PROCEEDINGS OF THE 13th ANNUAL WESTERN INTERNATIONAL FOREST DISEASE WORK CONFERENCE

Kelowna, British Columbia
September 1965

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PAST MEETING PLACES AND EXECUTIVE COMMITTEES

Meeting		Executive Committee		
Date	Place	Chairman	Sect-Treas	Program Chairman
1953	Victoria, B. C.	R. E. Foster	- - -	- - -
1954	Berkeley, Calif.	W. W. Wagener	P. C. Lightle	- - -
1955	Spokane, Wash.	V. J. Nordin	C. D. Leaphart	G. P. Thomas
1956	El Paso, Tex.	L. S. Gill	R. W. Davidson	V. J. Nordin
1957	Salem, Ore.	G. P. Thomas	T. W. Childs	R. L. Gilbertson
1958	Vancouver, B.C.	J. W. Kimmey	H. R. Offord	A. K. Parker
1959	Pullman, Wash.	H. R. Offord	R. E. Foster	C. G. Shaw
1960	Centralia, Wash.	A. K. Parker	F. G. Hawksworth	J. R. Parmeter
1961	Banff, Alberta	F. G. Hawksworth	J. R. Parmeter	A. C. Molnar
1962	Victoria, B. C.	J. R. Parmeter	C. G. Shaw	K. R. Shea
1963	Jackson, Wyo.	C. G. Shaw	J. E. Bier	R. F. Scharpf
1964	Berkeley, Calif.	K. R. Shea	R. F. Scharpf	C. D. Leaphart
1965	Kelowna, B. C.	J. E. Bier	H. S. Whitney	R. V. Bega

FOREWORD

The thirteenth Western International Forest Disease Work Conference was held at the Capri Motor Hotel in Kelowna, B. C., September 7-11, 1965.

Sixty-eight members registered on Tuesday September 7, arriving from as far away as Alaska, New Mexico, New Brunswick and Washington, D. C. The heated patio-pool provided welcome relaxation for many road-weary forest pathologists. Those who were too tired to make it to the pool found their conference legs in the quiet confines of their campaign manager's headquarters.

Conference sessions were held in a well appointed salon that opened onto a garden at one end of the patio. Morning and afternoon coffee was served 'al fresco' which provided the punch that is often lacking in a cup of coffee.

Chairman Bier opened the meeting with the reminder that there was a lot of 'forest pathology' present and that each of us should take advantage of the situation. He then introduced Mr. Lorne F. Swannell, B. C.'s Chief Forester. Mr. Swannell welcomed the members to B. C. and to Kelowna and asked that consideration be given to language-communication between research and the forest industry.

The usual uninhibited enthusiasm prevailed throughout the happy hours of the banquet. Gardner Shaw took the evening by storm and consequently lost all his chances of being awarded any prizes. The coveted Hansborough-Nordin trophy was unanimously awarded to Art Parker who has consistently turned in an unbelievably well balanced performance. Amid heated argument and debate as to the correct spelling of Calona (Red Dry) vs Kelowna (Ordinaire), Ray Foster, Ray Hansborough and Gardner Shaw, alias Alex Molnar, presented information and interesting comments regarding the approaches of the Canadian Government, the United States Government and Universities towards research in forestry.

The meeting adjourned Friday afternoon with Chairman Jack moving a vote of thanks to the program committee, the secretary and to those involved in local arrangements. Some members left Kelowna that afternoon but many stayed an extra day or two to take in one of three field trips: a local "show me" tour of Kelowna and district with Wolf Ziller, Dick Smith and Al Funk; to blister rust and back by Whirly Bird with Dennis Glew and Larry Weir; and Poria prospecting with Gordon Wallis.

<u>Executive Committee</u>

Jack Bier, Chairman,
Stu Whitney, Secretary-Treasurer

<u>Program Committee</u>

Bob Bega, Chairman
Art McCain
John Powell

<u>Local Arrangements</u>

Alex Molnar
Dick Smith
Larry Weir
Dennis Glew

OPENING REMARKS

Ladies and Gentlemen:

Welcome to the meetings of the 13th Western International Forest Disease Work Conference.

Information and reports leading to discussion of controversial subjects comprise important keynotes to the meetings. For the particular benefit of younger members it is emphasized that a tremendous amount of talent, ability and experience in the discipline of Forest Pathology attend the meetings. Therefore, it would seem imperative that younger members take advantage of all opportunities including individual discussion with persons that may be of invaluable assistance in the planning and future prosecution of Research.

On your behalf I should like to gratefully acknowledge the paramount efforts of your Program Committee consisting of Bob Bega, Art McCain and John Powell. It was most unfortunate that Bob and Art were not able to attend. Furthermore, your Local Arrangements Committee consisting of Alex Molnar, Gordie Wallis, Larry Weir and Dick Smith are to be commended for their valiant and successful efforts in solving a multitude of attendant problems.

It is now my great pleasure to introduce Mr. L. F. Swannell, Chief Forester, British Columbia Forest Service, Victoria, to present a welcoming address to the members.

John E. Bier
Conference Chairman.

WELCOMING ADDRESS

L. F. Swannell

Thank you Jack. Ladies and Gentlemen:

My task is relatively simple - to welcome you. I note from the program that one hour is set aside for Jack and myself, I am very grateful that Jack used only one and a half minutes!

British Columbia is fortunate in possessing a wealth of natural resources; in fact, the forest industry produces approximately 40 to 50 cents of our primary dollar. It is therefore only natural that the continued health of our forest resource should be a matter of concern.

With a resource of over 118 million acres of commercial forest, tree diseases are only one of our many problems. But the losses caused by forest tree diseases are of serious concern. The annual drain attributed to forest diseases in this Province is estimated to be in excess of 680 million cubic feet. Although a considerable portion of this is the result of decay-producing organisms whose activity should be sharply reduced once we have harvested our over-mature and decadent stands, we will still be faced with severe losses from Poria weirii and white pine blister rust, to name but two of our most destructive forest tree diseases.

As you are probably aware, our forestry economy is changing from a sawlog economy to pulp economy. There are no less than five new pulp mills under construction and as many more under active consideration. Tops, chunks and culls as well as small diameter material that was formerly left in the bush are going to be needed to supply these mills. The primary effect of this change is going to be the evolution of a new set of utilization standards, but once these mills are in operation there is going to be a demand for better protection, more reforestation and increased yields on a per acre basis. The economics of harvesting will not only improve utilization but they will also reflect into forest disease research since there will be a greater incentive to undertake control measures. Before this can be done it is important that the necessary research be carried out.

In British Columbia we are fortunate in that the Federal Government has volunteered to carry out the necessary research in this field, and over the years we have received splendid cooperation from the Canada Department of Forestry, but we are going to need much more. The pressures in the next decade which are going to develop as the result of this change in our economy are going to necessitate a second look at the situation. We are going to have to carefully re-examine the literature to ensure that we have not missed some vital information which could assist in reducing our losses. We are also going to have to make an effort to better understand some of the published information. You, on the other hand, are going to have to learn to appreciate our needs and wherever and whenever possible to simplify your results so that they become readily understandable. This will not always be possible, but, there are many cases where we are not implementing your findings simply because we do not understand them.

Technical jargon, and I do not mean the term to be slighting, is necessary, but to convince and not to confuse the layman, administrators and politicians, it must be translated.

Not only do we need more and better information, we also need control measures that we can afford. This is why we have embarked on a cooperative program using antibiotics to combat some of the more important diseases. We do not know whether the materials tested to date will effect the hoped for control but we do feel that the most feasible economic method of combating forest tree diseases on a large scale is by the use of a systemic and to this end we hope that you will continue to preserve with this type of control, for if this or alternative methods of control do not work, all that remains is to try to salvage each infected tree on an acre to acre basis, and this over 118 million acres is a physical impossibility.

Another thing, I hope that you will realize that the investigation of diseases of over-mature stands is primarily one of inventory. We hope that sooner or later we will be dealing with second growth - the prevention of disease in these stands is more important than investigations in over-mature.

In concluding I would not only like to welcome you to British Columbia but also to express my pleasure that you have chosen to meet in the Okanagan. I know that your meeting will be successful. We as administrators need your knowledge and skill. I hope that in looking at the trees you don't miss the forests.

(Swannell, L. F., B.A., B.A.Sc. Forest Engineering with first-class honours. B. C. Forest Service prior to 1939. Royal Canadian Artillery 1939 to 1946, overseas service, attained rank of major. District Forester, Prince George, B. C. 1947-1952, Kamloops, B. C. 1952-1958. Assistant Chief Forester Operations 1958-1965. Chief Forester 1965. An administrator who believes in getting out in the field).

PANEL I. GROWTH IMPACT AND ECONOMICS

OF DWARFMISTLETOE CONTROL

R. F. Scharpf - Moderator

GROWTH IMPACT AND CONTROL OF DWARF MISTLETOE IN PINE STANDS IN ALBERTA.

J. A. Baranyay

Lodgepole pine and jack pine, the two hosts of lodgepole pine dwarf mistletoe, Arceuthobium americanum Nutt. ex Engelm., represent 23% of timber volume in Alberta's forests. Dwarf mistletoe and Atropellis canker are the two most destructive diseases, both causing considerable growth and mortality losses. Dwarf mistletoe is widespread in the region, but we do not know the precise area of pine that is affected. Our rough estimate is 10% of the accessible merchantable area. Dwarf mistletoe growth-impact studies were initiated in 1960 to evaluate the affect of the disease, and to provide firm basis for preventative and control measures.

Volume reduction and tree mortality were measured in 5 stands, in 2 sites (dry and wet) and 4 age classes (37 to 117 years). Volume reduction was measured by comparative stem analysis of diseased and healthy dominant and codominant trees. The sample trees were cut as close to each other as possible to minimize effects of environmental differences. Initially, four infection classes were recognized: 1. trees with multiple witch's brooms (designated Ib) 2. trees with heavy branch infections, i.e., over 50% of the crown infected (designated Is) 3. trees with light branch infections, i.e., less than 50% of the crown infected (Li) and 4. healthy trees (H). The volume differences between these classes were compared for an 86-year-old heavily infected stand growing in a dry site. Analysis of variance was used to investigate the following variables: volume, height growth and diameter reductions at different heights of the stem.

Although there was an inverse trend between volume and successive infection classes, no significant differences were detected between infection classes Ib - Is and Li - H (Table I). The same conclusion was reached from the analysis of other variables. It would appear that heavy brooming does not affect tree growth any more than branch infections do provided a high percentage of branches are infected. By combining infection classes Ib - Is and Li - H, a significant difference (at the 1% probability level) was found for volume and height reduction. The non significant treatment difference at stump height can be explained by the nature of diameter reduction of infected trees. Figure 1 shows that infected trees have comparable diameter at stump height to that of their healthy counter parts, although tapering faster than healthy trees. Therefore when an analysis of variance was performed on diameters at 9, 17 and 25 feet heights above ground level, significant differences were detected.

On the basis of these preliminary experiments it was my feeling that for survey purposes, where well-defined classes are required for proper damage appraisal, Ib + Is and H infection classes should be retained. Accordingly, my later studies were based on this classification.

It was planned at the outset of the study to also investigate the effect of site. Unfortunately it is difficult to find dwarf mistletoe infected stands in wet sites and only one 86_year_old stand was found and sampled. The results of statistical analyses of data corresponded with that of the dry site, except that height reduction differences were not significant between infected and healthy trees. Consequently the growth loss was less but still significant.

The results of the growth loss study for all age classes are included in the following table. (Table II).

The greatest volume loss had occurred in the youngest stand. This can be explained by the infection index, which relates infection age with stand age. In other words, at Settlers Road, 76% of the 37 years that the stand had been growing showed effects of dwarf mistletoe infection. This index is acceptable for age classes under 100 years, i.e., where the living crown is extensive and it is possible to age the earliest infections. In older stands, where the crown is proportionally smaller, the older infections have occurred on branches that have been self pruned. Hence, precise determinations of infection-age are difficult if not impossible. This is illustrated in a 117 year-old stand (Whirlpool River), where the infection index was low but volume loss was greater than in younger stands with higher indices. It seems, therefore, that growth loss increases with increasing infection age, and also with the regeneration history of individual stands. The volume and quality of trees are seriously affected if infections occur at an early age, e.g., in the first half of their rotation age. Stands are most seriously affected when they have originated from an evenly distributed infected overstory of seed trees, or from some other form of residual stand during the regeneration period. In these circumstances it is unlikely that a commercial stand will develop.

Mortality caused by dwarf mistletoe was studied in 1/5-acre plots, where all trees were tallied in three classes: healthy, infected, and dead (Table III). The number of dead trees and the number of trees infected seemed to be directly related to stand age. There was a significant difference in mortality between dry and moist sites. Control plots were used in the healthy portion of stands to determine the extent of natural mortality.

On the basis of surveys, we estimate that 10% of the merchantable accessible lodgepole and jack pine forest in Alberta is infected by dwarf mistletoe. If the estimate is correct, the annual drain from dwarf mistletoe is in the nature of 9 million cubic feet, which is too large a loss by any reasonable standard. The initial steps toward dwarf mistletoe control, and perhaps the only feasible steps for the moment, would be to adopt measures to prevent dwarf mistletoe from becoming established in areas that are to be regenerated to either lodgepole or jack pine. In consultation with senior members of the Alberta Forest Service, I have suggested a system of treatment for infected stands, based on priorities that would in my opinion give the greatest return for the control dollar. These priorities are as follows:

Priority 1:

The clear cutting of evenly scattered mistletoe infected logging residual trees. These trees are usually heavily infected, overtopped trees which do not have any commercial value, which is why they were left. These trees create a most dangerous mistletoe hazard, the inevitable result of which is early and uniform infection of the new stand. It is most unlikely that the new stand will ever reach merchantability.

Priority 2:

The clear cutting of small or large groups of infected fire residuals. These groups are usually located on ridges, or in wet areas where they have escaped fire. If these groups are abundant the entire new stand will become infected before the end of the rotation. However, mistletoe is a slow spreading disease, and stands under these conditions become infected rather slowly from one infection center to the next. A great variety of damage (from light to heavy) exists between the fire residual groups. Stands that develop under these conditions have limited commercial value.

Priority 3:

Preparation of clear-cut zones in pine regeneration, 60 feet or more wide depending on the height of infected old stands at the margins of burns to prevent the slow spread of mistletoe into new stands. In cases like this damage is limited, but mistletoe may survive from rotation to rotation.

Priority 4:

Preparation of clear-cut zones around heavily infected non merchantable stands which are the result of conditions discussed under priority one. The transformation of these stands, after complete eradication by either planting different non susceptible species or healthy pine seedlings, has to wait for some time. The clear-cut zone would prevent the spread of the disease into surrounding healthy stands.

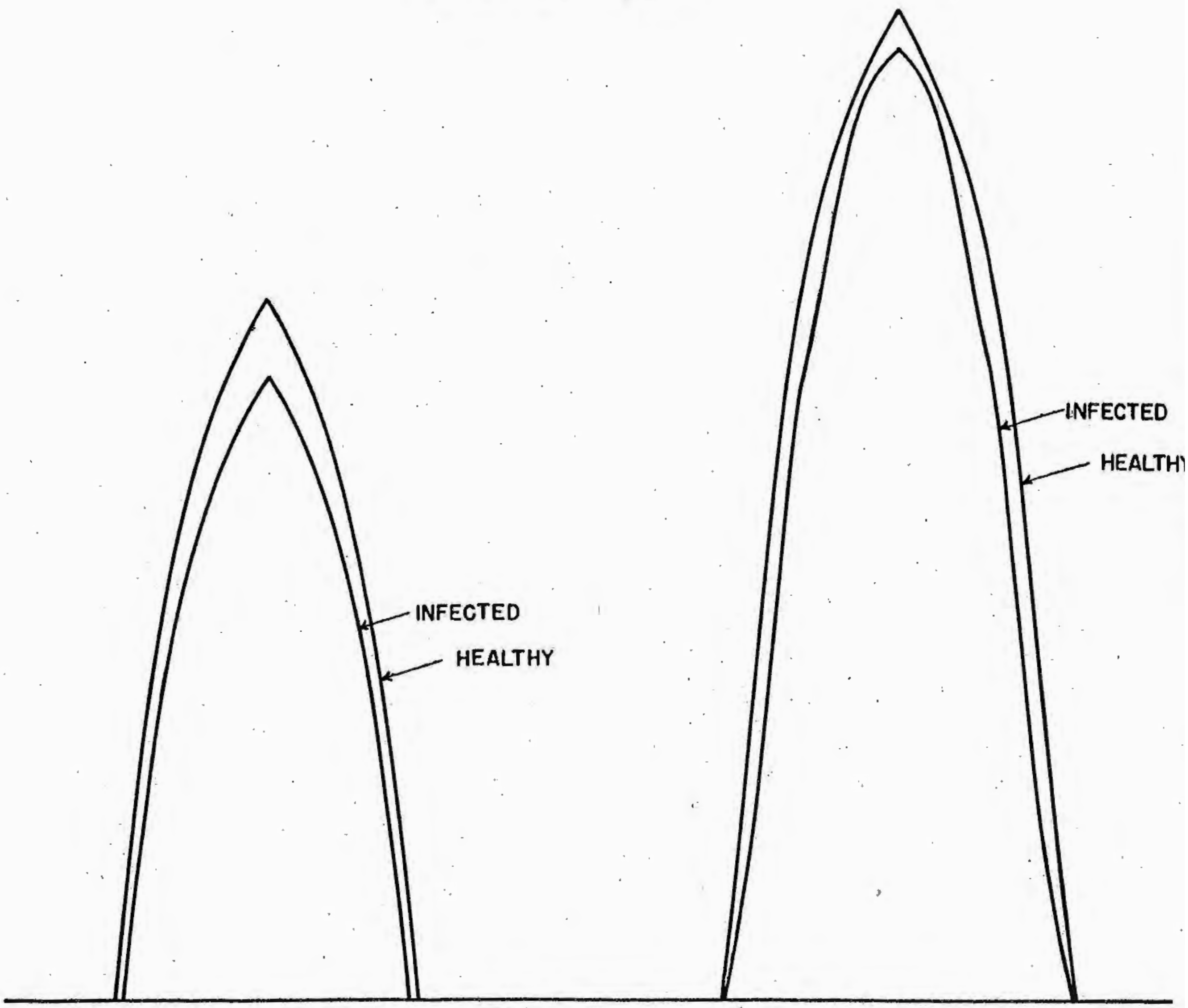
Priority 5:

Sanitation cuttings in unevenly infected stands having some commercial value. These stands are the result of conditions discussed under priority two, and are the most common in the post-fire natural lodgepole pine stands in the east slopes area of the Rocky Mountains. During cutting operations, all pine should be removed, leaving only spruce and aspen for soil protection.

All of these control and preventive measures were recently proposed to the Alberta Forest Service for immediate and future application. Priority 5 has been practised in Alberta since 1960. Indications are that in most of our Provincial Forests, where pine stands represent commercial value, control work will commence this fall on the basis of the discussed priorities.

The commercial value of pine as excellent pulp material is widely recognized. The construction of two additional pulp mills is planned in the near future in Alberta. This means more intensive utilization of our pine stands, consequently more intensive silviculture. We believe that intensive forestry practices will solve our mistletoe problem, without the application of expensive and uncertain chemicals.

EFFECT OF DWARFMISTLETOE ON TREE GROWTH IN DRY AND WET SITES



		DRY SITE	WET SITE
Age:		86 yrs.	86 yrs.
Average height:	H =	43.3'	61.6'
	I =	40.0'	59.5'
Average volume:	H =	4.80 cu. ft.	9.76 cu. ft.
	I =	4.13 cu. ft.	7.99 cu. ft.

Figure I

TABLE I

Summary of results of statistical analysis.

Jumping Pound and Dutch Creek, 86 yr. old stand.

(Sample size: 80 and 40 trees)

Variables	Ib versus Is	Li versus H	(Ib +Is) versus (Li + H)
	Mean values		
Dry site			
Volume (cu.ft.)	3.91-4.23	4.61-4.98	4.13-4.80 **
Height (ft.)	39.3-40.7	42.8-43.8	40.0-43.3 **
Diameter(ins.) at:			
stump hgt.	6.1-6.2	6.3-6.5	6.13-6.36
9' hgt.	5.2-5.4	5.5-5.7	5.28-5.58 **
17' hgt.	4.6-4.8	4.9-5.1	4.66-5.01 **
25' hgt.	3.7-3.9	4.1-4.3	3.77-4.20 **
Wet site			
Volume (cu. ft.)	-	-	7.99-9.76 *
Height (ft.)	-	-	59.5-61.6
Diameter(ins.) at:			
stump hgt.	-	-	7.32-7.35
9' hgt.	-	-	6.24-6.81 *
17' hgt.	-	-	5.73-6.32 *
25' hgt.	-	-	5.25-5.81 *

Note: ** Significant at 1% probability level.

* Significant at 5% probability level.

TABLE II

Volume loss caused by dwarf mistletoe.

Location of sampled stand	Avg. Age of Stand	Avg. Volume		Volume loss		Infection Index
		Healthy	Infected	Cu. foot	Percent	
Settlers Road	37	1.668	1.143	0.525	31.5	76
Thompson Trail	59	4.678	3.503	1.175	25.1	70
Jumping Pound - Dry	86	5.023	4.029	0.994	19.8	52
Dutch Creek - Wet	86	9.755	7.990	1.765	18.1	58
Whirlpool River	117	14.731	10.835	3.896	26.4	(50)

TABLE III

Mortality caused by dwarf mistletoe.

Location of sampled stand	Age	Sampled area (acre)	No. of trees per acre	Living trees		Dead trees	Regeneration	
				Healthy	Infected		Healthy	Infected
				percentage				
Dry site								
Settlers Road	37	1.0	1,359	50	48	2	-	-
Control						4	-	-
Thompson Trail	59	0.8	663	3	80	17	-	-
Control						6	-	-
Jumping Pound	86	0.4	935	19	58	23	-	-
Control						9	-	-
Whirlpool River	117	2.0	416	8	62	30	96	4
Control						22	-	-
Wet site								
Dutch Creek	86	0.6	960	51	35	14	-	-

CONSIDERATIONS FOR CONTROL OF DWARFMISTLETOE OF PONDEROSA PINE

Keith R. Shea

Since my experiences with dwarfmistletoe in the Pacific Northwest have been limited mainly to ponderosa pine, I have chosen to confine this presentation to that host-parasite relationship. Also, I will not attempt to elaborate on the economic details presented. Many may not agree with what follows. In this case, the purpose of the meeting - - to provoke constructive discussion - - will have been served.

The commercial ponderosa pine type occupies over 11 million acres of the ponderosa pine subregion in the Pacific Northwest with a net volume in excess of 98 billion bd. ft. (13). Net annual growth is about 661 million bd. ft. or 60 bd. ft./A./yr. Annual cut exceeds net growth by 1 billion bd. ft. At least 75 percent of the ponderosa pine type is site IV which will produce trees 79 feet tall in 100 years (8). Typically, ponderosa pine forests are fairly open, all-aged, and pure, but mixtures with other species occur, especially on moister sites.

Partial cutting has been the principal method of harvest. Earlier, the diameter-limit cuts were the rule but more recently methods based on some form of tree selection have been developed. The susceptibility of ponderosa pine forests to beetle attacks has resulted in sanitation-salvage logging in which "high-risk" trees as defined by Keen (7), Bonberg (2), and Dunning (6) are removed. In some forests, unit-area logging has received acceptance. Until the virgin stands have been converted to younger, more vigorous ones, it is likely that some form of sanitation-salvage logging based on tree or group selection will continue.

Dwarfmistletoe is prevalent in a patch-like pattern throughout the range of ponderosa pine. Before control programs can be contemplated, it is essential to determine the location and extent of the infestations. Roadside or strip surveys (1) or prism inventories (12) serve this purpose. In one prism inventory of a 49,000-acre tract we (12) found dwarfmistletoe in timber types occupying 29 percent of the area, less than half of which was moderately to severely infected. Within infected timber types, infected trees accounted for 29 percent of all trees. About 8 percent of the gross cubic volume was in infected trees 6" d.b.h. or larger. This volume was divided about equally among trees with light (36%), moderate (34%), and severe (30%) infections. Among infected trees, 46 percent were below sawlog size (16" d.b.h.) and comprised 12.4 percent of the cubic volume.

Recent reports (5) have emphasized growth losses associated with infection. The reports are in general agreement - - light infections have little if any effect on diameter growth; moderate infections reduce diameter growth by 10-20 percent, and severe infections by 40-50 percent. Height growth is affected even more and in severely infected stands the site index may appear to be one whole class lower than it really is.

It is likely that about 30 percent (3.3 million acres) of the ponderosa pine type in Oregon and Washington is infected by dwarfmistletoe. About 20 percent of the total type may be classed as moderately to severely infected (3). Childs (3) has estimated the annual mortality at 110 MM bd. ft. and growth loss at 63.4 MM bd.ft. for a total of 173.4 MM bd. ft. At a stumpage value of $30/M, an annual loss of $5.2 million is represented or about $0.47/A./yr. for the entire pine area. For infected acreage only, the loss is about 50 bd.ft./A./yr. worth $1.50/A./yr. While these estimates are not accurate, they do suggest the order of the economic loss caused by dwarfmistletoe.

Childs (4) summed up the guiding principles for practical control of dwarfmistletoe with the statement - - "Except in lightly infested and sparsely stocked young stands, control is now economically practical only where thinning is practical." Certainly, thinning should not be practiced in infected stands without mistletoe control nor should expenditures for mistletoe control in the understory be made without thinning to increase growth. The question - - Is thinning sound on site IV lands which make up the bulk of ponderosa pine stands? - - is basic. Until a market for small materials or chips is developed, thinning ponderosa pine will continue to be sub-marginal in the Pacific Northwest.

Some alternatives having a bearing on the economics of dwarfmistletoe control in ponderosa pine bear consideration.

The first and obivous approach is to do nothing. That is, continue pine management on a sanitation-salvage basis designed primarily to reduce insect hazard, increase net recovery, encourage natural regeneration, and perpetuate an all-aged forest. As far as dwarfmistletoe is concerned, this is somewhat like pregnancy - - ignoring it will not prevent the problem from developing. Numerous cases of past mismanagement which favored dwarf-mistletoe can be cited. Ignoring the problem will not require a cash outlay now but in many stands, dwarfmistletoe will become increasingly costly in the future as productivity and quality of raw material are lowered. This approach has little merit.

A second approach is to remove high-risk trees and all infected merchantable trees during the course of logging, understory treatments to be deferred until a market for small materials is developed. This will cost very little. However, average log grades will drop with the inclusion of smaller and poorer trees and may develop marketing problems. Also, increasing the cut in a dwarfmistletoe-infected stand may reduce the harvest of "high-risk", larger trees on another area resulting in their death and the loss of the higher quality logs. This approach does reduce amount of infection by eliminating overstory sources and can be considered for use where the overall condition of the forest or the allowable cut and market conditions permit.

A third approach is about midway between the first and second. It differs primarily in the method for removal of merchantable infected trees. The high-risk element in the stand would be cut as is now common and all merchantable trees with severe infections removed because of their greatly reduced growth rates. In addition, all merchantable trees with moderate or light infections would be removed in order of severity of infection only if they pose a serious threat to adjacent understory. If they do not, they would be left for later harvest since light or moderate infections do not reduce growth markedly (5,8). This procedure would increase the cut somewhat and the supply of low-grade logs but, overall, it would not affect greatly the present salvage-logging practices. Many small and unmerchantable but infected overstory trees would be left which would continue to infect the understory. Some measure of control, however, would be achieved and with each subsequent harvest - - at 10-20 year intervals - - high-risk and infected trees would be continued to be removed. Direct costs would remain negligible.

A fourth approach would go further than the second one in which high-risk trees and all infected merchantable trees were cut. In addition, all other infected overstory would be cut and the understory thinned and sanitized with one or two follow-up sanitation cuts at 4 - to 5 - year intervals. The objective is to bring about a sanitized stand in a short time interval. This approach is the one most commonly envisioned for control of dwarfmistletoe and might result in the greatest growth of the reserve stand. Clear-cutting of some patches and essentially even-aged management on some acres might result, at least initially. Most pathologists agree that this would best control dwarfmistletoe. Although complete sanitation might be scientifically sound, many pathologists and forest managers remain skeptical of the economics of this approach. The greatest opportunity for financial success appears to be on site IV or better lands not greatly overstocked by reproduction and supporting lightly to moderately infected stands. As infection and the level of stocking increase, costs of control become prohibitive and chances for success greatly reduced. The follow-up operations must be carefully timed, and costs kept to a minimum. The difficulties of complete eradication of the parasite (4,10,14) indicate that in most instances a low level of infection must be accepted and kept in check by future commercial harvests and thinnings.

The method selected for management of dwarfmistletoe-infected ponderosa stands must meet several requirements. Among these are the following:

(A) It must be consistent with the ecological requirements of ponderosa pine.

The ponderosa pine type is essentially an all-aged forest. I believe, that any scheme for management that does not take the all-aged condition into account is ecologically unsound. On many areas, even-aged management may be desirable from the dwarfmistletoe standpoint, but I doubt that the even-aged condition can be maintained except, perhaps, in small patches, without considerable expense and risk of catastrophic occurrences.

(B) It must provide for periodic removal of high-risk trees wherever they occur on the forest management unit.

(C) It must leave an adequate seed source. For the time being at least we must rely on natural reproduction on most ponderosa pine lands.

(D) It must provide some measure of dwarfmistletoe control -- at least harvests should not increase the problem.

(E) It must be economically sound under prevailing economic conditions.

(F) It must be sufficiently flexible to permit changes as markets and utilization change, to permit salvage following catastrophes, and to permit econimic sanitation-salvage that decreases the chances of insect epidemics.

Until a market for small, presently unmerchantable trees is found, I favor the third approach: In essence, learning to live with the problem without worsening the situation. As markets change and demands develop for smaller logs or chips, presently unmerchantable trees and thinnings from the understory can be harvested, thus permitting a greater degree of control. Areas previously logged can be re-logged for smaller infected trees, permitting increased dwarfmistletoe control. Such gradual conversion of virgin stands to younger, vigorous ones should tend to reduce the danger of an abrupt conversion as well as reduce the fire hazard and costs of slash disposal when heavy cutting of unmerchantable trees is practiced. Such a system calls for expert marking of trees to be cut and appreciation for the ecological requirements of ponderosa pine and the problems of managing an all-aged forest.

The main points in favor of the third approach are:

(A) The ecology of the all-aged forest will not be drastically changed.

(B) When the system is properly applied, partial control of the parasite can be achieved.

(C) It will cost little beyond those costs already acceptable.

(D) It will permit continuation of sanitation-salvage logging which will reduce insect hazard and other losses in the forest without disrupting cutting budgets markedly.

(E) Investment of capital for more intensive dwarfmistletoe control can be made on a sound economic basis as markets and utilization permit, avoiding the uncertainties of long-term investment with low interest rates.

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IMPACT AND ECONOMICS OF DWARFMISTLETOE CONTROL IN SOUTHWESTERN UNITED STATES

Paul C. Lightle

(Presented by J. Riffle)

This is the title that was assigned. The bulk of the material presented, however, will concern the Whitetail Logging Unit on the Mescalero Apache Indian Reservation, better known as the Mescalero Dwarfmistletoe Control Project.

Ponderosa pine dwarfmistletoe is the most damaging disease agent affecting this pine species in Arizona and New Mexico. In 1960 Andrews and Daniels (1) published the results of a regional damage-appraisal survey. It showed that dwarfmistletoe is widely distributed throughout the ponderosa pine sawtimber stands in the Southwest and is estimated to be present on 2.5 million acres of commercial ponderosa pine timberland. It is more abundant in the Sacramento-White-Capitan Mountain area of New Mexico than elsewhere in the region.

Andrews and Daniels (1) reported significantly more mortality in the dwarfmistletoe-infected plots than the healthy plots. Based on the number of recently dead standing trees with bark intact, expressed as a proportion of the total living and dead merchantable-sized trees, the infected plots had 11 percent tree mortality with 7.2 percent volume loss compared to 6 percent tree mortality and 3.6 percent volume loss on the healthy plots. The infected plots had approximately twice the mortality and volume loss as the uninfected. As the intensity of infection in the sawtimber stands increased the average number of living trees and merchantable volume decreased; whereas the average number of dead trees and periodic mortality increased. Infected plots with a light intensity rating had an average volume of 6,620 board feet per acre, moderate intensity had 5,470, and heavy 3,970. Merchantable volumes of recently dead trees in the same classes were 500, 690, and 920 board feet.

The results of a survey on the Mescalero Apache Indian Reservation were published by Hawksworth and Lusher (2) in 1956. This reservation, in the heart of the most heavily dwarfmistletoe-infested stands in the Southwest, covers a gross area of 460,000 acres, about half of which is commercial forest (2). Ponderosa pine is the predominant commercial species.

The virgin ponderosa pine stands are essentially two-storied with mature and overmature trees above a rather dense understory of saplings and poles. Although dwarfmistletoe had been noted in these stands for years, it was not until the late 1940's that concern developed over the high mortality in residual stands after cutting (2). In 1950 the marking rules were modified to provide for the cutting of all visibly-infected ponderosa pines of merchantable size in regular timber sales. These heavier cuts were intended to anticipate future mortality and eliminate infection sources, but required a major revision of the management plan. Since an accurate appraisal of dwarfmistletoe damage was an important prerequisite to any revision, a cooperative survey was undertaken in 1952-53 by the Bureau of Indian Affairs and the Albuquerque, New Mexico office of the former Division of Forest Pathology. Early in the course of the survey the cooperators met with representatives of National Forest Administration and Research and the Mescalero Tribal Council to consider the dwarfmistletoe problem on the Reservation. It was agreed that the survey should continue, but, in the meantime, some form of direct control could be applied to the understory in the Whitetail Logging Unit where heavily infected stands were being cut under the revised marking policy. As a result, control under the provisions of the Forest Pest Control Act was started in 1952.

The plan for dwarfmistletoe control in the Whitetail Unit consisted of three main phases to be carried out in the following order:

1. Logging of infected merchantable trees.

2. Direct control in the infected understory.

3. Follow-up operations in both over- and understory.

Work started in November, 1952 and continued until March, 1955.

Infection in overstory trees must be reduced to a minimum before control measures are applied to the understory. It is seldom possible to mark every infected tree because light infections high in the crowns of merchantable trees are difficult to detect from the ground even though marking is done only on sunny days. Then too, a few marked infected trees are usually skipped by the felling crews. Missed trees may be disposed of by small sales but usually insufficient volumes are involved for a profitable operation. These trees must, therefore, be disposed of by felling or poisoning. Girdled trees take too long to die. Since most of the volume of the infected overstory is salvageable, the cost of step 1 is not usually chargeable to dwarfmistletoe control.

The Whitetail Logging Unit contains 16,000 acres of commercial forest, and in 1937, had an estimated net volume of 51 million board feet of ponderosa pine. The dwarfmistletoe salvage cut removed approximately 26 million board feet, or 51 percent of the 1937 cruise volume.

Direct control in the understory - - step 2 - - started immediately after logging in some parts of the control area, but as much as 3 years later in others. It was virtually impossible to cover the area for direct control as rapidly as it was cut over during the timber sales. The control area covered the northern two-thirds of the Whitetail Logging Unit consisting of 12,954 gross acres of which 9,509 are forested. Even though dwarfmistletoe was not found on about one-third of the unit, all of the gross area was covered in the operation because disease-free stands intermingled with the diseased. Control was applied to all infected stands regardless of the intensity of dwarfmistletoe. This was contrary to the original plan. Heavy control was necessary on less than 1/4 of the area treated and more than 60 percent of the original trees in these heavily infested stands remained after initial control, although the major proportion of the residual stand was in seedlings and saplings. Some areas that previously consisted mainly of pole stands had only smaller size classes in adequate numbers after control. In the most heavily infested stands, control reduced the age of the predominate understory by one 20-year age class.

Hawksworth and Lusher (2) indicated that step 3, the second cleaning, should be done when a maximum number of latent infections became perceptible but before a significant amount of reinfection occurred. They established a series of observation plots, arbitrarily located in stands that had been severely infested prior to control, which were to provide estimates of dwarfmistletoe development that would serve as a basis for timing the first recleaning operation. Data from these plots indicated that development of most latent infections had occurred by 1958 and recleaning should probably be started as soon as funds were available.

To provide the additional information needed to plan and conduct the recleaning operation, a random 0.1-acre plot cruise, amounting to a 0.13 percent sample, was made of the control area. The cruise data indicated that the most serious problem existed in the small area covered in 1955. They also indicated that, with a sampling error of 31 percent, there were about 10,300 merchantable trees and about 148,000 smaller stems or a total of 158,900 infected trees on the area. About 8 percent of the merchantable trees and 27 percent of the sub-merchantable trees were estimated to be prunable.

Recleaning operations started in March, 1961 and continued with only minor interruptions until October, 1964. During the 3 1/2 years required to reclean the entire area 177,357 trees were felled and 18,336 were pruned, for a total of 195,693 trees treated. Of this number about 4,830 merchantable trees were felled. No data are available on how many merchantable trees were pruned. Based on numerous actual counts, visible infection immediately after cleaning was reduced to less than 1 percent.

Before we go any farther, perhaps a few words ought to be said about pruning. Hawksworth and Lusher (2) noted that pruning infected branches is a costly method of eliminating dwarfmistletoe infections. In the original cleaning operation, pruning was considered appropriate only for lightly infected trees in which few latent infections could be expected. Pruning guides for the first cleaning defined a prunable infection as one no closer than 12 inches to the bole, less than 17 feet high, and, in addition, the tree had to be silviculturally desirable for retention. However, a prunable infection was considered by the control crew to be one that was no closer than 15 inches to the bole and could be reached with an axe from the ground. During the recleaning of the area, pruning branch infections was thought to be feasible in individual trees if the infections were few in number, no closer than 12 inches to the bole, and less than 20 feet from the ground. The weakness here, apparently, was the number of infections constituting "a few". If pruning the tree required more time than felling, it was considered unprunable by the control crew. Thus, if a pole-size tree or smaller had more than 2 or 3 infections it was felled rather than pruned. This difference in opinion of whether trees were prunable accounts for some of the difference between the estimated number of prunable trees and the number actually pruned.

The cost of the original cleaning, based on 9,509 forested acres, was $5.26 per acre. A crew of 10 men - - 6 axemen, 3 chain-saw operators, and a foreman - - was considered to be the optimum crew size. The axemen cut 370 trees per man-day and the chain-saw operators cut 286. The average cost per tree was 3 cents for those cut by axe and 5 cents for those cut by saw or an average of 3.3 cents per tree.

For recleaning the same area the average cost per acre was $7.09. A crew of 6 men - - 2 axemen, 2 pruners, a chain-saw operator and a foreman - - considered to be the optimum size crew. Axemen cut 51 trees per man-day, and the chain-saw operator cut 78. The average cost per tree was 35 cents for those cut by axe, 34 cents for those cut by saw and 35 cents for trees pruned or an average of 34.7 cents per tree treated. Total cost for the 2 cleanings has been $12.35 per acre.

There was apparently a great difference between the unit cost of the original cleaning and the recleaning. The recleaning costs include wages, travel, equipment, and equipment maintenance and repair, but the unit cost figures for the original job are for wages only. The cost of the surveys is not charged to either control job, nor is there any over-head, clerical work, telephone calls, payrolling, etc. included in the figures.

There was a big difference in the cost of labor. During the original cleaning, the foreman received an average wage of $1.76 per hour, but during the recleaning his average hourly rate was $2.44. Similarly, power-saw operators received $1.49 per hour average in 1952-55, compared to $2.34 during 1961-64, and axemen received $1.30 compared to $2.02.

Because the average tree treated was larger, and there were fewer trees to treat, axemen cut 51 trees per man-day and chain-saw operators cut 78 during the recleaning, compared to 370 for axemen and 286 for chain-saw operators during the original cleaning. Whereas between 700,000 and 750,000 trees were treated in the original control work, less than 196,000 trees were treated in the recleaning. The same area had to be covered and every tree scanned, thus increasing the unit cost. There are undoubtedly other factors which contributed to the somewhat higher cost of recleaning.

To summarize, then, dwarfmistletoe is wide-spread in the ponderosa pine stands of the Southwest, affecting an estimated 2.5 million acres of ponderosa pine timber. Mortality and volume loss is about twice as much on infected acres as on uninfected. Control efforts in the heavily infested stands reported here reduced merchantable volume by 60 percent and reduced the predominant age class of the residual stand by about 20 years. The cost of direct control in the residual stand is high. Whether it is economically worthwhile depends on the views and situation of the landowner.

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MODERATOR'S CONCLUDING REMARKS

R. F. Scharpf

People are different. The agencies growing and managing timber are different. Dwarfmistletoes are different and the hosts on which they occur, as well as the ecological conditions in which they are found, are considerably different. We might expect, therefore, that dwarfmistletoe impact and the concepts and approaches to economic control will also be quite different. Today, we have discussed several approaches and concepts concerning impact and control; each designed to best fit the mistletoe situation in a given area.

It appears to me that we not only have to take a broad look at dwarfmistletoe control and impact, but also take into consideration the differences in host, parasite and ecology in evaluating the impact of dwarfmistletoe and the economics of control.

PANEL II INSECT-DISEASE RELATIONSHIPS

J. M. Powell - Moderator

Insect-Disease relationships is an extremely broad subject, but we hope to provoke interest in a few aspects of it today. A couple of years ago some members of this Conference made an unsuccessful attempt to have a combined one day session with our entomologist counterparts. Today we are hoping to be more successful in breaking the ice on this topic, which from listening to new project announcements appears to be coming more to the fore.

Today we have two guest entomologists on our panel, Drs. John Chapman and Rob. Reid, who have worked increasingly with pathologists in western Canada and we look forward to hearing their contribution. Rob. Reid has cooperated with Dr. Stu Whitney to give us a joint paper. We also have a guest pathologist, Mert. Stillwell from the Forest Research Laboratory, Fredericton, New Brunswick, who has perhaps come further than anyone to be present at our meeting. We had also hoped to have a further paper by a pathologist, but through illness Harvey Waldron is unable to be with us today, and we will have to wait until a future date to learn of his study on "The role of insects in the dissemination of *Polyporus volvatus*". We are fortunate to again have a well known member of this Conference contribute to our meetings; and at this time I should like to call on Dr. Willis Wagener--generally known as Wag. to start the panel off on the right lines.

RELATIONSHIPS BETWEEN INSECTS AND DISEASES AFFECTING FOREST TREES AND PRODUCTS - AN INTRODUCTION

Willis W. Wagener

I am gratified over the opportunity to introduce this panel; the first, so far as I can remember, on insect-disease relationships to be given a place on the programs of this Conference in the 13 years of its existence. I very much hope that it will not be the last. At the second Conference an abortive attempt was made to hold a joint meeting with the Western Forest Insect Work Conference to discuss relationships between insects and diseases but because of a breakdown in arrangements for the program it never really got off the ground.

Twenty-five years ago J. G. Leach, in the introduction to his text, "Insect transmission of plant diseases", observed that the field was a borderline one which both pathologists and entomologists have seemed reluctant to explore. He called attention to the frequent failure of cooperative effort by workers in the two disciplines to accomplish as much in joint attacks on problems in the field as desirable because of personal, administrative, or traditional factors, and stated "For the greatest success the invisible, though very real, wall separating the two fields of research must be broken down. This may be rather difficult but it can be done."

At the time that Leach was writing, economic necessity had forced close cooperation between pathologists or virologists and entomologists on such virus diseases as the curly top of sugar beets. In trees, this trend has been accelerated in more recent years by virus diseases such as the phloem necrosis of elm, quick decline of citrus, and pear decline, and by fungus diseases such as Dutch elm disease and oak wilt. In forest diesases in the West, however, there has not been quite the same pressure for joint attacks on insect-disease problems, and, with some conspicuous exceptions, their investigation has lagged. One of these exceptions has been the study of sap-stains associated with primary bark beetles in the West by workers such as Ross Davidson and Robina Robinson-Jeffrey. However, the role of the entomologists in these investigations has often been the passive one of accomodating cooperators rather than that of full partners in the studies.

More than thirty years ago Ernest Wright obtained strong field indications that larval broods of the beetle, <u>Scolytus ventralis</u>, could not succeed unless an associated fungus, which he named <u>Trichosporium symbioticum</u>, preceded them into the green wood of the outer annual ring of the attacked fir to reduce the moisture content and diminish their chances of being overwhelmed by resin. One would think that an association apparently as vital as this to the beetles would deserve further investigation to confirm or disprove the field indications but, so far as I am aware, it has not received renewed attention.

I feel that, for many years, there was an especial lag in cooperative studies of the deterioration of timber killed by fire, defoliation or blowdown in the West. Wood borers, stains and decays are usually intimately associated in the degrade or loss of merchantability in such timber, yet we still note cases in independent investigations of insect or fungus phases of such losses, resulting in separate papers, each giving only a part of the total picture, when the information would be much more usable to those concerned with the dead timber if a well-coordinated presentation of all potential causes of loss was available to them.

About eight years ago a large plywood corporation purchased the stumpage of fire-killed or damaged timber on a burn in the inner Coast Ranges of northern California. Although logging was relatively prompt, much more sapstain, resulting in heavy degrade, was encountered in parts of the burn than had been anticipated, to the dismay of the corporation. The case stimulated me to make a preliminary exploration of the factors that might influence stain development in such timber, looking toward the possibility of developing experts who might be able to make reasonably accurate predictions in this field, much as meteorologists attempt to do for the weather. The exploration convinced me that the relationships between influencing factors were extremely complex, and that any expert in this field would have to have behind him years of knowledge and experience in entomology, pathology and meteorology, plus very close contact with current insect surveys, to attempt predictions with any assurance. The difference that location can make in the damage resulting after fire was brought home to me some years ago when I accompanied a group of National Park Service officials to judge the prospects for survival of fire-damaged pines on a burn on the Saguaro National Monument in Arizona. Lest the circumstance of fire-damaged pines on a national monument established primarily for the preservation of giant cacti seem a bit incongruous I should explain that the Monument includes part of the Rincon Mountains, reaching an altitude of about 11,000 feet, where saguaros are supplanted by a pine forest. The fire had crowned in patches of closely spaced young timber but elsewhere had been primarily a ground fire. It had killed patches of cambium on the lower boles of many trees. As compared with most California burns, however, I was amazed at the relative absence of borer work and of the lack of evidence of attack by bark beetles such as Dendroctonus valens, which are characteristically attracted by fire-damaged inner bark at or near ground level in many parts of the West. As a result, the prospects for survival of fire-damaged trees seemed much more promising than would have been the case on a similar burn in California.

Looking ahead, the prospects seem encouraging for greater attention to insect-disease relationships in the forests of the West. Not only does interest in such problems seem to be on the increase, but the administrative climate for their investigation seems to be improved. Close-knit research organizations, such as that of the Weyerhauser Company, have shown especial facility for carrying out investigations in this field, and more unified overall direction of the programs of public agencies augurs well for future accomplishment.

Plenty of questions still await elucidation. For example, the sporophores of Polyporus volvatus, the pouch fungus, appear at such a constant period of time following the death of many conifers that the entomologists often use the presence of conks of the fungus to date the probable time of attack by the primary bark beetles of trees bearing the conks. Many species of insects can be found within the pouches formed by the sporophores, apparently seeking shelter there, but which ones commonly transport the spores to the cambial regions of dying or dead trees, and what types of insects are they? I am glad to learn that work on the volvatus-insect relationship is now under way at Washington State University. Or, how do bluestain fungi gain access to the sapwood of trees invaded by borers, such as species of Melanophila, the eggs of which are laid in crevices on the outside of the bark rather than in galleries constructed underneath by the adults, as is true for the primary bark beetles?

The field is one of real economic importance, especially in forests subject to damage by fire or other catastrophes and it is well worth added attention.

Some of the recent work in insect-fungus relationships is covered in the papers to be presented by the other members of this panel.

A REVIEW OF THE RELATIONSHIPS BETWEEN FUNGI AND SCOLYTID BEETLES - A SUMMARY

J. A. Chapman

The Order Coleoptera is the largest of the insect Orders. Most Coleopterists place the family Scolytidae (and the closely related Platypodidae) at the apex of the beetle phylogenetic tree. We are, thus, dealing with a highly evolved group of insects. Bark beetles tunnel under the bark, feeding as adults and larvae in the phloem, cambium and outer xylem regions. Abrosia beetles tunnel into sapwood and introduce fungi there upon which they depend for food; a symbiotic relationship occurs between these beetles and their fungi, which form a characteristic succulent layer or mat lining the galleries. This fungus layer was termed "ambrosia" (food of the gods) before its true nature was recognized and today wood-boring beetles associated symbiotically with such fungi are called ambrosia beetles.

Most species of the Scolytidae restrict their activity to bark, but there are many ambrosia beetles in this family. The Platypodidae consist entirely of ambrosia beetles. These two families will be considered together in this discussion, but after some generalities on their biology, the bark and the ambrosia beetles will be treated separately in regard to their fungus relationships.

Biology of bark and ambrosia beetles

Some are monophagous, others polyphagous. The number of generations per year ranges from one to several. Some overwinter within the brood tree or logs, but others leave and overwinter in bark or forest litter. The overwintering behaviour is important in relation to the problem of fungus transport from one brood location to another. The length of larval gallery is considered to be significant from the standpoint of nutrition, as it represents the amount of food that must be eaten to reach the pupal stage. The shorter the gallery, the richer the food is assumed to be. Bark beetle larvae make much longer galleries than ambrosia beetles, whose larval niches, when present, are only large enough to contain the pupa.

An important characteristic of these beetles is their highly developed ability to find suitable host material. Their ecological niche is primarily dead or dying trees, windfalls, snowbreaks etc., material that is often widely scattered in natural forests. Their success in establishing themselves on this material, whose suitability for them is transient, is dependent upon their finding it, which they do with their sense of smell.

Recent work has shown that initial beetle attack may be followed by strongly increased attraction to other beetles of that species, and such "secondary" attraction appears to be widespread in this group of insects. The scattered nature of brood material, and the fact that bark and ambrosia beetles represent the pioneer fauna in the ecological sequence of life that result in deterioration of dead trees, are of significance to any associated fungi. Considering forest areas of the world over a period of time, dead tree material represents an abundant source of food and a habitat with many other "advantages" (e.g., suitable moisture, protection). Both beetles and fungi have evolved to utilize this habitat effectively and it is to be expected that many types of association between them should occur.

Ambrosia beetles

This group is almost entirely tropical in distribution although some important species occur in temperate zones. In 1844 Hartig recognized "ambrosia" to be fungus growth. In the following years of that century there were many observations on ambrosia beetles and their fungi, but although the problem of how a symbiotic fungus was transported by a beetle from one brood site to another was clearly recognized, no explanation other than external, accidental spore transport was suggested.

In the early 1900's two men, Schneider-Orelli and Neger, worked intensively on the problem of fungus transport in the common ambrosia beetle, Trypodendron lineatum. They both cultured the fungus readily, Schneider-Orelli by starting with spores from the beetle. Both found fungus cells in the gut and came to the conclusion that these cells were carried from place to place in the intestine of the beetle. Schneider-Orelli suggested regurgitation to be the means of fungus inoculation, but Neger believed that viable spores passed through the intestine with the faeces and were introduced into new galleries in this way.

In succeeding years a variety of short studies and observations were made on ambrosia beetles and their fungi. Many workers found spores of various fungus species attached externally on beetles, to bristles, legs, wings, or in integumentary pits that were reported to occur in many platypodid species. Many fungi were cultured from galleries, but there was confusion as to which were the true symbionts and which were contaminants. Many different fungi, some known to be common wood- or blue-stain species, were found in galleries of various species of beetles.

Francke-Grosmann reported a major advance in knowledge in this field in 1956. She had found distinct integumentary "glands" to be the fungus transport organs in several ambrosia beetles. Different structures were involved in beetles of different genera. She had approached the problem of finding where the fungi were carried by culturing different parts of beetles after fractional sterilization (specimens were kept moist three days, then dried three days and this cycle repeated three times). This treatment functioned as intended by eliminating the external contaminating fungi without killing the true symbiotic fungi, which were protected because of their internal location. Thin sections were then studied to locate the fungus deposits.

Francke-Grosmann reported that the integumentary glands involved in fungus transport contained a fatty or oily secretion. She postulated that glands of this type were wide-spread in the early evolving beetles of this group and functioned either to lubricate body parts against physical stresses involved in bark or wood boring, or in protecting beetles from resins or excessive moisture associated with their gallery habitat. She suggested that the secretions picked up fungus spores readily and that eventually certain wood-inhabiting fungi became adapted to the gland habitat and became dependent on the beetles for transport from one log to another. Other workers have speculated since, on the basis of additional data on types and locations of fungus deposits in ambrosia beetles and the greater structural similarity between certain ambrosia and bark beetles than among the ambrosia beetles, that symbiotic associations of these beetles with fungi were polyphyletic in origin. Schedl suggested that ancestral wood-eating Coleoptera probably only entered wood after decay had commenced and that they relied on activity of fungi and bacteria to reduce the wood to a more suitable nutritional state.

Since Francke-Grosmann's above-mentioned work, there has been an intensified effort to find fungus "depôts" in various other ambrosia beetles. Schedl and others have described a number and variety of them. Schedl, for example, found eight different types in 26 beetles species examined. In the head there may be mandibular joint pockets, pharyngeal pockets, external ventral pockets; in the thorax there may be internal tubular "glands", dorsal pits or pockets, coxal (base of leg) cavity concentrations, or pockets in the elytra. Batra has called the structures containing symbiotic fungi "mycangia". While most mycangia are found only in the females of a species, some occur only in the males.

Both Batra and Baker have recently (1963) summarized published information on ambrosia beetle fungi. Baker listed 33 species of beetles whose fungi had been studied, but there has been no identification of the fungus in 18 of these instances. The fungi that have been identified belong to one of the following genera: Leptographium, Ceratocystis, Monilia, Botryodiplodia, Cladosporium, Cephalosporium, Monacrosporium, Ambrosiamyces, Endomyces. Many other fungi were found in these studies to be frequently associated with the ambrosia fungi in beetles galleries. The genera Fomes, Ceratocystis, Aspergillus, Fusarium, Diplodia, are represented in these and yeasts were often reported to be present in cultures from galleries.

Batra and Michie (1963) suggested that the superficial resemblance in growth and function of many unrelated fungi is the result of their parallel ecological adaptation to the beetle gallery habitat. They found a plemorphism to be typical for ambrosia fungi, which show both a yeast-like form and a mycelial type of growth, depending on culture conditions (this has been confirmed independently by Funk). They also reported, as many earlier workers had, that contaminating fungi became dominant in the galleries if the beetles were removed.

Bark beetles

There are a number of early reports from North America and Europe drawing attention to the frequent association of certain bark beetles and blue-stain fungi. Craighead (1928) was one of the first to suggest that these fungi helped the beetles kill trees, in that the mechanical girdling effect of the beetles often did not appear to be sufficient to account for tree death. Leach, Orr and Christensen (1936) studied two species of Ips bark beetles in relation to blue-stain in Norway pine. They cultured blue-stain fungi from beetle galleries, noted that these galleries were always associated with blue-stain, and concluded that the fungi were introduced into logs only by the beetles. They also found yeasts to be consistently associated with the beetles. Beetles alighting on logs were found frequently to carry fungus spores adhering to legs, wings and other parts of the body. Several kinds of fungi were represented in such spores, but ascospores of *Ceratostomella* were most common and abundant. Fungus spores were also found in the intestine, in sectioned material. They concluded that the fungi made it possible for the beetles to kill trees they could not otherwise kill.

Wright (1935) made a careful study of the relationship between *Scolytus ventralis* and a blue-stain fungus *Trichosporum symbioticum* and concluded that a symbiotic relationship existed between the two. Other studies in North America were made by Rumbold (1936) who found three blue-stain fungi associated with bark beetles (and, again, reported yeasts to be common in cultures from beetles) and Verral (1941) who found a high percentage of *Ips* and *Orthotomicus* carried *Ceratostomella ips*, and cultured fungi of several genera - *Graphium*, *Alternaria*, *Pullularia*, *Cladosporium* - from *Ips* collected in millyards. Hetrick concluded that bark beetles could kill trees without associated blue-stain fungi; Callaham and Shiffrine reported the wide-spread occurrence of yeasts associated with bark beetles; Mathre (1965) recently reported close associations of *Ceratocystis* species with various *Dendroctonus* and *Ips* bark beetles; Molnar (1956) found the bark beetle *Dryocoetes confusus* to carry four fungi (one quite virulent) in their attacks on Alpine fir.

Meanwhile many studies had been carried out in Europe, where blue-staining of lumber has been a factor of economic importance in Sweden, particularly, but also in Germany, England and Poland. Mathiesen-Karrick and Rennerfeld, in Sweden, have devoted much study to bark beetle-fungus associations and have summarized theirs and others' information. Some of the highlights of their work are as follows: blue-stain fungi belong to several different taxonomic groups; they grow saprophytically in wood or dead or dying trees or logs, living on nutritive substances in the living cells; they spread very quickly, most belong to *Ceratocystis* and are spread by insects; many bark beetles have specific or non-specific association with a fungus flora (mostly yeasts and blue-stain fungi) in their galleries. A large number of blue-stain fungi have been found which do not occur outside the beetle habitat and must be considered specialized forms. They belong to *Ceratocystis*, *Ophiostoma*, *Ceratostomella*, *Graphium* and *Leptographium* and to some other genera. These fungi typically sporulate in the beetle galleries and have conidia and spores coated with sticky mucilage.

Another important advance in knowledge in this field was made by Francke-Grosmann in 1963, when she reported finding specialized fungus-containing structures - mycangia - in the head of female *Ips acuminatus*. This bark beetle had long been suspected of a symbiotic relationship with a blue-stain fungus, *Trichosporium*. The mycangia contained spores of Trichosporium and she concluded that a truly symbiotic relationship, as in the ambrosia beetles, existed here.

Farris (Victoria Laboratory) has recently found mycangia in both males and females of the bark beetle Dryocoetes confusus, and clumps of fungus material to occur frequently in various body locations in three Dendroctonus bark beetles.

We may conclude this brief review by saying that knowledge of relationships between bark and ambrosia beetles and their symbiotic or associated fungi has increased greatly in recent years and the outlines of the different types of associations have become fairly clear, but that a large amount of study is yet needed to confirm some of the present ideas and particularly to fill in the details. There are many problems needing study and many questions yet to be answered in this field. Some examples are as follows:

The role of yeasts that are so often and abundantly associated with both bark and ambrosia beetles is not yet understood.

There is still not a single instance where the symbiotic relationship between an ambrosia beetle and its fungus has been rigorously demonstrated by the method of freeing the insect of the fungus, then proving its inability to exist without the fungus and recovery of this ability after replacement of the fungus.

There has been no serious attempt to study growth of ambrosia fungi in artificial beetle galleries (on wood) in the absence of beetles.

The specific requirements of the various symbiotic fungi for growth and for germination are quite incompletely known.

The role of ambrosia beetles in maintaining typical ambrosia "mat" growth on gallery walls, and in keeping down contaminants is not known; it is conceivable that antibiosis may be involved in the latter instance.

Only two or three ambrosia beetles have been reared so far on artificial fungus culture medium.

The taxonomic relationships between the ambrosia fungi of different species of beetles, particularly of beetles in the same genera, is still not clear.

It is not clear yet how mycangia become filled with fungus spores, or how the spores are released during gallery excavation, and the question of whether the fungi typically grow while within the insect is still open; the role of beetle gland secretions in fungus germination and growth in the insect is not known.

There are many fungi pathogenic for insects, and high humidity is usually a requirement for success of these fungi. The question of how bark and ambrosia beetles, whose adult habitat has very high humidity, avoid attack by pathogenic fungi (and they seem to) has not been touched.

The fungus transport mechanisms of most ambrosia beetles, and the question of how widespread among bark beetles such structures are, and of the nature of the various associations of bark beetles with blue-stain fungi are largely unknown at present. Recent studies mentioned above indicate that important knowledge will result from further work in this direction.

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REACTIONS IN THE STEM OF LODGEPOLE PINE TO ATTACKS BY THE MOUNTAIN PINE BEETLE AND CONCOMITANT INFECTION BY BLUE STAIN FUNGI

R. W. Reid and H. S. Whitney

General Description of beetle attack and fungus infection.

Lodgepole pines (*Pinus contorta* Dougl. var. *latifolia* (Engelm) resist attack by the mountain pine beetle (*Dendroctonus ponderosae* Hopkins) by the production of resin. Resin from two sources is involved, what we term primary resin, present within resin ducts and, secondary resin, that which forms adjacent to the beetle gallery within cells not normally associated with resin production. Our studies have indicated that blue staining fungi are associated with the formation of secondary resin, and that this resin is in many instances the major barrier to successful insect attack.

The main flight of the mountain pine beetle generally occurs near mid-summer but may vary by up to a month in the same region in different years and in different regions in the same year, depending on annual and regional weather patterns. Temperatures above 65-70°F are necessary for insect flight and a period of a week or so of hot dry weather prior to the time of flight is generally necessary to precondition the beetles. The tree at the time of emergence is generally dry (sapwood near 20% moisture content (o.d.w.)) and the inner bark region mainly eaten out or greatly mascerated. Brood trees commonly produce over 100 adult beetles per square foot of bark, approximately 2/3 of which are females. Females locate fresh host trees, move into bark crevices or beneath scales, and commence construction of entry holes into the inner bark. Once in that region they commence to extend their galleries vertically and the male enters soon after. Mating usually takes place very soon after entrance of the male.

Primary resin, from incised resin ducts, accumulates in the gallery at this stage, and may if in sufficient volume, flow out the entry hole and build up on the outer surface in conspicuous mounds termed pitch tubes. It may also occur in sufficient volume to either sweep the invading insects out or drown them within the gallery. In successfully attacked trees however the beetles are not greatly hindered by primary resin, which in any case generally ceases after several days. The female extends her gallery at a rate near $\frac{1}{2}$ inch per day during warm weather and boring dust builds up for a short while at the entrance hole. Once the gallery reaches near 3 inches in length, this boring dust is not evacuated but is packed into the gallery behind the advancing beetle. Galleries are generally extended for lengths of 7-14 in. Their length depends upon the rate at which the attacked tree deteriorates following entry of the beetles. This is affected in part by the rate at which the stem loses moisture (e.g. 2 weeks after a successful attack the outer sapwood drops from near 100-150% to near 40-60% moisture content). This in turn is affected by the success of the initial attacks and the density of the attacks. Egg laying females have a narrow tolerance to changing conditions within the inner bark region, and if the weather remains warm they will leave their first trees and establish second broods in fresher trees within three weeks after the first attacks.

The beetles are not alone when they arrive at the trees. In addition to two or three species of each of mites, nematodes and bacteria, they carry numerous species of fungi into the trees with them. The fungi can be broadly classed as "regular commuters" and "occasional hitch-hikers". The occasional hitch-hikers account for the wide variety. Most of these are Fungi Imperfecti that produce dry air-borne spores. Their presence with the insect broods probably results from chance contact prior to and during entry of the beetles.

The "regulars" amount to half-a-dozen or so fungi that are consistently isolated from bark beetles and tissues adjacent to the galleries. They produce sticky spores and are not ubiquitous as are many of the "occasional hitch-hikers". Some of the more prominent "regulars" are; Ceratocystis montia Rumb. which cannot be distinguished with certainty from C. ips (Rumb.) C. Moreau, an undescribed species of Europhium Parker, which is provisionally called E. clavigerum, and a Trichosporium-like fungus, that is perhaps the imperfect state of C. minuta (Siem) Hunt. Other regulars are; a yeast-like fungus, Candida Berkhout and species of the yeasts Hansenula Syd. and Pichia Hansen.

Of the regulars, C. montia and E. clavigerum have received the most attention to date. This is because they grow vigorously in the sapwood and are suspected of being intimately involved in the rapid death of beetle-attacked trees. C. montia and E. clavigerum occur either alone or together in the bark and sapwood and their brown hyphae that are primarily in the ray cells and directly responsible for the apparent blue stain. The other regular commuter fungi are confined, at least initially, to the tissues adjacent to the gallery walls. In addition to being involved in the early stages of sapwood infection, there is evidence which suggests that they are also important to the well-being of insect broods and to the production of the perfect state of the blue-stain fungi.

Both C. montia and E. clavigerum produce abundant asexual spores in the insect galleries beginning approximately 2 days after entry of beetle in the insect galleries. C. montia produces small oval conidia on unbranched conidiophores that arise singly or in synnemata whereas E. clavigerum produces larger elongate septate spores on a verticicladiate (Leptographuim) sporangenous apparatus. The conidia of these two fungi are often produced side by side in insect galleries. Also, their perfect states are sometimes seen next to each other on gallery walls. A black long-necked perithecium containing rectangular ascospores is produced by C. montia whereas E. clavigerum produces a spherical black cleistothecium containing hat-shaped ascospores. Perithecia are often embedded in the wood or bark surrounding galleries and pupal cells and have their necks protruding into lumens of galleries and pupal cells. Cleistothecia, on the other hand, occur mainly on the surface of the sapwood beneath the bark and at considerable distances from insect galleries. Neither C. montia nor E. clavigerum commonly produce a sexual state inculture; but cultures of the common strains of each fungus are easily recognized in the imperfect state by the differences in conidia and conidiophores.

Reactions in stems of non-resistant trees.

Immediately following entry of the beetle into inner bark tissue a white streak frequently develops above and below the insect engraving. This is due to embolism within the current year's xylem.

Within a week following the attack margins of the egg gallery possess a brown discoloration from which the regular commuters are regularly isolated.

Sapwood beneath the gallery exhibits a distinct dry appearance, the moisture content in that region having altered from near 100-150% to near 50-60%. Starch has hydrolized and mycelium can be detected in microsections removed from the outer portions of this drier appearing in sapwood. Within two weeks the dryness often extends to the heartwood interface, and sapwood immediately behind the gallery is non-functional and bluestained. Within a month, if temperatures are high, and attacks at the normal density, the sapwood is completely blue stained. These trees are doomed and the foliage commences to turn red that same year or early in the following summer. By the time of beetle flight they are usually red.

The vertical extension of blue stain is greater within the sapwood than on its surface.

Bark beetle eggs hatch in 7-10 days and the larvae initially mine out at right angles from the egg gallery. Fungi grow out larval mines and, broods from adjacent galleries and even from the same gallery soon intermingle so that fungi within the inner bark region become widely distributed and mixed.

By early summer of the following year broods are in the pupal and teneral stage and Europhium and Certocystis have produced abundant conidia and usually their perfect states.

Prior to emergence of the beetles transportation of C. montia and E. clavigerum is assured by the extensive growth of these fungi, particularly in the pupal cells. Tenerals have been observed feeding on the fungi growing on the walls of the pupal cells and after emergence of the beetles, these walls are void of fungal material.

Reactions in the stems of resistant trees.

The reaction in the stem of resistant trees to bark beetle attack and subsequent infection by blue stain organisms is very different to that which occurs in non-resistant trees. The attacking beetles may or may not be "pitched" out by the flow of primary resin.

Conspicuous changes occur in tissues adjacent to the original bark beetle gallery. These changes occur in a sequence and are most extensive above, beneath and behind the gallery. They can be described as follows: first there appears the white streak, which increases greatly with time and may after a month or so reach a distance of 50 feet above the wound. Less extensive and associated more closely with the wound, there occurs a region of reduced moisture and starch content. This is followed by bark adhesion in the same region. Within this latter region there occurs a resinosis and death of cells in the inner bark and sapwood. All these regions increase in space with time. Stabilization generally occurs the following year. At this time the resinosis reaction may have spread 18-20 inches above and below the insect gallery an inch or so lateral in the inner bark and sapwood and radially to the heartwood. As with the blue stain, the resinosis in the sapwood extends most rapidly below the sapwood surface. Following stabilization, callus tissue forms on the margins of the resinosis area, new vascular cambium forms over this together with a new periderm.

It was observed that extensive resinosis reactions were not associated with just any wound on lodgepole pine, but rather, with beetle wounds. In view of the constant close association between C. montia and E. clavigerum and the bark beetles, these fungi were tested to find out if they played a part in causing the reaction. The test fungi, with appropriate control treatments, were applied to numerous trees at several different times during the past three growing seasons. They were applied as wood-chip, rice poultice, agar or broth cultures. Measurements were made of resinosis reactions and attempts were made to recover the test fungi from the inoculated trees. In practically every case a reaction similar to that resulting from unsuccessful bark beetle attacks was produced by each fungus. The reactions in control treatments were always much less, usually not exceeding the size of the inoculation wound. These results show that the blue stain fungi were pathogenic to the trees inasmuch as they caused an extensive injury. Indeed, inocula placed on stems so as to girdle them, but not at one level, resulted in the death of trees. However, it was evident that the fungi were not 'happy' in these resistant reactions; they were confined to the reaction tissues, they did not sporulate, either asexually or sexually, blue stain did not develop and they died-out after a couple of years in localized reactions that were healing over. Furthermore, fungi could not be cultured from old lesions resulting from insect attacks that occurred 2 to 5 years previous. Thus the fungi in tissues of resistant reactions were not very successful. Nevertheless our results show that despite their poor growth, the blue stain fungi play an important part in aggravating and extending the necrotic resinosis reaction that originates from the initial insect attack in resistant trees. And by this aggravation they cause large amounts of secondary resin to be produced which in turn plays an important role in preventing successful establishment of bark beetle broods and hinders success of their own colonization.

Tests are currently underway to determine whether resistant reactions are induced specifically by blue-stain fungi and whether the inducement is associated with in vivo activity of the causal organisms.

WOODWASP - FUNGUS RELATIONSHIPS

M. A. Stillwell

In the Maritime Provinces, woodwasps commonly oviposit into the sapwood of injured and newly killed balsam fir. During oviposition oidia of the fungus Amylostereum chailletti (Pers. ex Fr.) Boidin, that are contained in intersegmental sacs located anterior to the base of the insect's oviposition, are introduced into the wood. Shortly thereafter the oidia germinate and the sapwood is rapidly decayed (almost 1/2 in. of radial penetration during the first growing season).

Investigations have shown that the fungus is closely associated with female woodwasps (Sirex juvencus L.) throughout their entire development. In fact, the woodwasps are unable to complete their development beyond the first instar in the absence of A. chailletii. Furthermore, it appears that the fungus is chiefly, perhaps solely, propagated by woodwasps in New Brunswick and Nova Scotia.

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THE ROLE OF INSECTS IN THE BIOLOGY OF POLYPORUS VOLVATUS PECK.

Harvey Waldron

Insects have long been recognized as vectors of fungi. In most instances specific insects are associated with a particular fungus. Polyporus volvatus Pk., a serious saprotter of conifers, appears to require an insect vector for the dissemination of its spores or mycelium or both. Large numbers of insects are associated with the fruiting bodies of P. volvatus. Of these, the group commonly known as bark beetles seems most likely to play a role in dissemination. Included are Dendroctonus, Ips, Scolytus, Buprestids, Cerambycidae, and a little known group completing its life cycle in either the fruiting body of P. volvatus or in the bark of conifers, the Cisidae.

P. volvatus is associated with conifers which have been killed by fire, insects, or disease and subsequently attacked by bark beetles. In every instance the fruiting body is produced at the entrance or exit of beetle tunnels or at wounds in the bark which expose the sapwood and then at the edges of such wounds. This indicates that the fungus is incapable of penetrating sound bark.

The fruiting body of P. volvatus differs from any other Polypore in that its pore layer is initially completely enclosed by a volva. When fully developed there is a relatively small ostiole in the volva near the point of attachment of the fruiting body. The volva traps most of the spores, preventing their escape into the air. A relatively small percentage of spores fall through or are pushed through the ostiole by insects. Nevertheless, isolated trees heavily infected with P. volvatus are frequently found far from any source of inoculum. Invariably these have been severely attacked by beetles.

By the time the ostiole develops millions of spores have collected within the volva. As soon as the ostiole is formed, insects can be found within the cavity formed by the volva. These enter through the ostiole, some chewing away its edges. Others bore directly through the volva or through the upper surface into the trama. Bark beetles are consistently found crawling through the mass of spores within the volva. Their bodies become covered with the spores as though dusted with powder. Insects thus covered with spores have been removed and placed on the surface of malt agar in petri dishes. At each point where an insect had stepped a small colony of P. volvatus began to grow.

There seems to be a direct correlation between the extent of P. volvatus and the severity of beetle attack. Where the attack is heavy numerous fruiting bodies appear, whereas if the attack is light only a few appear. Beetles may be of significance not only in dissemination but in fruiting. *P. volvatus* does not seem to be capable of penetrating the bark, but must have a wound penetrating to the sapwood to be able to emerge through the bark and produce a fruiting body. Therefore, in those cases of a light beetle attack, the fruiting of *P. volvatus* may be restricted.

In one experiment involving a stand of fire killed ponderosa pine a number of the trees were screened to prevent insect attack. Others were left unscreened as controls. No *P. volvatus* occurred within the screened portions of the trunks. Surrounding unscreened trees were severely attacked by beetles and large numbers of fruiting bodies of *P. volvatus* appeared on these trees. Conks were produced on two screened trees inoculated with *P. volvatus*.

A number of conks of *P. volvatus* attacked by insects were examined to determine the insects present. There were some scavengers, represented by Tenebrionidae; bark beetles such as *Xylechinus montanus* Blackman and a member of the Cisidae, *Plesiocis cribrum* Casey. *P. cribrum* is of particular interest in that it not only can complete its life cycle in the context and pore layer of *P. volvatus* but is also capable of attacking trees as a bark beetle. Larvae and pupae believed to be of this insect were found in the context and pore layer. Attempts will be made to hatch the pupae and to identify the adult insect. Adult *P. cribrum* beetles removed from conks have been trapped into ~~fir~~ bolts where they immediately began boring into the bark. Occurrence of *P. volvatus* will indicate that this beetle is capable of serving as a vector.

Buprestidae and Cerambycidae are commonly associated with trees infected with *P. volvatus*. None of the Buprestidae or Cerambycidae have been found in the conks of *P. volvatus*. Trees attacked only by beetles belonging to these two groups did not bear conks of *P. volvatus*.

The possibility of spread by means of mycelium is not ruled out. Small mycelial clumps occasionally form below loosened bark near a beetle tunnel. More rarely mycelium may be found lining a beetle's tunnel for a short distance. When new broods of beetles emerge from the tree in which they have developed, they might pick up pieces of the mycelium on their bodies and fly to a new host. Mycelial fragments might be dropped or rubbed from the insect as it tunnels in the sapwood.

PANEL III NEEDLE CAST DISEASES

A. K. Parker - Moderator

MORPHOLOGY OF THE HYPODERMATACEAE

C. C. Gordon

The basic and fundamental objectives of this research program have been: (1) to show the ontogeny of the ascocarps for species within the Hypodermataceae; (2) to find morphological evidence of the interrelationships within the Hypodermataceae and their phylogenetic position within the Ascomycetes; (3) to prepare an up-to-date, illustrated monograph of the species belonging to Hypodermataceae of conifers found in North America.

During the first year of this research project (March 1964 to March 1965) these objectives have been closely followed. Certain supplementary work has been pursued which was considered important in successfully achieving the major objectives.

Living specimens of the following Hypodermataceae were collected from western Montana, northern Wyoming, Grand Canyon National Park, Arizona, northern Idaho, Washington, Oregon and the Province of Ontario, Canada: Elytroderma deformans (Weir) Darker on Pinus ponderosa Law, P. contorta Dougl. and P. edulis Engelm.; Hypoderma saccatum Darker on Pinus edulis, and P. flexilis James; Hypoderma pini (Dearn) Darker on Pinus monophylla Torr. & Frem; Hypodermella abietis-concoloris (Mayr) Dearn, on Abies grandis (Dougl.) Lind.; A. lasiocarpa (Hook) Nutt; H. concolor (Dearn) Darker on Pinus contorta Dougl; H. montivaga on Pinus contorta; H. arcuata Darker on Pinus monticola Dougl; H. laricis v. Tubeuf on Larix occidentalis Nutt.; Lophodermium piceae on Piceae spp.

Thus far over 1600 herbarium specimens are being used in this study. These specimens have been obtained from the following mycological herbaria: Washington State University, University of Wisconsin, University of California (Berkeley), New York Botanical Garden, National Fungus Collection (U.S.D.A.), Smithsonian Institution, Harvard University (Farlow Herbarium), Chicago Natural History Museum, Pacific Northwest Forest and Range Experiment Station, (Portland, Oregon), U. S. Forest Service Disease and Research Division (Berkeley, California), Laboratory of Forest Pathology, Calgary, Alberta. Specimens were also obtained from individual collectors in Alaska, Canada and the United States.

Specimens have been selected from herbarium material using the following criteria: (1) to obtain specimens of each fungal species from their most southern, northern, eastern and western geographic ranges; (2) to obtain each fungal species on as many different coniferous hosts as possible; and (3) to obtain specimens of each species collected in as many different months of the year as possible over the last 80 years.

Ascocarps and conidial stages of species from herbarium and living specimens have been processed through a histological procedure into paraffin (Paraplast) and sectioned on the rotary microtome at various thicknesses (3 to 15 micra). The material is then deparaffinized and stained with a fast green and Feulgen's staining procedure. The sectioned material is studied with a phase microscope (Reichert Zetopan) and photomicrographs are being taken of the numerous morphological variations which occur in the ascocarps of most species. Photomicrographs are used extensively in comparing and matching ontogenetic similarities of the 50+ species being studied.

In temporary mounts, there is little difference between the hymenial tissues of living specimens and of some specimens which have been preserved for up to 80 years. The condition of the ascocarps and the hymenial layer in herbarium specimens of the same species varies greatly. This is thought to be due to the condition of the material at the time of collection, and methods used in drying material prior to placing specimens in a herbarium. Ascocarps collected on the same host species at approximately the same locality and time of year, but by different collectors, vary from excellent to unusable. Herbarium material gave excellent serial sections of the ascocarpic wall; however, the hymenial layer of herbarium material is seldom as good as fresh material when sectioned. That temporary mounts of herbarium material are sometimes as good as fresh material and seldom as good after serial sectioning can probably be attributed to hydrolysis of herbarium material by HCl or other chemicals or to heat.

The studies thus far carried out on the Hypodermataceae of conifers reveal 3 basic and 2 intermediate types of centrum ontogeny.

THE EPIDEMIOLOGY OF DOUGLAS FIR NEEDLE BLIGHT

A. K. Parker

INTRODUCTION

In 1957 Rhabdocline occurred at endemic levels in the Christmas tree region centered around Invermere in the East Kootenays of British Columbia. Only widely scattered areas, approximately 1/2 to 2 acres in size, were to be found with severe infection. The disease reached epidemic proportions during the next three years, however, and by the spring of 1960 there were a number of severely infected areas ranging in size from 3-4 acres up to 50 and 100 acres. The following year the epidemic had collapsed and the disease has been considered to be in an endemic state since that time. Areas of relatively high infection in the region are now the 1/2 and 2 acre areas first noted in 1957. A 7 year record of the level of infection on tagged trees in 3 of the small centres of infection is presented in Table I. The purpose of the study reported here was to determine the factors which governed the rise and fall of the needle blight epidemic.

TABLE I

INCIDENCE OF RHABDOCLINE ON ONE-YEAR-OLD NEEDLES FOR THE YEARS 1958 TO 1964 IN THREE LOCALITIES

Foliage initiated (year)	Percentage of one-year-old foliage affected by needle cast in three localities		
	A	B	C
1958	74	80	96
1959	83	91	100
1960	16	15	12
1961	13	15	45
1962	6	10	14
1963	5	25	48
1964	3	11	43

RESULTS

Spore dissemination

One of the conditions necessary for the occurrence of an epidemic is that the infectious agent, in this case ascospores, be discharged in large quantities. The number of spores available for dispersal increased from 1957 to 1960 by the intensification of infection on individual trees and by the expansion of infection centres. For two successive years the pattern of spore discharge was studied with the aid of 4 spore traps and hygrothermographs located in areas of high infection from the time of bud-breaking to the end of the first week in July. It was found that 80% of the spores were discharged during rain periods; dew accounted for 4%; showers for 1%, and dews combined with showers, for 15% (Table II). Dews and sudden

TABLE II

THE AVERAGE LENGTH AND INTENSITY OF SPORE DISCHARGE PERIODS DURING PERIODS OF HIGH HUMIDITY AT FOUR LOCALITIES DURING 1958 and 1959.

Spore discharge periods	Periods of high humidity			
	Rain	Dew	Shower	Dew and Shower
No.	25	54	13	38
Intensity[1]	56	8	3	14
Length (hrs.)	33	5	3	12

[1] Average number of spores on each square millimeter of spore trap surface.

showers are consistent features of the environment during June, but weather records showed rain periods to vary considerably from year to year. It appeared that only rain periods could initiate the release of the large number of spores required to produce an epidemic. The spore trap data also showed that the length of time the hygrothermographs recorded 90% RH coincided well with the length of periods of spore discharge, so after 1959 only hygrothermographs were used for gathering spore discharge data. A comparison of rain periods and the incidence of disease is presented in Table III.

TABLE III

THE RELATION OF THE NUMBER AND LENGTH OF RAIN PERIODS TO THE INCIDENCE OF DISEASE

Locality	Foliage initiated (year)	Rain periods:		Incidence of disease
		No.	Hours of 90% RH	
B	1958	7	165	80
	1959	4	106	91
	1960	0	0	15
	1961	1	24	15
	1962	1	14	10
	1963	4	93	25
	1964	4	68	11
C	1959	4	163	100
	1960	2	27	12
	1961	3	59	45
	1962	1	22	14

The infection court

Another requirement to be met before an epidemic may occur is the transport of the infectious agent to the susceptible parts of a susceptible host. Only young needles of the current year are susceptible to invasion by the fungus. This was demonstrated by protecting the new shoots from inoculation during the approximate 6-week period when ascospores are available, and then either inoculating them artificially or exposing them to sources of infection in subsequent years. Inoculated needles remained healthy in all the experiments.

Douglas fir of the intermountain variety are found to vary from highly susceptible to completely resistant. On highly susceptible trees the fungus has a one-year life cycle. The new needles are infected shortly after they emerge (invasive hyphae have been demonstrated in the mesophyll 2 weeks after inoculation) and inoculation studies have shown the needles to be susceptible until they are at least 5 weeks old. Mature apothecia appear the following spring and infected needles are cast at 13 to 14 months of age. On some trees with partial resistance mature apothecia do not appear until 2 years after inoculation, and the occasional appearance of apothecia on needles 3 to 6 years of age indicates that the fungus sometimes vegetates for even longer periods.

Since the new shoots must be exposed during ascospore dissemination before infection may occur, data were collected in the time of bud-break each year in infection centres. In 1960, the year the epidemic collapsed, there were no rain periods from the time of 50%-bud-break (when spore traps and hygrothermographs were placed in the field) to the casting of infected needles early in July. One rain period, however, occurred after the buds began opening but before an average of 50% were open. The result was a very uneven distribution of infection on susceptible trees. Trees with late bud opening were unaffected while those with early bud opening were severely infected. On most trees only a few branches or just the lower branches were infected.

Conditions for infection

A third requirement to be met before an epidemic may occur is that the infectious agent meet with the conditions required for the initiation and development of infection. Throughout the study a series of inoculations of susceptible trees demonstrated that the required conditions were always present in the study areas although fewer lesions developed in some years (particularly in 1960) than one would expect from the heavy spore load applied. Because it appeared possible that some epidemics might collapse from the lack of suitable conditions for infection, even when spore dispersal was adequate, a series of inoculations was conducted in growth chambers in order to determine more precisely the environmental conditions required for infection. Preliminary results indicate that a period between 12 and 36 hours at 100% RH is required for successful infection and that a daily temperature regime of either 55° for 8 hours and 75° F for 16 hours, or a constant temperature of 55°F, was adequate. A RH of 100% for 12 to 72 hours at a temperature regime of 65° and 75°F was inadequate, but an RH of 100% at a temperature 55°F for 72 hours, and then a temperature regime of 65° and 75°F met the requirements for infection. Field data showed that periods of 100% RH greater than 12 hours in length are nearly always associated with rain periods, and only seldom with other types of weather. Nightly periods of eight hours or more with temperatures below 55°F were the rule rather than the exception, even in the absence of rain.

CONCLUSIONS

It appears that the conditions most favorable for infection are also those required for massive spore dispersal, and that the rise and fall of Rhabdocline epidemics are governed by the number and length of rain periods occurring from the time of bud-break to the casting of previously infected needles. An adequate and economical control may be possible by the eradication of the small centres of infection which are present during years when the disease is at an endemic level. Undisturbed, the small centres of infection will periodically increase, causing severe damage to large areas of Christmas tree stock.

DOTHISTROMA PINI - HISTORY AND INTERNATIONAL SIGNIFICANCE

C. Gardner Shaw

The recorded history of the Red Band Disease commences with the collection of specimens by Shattuck on the needles of Ponderosa pine in June of 1917. Shattuck's collection, made at Orofino, Idaho, became a part of the Weir herbarium which was later deposited in the National Fungus Collections, Beltsville, Maryland.

Weir sent a portion of Shattuck's specimen to P. A. Saccardo, who based his description of *Actinothyrium marginatum* on this specimen. Somehow Saccardo failed to associate the cylindrical to filiform spores produced by the red band fungus with the obvious black, locular stromata in which these spores are borne on the red bands of discolored host tissue. He saw the spores but associated them with the fruiting bodies of *Leptostroma decipiens* Petr. and *L. pinastri* Desm. which are common on dead needles of Ponderosa pine. Thus, a *nomen confusum* was created.

Sydow and Petrak recognized that *Actinothyrium marginatum* Sacc. was a *nomen confusum*. They rejected this binomial, considering the red band fungus identical with *Lecanosticta acicola* (Thum.) Syd., which causes brown spot of longleaf pine in Southern United States. Both Dearness and Hedgcock considered the red band fungus of Western United States and the brown spot fungus on longleaf pine the same.

It remained for R. L. Hulbary, in 1940, to describe the red band fungus as a distinct species. Hulbary selected as type of *Dothistroma pini* a specimen collected on Austrian pine in Le Kalb Co., Illinois. He failed to mention the red bands of discolored host tissue in which the fruiting bodies of Dothistroma pini are located. Admittedly, the red bands are not so obvious on Pinus nigra Arn. var. austriaca (Hoess) Aschers. & Graebn. as on ponderosa pine and lodgepole pine. Nevertheless, they are apparent in Hulbary's type.

Siggers in 1944 in his excellent study of the Brown Spot Disease, excluded the red band fungus from Lecanosticta acicola. He suggested that the red band fungus might be identical with Dothistroma pini, but did not extend his studies to this fungus.

Murray and Batko reported the occurrence of Dothistroma pini in Great Britain in 1962. They proposed that Actinothyrium marginatum and Dothistroma pini be considered conspecific.

It remained for Dr. B. D. Thyr and me to study and compare type and authentic specimens necessary to resolve all aspects of this nomenclatural puzzle. These studies confirmed the separate identity of Lecanosticta acicola and Dothistroma pini. Simultaneously, the red band fungus of Western United States was positively identified with Dothistroma pini. We did, however, find significant differences in the spore measurements of collections from Western United States and Eastern United States. Therefore, two varieties were distinguished: Dothistroma pini var. pini and Dothistroma pini var. linearis. The measurements of conidia from England (given by Murray and Batko) agree better with those of var. linearis than var. pini.

We recognized that the differences noted might be due to substrate or to climatological factors. The distinctions so obvious in the material available to us may break down, if additional material is studied. Mr. Michael Ivory (% The Director, E.A.A.F.R.O., P.O. Box 74, Kikuyu, Kenya), Dr. Gibson's associate, has a statistical study of spore measurements underway. Mr. Ivory would appreciate specimens from various areas in Western North America.

But enough of taxonomy and nomenclature. Forty-eight years have elapsed since the first collection of Dothistroma pini. For more than forty of those years the fungus has been primarily a mycological curiosity. It had been associated with blighting and casting of needles but not with severe defoliation and disease epidemics. In 1958 and subsequent years, several foliage diseases of conifers became epiphytotic in the Pacific Northwest. The red band disease was one of these. Immediately thereafter, reports of D. pini began to be received from other parts of the world. Its occurrence in England in 1960-61 on several species of pines has already been mentioned. Next, Dr. I. A. S. Gibson reported a severe epidemic on Pinus radiata D. Don in Kenya, Africa. Then, in 1964, it was noted in nursery stock in both Oregon and British Columbia.

The initial reports of Dothistroma pini in Oregon came to me from Lindsay Loring. In April of 1964 it was found on shore pine, Pinus contorta Dougl. var. latifolia Engelm. and Pinus pinaster Ait. Last fall a severe epiphytotic occurred in a Christmas tree plantation of shore pine near Otis Junction, Oregon. The disease is under investigation by John H. Thompson and Don Graham in Oregon. They have found red band on Scots pine (Pinus sylvestris L.) Austrian, Monterey and Japanese pines. It is most damaging in plantations less than two years of age. An extensive program aimed at control is underway. Antibiotics, including Phytoactin and Actidione, have not proven effective. Bordeaux has proven effective elsewhere, and is being tested in Oregon.

An interesting observation made by Loring and Thompson is that Dothistroma pini was not apparent in naturally regenerated shore pine. They suggest a direct relationship between lack of air circulation and the prevalence of the fungus. Dothistroma pini has now been found on the following two and three needle pines in British Columbia: Pinus jeffreyi Grev. & Balf., Pinus muricata D. Don., Pinus pinaster Ait., Pinus contorta Dougl., Pinus radiata D. Don., Pinus nigra var. calabrica Schneid. and Pinus Murrayana x banksiana Righter & Stockwell. It has tentatively been identified on Pinus monticola Dougl.

Dothistroma pini has now been reported from several midwestern states. Glen Peterson has been investigating the disease in the plains states.

Turning our attention to other parts of the world, Dothistroma pini is now known to occur in New Zealand and Chile as well as in England and Kenya. As in Kenya, the New Zealand and Chilean outbreaks are on Pinus radiata. Dr. Gibson suggests that new Dothistroma outbreaks are often preceded by very mild infections characterized by mild chlorosis and necrosis with scarcely any sporulation on the infected tissues.

In New Zealand the fungus has been reported by Dr. J. W. Gilmour, on Pinus attenuata Lemm., B.C. strain of P. ponderosa P. nigra, P. radiata and a hybrid of P. attenuata x radiata. Again the most severe damage has been on Pinus radiata and to stands 1-14 years of age. Stands older than 16 years have not yet been found infected. This suggests the more recent introduction of the pathogen than of the host.

Most reports of Dothistroma pini have been on two and three needle pines. However, it is reported on Pinus lambertiana from New Zealand and P. monticola from British Columbia. We have found a fungus similar to Dothistroma pini on Western White Pine in the lower crown of trees up to 30 years of age. However, the cycle of development of this fungus and associated symptoms seem different and its morphology differs from that of Dothistroma pini. We continue to call this fungus Lecanosticta sp. to indicate our uncertainty about it.

How do we explain the tremendous variation in severity of the disease caused by Dothistroma pini from one decade to the next in Western

United States and in the United States as a whole, and such countries as Kenya and New Zealand? Dr. Gibson has suggested that the impact of foliage diseases on forest production is in direct proportion to the impact of man on the natural plant community of the forest. In undisturbed, native forests, numerous foliage diseases may be present but seldom are they of economic importance. Essentially the same is true of managed native forests where the primary objective has been improvement through the selective removal of weed species. In nurseries the same foliage diseases that occur in the native forest may become of minor or moderate importance on indigenous species. Once exotic tree species are introduced, disease problems are compounded. Exotic species may be divided into two categories: (1) those with no close relatives in the native forest, and (2) species belonging to the same genera or families as indigenous species. In the former category it is unlikely that any native foliage pathogen will become serious on the introduced tree, or that an introduced pathogen will attack native species. The principle exceptions would be gregarious and cosmopolitan faculative pathogens, such as Aureobasidium pullulans, a fungus most indiscriminate in its substrates which include everything from pine needles to brine cherries and house paint.

If, on the other hand, a pathogen is introduced on an exotic species which is related to native species, the pathogen may become of extreme importance on the exotic host, on the related native species, or on both. A pathogen introduced simultaneously with an exotic species becomes a serious threat to the exotic if environmental factors are more favorable for its development in the new locality than in the original one. This seems to be the case with Dothistroma pini.

Gibson believes that Dothistroma pini blight has been present in Central Africa since 1943. Between 1957 and 1960 the severity of the blight became increasingly serious and by 1963 the established stands of P. radiata in Kenya were jeopardized; planting of this species was suspended.

In the Pacific Northwest the sequential pattern has not been the same in the Inland Empire as in coastal areas. Since the flare-up in 1958 to 1960, the disease has subsided in the Inland Empire area of Washington and Idaho. It can be found (now that we know what to look for), but is presently classified as a "minor" disease. This is certainly in contrast to the situation in the coastal areas of British Columbia and Oregon.

What are the reasons for the continuing epiphytotic in Kenya, the flare-up and subsequent subsidence of this pathogen in the Inland Empire and its appearance in coastal areas of the Pacific Northwest? Environmental factors seem to be the key. In Kenya, defoliation varies in severity in direct relation to rainfall. In that country it is now accepted that regions with an annual rainfall of more than 50" are likely to suffer severe losses from Dothistroma blight. In the Inland Empire area, the pathogen is found in areas with 25" to 45" rainfall. In contrast, in most coastal areas of British Columbia and Oregon the annual rainfall exceeds 50". Total rainfall undoubtedly is not the significant factor, but rather temperature, humidity and duration of free moisture as influenced by rainfall.

Sporulation of the pathogen may vary with climate. In Idaho, viable spores can be obtained at any time of the year from attached infected needles. In the Kenya Highland both sporulation and dispersal of the fungus can occur during most of the year. Murray and Batko reported a peak of sporulation in the spring in England.

Sporulation and climatic conditions favorable for infection are not the only factors involved in establishing infection. The fungus must be able to penetrate the tissues of the susceptible host. This period of host susceptibility may be short. For many needle diseases, even though inoculum is produced throughout the year and climatic conditions remain favorable for long periods, infection might occur only during short periods of host susceptibility. For needle pathogens the prime susceptible period appears to begin with the rupture of the fascicle sheath and to terminate when needle elongation is complete. Thus, in the United States heavy infection occurs in the field only if there is considerable rain from late May through June. In Kenya and other areas, it might be that climatic factors not only favor sporulation, dispersal and infection, but also prolong the period of host susceptibility.

We have placed particular responsibility on environment for the conversion of minor foliage diseases to major problems on new hosts or on old hosts in new locales. Let us enumerate at least a few of the ways in which environment may act. The new environment may:

(1) increase the pathogen's reproductive capacity, either by increasing the number of spores produced per infection in a given period of time or by prolonging the period of spore productivity;

(2) prolong the viability of inoculum;

(3) provide more efficient means of, and prolonged periods for, dissemination;

(4) decrease the period required for germination and penetration;

(5) provide longer periods of time during which free moisture is present;

(6) shorten the time interval required for either the sexual or asexual reproductive cycle;

(7) provide more or different portals of entry;

(8) weaken or eliminate a natural barrier possessed by the suscept;

(9) otherwise increase the host's susceptibility.

Dothistroma pini is a good example of how difficult it can be to guard against the intercontinental spread of a potentially dangerous forest pathogen. It took us forty years to realize that a mycological curiosity might be dangerous to our two or three needle pines. By the time we were in a position to warn others, research workers in East Africa and/or England had already discovered the pathogen; it was apparently more damaging in these areas than where it was first found. Now New Zealand and Chile have outbreaks. Furthermore, it is significant that *Dothistroma pini* has yet to be found on *Pinus radiata* in its native habitat. Yet, this is the host upon which it has become most severe in exotic localities.

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N. B. references to earlier literature are contained in these two papers.

THE PERFECT STATE OF DOTHISTROMA PINI HULBARY

A. Funk

In 1964 A. K. Parker found an ascomycete in the red bands of needles of *Pinus contorta* blighted by *Dothistroma pini* Hulbary. Ascospores taken from these specimens were grown on malt agar and produced colonies and conidia identical to those grown from conidia of *D. pini*. Fruiting bodies were also found in which both states originated from a common stromatic base.

The ascigerous state of *D. pini* consists of a multiloculate stroma in which one to several rows of sphaerical locules form. They are formed subepidermally and are later erumpent. The asci are bitunicate. The ascospores are hyaline, 2-celled, broadly fusiform to cuneate. We consider it to be a new species of *Scirrhia* Fuckel of the Mycosphaerellaceae, closely related to *Scirrhia acicola* (Dearn.) Siggers, the brown spot needle blight fungus. It differs in the following ways from *S. acicola*:

1. ascostromata are much shorter, but stouter,
2. it produces a red band in pine needles,
3. ascostromata contain a KOH soluble red pigment,
4. conidialstate is different,
5. produces red pigment in culture,
6. interthecial tissue persists,
7. ascospore germination is different.

We have also found structures which appear to be the sexual organs of the fungus. These consist of a microconidial state and trichogynes, which closely resemble homologous structures in *Scirrhia acicola*.

DOTHISTROMA NEEDLE BLIGHT IN THE GREAT PLAINS

Glenn W. Peterson

Needle blight caused by Dothistroma pini Hulbary is widespread and causing serious damage to Austrian and ponderosa pines in the central and southern Great Plains (Nebraska, Kansas, Oklahoma). During a 1960 survey in Nebraska, this fungus was found on ponderosa pine in 11 of 27 windbreaks (20-22 years old) and on Austrian pine in 6 of 9 windbreaks. D. pini has not been found on pine seedlings in Plains nurseries, but has damaged 6-year-old Austrian pine transplants in an eastern Nebraska nursery. Christmas tree production (Austrian and ponderosa) in eastern Nebraska has been hampered by D. pini. Damage to Austrian pine on the Nebraska National Forest, Bessey Division, near Halsey had reached such intensity that a direct control program was planned for this year; the disastrous fire which destroyed nearly one-half of the timber on this forest precluded its implementation. D. pini has also been found on Mugho and Scots pines in Nebraska; no serious damage to the latter species has been observed.

The following remarks pertain to observations made during work on this disease in the central and southern Great Plains during the last several years. The chronology of events is likely to be different in other areas; it is known to be different in East Africa (Gibson et al., 1964).

Both current and previous seasons' needles may be infected in a given year. Symptoms are first evident on ponderosa and Austrian pines in the fall. Yellow to tan spots appear, followed by affected parts of the needle becoming light green, then yellow. The spots become darker brown to reddish brown; bands which encircle the needle are common. Usually the distal end of infected current season's needles becomes necrotic. Evidence indicates that older tissues on a given needle are more susceptible than younger tissues. Previous seasons' needles may have lesions along their entire length; such needles often become wholly necrotic soon after symptoms appear. Though symptoms are not confined to any particular part of the crown, the first damage is usually observed in the lower crown.

There is considerable seasonal variation in time of first appearance of symptoms. They have been observed as early as September 9 and as late as mid-November.

Infected needles are cast early. In eastern Nebraska, heavy casting usually occurs in late spring and early summer, but infected needles may be cast in the late fall or early winter of the year of infection.

The developing stromata of D. pini result in a raising of the needle epidermis; this is first evident in spring (March). Stromata first cause longitudinal rupture of the epidermis; later, transverse ruptures occur. Epidermal tissues often remain attached to fully erumpent stromata. Some stromata are fully erumpent by mid-April; numerous stromata are fully erumpent by mid-May. Austrian and ponderosa pine needles were just emerging from leaf sheaths in mid-May of three years observed.

Conidia of D. pini have been trapped on vaseline-coated slides in May. The first heavy deposit of conidia occurred June 9 in 1964 and May 27 in 1965. First infection by D. pini occurred during the period June 16 to 23 in 1964. The largest conidial deposits were obtained in mid-June in both 1964 and 1965. Conidia have been trapped throughout the growing season, though numbers obtained during August, September, and October have been relatively low. Conidia were trapped only during those exposure periods in which some rain fell.

Direct control of Dothistroma needle blight in many plantations and natural stands is precluded by expense. In the Plains, however, direct control would be economically feasible for some windbreaks, most ornamental plantings, and all Christmas tree plantings. Fungicides have been evaluated for the last three years in Nebraska. The methods have involved using individual shoots as experimental units. In this way, several chemicals can be evaluated on a single tree. Bordeaux mixture, Puratized Agricultural Spray, Zineb, and Captan were tested in 1963. Only Bordeaux mixture gave good control (Peterson, 1965).

These fungicides were tested in 1964: Bordeaux mixture and Puratized Agricultural Spray, with and without Plyac added; Commercial Bordeaux mixture; tribasic copper sulfate; C-O-C-S; TC-90; tetrachloroisophthalonitrile (DAC-2787); Difolatan; and Actispray. Excellent control was obtained with Bordeaux mixture and other copper-containing fungicides (tribasic, C-O-C-S, TC-90). The other fungicides were unsatisfactory.

Though other copper compounds give good control, Bordeaux mixture is recommended because of its highly persistent nature, a very important characteristic when effective control is being sought through a limited number of fungicide applications.

Currently we are recommending not more than three applications of fungicide, with the first application to be made by mid-May so as to protect old needles. These are usually spaced about three weeks apart. Results from such programs have been excellent.

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SPECIAL REPORTS

VAPOUR STERILISING AGENTS FOR WOOD AND THEIR EFFECTS UPON THE SUBSEQUENT DECAY OF WOOD BY LENTINUS LEPIDEUS AND L. KAUFFMANII

Roger S. Smith

INTRODUCTION

Wood may be sterilised by the use of dry heat, moist heat, chemicals in liquid or vapour phase, radiation and sonic disintegration. Heat is commonly employed but can result in some breakdown or loss of the wood materials or of chemicals which have been deliberately placed in the wood for toxicity test studies. Such losses can be avoided by the use of a suitable vapour sterilising agent which should display good toxicity towards fungi and bacteria, and have a rapid rate of diffusion. Formaldehyde has been widely used as a vapour sterilising agent (Sykes, 1958), but suffers from the disadvantage of having a poor rate of diffusion and a rapid rate of polymerization, which leads to the difficulty of removing it from the wood after treatment. Ozone has also been used as a vapour sterilising agent, but due to its great reactivity it lacks the ability to penetrate organic material to any depth and is thus only suitable as a surface disinfectant (Sykes, 1958).

The disinfecting power of propylene oxide has been examined by various workers. Ark (1947) found that propylene oxide under vacuum at concentrations of 1 ml. per litre killed *Fusarium solani*, *Verticillium sp.*, and a number of bacteria after only 10 minutes exposure at room temperature. The use of propylene oxide for sterilisation of liquid agar media is possible and seems to have no deleterious effects on fungi subsequently inoculated onto the treated agar (Klarman and Craig, 1960). Phillips (1949) and Kaye (1949) have made a useful study of propylene and ethylene oxides as well as other heterocyclic materials to be used as gaseous sterilising agents. They found that ethylene oxide was about twice as active as propylene oxide as a disinfectant and also could be more readily removed from the sterilised material after treatment. Brown and Fuerst (1963) successfully used 1% (v/v) ethylene oxide to sterilise liquid tissue culture media, but at this level residual ethylene oxide inhibited growth of the mammalian tissue cells. Unfortunately ethylene oxide forms explosive mixtures with air which tends to curb its general use, but its explosive nature can be overcome by mixing it with Freone or carbon dioxide and has been widely used in this form (Schley, Hoffman and Phillips, 1960, also Phillips and Warskowsky, 1958). The effect of a mixture of 10% ethylene oxide and 90% carbon dioxide on wood destroying fungi growing on wood has been examined by Kowalik and Sadurska (1962), who showed that periods of exposure of only four hours inhibited growth of these fungi.

Roff et al (1963) have suggested that residues of propylene oxide left in the wood blocks after a sterilisation process using this gas reduced the growth of some brown rot fungi. Inhibition of growth of L. lepideus Fr. in toxicity tests to British Standard 838 was ascribed to the same cause so the use of propylene and ethylene oxides and also methyl alcohol as volatile fungicides was examined more closely. Preliminary experiments indicated that the age of the L. lepideus F.P.R.L. No. 7B cultures might affect the ability of the fungus to withstand traces of propylene oxide, so additional experiments were carried out to verify this observation.

MATERIALS AND METHODS

Beech, Scots pine and western hemlock sapwood blocks were used in these tests in order to compare timbers differing greatly in their permeability to gases, beech being the more permeable. The wood blocks, 5 x 2.5 x 1.5 cm., were oven dried at 100°C. for 18 hours and their initial dry weights recorded. Replicate samples of four blocks were then sterilised by exposure, either to propylene oxide or methyl alcohol vapour for 6, 12, 18, 24 and 48 hours. Approximately 10 ml. of liquid propylene oxide or methyl alcohol were used in a sterilisation chamber of about 6.2 litre capacity. After the required sterilisation period the sterilising chamber with its lid removed was placed in a sterile air stream in a ventilated sterile hood (Harris-Smith, Pirt and Firman, 1963). Replicate samples of four blocks each were removed from the chamber after 6, 12, 18 and 24 hours of ventilation and were exposed to attack by L. lepideus for three months at 22°C. following the method laid down in B.S.838.

At the end of the incubation period the blocks were examined for signs of decay; the necessary weight measurements were recorded and the moisture contents and dry weight losses of the blocks calculated. The moisture content of all the test blocks was found to be suitable for fungal growth. Control blocks which were sterilised by autoclaving at 121°C. for 30 minutes were included in each test.

The effects of propylene oxide on cultures of L. lepideus and L. Kauffmanii of different ages was examined by placing wood blocks (5 x 2.5 x 1.5 cm.), after gaseous sterilisation, on cultures from 3 to 28 days old in Kolle flasks or petri dishes. The blocks were sterilised by a treatment of 24 hours in propylene oxide vapour followed by ventilation in a sterile air stream for 24 hours. The effect of age of fungal culture upon the rate of decay of wood blocks which have been sterilised by autoclaving at 121°C. for 45 minutes was also tested.

The efficacy of ethylene oxide as a gaseous sterilising agent was examined by placing wood blocks in a vacuum vessel and after evacuation passing into the vessel 70% by volume of ethylene oxide vapour at room temperature. Water vapour must be present to achieve suitable sterilisation and 10 ml. of water were included in the vacuum vessel. After 24 hours sterilisation a vacuum was drawn for 10 minutes using a water pump which safely removed all ethylene oxide. The blocks were then removed aseptically from the vessel and ventilated in a stream of sterile air for 24 hours before planting on the cultures of L. lepideus and L. Kauffmanii in Kolle flasks and Petri dishes. These were examined for fungal decay after 3 months incubation at 22°C.

RESULTS AND DISCUSSION

When propylene oxide and methyl alcohol were used as sterilising agents for Scots pine sapwood blocks, exposure to the vapour for a period in excess of 12 hours was needed to completely sterilise the blocks. Although increasing the time of exposure of the blocks to methyl alcohol had a negligible effect on their subsequent rate of decay, when propylene oxide was used over increasing time periods, it reduced the rate of decay of the blocks and caused intense darkening of the fungus mycelium. However, the inhibitory effect of propylene oxide on the fungus can be minimized by increasing the period of ventilation of the blocks after treatment to about 24 hours. Also a short vacuum treatment after the gaseous sterilisation seems to be slightly beneficial to the subsequent rate of decay. Therefore, in further experiments using propylene oxide in this size of wood block, a standard sterilisation period of 24 hours followed by 24 hours ventilation in a sterile hood has been used. Such a treatment has negligible effect on 4-week old cultures of the fungi Coniophora cereballa, F. P. R. L. No. 11E, Poria vaporaria, F. P. R. L. No. 280, Merulius lacrymans, F. P. R. L. No. 12C and Polystictus versicolor, F. P. R. L. No. 28A, but will cause severe inhibition of the growth of L. lepideus.

Increasing the period of ventilation of the Scots pine blocks which had been sterilised with methyl alcohol had negligible effect on their subsequent rates of decay of L. lepideus. Since complete sterilisation of all blocks occurred using methyl alcohol for exposure periods in excess of 12 hours, these results would suggest that methyl alcohol is as efficient as propylene oxide as a disinfectant, but previous experience has indicated that methyl alcohol is very unreliable for sterilising wood blocks, especially beech. BS 838 tests carried out previous to these experiments using propylene oxide and methyl alcohol as alternative vapour sterilising methods for Scots pine sapwood blocks have resulted in many of the methyl alcohol treated blocks becoming contaminated whilst the propylene oxide treated blocks were free of contamination. In the present tests for exposure periods of 6 to 12 hours propylene oxide gave better sterilisation of Scots pine blocks than methyl alcohol, although both gases were unsatisfactory at these levels.

Sterilisation of wood blocks with ethylene oxide for 24 hours followed by ventilation in the sterile hood for 24 hours, gave excellent disinfection of the wood, and when the blocks were subsequently planted onto 4-week old cultures of L. lepideus in Kolle flasks no inhibition of the fungus resulted. The average dry weight loss of the ethylene oxide treated blocks was slightly greater than that of the autoclaved controls and much greater than that of the propylene oxide treated blocks. Using beechwood blocks, ethylene oxide gave more reliable sterilisation than propylene oxide, which sometimes failed to kill all the contaminating fungi within the wood. Further experiments using Petri dish culture chambers and a less efficient method for ventilation in the sterile air stream have resulted in the complete killing of all cultures, thus emphasizing the importance of adequate ventilation after sterilisation.

When propylene oxide was used to sterilise Scots pine beech and western hemlock blocks, the effect of toxic residues within the blocks on L. lepideus was affected by the age of the fungus culture, this depending on the strain of fungus. Scots pine and western hemlock blocks sterilised for 24 hours in propylene oxide and ventilated for 24 hours in sterile air did not appreciably inhibit the growth of young L. lepideus cultures but with older cultures severe browning of the fungal mycelium occurred and checking of hyphal growth. Beech blocks sterilised with propylene oxide similarly affected the growth of L. lepideus where much younger cultures showed inhibition by this treatment. This slightly greater inhibition of cultures by the beech blocks is probably a consequence of the greater permeability of beech to gas, the propylene oxide being able to penetrate deeper into the blocks and hence leave greater toxic residues within the blocks. The rate of decay of propylene oxide sterilised Scots pine and western hemlock sapwood blocks was also affected by the age of the L. lepideus cultures used. Very young cultures gave normal rates of decay, but older cultures decayed the wood blocks more slowly. These results indicate that there may be a physiological change which occurs with age in the L. lepideus mycelium which renders the older hyphae more sensitive to propylene oxide or perhaps the younger hyphae are more resistant to the toxic residues.

The rate of decay of autoclaved Scots pine and western hemlock blocks due to attack by L. lepideus was independent of culture age between 3 and 28 days. However, the dry weight losses of autoclaved blocks were slightly lower than those of propylene oxide treated blocks with young cultures, this difference being statistically significant at the 0.1% level. Thus, autoclaving with Scots pine blocks would seem to be slightly deleterious to the subsequent rate of attack by L. lepideus.

In the BS 838 (1961) which covers methods of tests for the toxicity of wood preservatives to fungi, the use of propylene oxide is recommended as a gaseous sterilising agent for wood blocks. However, since L. lepideus is one of the test fungi used (normally when fully covering the agar in the Kolla flasks, (i.e. about 4 weeks old) such a gaseous sterilisation treatment is no longer acceptable. Either ethylene oxide should be used with the normal 4-week old cultures of L. lepideus of a suitable strain or propylene oxide in conjunction with very young cultures.

Various workers have advocated the use of propylene and ethylene oxides as vapour sterilising agents for biological materials and have incorrectly assumed that no toxic residues remain adsorbed onto the material (Hansen and Snyder, 1947). From the tests presented in this paper it is evident that care must be taken to examine each fungal species, indeed each fungal strain, in its various stages of growth before concluding that no toxic residues remain in biological material sterilised by these gases.

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THE USE OF ANTIBIOTICS TO CONTROL BLISTER RUST ON WESTERN WHITE PINE IN BRITISH COLUMBIA

Denis R. Glew

Although antibiotics have been used as a control measure applied to the tree in the form of a basal spray, the physical and economic limitations of this form of application in British Columbia have favoured foliar application by helicopter. Thus, in duscussing the efficacy of antiobitics as a control measure against blister rust, the observations contained in this paper are limited to the results obtained following the foliar application of Phytoactin L318 applied at 7.6 gms. per acre. The acreage sprayed to date is approximately 5,500 acres over the period 1962-1964. In fact discussion will be limited to the results obtained following the 1962 and 1963 applications. In order to appreciate the findings to date it will be necessary to outline the methods and procedures which have been set up to evaluate the project.

In British Columbia evaluation of control is based on a total stand concept i.e. no attempt has been made to select a specified type of tree or canker. Transects are run through the forest and all western white pine along the transect are described prior to spraying. Information is collected pertaining to the host, the parasite and the environment. This and other field information is then coded and punched on cards for processing on an IBM 1620. In addition scale drawings are made annually for each blister rust canker.

The use of antibiotics to control forest tree diseases is a fascinating concept. However, evaluation of the efficacy of antibiotics used to control white pine blister rust is an extremely complex problem involving a range of variables. Variables occur in the host, pathogen, environment and finally in the formulation and application of the antibiotic. This has led to the exploration of many different avenues in an attempt to find criteria and it has been decided that the only acceptable parameters are growth and mortality of blister rust cankers. It would appear that the ultimate success of a white pine blister rust control program can only be interpreted in terms of tree growth and tree mortality. These terms can only be obtained over an extended period and so in the interim it is necessary to consider alternative criteria viz:- rust - canker growth and rust - canker mortality.

In examining these parameters one is forced to recognize yet another problem; namely that canker mortality is extremely difficult to diagnose. The only dead cankers which have been observed in the treated area of British Columbia which can confidently be classed as dead, were on dead trees. Experience has shown that individual cankers exhibit a wide range of symptoms and that many of the criteria originally used for evaluation may be masked. For instance, the production of aecia in British Columbia is often extremely irregular and the absence of aecia is therefore not an acceptable criterion. Inasmuch as an assessment based on the physical characteristics of a canker would be extremely useful, attempts were made to determine the significance of the various colour changes in individual cankers by X-rays and qualitative sugar starch analysis. Although some success has been obtained in differentiating colour zones, the final evaluation should depend on more precise data.

Logically it is reasonable to assume that cankers grow at different rates depending on variables associated with the host, pathogen and environment. In analysing the data an attempt has been made to ascertain which factors affect canker growth by analysing our data in a step by step multiple regression. This approach has been used because there is always a possibility that technical limitations in dosage, formulation or application may be responsible for the apparent failure of a programme.

Thus attention initially has been focused on changes in percentage of girdle and canker size. Step by step multiple regression analyses using 15 variables suggest changes in canker size are influenced primarily by original canker size and site index, in this instance an expression of tree vigor, whereas changes in percentage of girdle are affected by the d. b. h. of the host, original percent of girdle, growth in canker size and the area of the canker. The analysis also suggests that the number of lethal branch cankers, i.e. cankers within 12 inches of the bole, is more important than originally anticipated.

Tests of significance between treated and untreated trees indicate no differences in rate of growth of cankers and growth expressed in terms of change in girdling. These tests substantiate visual observations.

In field examinations particular attention is paid to the presence of fungi on the blister rust canker. To date, seven different fungi have been identified, of which Tuberculina maxima and Dascypha agassizii are the most common. In assessing individual cankers particular attention is paid to cankers having Tuberculina maxima on them.

In conclusion, while the analysis is not yet completed, it suggests that the foliar application of Phytoactin L318 in British Columbia has not produced the desired results. However it would be premature to make any conclusions until the data have been fully analysed. Nevertheless, no differences in the rate of canker growth or growth expressed in terms of change in girdling have been detected either by direct observation or through appropriate tests of significance nor have dead cankers on living trees been observed in any of the treated areas. The results to date are not satisfactory and the need for a systemic antibiotic which can be used economically in the forest still remains.

APPENDIX I

ACTIVE PROJECTS, NEW

(Project leaders' affiliation and address are given in Appendix VII)

A. Forest Disease Surveys - None

B. Noninfectious Diseases - None

C. Cone, Seed, and Seedling Diseases - None

D. Root and Soil Diseases or Relationships

65-D-1 The pathogenicity of *Verticicladiella wagenerii* to *Pinus* spp. (R. S. Smith).
Objectives: a. To determine the impact in natural stands of pines. b. To investigate the host-pathogen interrelationships.

65-D-2 *Fomes annosus*, is it a threat to immature stands in British Columbia? (G. Wallis).
Initially three phases which would influence disease intensification are to be investigated.
Objectives: a. Measurement of aerial spore populations at specified periods throughout the year using rough quantitative methods. b. Determination of the susceptibility of stumps to spore infections, particularly stumps of Douglas fir, western hemlock and western cedar. c. If stumps are susceptible to infection, to ascertain if the fungus is able to infect the roots of adjacent residual trees.
In addition to the above, investigations are underway to determine if bark beetles and ambrosia beetles could be responsible for spread of the disease by a transfer of spores to uninfected tissue.

65-D-3 Inter-relationships Between Root-Pathogenic Fungi, Especially *Fomes annosus*, and Bark Beetle Infestations in Coniferous Forests. (F. W. Cobb, Jr., principal investigator, with J. R. Parmeter, Jr., R. W. Stark, D. L. Wood, and E. Zavarin).
Objectives: To determine: a. The importance of *F. annosus* and other root-disease organisms in initiating foci of bark beetles. b. The changes in host physiology induced by root-pathogenic organisms as those changes may be related to susceptibility to bark beetles.

Studies aimed at the second objective initially will include investigations of the effect of infection of F. annosus on oleoresin exudation pressure, volatile terpene constituents, the olfactory responses of various beetles to tissues from diseased trees, and susceptibility of diseased trees to blue stain fungi.

E. Foliage Diseases - None

F. Stem Diseases - Malformations, Witches brooms, Dwarf mistletoe, etc.

65-F-1 A study of the factors influencing reproduction and parasitism by Arceuthobium americanum Nutt. (J. A. Muir). Objectives: a. to study the spread and intensification of dwarf mistletoe in young stands. b. to study seed production and flowering of A. americanum in relation to various environmental factors and on different sites. c. to study the development and epiphytology of hyper-parasites of the dwarf mistletoe.

65-F-2 The effect of dwarf mistletoe on growth of Western Hemlock (Kenelm W. Russell).
Objectives: Determine quantitatively how much Western Hemlock growth is influenced by dwarf mistletoe through: a. Detailed mensurational individual tree studies. b. Later application of above data to infected stands versus disease free stands.

G. Stem Diseases - Stains and Decays

65-G-1 Factors influencing resistance of lodgepole pine to attack by the bark beetle-blue stain fungi complex.--Pathological aspects. (H. S. Whitney).
This is a new title for a project (59-G-2) formerly called: Studies on blue stain of bark beetle infested lodgepole pine. The new title represents a re-orientation and integration of this project into a 'multidicipline approach' to the bark beetle problem. Dr. R. W. Reid, Entomologist and project coordinator and Dr. D. M. Shrimpton, Plant Physiologist, are full time collaborators. The overall objective is to increase our knowledge of factors influencing resistance of forest trees to attack by bark beetles and their associated blue stain fungi. The long term objective of the pathological aspects is to determine the role of blue-staining fungi in the mortality of lodgepole pines and the interrelationships between these organisms and the associated bark beetles.

H. Stem Diseases - Rusts and Cankers

65-H-1 Inoculation of sugar pine with *Cronartium ribicola* through bark grafts. (H. H. Bynum).
Objectives: To investigate techniques of grafting blister rust-infected bark onto healthy sugar pine to provide infections with a high standard of uniformity for fungicidal control studies.

65-H-2 Treatment and sampling of western white pine trees for bioassay of actidione. (Charles D. Leapheart; cooperative study with W. R. Phelps, Lake States Station).
Objective: To determine, by bioassay, the translocation and persistence of actidione in western white pine and to compare the pattern of distribution and persistence found in western white pine to the pattern observed for eastern white pine.

65-H-3 Western gall rust epidemiology, symptomatology and life cycle. (F. W. Cobb, Jr., J. R. Parmeter, Jr., David L. Nelson).
Objectives: To investigate: a. Aeciospore viability in storage and *in vivo*; germination *in vitro* on artificial and host surfaces under controlled conditions. b. Conditions for infection of the host by aeciospores involving temperature, moisture, time, and susceptible host tissue requirements. c. Mode of aeciospore germ-tube penetration and early disease symptom development. d. Host range of *Peridermium cerebroides* and *P. harknessii* on *Pinus*, *Quercus* and *Castilleja* species.

65-H-4 Cytology of western gall rust fungi. (J. G. Christensen).
Objective: To examine nuclei of *Peridermium harknessii* (including the albino variant) in relation to short-cycling on pine.

65-H-5 Cytospora canker associated with dieback of dwarf mistletoe infected branches of red fir in California. (R. F. Scharpf, R. S. Smith).
Objectives: To investigate: a. The frequency of *Cytospora* associated with dwarf mistletoe-infected branches. b. The mode of entrance of *Cytospora* into mistletoe-infected branches. c. The pathological anatomy and host-parasite relationships of the infected branches. d. The variation of the fungus and its growth in culture.

I. Wilt and Blight Diseases - None

J. Defects and Decays of Forest Products

65-J-1 Incense cedar pocket rot: effects of infection and biology of the causal fungus. (W. Wayne Wilcox).
Objectives: a. To determine the nature of the effects upon wood microstructure and composition produced by *Polyporus amarus* infection. b. To determine properties of the fungus or its substrate which may contribute to the high degree of host-specificity and to the production of the pocket form of decay.

65-J-2 The use of gas chromatographic methods for carbon dioxide detection in the respiration of fungi attacking wood. (Roger S. Smith).
Objectives: a. Acceleration of preservative testing methods. b. General physiology of white rots, brown rots, etc.

K. Miscellaneous Studies

65-K-1 Environmental requirements of *Tuberculina maxima* in culture. (H. H. Bynum).
Objectives: To study the *in vitro* environmental requirements of *T. maxima*. Particular attention will be given to factors affecting sporulation.

65-K-2 The incubation period of *Tuberculina maxima* Rostr. (James W. Kimmey and Ed F. Wicker).
Objective: To determine how soon, under measured temperature and humidity conditions, after a susceptible blister rust canker is successfully inoculated with viable *T. maxima* spores will infection become macroscopically visible, e.g., produces new *T. maxima* spores.

65-K-3 Fungi associated with *Peridermium cerebroides* Meinecke on *Pinus radiata* D. Don. (James W. Byler, F. W. Cobb, Jr., J. R. Parmeter, Jr.).
Objectives: a. Examine rust galls at various stages of development to collect data concerning non-uredinaceous fungi associated with them. b. Determine by inoculation the effect of certain of these fungi on rust and gall development, and conditions favoring their action. c. Study histologically the location and action of these fungi on rust and host tissues.

65-K-4 *In vitro* testing of fungicides on spores of *Cronartium ribicola*. (H. H. Bynum).
Objectives: To investigate the feasibility of using *in vitro* tests as a basis for selection of fungicides which warrant screening in the field.

65-K-5 Survey of naturally inactivated lethal-type blister rust cankers on young western white pine in the Inland Empire. (James W. Kimmey).
Objective: To determine the present level of natural biological control of blister rust in western white pine stands to 35 years of age on areas not treated by antibiotic spraying in the Inland Empire.

65-K-6 The effect of treating western white pine stands with antibiotics on the normal fungal population (Orson K. Miller).
Objective: To enumerate the species of higher basidomycetes which occur in treated and untreated western white pine stands to see if alterations of fruiting patterns are observed following treatment with antibiotics.

APPENDIX II

TERMINATED PROJECTS

56-G-2 Distribution and damage survey of the dwarf mistletoes. (D. P. Graham).

63-G- The nutritional requirements for Fomes pini. (Orson K. Miller).

63-K- A monograph of the western species of the genus Lentinus Fries. (Orson K. Miller).

63-K- Translocation of cycloheximide into new growth of western white pine seedlings. (W. T. Collins and J. W. Koenigs).

63-K- Affinity of cycloheximide for water. (W. T. Collins and J. W. Koenigs).

53-D-6 Phytophthora cinnamomi Root Rot of Douglas-Fir. (L. F. Roth). Experience previously gained concerning behavior of this fungus in the field and in soil temperature tanks in the greenhouse, has been interpreted in the light of recent studies out-of-doors where the soil environment was partially controlled. Soil temperature tank studies disclosed a threshold for pathogenesis at 60°F. The recent studies have shown that winter soil temperatures are always below this threshold and also that summer soil moisture is consistently below the point required (approximately field capacity) for fungus growth, consequently we have advised our Forestry people that this disease is unlikely to become a problem in Forestry in Western Oregon, because summer soil moisture and winter soil temperature are too low for pathogenesis. It is interesting to note that these adverse influences are on pathogenesis rather than on survival of the fungus.

Fungi Associated with Douglas-Fir Seed During Development and Early Storage. (L. F. Roth).
A distinctive fungal flora is associated with the seed of Douglas-fir. This flora undergoes both quantitative and qualitative changes from the time the budscales are shed and the seedsbegin development, through harvest, into storage, and through storage into the soil. The significance of these fungi has not been determined, but there is evidence that biotic protective influences are involved. Lewin Gordon has recently followed the development of the fungal flora from bud burst through brief storage. The numbers of both individuals and species increases as the cone develops and remains high through maturity and seed harvest. Both species and numbers decrease rapidly as seed storage continues. The data shows presence of a "field flora" comparable to those described for small grains and the seed of agricultural crops. This flora contains mostly saprophytic fungi, but genera containing

pathogenic species are common. As a whole these organisms are evanescent and drop to very low levels in storage. The fungal floras from harvested cones and from seed naturally discharged in nature were very comparable.

APPENDIX III

NEW OR MODIFIED TECHNIQUES

POLYTHENE BAGS FOR CULTURE CHAMBERS
J. W. Roff

In Forest Products Pathology we are occasionally required to inoculate relatively large pieces of wood in order to study the effects of specific fungi upon strength, pulping, colour etc., or perhaps to examine the development of decay from early to late stages. Using the larger sample of wood rather than the usual small, cube type, the intent is to simulate conditions for fungal growth which pertain to timbers or logs in which a large bulk of wood is involved.

In any event large samples involve large sterile containers or chambers to hold the material and as the rate of decay may be slow in a bulky piece, the chamber may be required for perhaps months. While containers of this general type are available, dessicators, battery jars, chromatography tanks, bell jars etc. they are bulky, expensive and difficult to sterilize. We have found the common polythene bag to be a useful substitute.

Wood blocks up to 5 x 10 x 10 cm. are prepared for inoculation by boring a central (1 cm.) hole approximately halfway through the face, and then they are surface sterilized. Inoculum is then placed into the hole which is closed with a sterile cork and the block placed aseptically into the bag. We have placed four blocks together into a 16 lb. bag and the ends are drawn together with an elastic band around a bent glass tube for aeration. Sterile water may be added if required.

Our experience has been limited to *Fomes pini*, *F. laricis*, *Poria carbonica* and *P. monticola*.

The bags are durable and sufficiently transparent for photography and for classroom display. The material can be handled through the bag and inspected on all sides with little or no danger to the culture.

Admittedly sterilization is minimal. However, the fresh unused bags are apparently clean and, so far, we have not been held up by contaminants. Some moulds have appeared but we find that these are overgrown and do not halt the deep-seated decay.

QUANTITY INOCULATIONS WITH DWARF MISTLETOE

L. F. Roth

Inoculations with dwarf mistletoe have been tedious because of the necessity of individually removing the seeds from the substrate on which they were originally collected and transferring them to the foliar axils of the host to be inoculated. Such procedures are so time-consuming as to be completely impractical for conducting large studies on mistletoe seed retention or for mistletoe resistance testing. While outplanting of trees to be inoculated as an understory below an overstory has some possibilities, there are many disadvantages to this procedure also. The more important are: low seed volumes, even under the most severely infected overstories, and lack of uniformity of seed dispersal.

Knowledge that mistletoe seeds are intercepted by the foliage rather than the stems of the suscept, along with the now commonly employed procedure of collecting seed in paper bags, have removed certain obstacles to quantity inoculations. Most mistletoe seed is intercepted by foliage of the current season's growth and the wood bearing this foliage is the most susceptible. Seed placement on needles of the current season therefore seems correct. We have found this placement quite easily accomplished by cutting a square with adhering seed, approximately three inches on the side, from the bag which the seed were collected in, and placing the face of the square, face down against the terminal bud of the shoot to be inoculated. By providing back pressure with the palm, the paper can be rotated slightly against the flaring needles, causing the seed to be transferred from the paper to the needles of the pine shoot. Transfer is so complete that where papers are employed bearing a known number of seed, it is possible to make transfers that are numerically comparable.

USE OF AN ELECTROSTATIC PRECIPITATOR TO REMOVE AIRBORNE SPORES

J. C. Hopkins

The electrostatic precipitators now available provide an efficient means for reducing contamination in inoculation chambers and other small rooms. This method of spore removal has the advantage over steaming in that it leaves the room pleasant to work in. It can be used in any room in which a 110-volt and 60 cycle power supply is available. Electrostatic precipitators operate by blowing air through a high voltage grid to impart a positive charge onto each spore and then through a negatively charged grid to attract and collect the spores. The following notes relate some test results obtained with the Honeywell F38A portable electronic air cleaner. Other manufacturers also make somewhat similar units.

The Honeywell portable unit was tested in a room 14 feet long by 6 feet wide and 8 feet high. The unit was placed centrally with its base 2 feet above the floor. A spore trap, of the type which pulls air in through a small orifice and then impinges the air and accompanying spores onto a vaseline covered slide, was placed beside the precipitator with the inlet tube directed towards the initial spore source. A powerful fan was used for 3 minutes to distribute Penicillium spores (spherical spores 4.2-6.3 μ in diameter from a mouldy orange) throughout the room. Spores were trapped for a 2 minute period immediately after spore distribution and after 15 minute periods in which the precipitator was used. The precipitator was switched off while the spore trap was operated although the internal fan was left on to continue circulating air. The initial spore count was 1,200,000. Subsequent counts were 20,000; 2,250; 102; and 22. The last count thus represents the figure obtained after operation of the precipitator for a total period of one hour. The extent of sedimentation during the experiment was estimated by leaving Petri plates containing agar open on the floor for one hour. However, relatively few colonies developed and it was concluded that the precipitator was responsible for virtually all the reduction in the spore count.

A subsequent test under similar conditions but employing Rhizopus spores (4.8-7.8 x 9.5-12.7 μ) produced successive counts of 4,500; 187; 44; 8; and 6.

Subsequent experience with the Honeywell unit has confirmed its utility. However, an additional procedure has been found necessary in cleaning rooms in which sedimentation has occurred. Accumulated settled dust is dispersed with a portable fan passed systematically over the entire floor and wall surfaces at a few inches from the surfaces concerned. Meanwhile, the precipitator is left running. This reduces the possibility of spores becoming airborne when the floor and wall surfaces are disturbed as for example by walking.

ANOTHER METHOD FOR PRESERVING FUNGUS CULTURES

H. S. Whitney and A.H.H. Grinchenko

If you want to preserve fungus cultures without using adhesive and Parafilm, which is rather troublesome, or without preparing cellophane cultures, which is unsatisfactory for many "cellulose eaters", you might try growing them in plastic Petri plates (Falcon Plastics) 6 cm. diam. on their favorite medium in 2.5% agar. This medium does not adhere to plastic as it does to glass. Furthermore, at least under our conditions which are admittedly fairly dry, the cultures did not curl when left on the lab bench to dry. They dried flat, forming a thin wafer that could be placed in a cellophane bag, mounted on a white card and filed in a box. Numerous fungi have been so preserved with hardly any more effort than that required to slip the dried culture into a cellophane bag.

Just to see if it would work, and it did, we fumigated (formaldehyde) some cultures at different stages of development, up to 2 weeks at 2 day intervals, before letting them dry. The fumigation did not affect lack of adhesion to the plastic or the non-curled drying and we obtained a series of wafers of cultures in different stages of development. It seems important to begin with at least 5 ml. of medium in the plates.

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APPENDIX V

MINUTES OF THE BUSINESS MEETING OF THE 13th WIFDWC

The business meeting was called to order by Chairman, Jack Bier, at 7.30 P.M. Thursday evening, September 9, 1965. J. C. Hopkins was acting secretary possibly due to Whitney's over indulgence at the banquet.

Secretary's Report: The minutes of the 12th meeting were adopted as they appeared in the Proceedings.

Treasurer's Report ($U.S.)

	Credit	Debit
Balance from 12th WIFDWC	$288.30	
Registration and banquet	571.45	
Banquet and hotel expenses		$473.84
Miscellaneous (coffee, registration, gratuities, rentals, etc.)		135.69
Total.	$859.75	609.53
Balance (January 1, 1966). . . . . Wells Fargo, Berkeley, California	250.22	

G. Wallis expressed concern that cash on hand should not be allowed to accumulate beyond $100.00. Most members agreed.

Mistletoe Committee Report: See Appendix VI for report circulated at the meeting. Ed Wicker's contribution has been incorporated.

Dick Parmeter and Keith Shea noted that it was time (3 years) to rotate the chairmanship of the Mistletoe Committee and moved that Joe Baranyay be appointed. Seconded by Don Lephart. Acceptance of the report was proposed by Shaw and seconded by Lephart. Carried.

Forest Disease Recreation Committee Report: The forest disease-recreation committee as constituted at the 10th annual meeting of WIFDWC continued with the surveillance of problems and techniques of interest to forest pathologists in the rapid enlarging field of recreation research.

Research priorities and problem selection as affected by recreation needs and the widespread interest of forest and park managers in the survey and appraisal of hazardous trees in campgrounds, continued to be the two areas of greatest concern to forest pathologists. Your committee calls attention to a new study by Lee Paine at the Pacific Southwest Station on decays in lodgepole pines of high elevation recreation areas in California. Recreation research at PSW Station is cooperating in this study which has been assigned top priority, not because of the commercial value of lodgepole as a forest species in California, but because of its prevalence in many of the campgrounds and recreation areas in the State.

Furthermore, there is still much to be done by pathologists in expanding our practical knowledge of tree hazards and the impact of decay and disease on the longevity and stability of forest trees. Willis Wagener continues to receive questions as well as praise for his excellent publication in this field.

The committee concludes this brief report to the 13th WIFDWC with two recommendations: - 1. That a disease-recreation committee continue to serve WIFDWC in matters both substantive and procedural to encourage orientation of disease research towards recreation needs and to stimulate discussions of related pertinent subjects at annual meetings. 2. That in keeping with established policies of this work conference the present chairman and committee be honourably discharged having now served a 3-year term and a new committee be appointed to continue with this useful assignment.

Ray Foster, George Harvey, Harold Offord (Chairman)

After some discussion, Lee Paine was appointed Chairman of the new committee with Gordie Wallis and Harold Offord as committee members.

Committee on Ecology and Forest Diseases (Not a standing committee):

Dick Smith, Victoria, made an appeal for comments on the information sent out last year with the Proceedings. After discussion it was agreed that a list of ecological references oriented more towards pathology would be valuable: and it was suggested that such a list be prepared either for inclusion in the Proceedings of this meeting for distribution with the Proceedings. Dick Smith agreed to continue "committee" operation, but appealed again for assistance.

Old and New Business:

Honourary Life Members: On the suggestion of Jack Bier, the following persons were proposed for honourary life membership. Mr. L. J. Farmer, Mr. H. R. Offord, Dr. William G. Solheim, Dr. W. W. Wagener and Dr. E. Wright. This was not intended to be a complete list of those eligible for honourary life membership. Bob Scharpf noted that these names wereto be listed separately in the Proceedings. Agreed.

The secretary was instructed to send a telegram to Frank Hawksworth expressing regret that he could not be present and wishing him a speedy and complete recovery. A "thank you" letter was received from Frank on October 1, 1965.

14th and 15th WIFDWCs: The virtues of holding the 14th WIFDWC in the area of Bend, Oregon, were extolled by Don Graham. Gardner Shaw moved and Ed Wicker seconded that the 14th WIFDWC be held at Bend, Oregon. Carried.

Chairman Bier suggested, after discussion, that the incoming chairman correspond soon with our contacts in Mexico regarding the possibility of obtaining an invitation to hold the 15th WIFDWC in Mexico.

Interim Program Chairman, Ed Wicker, mentioned the following topics for consideration at the next meeting: terminology and communication in Forest Pathology; *Tuberculina maxima*; Hyperparasitism and Commensalism, to include *T. maxima*; Diseases of the Bend area; Wider Aspects of Fungal Deterioration of Wood Products.

Election of Officers:

Don Lephart was elected Chairman and Don Graham, Secretary-Treasurer of the 14th WIFDWC.

APPENDIX VI

COMMITTEE REPORT ON STATUS AND NEEDS OF RESEARCH ON DWARF MISTLETOES

(COSANOROD)

J. A. Baranyay, F. G. Hawksworth, K. R. Shea,

and J. R. Parmeter, Jr. (Chairman)

Highlights of 1965 Research

I. Taxonomy, Hosts, and Distribution

a. Greenhouse inoculations using naturally disseminated and germinated *A. campylopodum* seed collected from western hemlock (f. *tsugensis*) were carried out in the Spring of 1964 and 1965. Successful infections from the 1964 series have occurred on coastal hemlock, interior hemlock (Arrow Lakes area), white spruce, and interior lodgepole pine. First shoot emergence noted was on November 25, 1964 on a lodgepole pine inoculated April 28, 1964. Most significant is the susceptibility of hemlock from the interior of B. C. - - an area where mistletoe has not yet been found on hemlock.

Inoculations on outplanted trees were continued in October, 1964. A check in May, 1965 showed that retention (2583 of 2730 seeds) and germination (743) with radicles) were higher than for the 1963 inoculations. Several swellings (some with shoots) have resulted from the 1963 inoculations. (Smith, Victoria).

b. Field studies of *Arceuthobium* were made in Baja California, Mexico. The results indicate that two members of the genus are present in this state: *A. campylopodum* f. *campylopodum* on *Pinus jeffreyi* and *P. coulteri* and *A. campylopodum f. divaricatum* on *Pinus quadrifolia*. The latter has not been previously reported on this host or from Mexico. Both dwarf-mistletoes occur in the Sierra Juarez and in the Sierra San Pedro Martia, the two principal mountain ranges in Baja California. (Hawksworth & Lightle, RM, and Scharpf, PSW).

c. The committee report for 1962 contained a report by Wicker (WSU) that seedlings of the coastal form Douglas fir became infected with *Arceuthobium douglasii* as a result of artificial inoculation under greenhouse conditions. It can now be reported that the coastal form Douglas fir is susceptible to infection by *A. douglasii* when growing in its natural habitat in western Washington. (Wicker, INT-WSU).

II. Physiology and Anatomy

a. Anatomical studies of host-parasite relationships in infected fir failed to show any evidence to support the concept of "gliding" growth of host phloem around and past the cortical strands. Cortical strands were pushed out with the host phloem and in some instances were cut off by cork cambium. Spacial integrity of the endophytic system is apparently maintained by synchronous intercalary meristematic activity of the sinkers in the host cambial zone. (Parmeter, U.C., & Scharpf, PSW).

b. Dissection of stem infections in white fir showed that the development of large stem swellings or their absence apparently results from inherent variation in individual mistletoe plants, rather than to characteristics of the host at the time of or following infection. Infections of nearly the same age on the same tree often varied greatly, some showing marked swelling, others showing little or no swelling. Rates of longitudinal and tangential spread in the stem were also highly variable. (Parmeter & Platt, U. C., and Scharpf, PSW).

III. Life Cycle Studies

a. Seed traps placed around an isolated western hemlock (30 ft. high) yielded 284 seeds. Based on a 4 per cent coverage of the ground, it is estimated that 7100 seeds were produced and projected successfully from the tree. Dispersed seeds reached an area of 2600 sq. ft. surrounding the tree. Production of seed and coverage was less in a 63 ft. western larch (1025 seeds and 1100 sq. ft.). Peak period of dissemination for hemlock was the third week of October, and for larch the middle of September. (Smith, Victoria).

b. Dissection of 43 infections of known age established by inoculation of red fir showed that, on the basis of swelling in annual rings, the year of infection could be determined in about 65 per cent of the cases. Age of the remaining 35 per cent could be determined to within 1 year. (Scharpf, PSW, and Parmeter, U. C.).

c. Information on the "incubation period" of Arceuthobium americanum in Colorado is being determined by annual examination of about 6,000 seeds. The results to date indicate that about 85 per cent of the resulting infections first bore shoots in the third or fourth year after seed dispersal. The extremes range from 2 to 6 years. (Hinds & Hawksworth, RM).

d. Meiotic chromosome counts have been completed on most of the U. S. members of Arceuthobium. All show a basic number of n = 14, the same as in Phoradendron. These studies show that there are two periods of meiosis in Arceuthobium: The members of the A. campylopodum and A. vaginatum complexes undergo meiosis (microsporogenesis) a few weeks prior to flowering while in some spring-flowering mistletoes (A. americanum, A. douglasii, A. pusillum, and A. gillii) meiosis takes place during the preceding fall, usually in September. (Wiens, Univ. of Utah, & Hawksworth, RM).

e. Methods of collection, field and laboratory storage, viability testing, and germination of dwarf mistletoe seeds are reported in Wicker's Ph.D. thesis, 1965. (Wicker, INT-WSU).

f. Treatment of freshly collected seeds of Arceuthobium americanum, A. campylopodum f. campylopodum, A. c. f. laricis, and A. douglasii with 3 per cent H_2O_2 indicates that a short period of dormancy (ca. 24 days) exists for these taxa, providing that the assumption that seeds are mature when naturally expelled is valid. (Wicker, INT-WSU).

g. Results of investigations of the klendusic factors of target area and seed destiny for Douglas fir and western larch and six taxa of Arceuthobium enlighten the explanation of the lack of infection in natural stands of young susceptible seedlings. Klendusity, especially the small target proffered by seedlings, and snow and rain removal of dwarf mistletoe seeds, combined with the fact that infection may be lethal to small seedlings, explains the failure to observe infected seedlings in natural stands. Height, sufficient to overcome these factors, rather than age per se, determines when initial persisting infections occur. (Wicker, INT-WSU).

IV. Host-Parasite relations - (no reports)

V. Effects on Hosts

a. Impact of dwarf mistletoe on the growth of western hemlock. Data from 30 trees being processed. (Smith, Victoria).

b. Dwarf mistletoe and its effect on growth and mortality in lodgepole pine stands of Alberta. The project was terminated, results will be discussed under panel 1. (Baranyay, Calgary).

c. A. vaginatum on ponderosa.

At Mescalero, uninfected trees had an average basal area increase per tree of 0.07 sq. ft. over a 10-year period. Increase for trees initially rated as 1, by the Hawksworth system, was slightly more but as the dwarf mistletoe rating increased above 1 the average basal area per tree decreased and the trees initially rated 6 had a minus 0.02 sq. ft. after 10 years. The zero line was crossed between ratings 5 and 6.

Trees on untreated plots at the Grand Canyon, over essentially the same 10-year period, showed that uninfested trees had an average basal area increase of 0.05 sq. ft. per tree. Increase for trees initially rated 1 was 0.11. As the Dwarf mistletoe rating increased above 1, the average basal area per tree decreased. The zero line was crossed between ratings 2 and 3 and trees initially rated 6 had a minus 0.80 sq. ft. after 10 years.

For Grand Canyon the greatest impact of dwarf mistletoe was to intermediates where trees initially rated 6 had a minus 2.3 sq. ft. average basal area per tree after 10 years. Least impact was to saplings where the impact was 0.03 sq. ft. Data for saplings and poles combined closely approximated that from the Mescalero. (Grand Canyon stands are virgin and multi-aged while those at Mescalero are heavily cut-over and consist of reproduction, saplings, and poles). Dwarf mistletoe intensified by about 1 rating point over the 10-year period. (Lightle, RM).

VI. Ecology - (no reports)

VII. Control-chemical - (no reports)

VIII. Control - Biological

a. Colletotrichum gloeosporioides was found on Arceuthobium campylopodum f. divaricatum on Pinus quadrifolia in the Sierra Juarez Mountains, Baja California. (Scharpf PSW & Hawksworth RM).

b. The fungus Pestalotia maculiformans Guba & Zeller was collected on shoots of A. c. f. abietinum. The mode of life of the fungus with respect to dwarf mistletoes is unknown.

c. Larvae of Callophrys spinetorum (Hew.) were found feeding on the shoots of A. americanum, A. campylopodum f. campylopodum, and A. c. f. laricis. The larvae were not abundant and dwarf mistletoe shoot destruction was only minor in the areas where collections were made. Larvae were more often found feeding on male shoots than on female shoots. They were similar in color to the male flowers on the host shoot and were thus camouflaged. (Wicker, INT-WSU).

IX. Control - silvicultural

a. This year we were finally able to publish the results of the pruning out of dwarf mistletoe on a plot established in 1926 in young ponderosa and Jeffrey pine second growth infected with Arceuthobium campylopodum near the eastern boundary of the Lassen National Forest in California. Nine years of annual removal of infections and prevention of seedling by the parasite failed to completely eliminate the parasite from central portions of the plot, which were beyond the limits of mistletoe seed dispersal from outside the plot. Spread back into the plot by the parasite averaged about 0.9 feet per year. Jeffrey pine had almost twice as many infections as ponderosa pine. Re-establishment of the parasite in the plot has been slow and will not seriously damage the present stand. (Wagener, PSW).

b. A cooperative study by Region 2 Pest Control and the RM Station was begun on silvicultural control of dwarfmistletoe in young lodgepole pine. Dwarfmistletoe control is being tested in plots of various ages and degrees of infection. The objective of the study is to determine which stands can be sanitized and which should be destroyed and begun anew. (Stewart & Landgraf, R-2, Denver, and Hawksworth & Hinds, RM).

X. Surveys

a. Research on the dwarf mistletoe aerial survey was not continued in 1964 because of technical difficulties with the contracting company. (Baranyay, Calgary).

XI. Miscellaneous - epidemiology

a. A study of the infection rate (rate of increase) of dwarf mistletoe in young stands of lodgepole pine has been started. In a dense and a fairly open stand, no difference in infection rate over the last seven years was found. It appeared in one area that mistletoe spread more rapidly from isolated, infected, residual trees than from the margin of infected residual stands into the young regeneration. (J. A. Muir, Calgary).

Needed Research

a. An objective, quantitative method for measuring the amount of disease caused by dwarf mistletoe is urgently needed. It appears that studies on growth impact, distribution and epidemiology of dwarf mistletoes are quite limited due to a lack of quantitative evaluation of disease intensity. (J. A. Muir, Calgary).