Health Initiative - D. W. Johnson

3. Adaptation of Recent Advances in Biotechnology to Forest Pathology - E. Hansen

4. Changes in Regulations Regarding Culture Exchanges - T. Shaw (suggests presentation by APHIS representative)

5. Panel on *Heterobasidion annosum* - anonymous

6. Changes in Policy Regarding Dwarf Mistletoe Control - D. W. Johnson (suggests presentation by WO Forest Service)

7. Panel on Diverse Views on Disease Problems with representatives of media, policy (planner), silviculture, forest economics, other resources (wildlife, recreation) - J. Schwandt

8. Panel on Control of Black Stain Root Disease - D. J. Goheen

9. Panel on "Miscellaneous" Pathogens on Conifers. Interest is in frequency of occurrence and conditions favoring "minor" pathogens - S. Hagle

TREASURER'S REPORT, THIRTY-FIFTH WIFDWC

Balance on hand at close of thirty-fourth meeting.	($U.S.) 913.31
Adjustment for 1986 (34th) Proceedings cost (Original estimate was $1150.00; actual cost was $981.46)	168.54
Interest paid July 1, 1986 through June 30, 1987	121.36
Miscellaneous Proceedings sales (24) from 1/1/87 to 12/31/87	138.00
Transfer of funds, Int'l bank draft	(3.00)
Nanaimo meeting advance, $500 travelers check cost (not used)	(1.00)
Park City meeting advance for 1988	(250.00)
U.S. checks from Nanaimo deposited in Credit Union, 8/25/87	1671.58
Int'l bank draft ret. in $Can. to local arr. com., 8/25/87	(1672.00)
Adjustment for Canadian check accidently brought to U.S.	(12.88)
Sub-total	1073.91

Thirty-fifth WIFDWC statement from Nanaimo meeting

Receipts: (Converted to U.S. $)

Regular participants	69	
Students	18	
Honorary life members	3	
Total registration	90	$2895.36
Meals		3174.24
Sub-total		6069.60

Expenses: (Converted to U.S $)

Meals, Hospitality Room and Audio/Visual	3801.67
Hospitality Refreshments	148.27
Field Trip	904.63
Photocopying	133.40
Gibson Spoon Mementos	295.06
Honorarium (banquet)	37.07
Name tags	10.32
Proceedings printing estimate (adjustment will be made next year)	750.00
Sub total	* 6080.42

* Local arrangements chose to absorb the $10.82 deficit.

Balance at close of thirty-fifth meeting 1073.91

Continuous account number 936258 held at the Washington State Employee's Credit Union. PO Box WSECU, Olympia, WA 98507. Phone (206) 943 7911. Official signatures for withdrawing funds are Walt Thies, Ken Russell and Fields Cobb. Ken Russell, December 16, 1987.

Dwarf Mistletoe Committee Report

John A. Muir, Chairman

1. Taxanomy, Hosts, and Distribution

1.1 Mexico continues to yield dwarf mistletoe surprises. A new species was found on pines in Sonora. The fir mistletoe, A. abietinum, was found in Chihuahua, the first record of this species in Mexico, a range extension of 400 km south of its previously known southern limits in Arizona. The Douglas-fir dwarf mistletoe was found for the first time in Chihuahua. With these additions, 22 dwarf mistletoes (more than half the known species in the world) are from Mexico (F. Hawksworth, C. G. Shaw, and J. Beatty).

1.2 Studies are underway to help determine the appropriate taxonomic status of the three putative races of the hemlock mistletoe (western hemlock, mountain hemlock, and shore pine) as outlined in last years' WIFDWC proceedings (p. 45 - 46). Isozyme studies will be conducted by D. Nickrent of the University of Illinois, and we will do the morphological, phenological and host studies (F. Hawksworth and D. Wiens).

1.3 The Forest Service has given its blessing to our proposal to redo the 1972 dwarf mistletoe monograph, which is not only out of print but also out of date. The revision will consider the dozen new species that have evolved since 1972. As envisioned the new monograph will be more than just an update as it will include several new topics: ecological relationships, host effects, bird and mannual associates, the endophytic system, biological control agents, reproductive biology, and chemotaxonomy. New maps showing distribution of each species by counties will be prepared (F. Hawksworth and D. Wiens).

3. Life cycle studies

3.1 A masters study at Northern Arizona University has shown that ponderosa pine seedlings of various ages differ markedly in their susceptibility to Arceuthobium vaginatum. For trees grown outdoors in a lathouse, infection ranged from 50% in 2 months-old seedlings to none in 14 month-old seedlings. In another study where seedlings were kept in a greenhouse, infection ranged from 61% in 1-year old seedlings to none for 3- and 4- year old seelings. An inoculation study was begun to determine the seedling suceptibility of several species of white pines to Arceuthobium apachecum, A. blumeri, A. californicum and A. cyanocarpum but the results are not yet available (G. Orr, Nor. Ariz. Univ.).

4. Host-Parasite Relations

4.1 A cooperative Rocky Mountain Station study is underway to measure the rates of intensification of Douglas-fir dwarf mistletoe in Southwestern mixed conifer stands. The study entails dissection of trees of various current mistletoe ratings to determine what their infection level was 10 years previously. We plan to obtain this information in about 400 trees of various size classes, dominance classes, stand structures, site indices, and habitat types. This information is needed for a growth and yield model that has been under construction by the RM Station for some time (R. L. Mathiasen).

5. Effects in Hosts

5.1 A study is being conducted in Arizona and New Mexico to determine the rates of mortality in Douglas-fir of various mistletoe infection classes. Permanent inventory plots which were rated for mistletoe at least 10 years previously are being revisited to determine the survival rates of trees in different infection classes (B. Geils and J. Sprackling).

5.2 A study is underway to determine mortality rates in Douglas-fir in relation to past mistletoe ratings and current spruce budworm intensity in eastern Washington and eastern Oregon. Forest inventory plots on the Okanagan Wenatchee ("toe jungle") and Willowa-Whitman National Forests are being revisited (G. Filip, J. Colbert, and C. Shaw).

5.3 How long do mistletoe-infected ponderosa pines live? An analysis of 32-year survival rates of nearly 800 tagged trees (4 to 30 inches dbh) at Grand Canyon, Arizona, gives some data for Arceuthobium vaginatum. Mortality was strongly correlated with initial DM intensity. Mortality was less than 10% for non-infected and DMR Class 1 trees, but increased rapidly as DMR increased: Class 2 (25%), Class 3 (41%), Class 4 (61%), Class 5 (76%), and Class 6 (94%). Mean survival (half-life) of Class 6 trees was about 17 years, 21 years for Class 5 trees, 26 years for Class 4 trees and 39 years for Class 3 trees. Similar analyses are being made of other long-time ponderosa pine plots in the southwest (F. Hawksworth and B. Geils).

6. Ecology

6.1 The frequency and biological significance of long-distance seed dispersal of lodgepole pine dwarf mistletoe were studied at the Fraser Experimental Forest since 1982. In a 90-year old stand we found 1.7 isolated infection centers per hectare. More than two-thirds of the satellite centers were found near openings. Such openings are attractive habitats for birds that are the most likely vectors responsible for long-distance dispersal of dwarf mistletoe seed.

A total of 721 birds and 290 mammals were trapped and examined for dwarf mistletoe seed. Mist-net and trapping studies showed a total of 81 mistletoe seeds on 75 trapped animals (10 birds and 4 mammals). The most important vectors were the gray jay, Stellar's jay, gray-headed junco, Audubon's warbler, mountain chickadee, and least chipmunk. During the peak seed dispersal period as many as one-quarter to one-third of these animals carried mistletoe seeds. Thus, there is compelling evidence that these animals are indeed vectors of dwarf mistletoe seeds and that they are responsible for long-distance spread (F. Hawksworth, T. Nicholls, and L. Merrill).

7. Control-Chemical

7.1 We evaluated ethephon, an ethylene-releasing plant growth regulator, for control of dwarf mistletoe, Arceuthobium americanum, on lodgepole pine in Colorado. Tests were conducted on the Fraser Experimental Forest from 1982 to 1985 and at Cutthroat Bay in the Arapaho National Recreational Area in 1985. Ethephon at 2500 ppm with a surfactant was tested using three application methods: a bottle sprayer, backpack mistblower, and a hydraulic sprayer.

Dwarf mistletoe shoot abscission of 74 to 100 percent was consistently achieved using all three ground application methods. Mistletoe seed dispersal the year after ethephon application was significantly less in the treated plots than in the nontreated control plots. The tests are being monitored to determine how long it takes for mistletoe shoots to resprout and fruit. We feel that the chemical will reduce spread and infection by dwarf mistletoe for up to 4 years, and, perhaps longer. An aerial test of 2400 ppm ethephon by helicopter was made at Fraser in 1986, but the results are still being analyzed (T. Nicholls, L. Egeland, F. Hawksworth, D. Johnson and M. Robbins).

9. Control - Silvicultural

9.1 USDA-Forest Service Research Paper PSW-186, February 1987 "Pruning Dwarf Mistletoe Brooms Reduces Stress on Jeffrey Pines, Cleveland National Forest, California" by Scharpf, Smith and Vogler has been published and is available for distribution (R. Scharpf).

9.2 Dwarf mistletoe suppression projects were conducted over 7,211 acres on nine National Forests or Bureau of Land Management Areas in the Intermountain Region during 1986 (Hoffman & Tkacz).

9.3 Plans are to treat 4,714 acres of dwarf mistletoe infested stands on the Arapho and Roosevelt; Grand Mesa, Uncompahgre and Gunnison; Medicine Bow; Pike and San Isable; Rio Grande; Routt; Shoshone; and White River National Forests (D. Johnson, USFS, R-2).

10. Surveys

10.1 In the last two years, two FRDA dwarf mistletoe contracts were completed in the Prince George Forest Region: in 1985/86 a dwarf mistletoe roadside survey on 859 km of road in the Vanderhoof, McBride, Prince George East and Prince George West Forest Districts; and in 1986/87, a determination of the volume loss in dwarf mistletoe infected lodgepole pine trees on a poor site.

Currently we are developing another contract to complete more stem analysis for volume loss on different sites (good and medium). With this information, we will be able to apply volume loss to the roadside incidence data by inventory stand type and come up with a volume loss value due to dwarf mistletoe for the Prince George Forest Region (M. Curran).

10.2 Presuppression surveys for *Arceuthobium americanum*, *A. douglassi*, and *A. campylopodum* were conducted on over 73,250 acres of commercial timber land in the Intermountain Region. The data, collected in conjunction with stand examination surveys, will provide disease information for silvicultural prescriptions. In addition, the surveys provide a basis for determining future dwarf mistletoe suppression projects (Hoffman and Tkacz).

10.3 Presuppression surveys for dwarf mistletoes are planned for 14,096 acres on the Arapaho and Roosevelt; Medicine Bow; Pike and San Isabel National Forests (D. Johnson).

11. Miscellaneous

11.1 Work is continuing under a PSW internal grant to develop a rapid method of screening for dwarf mistletoe resistance and Jeffrey pines by using tissue culture techniques (R. Scharpf and A. Stomp).

11.2 While in Mexico we were shown some collections of a *Phoradendron* from *Pseudotsuga*. We were not able to visit the site (in southern Chihuahua) but we plan to collect from the population in October. This is of interest as it is the only known parasitism of a leafy mistletoe on Douglas-fir (F. Hawksworth, C. Shaw, and J. Beatty).

DISEASE CONTROL COMMITTEE
1987 INVESTIGATIONS

Kenelm Russell, Chairman

Rules and regulations about harvesting wild edible fungi do not necessarily come under the disease control committee, but it is a good place to inform you about issues surrounding them as a commodity.

Starting in 1985, the Washington state legislature introduced bills to regulate wild edible mushroom harvesting. This legislation did not make it out of committee, but the idea has not gone away and may succeed in the 1988 session. To my knowledge, this is the first legislation of its kind worldwide. The mushroom world is watching to see what we do.

The intent of new legislation is to license mushroom buyers and processors dealing in wild edible mushrooms. The bulk of funds received would go towards as yet undefined research on wild edible mushrooms. Dollar estimates of funds received would support a partial graduate student, probably at the University of Washington. Additional funds would come from interests within the industry or from other state departments or the university. The 1987 legislation had the same proposal, but included a daily picking limit which probably caused its defeat. In my opinion picking limits do not appear practical or enforceable.

The Washington Department of Natural Resources faces an interesting challenge. How does one go about selling wild mushrooms from state managed lands? Since wild edible mushrooms have become a commodity of value, the state can not give them away. It is illegal to give away any natural resource from state lands when it has a commercial value. The Department is looking at some kind of over-the-counter permit to solve the problem. Other forest land owners may want to look into the possibility of selling their wild mushrooms also.

France has a law that prohibits anyone from harvesting mushrooms or truffles on any land without written authorization from the landowner. A law like this in Washington would give landowners better control over who is taking resources from their land.

Interested persons can learn more about issues surrounding wild edible mushrooms by writing to me for the "Wild Edible Mushroom Issues" paper.

Another meeting dealing with edible fungi was organized largely by our friend Jim Trappe (retired Forest Service mycologist). The Second Western Congress on Truffles was held in Santa Rosa, California in early December, 1987. Interest in harvesting these delectables from forests is growing. Jim brought speakers from Europe, Mexico and the U.S. to enlighten us on all aspects including the laws of both natural and cultivated truffles and wild edible mushrooms. WIFDWC might like to address the fungi as commodities. Foresters too, should learn more about these important mycorrhizal fungi. They may be overlooking revenue right under their boots!

A new "Forest Health Plan" developed by the USDA Forest Service poses some exciting challenges for future Forest Pest Prevention Management. A draft is making its way through the system and should appear in final print sometime in the spring of 1988. It ties some loose ends of forest management together and brings Forest Pest Management by policy directive right into the total planning process. It is a wholistic plan which looks at the impacts of forest pests under any type of forest land use. Forest Pest Management Prevention, the basic principle of disease control may, be one of the best ways to improve forest and nursery production.

Listed on the following pages are your disease control projects for this year. The list is far from complete:

SEEDLING DISEASES--NURSERIES

1. Damping-Off, Nematode Feeding
   Host: Conifer Seedlings
   Causal Organism(s): *Fusarium* spp., *Pratylenchus penetrans*
   Control: Chemical
   Development Stage: Field Trial

   Basamid sealed with water and a plastic tarp was as effective as methyl bromide for reducing plant parasitic nematodes. Solar heating was less effective than the chemical treatments, but much better than the check. For reducing *Fusarium* spp., methyl bromide, solar heating, and ployethylene sealed Basamid were more effective than water sealed Basamid which was similar to the check.

   (D. Hildebrand, RM Region, USDA Forest Service)

FOLIAGE DISEASES

1. Needle Cast
   Host: *Abies concolor*
   Causal Organism(s): *Lirula abietis-concoloris*
   Control: Chemical
   Development Stage: Field Trial

   In Christmas trees a single fungicide application on new growth May 23, 1986 provided good control. Checks had 20% infected needles, benomyl had 3.4%, and mancozeb had 6.7%. Seven other chemicals were evaluated as well.

   (A. McCain, R. Scharpf, U of Cal and USDA Forest Ser., PSW Sta.)

DWARF MISTLETOES

1. Western Dwarf Mistletoe
   Host: Pinus jeffreyi
   Causal Organism(s): Arceuthobium campylopodum
   Control: Chemical
   Development Stage: Full operational

   Final phase of control project at Nevada Beach Campground, Lake Tahoe Basin NV was completed. Control included tree removal and pruning.

   (G. DeNitto, J. Schellenger, SW Region, USDA Forest Service, Forest Pest Mgt.)

2. Western Dwarf Mistletoe
   Host: Pinus ponderosa and Pseudotsugae menziesii
   Causal Organism(s): Arceuthobium campylopodum
   Control: Chemical
   Development Stage: Full operational

   Control results published in this volume 17 years after treatment. Eventually, more analysis will be done on volume growth and the degree of mistletoe infection.

   (K. Russell, Washington Department of Natural Resources, Olympia, WA)

ROOT DISEASES

1. Armillaria Root Rot
   Host: Karri, Eucalyptus diversicolor
   Causal Organism(s): Armillaria luteobubalina
   Control: Biological
   Development Stage: Field trial

   To date 120 Australian isolates of Trichoderma spp. and Gliocladium virens have been tested for ability to colonize karri stemwood and antagonize the Armillaria. The first field control study was installed and a second is planned for January, 1988.

   (E. Nelson, USDA Forest Service in cooperation with CSIRO, Western A.

2. Blackstain Root Disease
Host: Pinyon Pine
Causal Organism(s): <u>Ceratocystis wagneri</u>
Control: Chemical
Development Stage: Field Trial

A final evaluation of trenching, chemical barriers and silvicultural treatment of disease centers has been made. In all treatments the disease was found across barriers to underground spread.

(M. Sharon, USDA Forest Service, Rocky Mtn region, Forest Pest Management)

3. Tomentosus Root Rot
Host: Spruce
Causal Organism(s): <u>Inonotus tomentosus</u>
Control: Silvicultural
Development Stage: Full operational

Planning a stump removal trial for tomentosus root rot on a 15 ha. site with a D-8 cat with brush blade and an excavator.

(W. Martin, B.C. Forest Service)

TRIVIA QUIZ - 1987

Baby-Boomer Edition

1. What is the southern-most distribution of _Phellinus weirii_?
   Answer - Six Rivers National Forest, California

2. Name a forest pathologist who incubates his _Fomes annosus_ disks in newspapers written in Ukranian.
   Answer - Borys Tkacz

3. What forest pathologist has a Ph.D. in forest entomology?
   Answer - Jim Allison

4. Who is the only forest pathologist in British Columbia in the employ of a forest company?
   Answer - Janna Kumi

5. Which two WIFDWC "baby-boomers" were born in the same Catholic hospital in Colfax, Washington? What year?
   Answer - Terry Shaw and Don Goheen in 1948

6. What forest pathologist does not have indoor plumbing?
   Answer - Susan Hagle

7. What major professor present at this WIFDWC has the most graduated students also present?
   Answer - Fields Cobb (hotly contested by Everett Hansen and Bart Van der Kamp

8. Who developed a strange relationship with a member of the genus _Bufo_ in the Republic of Mexico?
   Answer - Terry Shaw

9. Which 3 baby-boomers have won the Social Achievement Award?
   Answer - Vivian Muir, Terry Shaw, and Fred Baker (now joined by Sally Cooley)

10. Who left a Hasselblad camera on a stump overnight (it was discovered the next day by his major professor)?
    Answer - Greg Filip

11. What western forest pathologists spent their honeymoons in mouse-infested cabins in northern Wisconsin?
    Answer - John Kliejunas, Dave Johnson, Walt Thies

12. What pathology graduate student was passed by the trailer he believed he was towing?
    Answer - Randy Fuller

13. What forest pathologist who has attended WIFDWC has encountered baboons in his plots?
    Answer - Mike Wingfield

14. What is the mating habitat of the long-eared owl?
    Answer - Douglas-fir dwarf mistletoe brooms

15. Name 3 forest pathologists who attended forestry school in the Show-Me state?
Answer - Larry Weir, Walt Thies, Dave Drummond

16. What is the most recently discovered *Phytophthora* species of Northwest conifers?
Answer - *P. pseudotsugae*

17. What forest pathologist attended Boy Scout Camp at Spirit Lake, Washington before Mt. St. Helens destroyed it?
Answer - Everett Hansen

18. Who posed for the strangest human picture ever to appear in the Journal of Forestry?
Answer - Walt Thies

19. What 3 names have been used in the last 2 years for the organism causing shoestring root rot? Which one is currently correct?
Answer - *Armillaria mellea*, *A. ostoyae*, *A. obscura* (the last is allegedly correct

20. What forest pathologist has been on the most junkets to Mexico next to Frank Hawksworth?
Answer - Jerry Beatty

21. What was the name and profession of the person who discovered black stain root disease?
Answer - K. A. Salman, a forest entomologist

22. Name one of the 3 forest pathologists in the west who won't travel anywhere without a hair drier/blower (it's not Art McCain)?
Answer - Bob James, Craig Schmitt, John Pronos

23. Name 2 WIFDWCers present at this meeting who have college degrees in English literature?
Answer - Detlev Vogler and Jerome Beatty

24. What forest pathologist has reached the summit of the highest peak in North America?
Answer - Bob Harvey

25. What 3 names have been used in the last 20 years for the organism that causes annosus root disease?
Answer - *Fomes annosus*, *Fomitopsis annosa*, and *Heterobasidion annosum*

26. What is the term describing the ratio of number of text pages to number of citations? Who invented it?
Answer - The Bob James Index (the inventor? hotly contested between Jerry Beatty and Jim Byler)

27. Who holds the record for the largest halibut ever caught by a woman and what is her profession?
Answer - Elaine Loopstra, pathology technician

28. What forest pathologist has acknowledged a rattlesnake in a biological evaluation report?
Answer - Ed Wood

29. What forest pathologist led the infamous Lost Lake fishing expedition? And who has kept the legend alive?
Answer - Rich Hunt and Fields Cobb, respectively

30. Who is B.C.'s sole consulting forest pathologist?
Answer - John Schulting

Not to be outdone by the Boomers, some of the old guard still find ways and means to keep themselves active in a variety of endeavors, as illustrated by the business card below.

World Traveler - Rodeo Cowboy - Soldier of Fortune
Champion of the Oppressed - International Lover
Casual Hero - Working Girls Friend - All Around Good Guy

Seeker of Peace

LAWRENCE C. WEIR

Wars Fought	Virgins Converted
Chickens Sexed	Uprising Qualled
Bears Bred	Dogfights Stopped
Alligators Castrated	Catfights Started
Tigers Temed	Bars Emptied
Cock Fights Organized	Computers Verified

MEETING LOCATIONS AND EXECUTIVE COMMITTEES

No.	Year	Location	Chairman	Secretary-Treasurer	Program Chairman	Local Arrangements
1	1953	Victoria, BC	R.E. Foster	--	--	--
2	1954	Berkeley, CA	W.W. Wagener	P.C. Lightle	--	--
3	1955	Spokane, WA	L.J. Nordin	C.D. Leaphart	G.P. Thomas	--
4	1956	El Paso, TX	L.S. Gill	R.W. Davidson	V.J. Nordin	--
5	1957	Salem, OR	G.P. Thomas	T.W. Childs	R.L. Gilbertson	--
6	1958	Vancouver, BC	J.W. Kimmey	H.R. Offord	A.K. Parker	--
7	1959	Pullman, WA	H.R. Offord	R.E. Foster	C.G. Shaw	--
8	1960	Centralia, WA	A.K. Parker	F.G. Hawksworth	J.R. Parmeter	K.R. Shea
9	1961	Banff, ALB	F.G. Hawksworth	J.R. Parmeter	A.C. Molnar	G.P. Thomas
10	1962	Victoria, BC	J.R. Parmeter	C.G. Shaw	K.R. Shea	R.G. McMinn
11	1963	Jackson, WY	C.G. Shaw	J.E. Bier	R.F. Scharpf	L. Farmer
12	1964	Berkeley, CA	K.R. Shea	R.F. Scharpf	C.D. Leaphart	H.R. Offord
13	1965	Kelowna, BC	J.E. Bier	H.S. Whitney	R.V. Bega	A.C. Molnar
14	1966	Bend, OR	C.D. Leaphart	D.P. Graham	G.C. Pentland	D.P. Graham
15	1967	Santa Fe, NM	A.C. Molnar	E.F. Wicker	L.C. Weir	P.C. Lightle
16	1968	Coeur d'Alene, ID	S.R. Andrews	R.G. McMinn	J.L. Stewart	C.D. Leaphart
17	1969	Olympia, WA	G.W. Wallis	R.L. Gilbertson	F.G. Hawkaworth	K.W. Russell
18	1970	Harrison Hot Sp, BC	R.F. Scharpf	H.V. Toko	A.E. Harvey	J. Roff
19	1971	Medford, OR	J.A. Baranyay	D.A. Graham	R.B. Smith	H.H. Bynum
20	1972	Victoria, BC	P.C. Lightle	A.H. McCain	L.C. Weir	D. Morrison
21	1973	Estes Park, CO	E.F. Wicker	R.C. Loomis	R.L. Gilbertson	J.G. Laut
22	1974	Monterey, CA	R.V. Bega	D. Hocking	J.R. Parmeter	--
23	1975	Missoula, MT	H.S. Whitney	J.W. Byler	E.F. Wicker	O.J. Dooling
24	1976	Coos Bay, OR	L.F. Roth	K.W. Russell	L.C. Weir	J. Hadfield
25	1977	Victoria, BC	D.P. Graham	J.G. Laut	E.E. Nelson	J. Bloomberg
26	1978	Tuscon, AZ	R.S. Smith	D.B. Drummond	L.C. Weir	R.L. Gilbertson
27	1979	Salem, OR	T.H. Laurent	T.E. Hinds	B. Van der Camp	L.C. Weir
28	1980	Pingree Park, CO	R.L. Gilbertson	O.J. Dooling	J.G. Laut	M. Schomaker
29	1981	Vernon, BC	L.C. Weir	C.G. Shaw III	J. Schwandt	D. Morrison/ R. Hunt
30	1982	Fallen Leaf Lake, CA	W.J. Bloomberg	W.R. Jacobi	E. Hansen	F. Cobb/ J. Parmeter
31	1983	Coeur d'Alene, ID	J.G. Laut	S.H. Dubreuil	D.W. Johnson	J. Schwandt/ J. Byler
32	1984	Taos, NM	T.E. Hinds	R.S. Hunt	J.W. Byler	J. Beatty/ E. Wood
33	1985	Olympia, WA	F.W. Cobb	W.G. Thies	R. Edmonds	K. Russell
34	1986	Juneau, AK	K.W. Russell	S.J. Cooley	J.G. Laut	C.G. Shaw III
35	1987	Nanaimo, BC	J. Muir	G. DeNitto	J.S. Beatty	J. Kumi
36	1988	Park City, UT	J.W. Byler	B. Van der Kamp	J. Pronos	F. Baker

SOCIAL ACHIEVEMENT AWARD WINNERS

Year	Location	Winner
1957	Salem, Oregon	Stuie Andrews
1958	Vancouver, BC	Stuie Andrews
1959	Pullman, Washington	Don Leaphart
1960	Centralia, Washington	Keith Shea
1961	Banff, Alberta	Phil Thomas
1962	Victoria, BC	Toby Childs
1963	Jackson, Wyoming	Alex Molnar
1964	Berkeley, California	Reed Miller
1965	Kelowna, BC	Art Parker
1966	Bend, Oregon	Gardner Shaw
1967	Santa Fe, New Mexico	Larry Weir
1968	Coeur d'Alene, Idaho	Bob Scharpf
1969	Olympia, Washington	Dick Parmeter
1970	Harrison Hot Spr., BC	Jim Kimmey
1971	Medford, Oregon	Ed Wicker
1972	Victoria, BC	Vivian Muir
1973	Estes Park, Colorado	Tom Laurent
1974	Monterey, California	Bob Bega
1975	Missoula, Montana	Art McCain
1976	Coos Bay, Oregon	----------
1977	Victoria, BC	Ray Foster
1978	Tucson, Arizona	John Hopkins
1979	Salem, Oregon	Oscar Dooling
1980	Pingree Park, Colorado	Tommy Hinds
1981	Vernon, BC	Fields Cobb
1982	Fallen Leaf Lk, California	John Laut
1983	Coeur d'Alene, Idaho	Bob Gilbertson
1984	Taos, New Mexico	Terry Shaw
1985	Olympia, Washington	Fred Baker
1986	Juneau, Alaska	Edna Miller
1987	Nanaimo, BC	Sally Cooley
1988	Park City, UT	

A. Forest Disease Surveys - General

71-A-4 Appraisal of damage caused by forest pests in British Columbia (R. Alfaro).
71-A-5 Forest insect and disease survey (G.A. Van Sickle).
71-A-7 Forest insect and disease survey in the prairie Provinces, and Northwest Territories (Y. Hiratsuka, H. Wong, H. Cerezke, B. Moody).
73-A-4 Forest disease: diagnostic and taxonomic services and research (A. Funk).
74-A-1 Disease (and insect) detection surveys in Colorado forests (J. Laut, M. Schomaker).
81-A-6 Mortality of _Chamaecyparis nootkatensis_ in southeast Alaska (T. Shaw, P. Hennon).
82-A-3 Disease and insect impact on young growth, mixed conifer stands in California (J. Pronos, L. Dolph).
84-A-1 Pest Impact Assessment Methodology-_Fomes annosus_ (J. Parmeter, G. Slaughter W. Otrosina).
85-A-1 Evaluation of seed tree mortality on the Powell Ranger District, Clearwater National Forest, Idaho (C. Stewart).
85-A-2 Disease Sampling in Douglas-fir plantations (W. J. Bloomberg).
85-A-4 Pathological aspects in the management of Alaska-cedar for timber production (P. Hennon).
85-A-5 Survey to describe the extent and impact of major root disease on non-federal timberlands in Oregon (A. Kanaskie).
85-A-6 Estimating extent and distribution of black stain root disease on state lands in Oregon (A. Kanaskie).
86-A-1 Black stain root disease survey, Oregon and Washington (W. Littke)
86-A-2 Surveys of pest incidence and damage in young plantations (J. Muir).
87-A-1 Assessing stand root disease mortality using ground and aerial rating systems (S. Hagle).

B. Non-Infectious diseases

80-B-2 Trend of ozone injury to conifers in the southern Sierra Neveda (J. Pronos).
86-B-1 Ozone in Puget Sound forests (R. Edmonds).
86-B-2 Acid fog in the Cascades (R. Edmonds).

C. Cone, Seed, and Seedling Diseases

76-C-1 Diseases of seeds and cones- PC-54-07 (J. Sutherland).
83-C-2 Assessment of new chemicals to control _Botrytis_ blight in nurseries (R. James).
83-C-3 Fungi associated with pine seedlings tip blight in Northern Rocky Mountain nurseries (R. James).
84-C-1 The effect of inoculum density of _Macrophomina phaseolina_ on conifer nursery production (A. McCain).
84-C-3 Studies of _Fusarium_-associated diseases of conifer seedlings at northern Rocky Mountain nurseries (James, Gilligan, Dumroese).
84-C-4 Characteristics and identification of _Phoma_ spp. associated with conifer seedling diseases (R. James).
85-C-8 Biological and chemical control of soil-borne fungi in forest tree nurseries (R. Blanchette).

85-C-16 Interactions between cover crops, fumigation, nitrogen availability and soil-borne pathogens in nurseries (E. Hansen).
86-C-2 Pathogenicity of Fusarium acuminatum to Russian olive (D. Hildebrand).
86-C-3 Comparison of solar heating, Basamid with polyethyl seal, Basamid with water seal, and methyl bromide-chloropicrin for control of soil-borne pests in fall-sown Eastern red cedar at Bessy Nursery (D. Hildebrand).
86-C-4 Influence of pre-sow phosphorus fertilization on incidence of stunting in bareroot Douglas-fir seedlings (A. Kanaskie).
86-C-5 Effect of Douglas-fir cone storage method on seed yield, viability, and occurrence of Fusarium spp. (A. Kanaskie).
86-C-6 Impact of seed-borne pathogens on seedling performance (W. Littke).
86-C-7 Cone and seed treatments to increase seed extractability, quality, and performance (W. Littke).
86-C-8 Impact of Fusarium and other pathogens during cold storage on seedling quality (W. Littke).
86-C-9 Measurement of Fusarium populations over entire crop cycle (W. Littke)
87-C-1 Biological control of Fusarium oxysporum (E. Hansen, P. Hamm).
87-C-2 Soil pest assay of the Basamid trial at the Lucky Peak Forest Nursery, Idaho (J. Hoffman).
87-C-3 Effects of seedling root colonization by Fusarium on Douglas-fir Outplanting survival (R. James, Dumroese).
87-C-4 Pathogenicity of Fusarium spp. on conifer seedlings (R. James, Dumroese).
87-C-5 Evaluation of Basamid granular to control root diseases in Northern Rocky Mountain nurseries (R. James, Myers).
87-C-6 Effect of form and timing of nitrogen fertilization on Fusarium hypocotyl rot of Douglas-fir seedlings (A. Kanaskie, S. Cooley).
87-C-7 Relationship between soil propagule counts of FUsarium and Pythium to 1-0 seedling disease (A. Kanaskie, P. Hamm, S. Cooley).
87-C-8 Evaluation of incorporation and sealing methods with Dazomet application at J. Herbert Stone Nursery (S. Cooley, B. Kelpsas).
87-C-9 Evaluation of Basamid for control of nursery pests at the Bessey Nursery, Nebraska (D. Hildebrand).

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

71-D-3 Relative species susceptibility to Phellinus weirii infection (E. Nelson).
71-D-2 Phellinus weirii root rot: epidemiology and control (W. J. Bloomberg).
71-D-3 Fomes annosus root and butt rot: epidemiology and control (D. Morrison).
71-D-4 Effects of nitrogen fertilization and interplanting red alder on root disease development in a thinned Douglas-fir plantation (E. Nelson).
73-D-3 Alnus rubra as a biological control agent for Phellinus weirii (E. Hansen, E. Nelson).
76-D-4 Simulation of root rot impact in second-growth coastal Douglas-fir stands (W. Bloomberg).
79-D-1 Surveys of root diseases in managed conifer stands in R-2 (D. Johnson, E. Sharon).
79-D-3 Verticicladiella wageneri on pinyon at Mesa Verde National park: disease spread characteristics (D. Johnson, K. Lister, E. Sharon).
79-D-5 Spread of Armillaria spp. disease centers in managed pine stands (D. Johnson, E. Sharon).
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-17 Evaluation of the incidence and impact of Fomes annosus in California fir stands (G. Slaughter, J. Parmeter).

79-D-18 Evaluation of borax stump treatment for control of Fomes annosus in California fir stands (M. Shultz, G. Slaughter, J. Parmeter).
79-D-23 Susceptibility of Pacific Northwest conifers to laminated root rot (W. Thies, E. Nelson).
79-D-25 Spatial relations of tree species in root disease areas (N. Martin).
80-D-2 Epidemiology and management of black stain root disease of western North American Conifers (F.Cobb).
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).
81-D-21 Role of mycorrhizae in plant succession in the Mount St. Helens devastation zone (J. Trappe).
82-D-4 Demonstration of Armillaria root disease control methods (S. Hagle, R. Becker).
82-D-5 Assessment of root disease development in young managed stands and plantations (J. Byler, R. James).
82-D-7 Armillaria root rot of young intensively managed lodgepole pine stands of Alberta (Y. Hiratsuka, P. Blenis).
83-D-5 Intensification of mortality from Armillaria following sanitation/salvage (S. Hagle, R. Becker).
83-D-7 Longevity and spread of annosus root disease in ponderosa pine plantations (J. Hoffman).
83-D-19 Mycorrhizal fungi associated with decayed logs in old-growth and young forests (J. Trappe).
85-D-4 Development of a method for rating stands of blue and Engelmann spruce in susceptibility to losses caused by Inonotus tomentosus root disease (F. Baker, B. Tkacz).
85-D-5 Incompatability reactions, cytology, and population biology of Phellinus weirii and Phytophthora species (E. Hansen).
85-D-7 Epidemiology and management of Fomes annosus (Heterobasidion annosum) in western forests (F. Cobb).
85-D-10 Distribution of Armillaria genotypes in Pacific Northwest inland forest (N. Martin, G. I. McDonald).
85-D-11 Pathogenicity of Armillaria genotypes on native conifers of the Pacific Northwest inland forests (N. Martin).
85-D-15 Root distribution and infection by Fomes annosus in young mixed conifer and true fir stands (J. Parmeter, W. Otrosina, G. Slaugter)
85-D-22 Susceptibility of conifers (Grand fir, Englemann spruce, Douglas-fir, Western larch, and Ponderosa pine) to laminated root rot (A. Kanaskie).
85-D-24 Incidence of root pathogens in residual trees and stumps in thinned mixed conifer stands attacked by insects (G. Filip).
85-D-33 Hypogeous fungi of southwestern Oregon and northern California compared with those of Spain for nursery inoculation (J. Trappe).
86-D-1 Genetic variability in Fomes annosus (R. Edmonds).
86-D-2 Fomes annosus 20 years after precommercial thinning in hemlock (R. Edmonds).
86-D-3 Pathogenicity of Armillaria spp. on artificially defoliated grand fir seedlings (G. Filip).
86-D-4 Annosus root rot in the Northern Region (S. Hagle, et al.).
86-D-5 Site and tree risk factors in black stain root disease (E. Hansen).
86-D-6 Stump treatments to reduce black stain spread rate/vector attractiveness in high value stands (W. Littke).
86-D-7 Long-range effects of precommercial thinning on Fomes annosus in western hemlock stands (W. Littke)
86-D-8 Interactions of Armillaria and herbicides that are used to manage forest vegetation (N. Martin).
86-D-9 De-stumping trials for tomentosus root disease (J. Muir).

86-D-10 Evaluation of root removal by mechanical de-stumping in interior areas (J. Muir).
86-D-11 Evaluation of root diseases in interior backlog areas (G. A. Van Sickle, W. Bloomberg).
86-D-12 Problem analysis of root diseases in coastal backlog areas (G.A. Van Sickle, W. Bloomberg).
86-D-13 Survey of wood chips for pinewood nematode in British Columbia (J. Muir).
86-D-14 Lethal effects of chloropicrin on Phellinus weirii in culture tubes in stumps (E. Nelson).
86-D-15 Rate of damage by Phellinus weirii in Douglas-fir stands (E. Nelson).
86-D-16 Variability in Verticicladiella wageneri (W. Otrosina).
86-D-17 Monitoring root disease in thinned ponderosa pine plantations in northern Idaho (J. Schwandt).
86-D-18 Carbohydrate reserves and maintenance respirations: Controls of mycorrhizal turnover in ponderosa pine (R. Molina, J. Trappe).
86-D-19 Biological control of root diseases using Trichoderma spp. and other antagonists (E. Nelson)
87-D-1 Stump infection by Fomes annosus (S. Hagle).
87-D-2 Everything there is to learn about Polyporus tomentosus (E. Hansen, K. Lewis).
87-D-3 Tree stress and susceptibility to Phellinus weirii (E. Hansen, W. Thies, E. Goheen).
87-D-4 Adaptations of the root disease model to Region 3 (T. Shaw, J. Beatty).
87-D-5 Mycorrhiza-nodule interactions of native legumes (J. Trappe).
87-D-6 Mycorrhizal ecology of timberline and alpine zones of the North Cascades (J. Trappe).
87-D-7 Susceptibility of 3 to 30 month-old jack pine stumps to Fomes annosus infection after roller-chopping, Nebraska National Forest (D. Hildebrand).

E. Foliage Diseases

82-E-3 Dothistroma pini of ponderosa pine in northern Idaho (R. James).
83-E-3 Swiss needle cast ecology and impact in northern Montana Christmas trees (S. Hagle).
86-E-1 Effect of fertilization and fungicides on Swiss needlecast (W. Littke).
86-E-3 Needlecasts of Scots pine Christmas trees in Montana (S. Hagle).
86-E-2 Role of Swiss neelecast in negative fertilizer interaction on coastal soils low in phosphorus (W. Littke).
87-E-1 Fungicide evaluation for controlling Marssonina leaf spot of aspen (W. Jacobi).

F. Stem Diseases: Malformations, Witch's-Brooms, Dwarf Mistletoe, Etc.

62-F-4 Taxonomy, hosts, and distribution of Arceuthobium (F. Hawksworth, D. Wiens).
63-F-1 Spread and intensification of dwarf mistletoe in ponderosa and Jeffrey pines in California (R. Scharpf, J. Parmeter).
71-F-1 Growth impact, associated mortality, and spread and intensification of dwarf mistletoe in stands of Douglas-fir,and lodgepole pine (J. Byler).
76-F-4 Inoculation studies to determine the host ranges of Arceuthobium campylopodum and A. occidentale in California (W. Mark, R. Scharpf, F. Hawksworth).
78-F-2 Control of dwarf mistletoe-caused losses in young true fir stands by thinning (R. Smith, R. Scharpf, D. Vogler).

78-F-3 Population dynamics of dwarf mistletoe on true firs in California (R. Scharpf, 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, R. Scharpf).

79-F-4 Dwarf mistletoe infection in inoculated young-growth western hemlock (T. Shaw, P. Hennon).

79-F-7 Growth loss in managed, even-aged, dwarf mistletoe-infested stands of ponderosa pine in the Pacific Northwest (E. Nelson, R. Harvey).

81-F-1 Resistance of Jeffrey pine to dwarf mistletoe, Arceuthobium campylopodum (R. Scharpf, B. Kinlock, J. Jenkinson).

81-F-4 Development of hemlock dwarf mistletoe following precommerical thinning of infected young stands in southeast Alaska (T. Shaw, P. Hennon).

82-F-4 Dwarf mistletoe-related mortality of ponderosa and Jeffrey pines in campgrounds in California (D. Vogler, R. Scharpf).

83-F-1 Thinning demonstration of dwarf mistletoe-infected lodgepole pine on the Targhee National Forest, Idaho (J. Hoffman).

83-F-5 Effect of N-fertilization on growth and development of dwarf mistletoe on red fir (R. F. Scharpf).

84-F-2 Field testing of dwarf mistletoe resistant Jeffrey pine seedlings (R. F. Scharpf, R. Smith).

85-F-2 The effect of dwarf mistletoe on the response of Douglas-fir to thinning (B. Tinnin, D. Knutson).

85-F-3 The effects of dwarf mistletoe on the response of young-Douglas-fir to thinning (B. Thinnin).

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

85-F-6 Dwarf mistletoe infection by seeds placed on western hemlock regeneration in coastal Alaska (T. Shaw).

85-F-7 Impact of Arceuthobium americanum in jack pine stands (F. Baker, D. French, K. Knowles).

85-F-8 Incidence of attack by dwarf mistletoe and western spruce budworm on Douglas-fir (G. Filip).

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

87-F-1 Dwarf mistletoe intensification and effects on growth and mortality of Douglas-fir in eastern Oregon and Washington (G. Filip, T. Shaw, J. Colbert, F. Hawksworth, P. Hessburg, M. Marsden).

87-F-2 effects of ethephon on Douglas-fir dwarf mistletoe and western spruce budworm in northeastern Oregon (C. Parks, G. Filip).

87-F-3 Intensification of Douglas-fir dwarf mistletoe in the Pacific Northwest (T. Shaw, F. Hawksworth).

87-F-4 Intensification of Douglas-fir dwarf mistletoe in the Pacific Northwest (T. Shaw, G. Filip, F. Hawksworth).

G. Stem Diseases: Stains and Decays

82-G-1 Bioactive metabolites of forest tree pathogens--Gremeniella abietina, blue stain fungi associated with mountain pine beetle, Condrostererum purpureum, Verticicladiella spp. (Y. Hiratsuka, W. Ayer).

85-G-4 Sexuality, genetics, and biology of Echinodontium tinctorium (J. Rogers, D. Wilson, O.C. Maloy).

85-G-5 Effects of thinning on tree wound response in western conifers attacked by insects (G. Filip).

86-G-1 Interactions of pine bark beetles, their fungus associates, and their hosts (D. Wood, J. Parmeter).

H. Stem Diseases: Rusts and Cankers

69-H-1 Thinning and pruning western white pine to control the blister rust disease (J. Byler, N. Martin).
71-H-3 Forest tree rusts of western North America (Y. Hiratsuka).
77-H-2 White pine blister rust pathology (R. Hunt).
81-H-1 Biology, cytology, and systematics of Xylaria (J. Rogers, B. Callan).
81-H-3 The etiology of Thyronectria canker on Colorado honeylocusts (W. Jacobi).
81-H-5 Biology and control of stem rusts of hard pines (R. Blanchette, D. French).
82-H-4 Western gull rust studies in relation to the genetic improvement program of lodgepole pine (Y. Hiratsuka, P. Blenis).
83-H-1 Hazard rating and ecology of comandra blister rust in the Rocky Mountain Region (W. Jacobi).
83-H-8 Distribution and parentage association of western gall rust infection in four ponderosa pine seed orchards (J. Hoffman).
85-H-1 Epidemiology and management of western conifer rusts (especially western gall rust and white pine blister rust) (F. Cobb).
85-H-8 Biology of limb rust on ponderosa pine (F. Baker).
85-H-9 Epidemiology of western gull rust (P. Blenis, Y. Hiratsuka).
85-H-10 Pathogenicity of Cytospora sp. on thin-leaf alder, dogwood, and hawthorn in eastern Oregon riparian zones (G. Filip).
86-H-2 Biological and economical feasibility of pruning and canker excision to control white pine blister rust (S. Hagle).
86-H-3 Evaluating performance of blister rust resistant white pine stock in the coast range of Oregon (A. Kanaskie).
87-H-1 Assessing the visual impact of limb rust in ponderosa pine (F. Baker).
87-H-2 Blister rust incidence and impact in young sugar pine plantations, southern Sierra Nevada (G. DeNitto).
87-H-3 Economics of intermediate stand treatments for white pine blister rust control (S. Hagle).
87-H-4 Monograph of pine stem rusts (Cronartium and Endocronartium) (Y. Hiratsuka).
87-H-5 Insects associated with comandra blister rust affected lodgepole pine (W. Jacobi, D. Leatherman).
87-H-6 Model testing genetic interactions in western gall rust and Monterey pine (B. Kinloch, D. Vogler, W. Libby, F. Cobb).

I. Wilt and Blight Diseases

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J. Defects and Decay of Forest Products

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87-J-1 Detection and evaluation of early stages of wood decay (W. Wilcox).

K. Miscellaneous Studies

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78-K-1 Effect of thinnings on the incidence and impact of Cystospora canker, fir engraver beetle, and Fomes annosus in white fir stands on the east-side Sierra Nevada (G. Ferrell, R. Scharpf, J. Parmeter).
80-K-3 Interactions among the pinewood nematode, fungi, and bark beetles in the Midwest (R. Blanchette).
81-K-2 Life histories and anamorphs of lignicolous Pyrenomycetes (J. Rogers).
83-K-1 Evaluation of aspen harvesting practices in Colorado and New Mexico (D. Johnson, J. Beatty).
83-K-4 Mistletoe and root disease control demonstration areas (J. Muir).
84-K-1 Evaluation of pests associated with underburning mixed conifer stands for fuel reduction (J. Pronos).
85-K-1 Use of remote sensing techniques for detection, survey, and damage appraisal of root diseases (J. Y. Lee, W. J. Bloomberg).
85-K-2 Potential of Beauveria bassiana for direct control of bark beetles (H. S. Whitney).
85-K-3 Interactions among forest tree diseases, insects, hosts, and humans (F. Cobb).
85-K-6 Ultrastructure of wood decompostion by Basidiomycetes (R. Blanchette).
86-K-1 Biocontrol of forest weeds (C. Dorworth, R. E. Wall).
86-K-2 Field guide to forest pests in Montana and Idaho (S. Hagle, S. Tunnock).
86-K-2 Development of a Tree Health Mgmt. Series (THMS) for recreational, urban, and community forestry-multivolume slide/video tape (M. Sharon).
87-K-1 ELISA for detection of pathogenic fungi (E. Hansen, B. Fichter).
87-K-2 Tree diseases: host defense reactions (G. Jensen).
87-K-3 ARNEWS plots - Acid rain national early warning system (G. A. Van Sickle).
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