SURVEY AND EVALUATION FOR BLACK STAIN ROOT DISEASE IN YOUNG COASTAL DOUGLAS-FIR PLANTATIONS

by

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FOREWORD

This report is one of a series of internal reports distributed by Forest Protection Branch, B.C. Ministry of Forests, to record accomplishments and interim or provisional results for the information of staff, colleagues, and others.

In the Canada-British Columbia Forest Resources Development Agreement (FRDA) 1985 to 1990, over 100 pest control projects were directly funded by the province and administered by protection staff. To facilitate application of the results, and development of improved forest health management strategies, the contractors reports have been edited and distributed as internal reports. Accordingly, any opinions and recommendations expressed are those of the contractor, and not necessarily those of the ministry or the FRDA management committee.

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The guidelines for internal reports outlined in the Protection Manual were adhered to as closely as possible. All manuscripts were altered to comply with a common format, but entire reports were not rewritten to conform to a standardized outline.

Most Executive Summaries were the work of Graham Hawkins of MoF Inventory Branch (formerly with Pacific Coast Forest Biology). All word processing was accomplished by Catriona Kaufman of Top Kat Services. Will Gordon of R. White Woods inc. prepared all maps and figures.

R. White, editor
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ABSTRACT

This project was initiated by Jeff Beale, Regional Forest Pathologist, Vancouver Forest Region, in order to quantify and evaluate the incidence of black stain root disease in young coastal Douglas-fir plantations on southern Vancouver Island. Further, possible correlations were to be investigated between disease incidence and severity and the effect of spacing and various ecological or other environmental factors. Black stain root disease has caused considerable localized damage in some United States plantations of similar type and age to those in B.C., and is thus of concern to forest managers. Insect vectors and certain environmental factors may exacerbate the problem. To date, the situation has not been closely scrutinized in coastal B.C. Therefore, there is a clear requirement for black stain surveys in this area of the province. A better understanding of disease distribution and possible correlating factors in B.C. could then be used to develop a method for assessing stand risk.

With the preceding as considerations, the MoF, Protection Branch, retained the consultants, Dr. W.J. Bloomberg and Graham V. Hawkins, of Pacific Coast Forest Biology, to conduct this project. The work was conducted in March 1990, near Sooke, Port Renfrew, Lake Cowichan, Ucluelet, Qualicum Beach and Campbell River on southern to central Vancouver Island. This report presents the results and analysis of the survey, together with some salient recommendations.

EXECUTIVE SUMMARY

The purpose of the black stain disease survey was to quantify and evaluate the incidence of black stain root disease in young coastal Douglas-fir plantations on southern Vancouver Island and to quantify and assess whether any significant correlations exist between disease incidence and severity and the effect of spacing and various environmental characteristics. Twenty-two representative sample units were selected within the CDF, CWHa, CWHb and CWHd biogeoclimatic subzones from southern to central Vancouver Island. Sampled stands consisted of at least 80% Douglas-fir not older than 30 years. Information was obtained on black stain infection levels, incidence of other diseases, evidence of insect activity, site index, soil type, rooting depth and topography within these sample units.

The disease was found to be aggregated in distribution. Severity (area affected) was highly variable, ranging from 0-48.7% in the areas surveyed. Despite some high local infection levels, the mean incidence (area affected) was 1.2% in the CWHb and CWHa, which is similar to the situation in Oregon and Washington. Disease levels were highest in the CWHb1, slightly lower in the CWHa1, and non-existent in the CWHd and CDF. Trends showed that spacing, compactible silty soils and shallow rooting depth may lead to higher incidence of the disease. No relationship was seen between *Armillaria* and black stain either within individual trees or infection centres. Either pathogen could initiate attack, but observations suggest that black stain is probably the initiator in most cases. Results were too inconclusive to assess the long-term risk to coastal plantations.

Susceptible stands should be monitored in the CWHb1 and CWHa1 in an ongoing manner. Very young plantations near Campbell River should be studied to determine disease establishment and spread rate. Surveys should be conducted to determine initial inoculum levels in the soil and their relationship, if any, to black stain incidence and severity. More data should be obtained on stress inducing factors, spacing and migration of insect vectors in order to develop an accurate risk assessment for susceptible areas. Black stain infection may result from the synergistic interaction of all the preceding factors. Thus, any further studies might best be performed in an integrated manner.

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1 INTRODUCTION

Black stain root disease, *Leptographium wageneri* Harrington & Cobb, was first reported in British Columbia in 1976 (Morrison & Hunt 1988). Since that date, it has been observed in coastal Douglas-fir plantations and in second-growth pine forests in the interior. Disease incidence and severity may possibly be greater in areas where stress, due to site disturbance or other reasons, is a factor (Cobb 1988). Stand age and composition, as well as site index, shallow rooting, soil compaction and off-site planting, are probable aggravating factors in this regard. In addition, insect vectors, notably *Hylastes nigrinus* (Mannerheim), *Pissodes fasciatus* LeConte and *Steremnius carinatus* (Boheman), are firmly linked to disease spread (Witcosky *et al.* 1986; Harrington *et al.* 1985). Damage from this pathogen has been severe in some United States plantations under conditions similar to those found in B.C. (Hansen *et al.* 1988). However, the pathogen appears to be very localized despite the presence of insect vectors and widespread stress inducing factors. Until recently the incidence and severity of black stain in young coastal Douglas-fir plantations had not been thoroughly investigated in this province.

Pursuant to the preceding concerns, a survey was conducted to quantify and evaluate the incidence of black stain in young coastal Douglas-fir plantations in order to better assess the risk from this disease and determine possible aggravating or causal factors in the environment, especially with respect to insect vectoring. In order to meet these objectives, data were obtained on disease incidence and extent, site index, soils, stand age and composition, disturbance particulars, and spacing activities in young Douglas-fir plantations over a broad study area. Evidence of insect activity and occurrence of other diseases was also recorded. The data were then subjected to statistical analysis.

2 MATERIALS AND METHODS

Representative sample units were used to obtain data on ecological factors and disease incidence and extent. A total of 22 sample units were selected within the CDF, CWHa, CWHb and CWHd biogeoclimatic subzones (Appendix A). The survey was designed to be as broad as possible, with survey areas in the vicinity of Sooke (GVWD), Port Renfrew, Cowichan Lake, Ucluelet, Tofino, Qualicum/Parksville and Campbell River. Areas were selected on the basis of stand age and type: 10-30 years old and greater than 80% Douglas-fir. In addition to the sample units a quick, non-quantitative roadside survey was conducted for the disease to locate any additional infected areas. Within each sample unit data was collected as follows.

2.1 Measurement of Disease Incidence and Extent

Area measurement was appropriate for measuring the extent of black stain because the disease has an aggregated distribution. However, because other root diseases, especially *Armillaria*, are often also present with black stain, individual tree sampling was necessary in order to estimate the proportion of each disease within each sample area. A combined extent and incidence sampling method was employed in the following manner.

Transects were run at 50m intervals. Examination for root disease symptoms was performed for 5m either side of line. The root collar and at least one main lateral root were examined on all symptomatic and adjacent trees. Diseases were identified and recorded according to standard disease symptoms. Any indication of insect activity on the root collar/lateral roots was also noted. Intersection lengths of affected (symptomatic) areas were measured. Depending on stand density, five to 10 adjacent trees within the transect were classified by crown symptoms and disease type at the start of each intersection length and at 20m intervals for the remainder of the infection centre. Standard codes were used according to Jacobi (1990).

Area affected was calculated from the sum of intersection lengths as a percentage of total transect length. Proportions of disease types within infection centres were calculated from the proportion of sample trees within each symptom and disease class and weighted by the intersection length using:

$$Pj = E\ pij \times ILi / E\ ILi$$

where Pj is the overall weighted proportion of trees of class j
pij is the proportion of trees of class j in infection centre i
ILi is the intersection length of infection centre i.

Incidence (percent area) of each class within the entire stand was calculated by multiplying the percent affected area by the weighted proportion.

2.2 Assessment of Ecological Factors

Sample units were established in ecologically homogenous areas, i.e., in areas with minimal variation in stand density, composition and ecological factors. Standard 3.99m radius (.005ha) silvicultural plots were employed within each sample unit to obtain ecological and stand data. The following information was recorded in each plot: stand density and composition, age, height, leader growth, radial increment, EISG species, slope, aspect, site disturbance particulars such as soil compaction or stumping activities, soil fine fraction, percent coarse fraction, rooting zone and LFH depth, and indicators of stress (chlorotic crown, abnormal growth). Stand density and composition/ha were calculated from the average number of stems, by species, per .005ha plot. Site ecotype was determined according to Green *et al.* (1988). EISG species were not used as the only determinants of ecotype because the study areas had been recently disturbed. Thus, site edatope (hygrotope and trophotope) was ascertained from all of the preceding factors in addition to the main indicator plant species present.

2.3 Statistical Analysis

Area affected and disease proportions and incidence of *Armillaria* and black stain were subjected to an analysis of variance and covariance (GLM) using untransformed and arcsin-transformed variables. Main factors were biogeotype and spacing. Covariates were stand age and stocking (stems/ha). Non-parametric one-way analysis of variance (Kruskal-Wallis) was applied to black stain proportions using the following factors: biogeotype, site, spacing, edatopic grid, soil fine fraction and rooting depth. Discriminant analysis was applied to black stain occurrence (presence/absence) using the preceding factors as discriminant variables. Cross-tabulation (contingency table) was used to test any association of black stain with *Armillaria* within stands and within individual trees. In addition, cross-tabulation was used to test association of symptoms with each disease within the four Port Renfrew sites. All statistical analysis was performed using NCSS statistical software (Pacific Ease Co., Santa Monica, Cal.).

3 RESULTS

3.1 Area Affected

Mean affected area was 5.1% for all diseases. Despite large differences (e.g., 48.7% at Renfrew #2 versus 0% for a number of sites) among individual sites, there were no significant differences among biogeotypes or spacing treatments, as tested by either ANOVA or covariance analysis (Appendix B, Tables 1 and 2). Large variation within these factors obscured statistical differences, although trends showed CWHa1 and CWHb1 to have approximately equal infected areas, and CDF and CWHd to have 0% infection. Spaced stands had twice the area infected as unspaced. The largest area occurred in spaced CWHb1 (17.6%). Black stain and *Armillaria* accounted for nearly all the infection in 90% of the stands. Laminated root rot, *Phellinus weirii*, was found in the remainder.

3.2 Black Stain Incidence and Extent

3.2.1 Proportion

Mean proportion of black stain in affected areas was 4.6%. There were no significant differences among biogeotypes or spacing treatments for the same reasons as in the preceding (Appendix B, Table 3). Trends showed the proportion was highest in CWHb1 (13.6%), lowest in CDF and CWHd (0%), and higher in spaced than in non-spaced stands. The highest proportion recorded was in spaced CWHb1 (27.2%). Neither stand density nor age was significant as a covariate.

Rankings by biogeotype, spacing, site, soil fine fraction and rooting depth, as tested by Kruskal-Wallis, showed no significant differences. This was probably attributable to large variation. Trends showed that CWHb1, medium site index, spacing treatment, silt loam soil type, and shallow rooting depth had the highest ranking in black stain proportions. CWHd and CDF, poor and medium-good sites, non-spaced, sand, sandy loam or sandy clay soil types, and moderate to deep rooting depth were lowest in black stain proportions.

3.2.2 Incidence

Mean incidence (percent affected area) of black stain was 1.2%. There were no significant differences among biogeotypes or spacing treatments for the same reasons as above. Trends showed the proportion was highest in CWHb1 (3.8%), lowest in CDF and CWHd (0%), and higher in spaced than non-spaced stands (Appendix B, Table 4). The highest proportion recorded was in spaced CWHb1 (7.2%). In addition, significant levels of black stain were found from age three to five years in a very young plantation in the CWHa1.

3.2.3 Occurrence

Biogeotype, soil fine fraction and rooting depth were significant in discriminating between presence and absence of black stain (Appendix B, Table 5). Wilk's lambda 0.411 indicated moderate predictability of these three variables. Three out of 22 cases were misclassified as having black stain present when it was actually absent; the other 19 cases were correctly classified, giving an accuracy of about 86% for the cases tested. Site also became significant when it was substituted for biogeotype, but the latter still retained a significant F-value. Inclusion of all three variables reduced Wilk's lambda to 0.371.

3.3 *Armillaria* Incidence

3.3.1 Incidence

Mean incidence (percent affected area) of *Armillaria* in affected areas was 1.6%. Again, there were no significant differences among biogeotypes or spacing treatments. Trends showed the proportion was highest in CWHa1 (3.4%), lowest in CDF and CWHd (0%), and higher in spaced than non-spaced stands (Appendix B, Table 6). The highest proportion recorded was in spaced CWHb1 (4.8%) and CWHa1(4.7%).

3.3.2 Association of black stain and *Armillaria*

A Chi-squared test for association of both diseases in the same stand indicated significant ($p = 0.05$) differences in their distributions. The greatest contributions to the Chi-squared test were at the lowest level of *Armillaria* (1-20%), which accounted for more than half of the total Chi-squared values (Appendix B, Table 7). A Chi-squared test for association of both diseases in the same trees indicated significant ($p = 0.05$) differences in their distributions. The greatest contributions to the Chi-squared test was with black stain present, accounting for more than half the total Chi-squared values (Appendix B, Tables 8 and 9).

A Chi-squared test for association of disease with symptom class showed significance at $p = 0.12$, indicating a slight tendency for differences among diseases with respect to their symptoms. Black stain alone was equally associated with 50% or more defoliation and dead, with less than 10% in the yellow-green class (Table 10). Black stain with *Armillaria* or with vector evidence was associated with predominantly dead trees. *Armillaria* alone was associated with a range of symptom classes from green-yellow to dead.

4 CONCLUSIONS

The CDF, CWHa, CWHb and CWHd biogeoclimatic subzones, from southern to central Vancouver Island, were examined in this survey. Sample stands consisted of at least 80% Douglas-fir not older than 30 years. Twenty-two sites were sampled for black stain incidence and severity. Ecological and stand factors were also recorded for these sites. Data were subjected to an analysis of variance, analysis of covariance, Kruskal-Wallis test, Chi-squared test and Wilk's lambda analysis. There was large variation between sites and within the biogeotype and spacing treatment factors. This variation masked disease trends caused by spacing, site index, soil type and disturbance.

According to the survey results, black stain root disease incidence and proportion is highest in the CWHb1, nearly as high in the CWHa1 and lowest in the CDF and CWHd biogeoclimatic subzones. The disease is probably non-existent in the CWHd, but could be present in the CDF under the appropriate stand and ecological conditions; a lack of suitable stands in the CDF probably accounts for absence of black stain. Silty compactible soil types, shallow rooting, off-site planting and spacing treatment are probably implicated in disease severity but this could not be conclusively proven. Disease distribution is similar to the situation in Oregon and Washington states, where a few aggregations of severe damage are widely distributed among susceptible plantations that exhibit very low endemic levels of this disease. No relationship could be found between black stain and *Armillaria* at either the individual tree or stand level. Further disease monitoring and related studies should be conducted in the CWHa and CWHb in order to determine the risk to young coastal Douglas-fir plantations in these areas.

5 RECOMMENDATIONS

The following recommendations result from this survey:

1. More surveys should be conducted in the Campbell River (CWHa1) area, especially in very recently established plantations. The Lost Lake site (Campbell River #1 and #2) should be closely monitored in order to determine spread rate and verify cause(s) of black stain establishment in very young plantations.

2. Soils should be sampled and processed to determine black stain inoculum levels in both affected and unaffected areas following the methods of Hicks *et al.* (1980). If possible, sample areas should be in the CDF, CWHa, CWHb and CWHd biogeoclimatic subzones from southern to central Vancouver Island. A complete range of soil types should be examined.

3. Susceptible plantations in the CWHb1 and CWHa1 should be closely monitored in an ongoing manner. This could perhaps best be performed as a part of regular stand surveying activities adjacent to known infected areas.

4. Stress inducing factors and insect vectoring should be studied further in order to better assess risk. Intensive monitoring for insect vectors in recently spaced stands under stress inducing conditions might be the best strategy.

5. An integrated approach to the study of this disease should be stressed in future since severe infection levels are probably the result of several environmental factors acting in a synergistic manner.

6 DISCUSSION

The low overall level of black stain in the sampling domain (plantations less than 30 years old, four biogeoclimatic zones, locations from southern to central Vancouver Island), but with localized high levels, conforms to the disease distribution reported in Washington and Oregon states (Hansen *et al.* 1988). In Washington and Oregon, low levels (<2%) were present in the majority of sites; however, epidemic levels prevailed in a few locales with high damage occurring. The significance of biogeotype, soil fine fraction and rooting depth in distinguishing between sites with black stain present at any level, and those without the disease, suggests that black stain might be quite widely distributed at very low levels, and detectable only by very intensive sampling. The question of whether such low levels are likely to increase to damaging proportions can only be determined by continuous monitoring.

The effect of spacing on disease distribution and severity was not borne out by the results. The indications are that in some biogeotypes, notably CWHb1, spacing could increase disease levels. However, the lack of significance of stand density and age as covariates suggests that they had little effect on disease incidence. Evidence of insect activity, notably weevil feeding damage at the base of many affected trees, was seen in spaced sites consistent with the findings of other researchers (Harrington *et al.* 1985). However, adjacent similar areas (the Port Renfrew samples) showed no disease incidence despite the very high susceptibility of these sites. In addition, very young, non-spaced trees at Campbell River #1 and #2 also showed ample indication of insect attack. In some instances black staining from the pathogen was observed immediately underneath insect feeding damage. This attack was probably due to stress from j-rooting due to soil compaction and site disturbance from stumping activities. All the preceding observations imply there is little or no effect due to spacing treatment over other stress inducing factors and/or migration rates of the potential vectors are very low. Confirmation of any increased vectoring and incidence of black stain after spacing will require intensive monitoring of insect populations.

The effects of site were confounded by biogeotype to some extent, as indicated by the discriminant analysis. A greater incidence of black stain might be expected on poorer sites but this could not be proved. Increased levels of black stain might be associated with shallow rooting and silty, compactible soil types as indicated by trends in the CWHa and CWHb1 biogeoclimatic subzones. These conditions, often associated with site disturbance during harvesting or site preparation, increase stand stress particularly in plantations that have been recently established. Overall, the presence of black stain in young plantations will probably depend on several factors acting synergistically:

1. Inoculum availability in the soil of the previous or adjacent stand.

2. Vector populations and activities at critical times, i.e., during spacing or times of stress.

3. Stand susceptibility, i.e., major Douglas-fir type, not older than 30 years.

4. Presence of site conditions conducive to the pathogen and vector but detrimental to host resistance.

5. Pathogen virulence.

Stands in the CWHd biogeoclimatic subzone probably did not have high inoculum levels in the soil since the previous stands consisted mainly of western redcedar, western hemlock and sitka spruce mixes. Thus, no infection occurred despite significant stress due to off-site planting and probable presence of suitable vectors. The lack of black stain in the CDF may be due only to a scarcity of susceptible stands in this zone during the present study. Initial inoculum levels may have been greater in the soil of some of the sites currently showing a high disease incidence. The generally poor-medium sites of CWHb1, combined with their general unsuitability for Douglas-fir establishment, may have produced stress levels which increased tree susceptibility. In other instances, shallow rooting and compactible silty soil could result in stress. If high initial inoculum levels and insect vectors are present, infection may occur during the presence of the preceding stress inducing factors or at critical times, such as spacing in stands less than 30 years old. In studies on pine, the pathogen has been recovered from soil immediately adjacent to tree roots and has been shown to enter unwounded fine roots close to, but not in contact with, diseased roots (Hicks *et al.* 1980; Hessburg & Hansen 1986). Wounding or root grafting is required to initiate black stain infection in Douglas-fir. Insect vectors, attracted to stressed and/or spaced stands, would initiate black stain attack through feeding wounds. Additional migration of the vectors and root to root contacts could then further exacerbate the problem very quickly.

There was no clear evidence of an association between black stain and *Armillaria*, either at the stand or the tree level. Either pathogen could act as the primary aggressor under the appropriate conditions. The appearance of mycelial mats overlaying the stain might suggest an initial attack by black stain in many instances. In addition, observations suggest a more rapid rate of disease progression than would be the case for *Armillaria* acting as the primary aggressor. Black stain is characterized by a very rapid progression of symptoms with mortality often occurring two to three years after infection. *Armillaria* infections usually exhibit noticeable reductions in leader growth, often accompanied by distress cone crops, which are not as evident with black stain infections. The slight association of crown symptoms with disease type was indicative of more rapid killing by black stain than by *Armillaria* alone, also an indication of the primary role of black stain. However, the differences were not clear enough to allow diagnosis on the basis of crown symptom alone. Inoculation studies using black stain and *Armillaria* isolates would be required in order to resolve this issue. Very little information has been obtained to date on inoculum levels in the soil of infected sites. Thus, data from this survey are insufficient to fully assess environmental factors and

stand risk at present. However, observations suggest that the most susceptible sites are within the CWHb1 and CWHa1, and have been excessively disturbed and/or spaced.

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APPENDIX A SUMMARY OF ECOLOGICAL CHARACTERISTICS BY SITE

Site Name	Treatment Type and Year	Biogeo. Unit	Edatopic Grid	Stand Comp.	Age Yr.	Stand Density Stems/Ha	Soil Fine Fraction	Percent Coarse Fraction/ Rooting	LFH cm	Slope %	Aspect
GVWD Kapoor	Spaced Spring 1984	CWHa1	1-2, b-c (Poor)	Fd (CwHW)	25	550	SL	60/ Shallow	1.0	30	N.
Sooke BoneY1	Non-Spaced	CWHa1	1-2, a-b (Poor)	Fd (HwCw)	30	4 800	SL	60/ Shallow	1.0	60	S.
Sooke BoneY2	Spaced Spring 1986	CWHa1	1-2, 1-b (Poor)	Fd	40	350	SL	70/ Shallow	1.5	60	S.
Sooke BoneY3	Spaced Winter 1975	CWHa1	2-3, a-b (Poor)	Fd(Pl)	25	700	SL	70/ Shallow	1.0	50	SSE.
Sooke BoneY4	Spaced Winter 1975	CWHa1	2-3, a-b (Poor)	Fd(PlPw)	28	600	S	70/ Shallow	1.0	50	W.
PtRen 1	Non-Spaced	CWHb1	3, a-b (Poor-Medium)	Fd(Hw)	20	800	SL	70/ Shallow	1.5	60	S.
PtRen 2	Spaced Spring 19?	CWHb1	3-4, c (Medium)	Fd(Hw)	21	700	SCL	60/ Shallow	2.0	40	WSW.
PtRen 3	Spaced ?	CWHb1	3-4, c (Medium)	Fd(HwCw)	20	700	SCL	50/ Shallow	1.0	50	WSW.
PtRen 4	Spaced ?	CWHb1	3-4, c (Medium)	Fd(SsHw)	19	600	SCL	60/ Shallow	2.0	40	WSW.
CowLk 1	Spaced Winter 19?	CWHb1	4, c (Medium)	FD(HwCw)	24	600	SCL	60/ Moderate	2.0	20	SE.
Qual. 1	Spaced Spring 1986	CDFa	3-4, c (Medium)	Fd(PlCw)	15	400	S	30/Deep	2.0	Flat	n.a
Qual. 2	Spaced Spring 1986	CDFa	2-3, c (Poor-Medium)	Fd(PlCw)	14	500	S	50/Deep	1.5	Flat	n.a
Qual. 3	Non-Spaced	CDFa	2-3, c (Poor-Medium)	Fd(PlD)	15	600	SL	40/Deep	1.5	Flat	n.a

Site Name	Treatment Type and Year	Biogeo. Unit	Edatopic Grid	Stand Comp.	Age Yr.	Stand Density Stems/Ha	Soil Fine Fraction	Percent Coarse Fraction/ Rooting	LFH cm	Slope %	Aspect
TofFl 1	Spaced Winter 1981	CWHd	5, c (Medium)	Fd (CwHW)	21	800	CL	10/Deep	10.0	Flat	n.a.
TofFl 2	Non-Spaced	CWHd	5, c (Medium)	Fd (CwHw)	28	1 200	CL	10/Deep	10.0	20	NW.
TofFl 3	Spaced 19?	CWHd	4, c-d (Medium-Good)	Fd(CwHw)	28	750	SCL	40/Deep	15.0	Flat	n.a.
CampR 1	Non-Spaced	CWHa1	4, a-c (Poor-Medium)	Fd(Hw)	5	1 500	SiL	30/ Shallow	4.0	15	NW.
CampR 2	Non-Spaced	CWHa1	4, a-c (Poor-Medium)	Fd(Hw)	58	1 800	SiL	50/ Shallow	1.5	25	S.
CampR 3	Spaced Winter 1988	CWHa1	4, a-b (Poor-Medium)	Fd(PwHw)	16	1 200	SiL	30/ Shallow	1.5	Flat	n.a.
CampR 4	Non-Spaced	CWHa1	4, a-b (Poor-Medium)	Fd(HwPw)	28	900	SiL	40/ Moderate	2.0	Flat	n.a.
CampR 5	Spaced Summer 1989	CWHa1	3-4, a-b (Poor-Medium)	Fd(HwPw)	16	700	SiL	60/ Shallow	1.5	30	SE.
CampR 6	Non-Spaced	CWHa1	3-4, a-b (Poor-Medium)	Fd(HwPw)	21	1 600	SiL	70/ Shallow	2.5	30	SE.

APPENDIX B STATISTICS TABLES

Table 1 - Percent Area and Trees by Disease Classes in Infection Centres

LOCATION NAME	% AREA	HEAL-THY	BLACK STAIN PHELL-INUS	BLACK STAIN/ ARMILL-ARIA	BLACK STAIN/	UN-KNOWN	ARMILL-ARIA	PHELL-INUS	BLACK STAIN/ VECTOR
GVWD	2.5	40	0	0	0	0	0	60	0
BONEYARD#1	6.5	0	0	0	0	40	60	0	0
BONEYARD#2	0	0	0	0	0	0	0	0	0
BONEYARD#3	0	0	0	0	0	0	0	0	0
BONEYARD#4	5.5	0	0	0	0	0	100	0	0
RENFREW#1	2.25	57	0	0	0	7	36	0	0
RENFREW#2	48.7	40	19	0	18	17	1	0	5
RENFREW#3	19.5	40	7	0	37	3	10	0	3
RENFREW#4	2.5	20	0	0	20	20	20	0	0
COWICHAN	0	0	0	0	0	0	0	0	0
QUALICUM#1	0	0	0	0	0	0	0	0	0
QUALICUM#2	0	0	0	0	0	0	0	0	0
QUALICUM#3	0	0	0	0	0	0	0	0	0
TOFINO#1	0	0	0	0	0	0	0	0	0
TOFINO#2	0	0	0	0	0	0	0	0	0
TOFINO#3	0	0	0	0	0	0	0	0	0
CAMPBELL R#1	30	20	17	0	0	25	7	0	0
CAMPBELL R#2	6	73	0	0	0	0	0	0	13
CAMPBELL R#3	32.5	38	0	0	0	23	39	0	0
CAMPBELL R#4	11.5	20	0	0	0	25	32	23	0
CAMPBELL R#5	18	44	0	0	22	0	34	0	0
CAMPBELL R#6	8.0	40	0	0	0	0	30	30	0

Table 2 - Analysis of Variance: Percent Area Infected - All Diseases

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A(BIOGEOTYPE)	3	429.0493	143.0164	0.71	0.5604	ERROR
B(SPACING)	1	39.91638	39.91638	0.20	0.6624	ERROR
AB	3	188.7313	62.91044	0.31	0.8153	ERROR
ERROR	14	2808.643	200.6173			
TOTAL(Adj)	21	3675.08				

Means And Standard Errors

Term	Count	Mean	Std.Error
ALL	22	5.1	
BIOGEOTYPE			
CWHal	11	10.7	4.3
CWHbl	5	10.0	6.3
CDF	3	0	0
CWHd	3	0	0
SPACING			
NO	8	3.5	5.0
YES	14	6.9	3.8
BIOGEOTYPE X SPACING			
CWHal NO	5	11.6	6.3
CWHal YES	6	9.7	5.8
CWHbl NO	1	2.25	14.2
CWHbl YES	4	17.7	7.1
CDF NO	1	0	0
CDF YES	2	0	0
CWHd NO	1	0	0
CWHd YES	2	0	0

Table 3 - Percent Black Stain Trees in Infection Centres

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A (BIOGEOTYPE)	3	371.6461	123.882	0.83	0.4981	ERROR
B (SPACING)	1	134.478	134.478	0.90	0.3580	ERROR
AB	3	559.8756	186.6252	1.25	0.3280	ERROR
ERROR	14	2084.083	148.8631			
TOTAL(Adj)	21	4136.773				

Means & Standard Errors

Term	Count	Mean	Std.Error
ALL	22	4.6	
BIOGEOTYPE			
CWHal	11	4.8	3.7
CWHbl	5	13.6	5.5
CDF	3	0	0
CWHd	3	0	0
SPACING			
NO	8	1.5	4.3
YES	14	7.7	3.3
BIOGEOTYPE X SPACING			
CWHal NO	5	6.0	5.4
CWHal YES	6	3.7	5.0
CWHbl NO	1	0	0
CWHbl YES	4	27.2	6.1
CDF NO	1	0	0
CDF YES	2	0	0
CWHd NO	1	0	0
CWHd4,YES	2	0	0

Table 4 - Analysis of Variance: Percent Black Stain Area

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A(BIOGEOTYPE)	3	29.51621	9.838736	0.45	0.7237	ERROR
B(SPACING)	1	10.65546	10.65546	0.48	0.4983	ERROR
AB	3	41.69915	13.89972	0.63	0.6073	ERROR
ERROR	14	308.5963	22.04259			
TOTAL(Adj)	21	472.3351				

Means & Standard Errors

Term	Count	Mean	Std.Error
ALL	22	1.2	
BIOGEOTYPE			
CWHal	11	0.92	1.4
CWHbl	5	3.8	2.1
CDF	3	0	0
CWHd	3	0	0
SPACING			
NO	8	0.29	1.7
YES	14	2.0	1.2
BIOGEOTYPE X SPACING			
CWHal NO	5	1.2	2.1
CWHal YES	6	0.66	1.9
CWHbl NO	1	0	0
CWHbl YES	4	7.5	2.3
CDF NO	1	0	0
CDF YES	2	0	0
CWHd NO	1	0	0
CWHd YES	2	0	0

Table 5 - Discriminant Analysis: Black Stain Occurrence

BLACK STAIN CLASSES: ABSENT (0), PRESENT (1)

Group Counts Report

Group	Count
All	22
0	16
1	6

Variable Selection Report

Classification Variable: BLACK STAIN CLASS

Variable	R-Squared	F-Value	F-Probability	R-Squared of X values
BIOGEOTYPE	0.274	6.0	0.0259	0.8777
SPACING	0.021	0.3	0.5649	0.2699
ROOTING	0.496	15.7	0.0011	0.7988
SITE	0.033	0.5	0.4718	0.6243
FINES	0.211	4.3	0.0554	0.6760

Classification Matrix

Group Counts Table

	P(All)	P(absent)	P(Present)
A(All)	22	13	9
A(0)	16	13	3
A(1)	6	0	6

Percent reduction in classification error due to X's 72.7

Linear Discriminant Functions

Group	Absent	Present
CONSTANT	-9.507605	-17.87548
BIOGEOTYPE	6.487234	11.88039
SITE	-1.699471	-0.470744
SPACING	6.033516	7.223504
FINES	4.447606	6.588281
ROOTING	-3.716072	-12.06155

Mis-Classified Rows

Row	Act	Pred	P(0)	P(1)
14 0	1		0.308	0.692
27 0	1		0.046	0.954
30 0	1		0.137	0.863

Predicted Classification

Row	Act	Pred	P(0)	P(1)
9 0	0		0.990	0.010
10 0	0		0.997	0.003
11 0	0		0.990	0.010
12 0	0		0.990	0.010
13 0	0		0.999	0.001
14 0	1		0.308	0.692
15 1	1		0.005	0.995
16 1	1		0.005	0.995
17 1	1		0.005	0.995
18 0	0		0.951	0.049
19 0	0		0.998	0.002
20 0	0		0.998	0.002
21 0	0		0.994	0.006
22 0	0		0.978	0.022
23 0	0		0.993	0.007
24 0	0		0.991	0.009
25 1	1		0.137	0.863
26 1	1		0.137	0.863
27 0	1		0.046	0.954
28 0	0		0.999	0.001
29 1	1		0.046	0.954
30 0	1		0.137	0.863

Table 6 - Analysis of Variance - Percent Area Infected by *Armillaria*

Source	DF	Sum-Squares	Mean Square	F-Ratio	Prob>F	Error Term
A (BIOGEOTYPE)	3	43.17576	14.39192	0.82	0.5059	ERROR
B (SPACING)	1	9.371632	9.371632	0.53	0.4779	ERROR
AB	3	9.415774	3.138591	0.18	0.9095	ERROR
ERROR	14	246.7326	17.62376			
TOTAL(Adj)	21	338.2055				

Means And Standard Errors

Term		Count	Mean	Std.Error
ALL		22	1.6	
BIOGEOTYPE				
CWHal		11	3.4	1.3
CWHbl		5	2.8	1.9
CWHd		3	0	0
CDF		3	0	0
SPACING				
NO		8	0.75	1.5
YES		14	2.4	1.1
BIOGEOTYPE X SPACING				
CWHal	NO	5	2.2	1.9
CWHal	YES	6	4.7	1.7
CWHbl	NO	1	0.81	4.2
CWHbl	YES	4	0	0
CDF	NO	1	0	0
CDF	YES	2	0	0
CWHd	NO	1	0	0
CWHD	YES	2	0	0

Table 7 - Association of Black Stain with *Armillaria* Within Stands

Black-Stain Percent Trees		Armillaria Percent Trees 0	20	40	60	80	100	Total
0	%	90.9	0.0	100.0	50.0	0.0	100.0	72.7
	X	0.5	2.9	0.4	0.1	0.0	0.1	4.1
20	%	9.1	25.0	0.0	0.0	0.0	0.0	9.1
	X	0.0	1.1	0.4	0.2	0.0	0.1	1.7
40	%	0.0	25.0	0.0	50.0	0.0	0.0	9.1
	X	1.0	1.1	0.4	3.7	0.0	0.1	6.2
60	%	0.0	50.0	0.0	0.0	0.0	0.0	9.1
	X	1.0	7.4	0.4	0.2	0.0	0.1	9.0
80	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	X	0.0	0.0	0.0	0.0	0.0	0.0	0.0
100	%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	X	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	%	100.0	100.0	100.0	100.0	0.0	100.0	100.0
	X	2.5	12.5	1.5	4.2	0.0	0.4	21.1

Chi-Square Statistics

Black-stain class vs Armillaria class

Chi-Square with 12 degrees of freedom	21.0625
Probability Level	0.0495

Distribution significantly different - no association

Table 8 - Association of Black Stain and *Armillaria* in Individual Trees at Renfrew #2

		Armillaria		
Blackstain		Absent	Present	Total
Absent	%	67.1	5.7	72.9
	X	0.1	1.0	1.1
Present	%	20.0	7.1	27.1
	X	0.4	2.7	3.1
Total	%	87.1	12.9	100.0
	X	0.5	3.7	4.2

Chi-Square Statistics

Chi-Square with 1 degrees of freedom	4.2161
Probability Level	0.0400

Distribution is significantly different - no association

Table 9 - Association of Black Stain and *Armillaria* at Campbell R. #5

		Armillaria		
Black-Stain		Absent	Present	Total
Absent	%	53.3	20.0	73.3
	X	0.8	0.9	1.7
Present	%	0.0	26.7	26.7
	X	2.1	2.4	4.6
Total	%	53.3	46.7	100.0
	X	2.9	3.3	6.2

Chi-Square Statistics

Chi-Square with 1 degrees of freedom 6.2338
Probability Level 0.0125

Distribution significantly different - no association