FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

GENETIC GAIN TRIAL TO MEASURE REDUCTION OF *DOTHISROMA* INFECTION WITH *DOTHISTROMA*-RESISTANT BREED - RESULTS TO AGE 3

J.R. Lee, S.D. Carson and L. Gea

Report No. 14 April 1995

FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

EXECUTIVE SUMMARY

GENETIC GAIN TRIAL TO MEASURE REDUCTION OF *DOTHISTROMA* INFECTION WITH *DOTHISTROMA*-RESISTANT BREED — RESULTS TO AGE 3

J.R. Lee, S.D. Carson and L. Gea

Report No. 14 April 1995

Early results (to age three) of a genetic gain trial of the Dothistroma resistant Breed showed that copper fungicide spraying can be very successful in reducing Dothistroma infection (from 45% in unsprayed blocks to 13% in sprayed blocks). Resistant seedlots had less infection than susceptible seedlots. Differences were about the same as predicted using quantitative genetic models and progeny trial results, but may increase as the trial matures. Differences in growth among seedlots were not yet apparent.

GENETIC GAIN TRIAL TO MEASURE REDUCTION OF DOTHISTROMA INFECTION WITH DOTHISTROMA RESISTANT BREED — RESULTS TO AGE THREE.

J.R. Lee, S.D. Carson, and L. Gea.

April 1995

INTRODUCTION

Parents with resistance to Dothistroma needle blight caused by *Dothistroma pini* Hulbary have been selected from the New Zealand radiata pine (*Pinus radiata* D. Don) breeding population. Estimates of genetic parameters indicate that such selection will result in reduced infection on all sites where Dothistroma infection is a problem in New Zealand (Carson 1989, Carson and Carson 1991). Parents identified for seed production display a high degree of Dothistroma resistance as well as good growth and form characteristics (Carson 1989).

Offspring of the 10 best parents mated in a control-pollinated orchard are predicted from progeny tests to have about 12% less infection than non-resistant parents. The genetic theory used for prediction, however, does not take into account the potentially large effect of a reduced spore population (Carson *et al.* 1990).

Accurate estimates of the genetic gain expected for a trait should be obtained in order to determine the desirability of expending resources on selection, the appropriate economic weights with respect to other traits, and the optimum strategy for the deployment of select material. The only way to obtain accurate estimates of gains from the Dothistroma-resistant breed is to plant resistant material in large blocks where the size of the spore population will be influenced by the resistance of the stand (Carson *et al.* 1990).

The objective of this experiment is to obtain an accurate estimate of the reduction in disease levels and the increase in growth rate that can be expected on high hazard sites from planting seedlots from the Dothistroma Resistant Breed (DR). The trial includes blocks in which the disease was kept to insignificant levels through fungicide application. These blocks can be used to evaluate the impact of Dothistroma infection itself on growth and yield of both resistant and less resistant seedlots.

Two series of large-block trials were planted for quantifying genetic gain from the Dothistroma-Resistant Breed. One site was planted in 1990 with open-pollinated (OP) seedlots and three sites in 1993 with control-pollinated (CP) seedlots (Carson and Firth 1990, Stovold 1993). This report presents results of the OP trial to age 3 from planting.

MATERIALS AND METHODS

Seedlots

This trial is made up of OP offspring from three highly select sets of parents, each set with a similar predicted gain for growth and form on non-Dothistroma sites but with different predicted gain in resistance (Table 1). These seedlots are expected to perform similarly for growth and form in the absence of Dothistroma infection, but are predicted to perform differently on high hazard Dothistroma sites. The seedlots used in the OP trial included only "875" and "268" parents (Table 1). Seedlot 1 is made up OP families of the best 6 parents of the DR breed, where selection placed equal emphasis on Dothistroma resistance and growth. Seedlot 2 is made up of OP families of 6 parents ranked highly for the Growth and Form breed, but with a relatively low expected gain in disease resistance. The third seedlot consists crosses among OP families of the best five parents available for growth and form. Seedlot 4 was an equal mixture of all three seedlots.

Trial Design

This trial was established on a high-hazard Dothistroma site at Kinleith Forest, Compartment D 6257, Landing Road and has 5 replicates of 7 treatments. The treatments were planted in large blocks of trees in a randomised complete block design (35 blocks). Each of the 35 blocks has 49 trees and is separated by four-row buffers of *Eucalyptus fastigata*. Each block has 7 x 7 trees planted at 4 x 4 m spacing (625 stems/ha). Buffers of *E. fastigata* were planted at 4 x 2 m spacing (1250 stems/ha).

Treatments A, B, C, and D (Table 2) received no fungicide spray and were seedlots 1-4 (Table 1), respectively. Treatments E, F and G were seedlots 1-3 (Table 1) and had fungicide applied as necessary to keep the disease at insignificant levels. The fungicide was made up of 150 gm copper oxychloride with 15 litres of water and 2%

spraying oil. This was sprayed over the entire tree using "Solo" knapsack sprayers in November of 1991, 1992 and 1993.

For planting, treatment D was divided into 16 contiguous three-tree sub-plots and one tree from each seedlot was randomised within the sub-plot. The one extra space in each block was planted with a tree randomly selected from one of the three seedlots.

Assessment and analysis

Annual assessment the of level of Dothistroma infection, in 5% increments, and height (cm) was carried out over the first three years after planting. Assessment of diameter at breast height (dbh) was carried out at age three.

A major infestation of broom was evident in the trial, and its effect on the levels of Dothistroma infection, height and diameter growth was investigated. Trees were released from the broom on two occasions, and this has resulted in the taller broom falling in on the trees in many situations. The amount of broom surrounding each tree was assessed at age three on a 1 to 5 scale, with 1 being no broom interference and 5 being total broom cover (Figure 1).

The analysis of variance structure shown in Table 3 was used to test all main effects and the interaction of seedlots x treatments. Comparisons of seedlots 1-3 with no fungicide treatment (treatments A, B, and C) with seedlots in the mixture planting (Treatment D) were carried out by partitioning the treatment effects. Tests of the difference between seedlot blocks without fungicide treatment (treatments A-C) and the same seedlots with fungicide treatment (Treatments E-G) were done similarly. Additional contrasts were tested if appropriate (Table 3). The data obtained from the experiments was analysed using the PROC MEANS, PROC CORR and PROC GLM Procedures (SAS, 1989).

RESULTS

The differences in Dothistroma infection among unsprayed seedlots (1, 2 and 3), mainly between seedlot A and the other two, became more apparent with age (Table 4). At age three there was a 4-5% difference in the mean Dothistroma infection level between the resistant seedlot (1) and the less resistant seedlots (2, 3) in the unsprayed regime, although differences were not statistically significant at any age

(Tables 5-7). Dothistroma infection of the mixed seedlot (4) was not significantly different than the average of seedlots 1, 2 and 3, although it was closer to the resistant seedlot (1) at age 3.

Application of fungicidal spray had a large effect on the level of *Dothistroma pini* infection (Table 4). Differences between the sprayed and unsprayed treatments are apparent and highly significant (Tables 6 and 7) with a reduction in Dothistroma infection of around 15% at year 2 and 30% at year 3. At age 1, before spray treatments were carried out, the unsprayed treatments were more infected than the treatments which were subsequently sprayed. This was completely turned around by years 2 and 3 when the sprayed treatments showed much less Dothistroma infection.

There are only small differences among treatments in height and diameter at age three, with mean heights of treatments ranging between 311 cm and 335 cm and mean diameters ranging from 40 mm to 50 mm (Table 4). Significant differences among seedlots in height disappeared at age 3, when neither height or diameter differed significantly among seedlots (Tables 8-11).

Analysis of variance of broom score (Table 12) suggests that the amount of broom was significantly different among replications, but did not differ among treatments, suggesting that broom scores did not affect treatment means. Graphs of plot means with broom scores (Figure 2, 3 and 4) suggest that the relationship of the variables of interest (Dothistroma, height and diameter) were not highly affected by the broom. At the individual tree level, correlation coefficients of broom score with Dothistroma infection, height and diameter (Table 13) were significant for most measurements, but explained only about 2% or less of the variation in diameter at age three. Analysis of variance with broom included as a linear covariate gave the same indications of significance as without broom as a covariate (Tables 14-16).

DISCUSSION

Dothistroma infection in this trial has been reduced by spraying copper fungicide. Nearly 30% reduction in the percent of needles with Dothistroma infection was observed across all seedlots at age 3. If this level of reduction in infection can be maintained, growth loss due to Dothistroma infection should be well quantified in this trial.

Differences in Dothistroma infection among the unsprayed seedlots were not statistically significant, but were about the same as predicted by progeny test results for open-pollinated seedlots. A difference in resistance gain of 5 % was expected (Gea. *et al.*, 1993, Table 1) with a 4-5% difference observed between the resistant seedlot and the less-resistant seedlots at age three, suggesting that genetic resistance is being displayed. Differences in infection among the seedlots may increase as the trial matures, as the epidemiological effect on spore populations is compounded (Carson *et al.*, 1990). The control-pollinated trials established in 1993 should show a greater difference between the seedlots as they are made up of seedlots with GF 25 - GF 26 but vastly dissimilar expected Dothistroma resistance (DR 0, DR 7 and DR 16).

The expected growth loss associated with Dothistroma infection is not yet being observed. All unsprayed seedlots are expressing similar performance with a mean height of 328.2 cm and a mean diameter of 45.5 mm at age three. The age of the trial may account for the lack of difference in growth under both sprayed and unsprayed regimes. Volume loss on an individual tree basis was approximately proportional to disease levels (Van der Pas, 1981). However, growth loss lagged behind disease progress in that disease incidence did not show noticeable effects until the following year (Van der Pas, 1981). This trial was probability too young to show any significant reductions in growth through Dothistroma infection or the growth benefits of the resistant breed.

Results probably have been effected by the invasion of broom. Broom is probably suppressing the growth of some of the trees and possibly limiting the spread of Dothistroma spores. The ability of the Dothistroma spores to move from tree to tree is probably limited by the broom infestation because it becomes a buffer against the splash dispersal process. The effect of genetically resistant seedlots on the spore population of *D. pini* may not be as great as it might be had there been no weed problem.

ACKNOWLEDGMENTS

The authors would like to thank Mark Kimberley and Paul Jefferson for their greatly appreciated suggestions on this analysis. A great of deal credit is due to Tony Firth and to Fred Burger (Carter Holt Harvey Ltd) for maintaining the trial and carrying out fungicide treatments and weed eradication. The highly competent GTI field crew planted and measured the trial.

REFERENCES

Carson, S.D. 1989. Selections for the Dothistroma Resistant Breed. New Zealand Radiata Pine Breeding Cooperative. Report No. 12. 18p.

Carson, S.D. 1989. Selecting *Pinus radiata* for resistance to *Dothistroma* needle blight. New Zealand Journal of Forestry Science. 19(1): 3-21.

Carson, S.D., A.M.P. Dick, and G.G. West. 1990. Benefits of the Dothistroma-resistant breed of radiata pine. In Allen, J.C, and A.G.D. Whyte. Proceeding Australia and New Zealand Institutes of Forestry Conferences. "New Directions in Forestry: Costs and Benefits of Change". Sept 30-Oct 5, 1991 Christchurch, New Zealand. pp 251-262.

Carson, S.D. 1990. Workplan for the genetic gain trial to measure reduction of *Dothistroma* infection with Dothistroma Resistant Breed. NZ FRI Work Plan No. 1931.

Carson, S.D. and M.J. Carson. 1991. Realising Gains in Resistance to Dothistroma. Proceedings-11th Meeting of Research Working Group 1 (Forest Genetics) Australian Forestry Council, 11-15 March, 1991. Coonawarra, South Australia. P 71-75.

Gea, L.D., S.D. Carson and P.A. Jefferson. 1993. Predictions of parental values for Dothistroma resistance over sites and series. New Zealand Pine Breeding Cooperative. Report 12.

SAS. 1989. SAS Language and Procedures. SAS Institute Inc.

Stovold, G.T. 1993. Establishment report for the Dothistroma genetic gain trials. NZ FRI Workplan (in prep).

Van der Pas, J.B. 1981. Reduced early growth rates of *Pinus radiata* caused by *Dothistroma pini*. N. Z. Jour. For. Sci. 11(3): 210-20.

Table 1. Seedlots used in OP trial

Series	Parent	Expected gain in % of needles with Dothistroma infection.[a]	GF rank[b]	Dothi rank[b]
Seedlot 1 - Best for Dothistroma Resistant Breed				
268	1	3.17	2	8
268	2	6.54	21	1
875	3	4.16	10	10
875	4	8.53	1	4
875	5	9.63	15	3
875	6	6.73	6	13
average		6.34	GF19	DR16
Seedlot 2 - Best for Growth and form, but with low resistance				
268	1	2.65	5	28
268	2	1.84	7	38
268	3	1.34	14	52
875	4	4.36	2	62
875	5	0.15	13	80
875	6	0.04	3	64
average		1.77	GF21	DR12
Seedlot 3 - Best for Growth and form				
268	1	1.66	6	15
268	2	3.67	2	8
268	3	1.84	7	38
268	4	3.78	8	20
875	5	4.86	2	62
average		2.88	GF21	DR14

a. from Gea *et al.* 1993.
b. 1= Best.

Table 2. Trial treatments.

Treatments	Treatment regime	
	Seedlot	Fungicide control
A	1	No
B	2	No
C	2	No
D	1, 2, & 3	No
E	1	Yes
F	2	Yes
G	3	Yes

Table 3. Analysis of Variance Structure.

The following analysis of variance structure was used.

Source	df	Expected Mean Squares
Replicate	4	$\sigma^2_E + \sigma^2_{RT} + \sigma^2_R$
Treatment	6	$\sigma^2_E + \sigma^2_{RT} + \sigma^2_T$
Replicate x Treatment	24	$\sigma^2_E + \sigma^2_{RT}$
Residual Error within plot	150	σ^2_E

In addition, the treatment effect (if significant) was partitioned into the following contrasts.

		Contrasts						
	df	A	B	C	D	E	F	G
Spray vs unsprayed	1	1	1	1	0	-1	-1	-1
D vs unsprayed (A,B,C)	1	1	1	1	-3	0	0	0
A vs B	1	1	-1	0	0	0	0	0
A vs C	1	1	0	-1	0	0	0	0
B vs C	1	0	1	-1	0	0	0	0

When the comparison of the sprayed and unsprayed treatments was significant, the contrasts below were examined.

Source		Contrasts						
	df	A	B	C	D	E	F	G
E vs F	1	0	0	0	0	1	-1	0
E vs G	1	0	0	0	0	1	0	-1
F vs G	1	0	0	0	0	0	1	-1

Table 4. Treatment means for height, broom invasion and Dothistroma infection at ages 1, 2, and 3 years from planting

Spray[1]	Seedlot[2]	Treatment[3]	Dothistroma (% needles infected)			Height (cm)			Diameter (mm)	Broom (scale 1-5)
			age 1	age 2	age 3	age 1	age 2	age 3	age 3	age 3
0	1	A	35.0	33.8	41.3	88.0	195.6	325.0	44.0	3.28
0	2	B	40.3	36.0	46.6	87.2	193.5	311.5	39.8	3.58
0	3	C	39.6	36.0	46.6	94.4	207.0	333.5	48.1	2.89
0	4	D	38.5	34.9	42.3	89.6	199.5	331.2	50.6	3.25
1	1	E	42.1	20.6	14.0	86.6	191.1	329.4	44.5	3.37
1	2	F	44.5	21.9	12.9	92.2	203.6	335.3	44.0	3.71
1	3	G	44.8	20.6	13.3	91.3	196.4	332.1	47.5	3.22

[1] 0 = Not sprayed with copper fungicide, 1= Sprayed with copper fungicide
[2] See Table 1
[3] See Table 2

Table 5. Analysis of variance of *Dothistroma* infection at age 1 year from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	3633.01	908.25	0.26	NS
Treatment	6	17497.50	2916.25	0.84	NS
Rep*Treatment	24	83648.15	3485.34	1.00	NS
Error	1482	910693.67	614.50		
Corrected Total	1516	1012795.29			

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 6. Analysis of variance of *Dothistroma* infection at age 2 year from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	9959.96	2489.99	7.53	**
Treatment	6	69139.08	11523.18	34.85	**
Rep*Treatment	24	7936.28	330.67	1.00	NS
Error	1423	115396.18	81.09		
Corrected Total	1457	204818.95			

Partitioning of Treatment Effects -Tested over Rep*Treatment effect.

Sprayed vs unsprayed	1	60239.88	60239.88	182.18	**
D vs unsprayed	1	21.51	21.51	0.06	NS
A vs B	1	507.81	507.81	1.54	NS
A vs C	1	500.29	500.29	1.51	NS
B vs C	1	0.04	0.04	0.00	NS
E vs F	1	121.13	121.13	0.36	NS
E vs G	1	19.58	19.58	0.06	NS
F vs G	1	44.66	44.66	0.13	NS

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 7. Analysis of variance of *Dothistroma* infection at age 3 years from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	8001.12	2000.28	0.96	NS
Treatment	6	326393.14	54398.86	32.30	**
Rep*Treatment	24	50157.75	2089.91	1.00	NS
Error	1397	182197.01	130.42		
Corrected Total	1431	573631.28			
Partitioning of Treatment Effects - Tested over Rep*Treatment effect					
Sprayed vs unsprayed	1	292382.58	292382.58	139.90	**
D vs unsprayed	1	1102.21	1102.21	0.53	NS
A vs B	1	92.58	92.58	0.00	NS
A vs C	1	2220.65	2220.65	1.06	NS
B vs C	1	1860.84	1860.84	0.89	NS
E vs F	1	3072.97	30.72.97	1.47	NS
E vs G	1	2661.56	2661.56	1.27	NS
F vs G	1	17.81	17.81	0.00	NS

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 8. Analysis of variance for height at age 1 year from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	19944.22	4986.05	1.76	NS
Treatment	6	10953.80	1825.63	0.64	NS
Rep*Treatment	24	67626.14	2817.76	1.00	NS
Error	1482	621308.70	419.24		
Corrected Total	1516	717687.47			

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 9. Analysis of variance for height at age 2 year from planting.

Source	DF	Sum of Square	Mean Square	F Value	Pr > F[a]
Rep	4	45035.76	11258.94	0.73	NS
Treatment	6	45950.77	7658.46	0.49	NS
Rep*Treatment	24	369804.38	15408.51	1.00	NS
Error	1423	2893254.11	2033.21		
Corrected Total	1457	3341765.88			

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 10. Analysis of variance for height at age 3 years from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	66385.75	16596.44	0.64	NS
Treatment	6	77182.16	12863.69	0.49	NS
Rep*Treatment	24	624096.42	26004.02	1.00	NS
Error	1397	5732036.52	4103.10		
Corrected Total	1431	6492377.58			

Partitioning of Treatment Effects.

Sprayed vs Unsprayed	1	16013.44	16013.44	0.62	NS
D vs unsprayed	1	9232.34	9232.34	0.35	NS
A vs B	1	15454.46	15454.46	0.59	NS
A vs C	1	10066.21	10066.21	0.38	NS
B vs C	1	50997.53	50997.53	1.96	NS
E vs F	1	6344.90	6344.90	0.24	NS
E vs G	1	5274.90	5274.90	0.2	NS
F vs G	1				

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 11. Analysis of variance for diameter at age 3 years from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	22461.05	5615.26	4.27	**
Treatment	6	5054.88	642.48	0.49	NS
Rep*Treatment	24	31576.45	1315.66	1.00	NS
Error	1354	362260.23	267.55		
Corrected Total	1388	419909.11			
Partitioning of Treatment Effects - Tested over Rep*Treatment effects					
Sprayed vs Unsprayed	1	1197.44	1197.44	0.91	NS
D vs unsprayed	1	558.25	558.25	0.42	NS
A vs B	1	1137.85	1137.85	0.86	NS
A vs C	1	224.06	224.06	0.17	NS
B vs C	1	2402.74	2402.74	1.82	NS
E vs F	1	670.09	670.09	0.5	NS
E vs G	1	93.54	93.54	0.07	NS
F vs G	1	1284.19	1284.19	0.97	NS

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 12. Correlation (r) of broom scores for individual trees with individual tree values for Dothistroma infection (years 1-3), heights years (1-3) and diameter (Year 3).

	Dothistroma			Height			Diameter
	Age 1	Age 2	Age 3	Age 1	Age 2	Age 3	Age 3
Pearson Correlation Coefficient	-0.041	0.11	0.14	0.04	0.07	-0.04	-0.31
Prob>|R| under Ho: r=0	NS	0.0001	0.0001	0.07	0.0037	NS	0.0001
Number of observations	1434	1440	1428	1434	1440	1428	1443

Table 13. Analysis of variance of broom at age 3 years from planting.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Rep	4	792.53	198.13	5.73	**
Treatment	6	85.00	14.16	0.41	NS
Rep * Treatment	24	829.66	34.56	1.00	NS
Error	1408	2081.94	1.47		
Corrected Total	1442	3802.79			

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 14. Analysis of variance of *Dothistroma* infection at age 3 years from planting with broom as covariate.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Broom	1	7850.83	7850.83	4.32	*
Rep	4	3438.12	859.53	0.47	NS
Treatment	6	331269.70	55211.61	30.44	**
Rep*Treatment	24	43533.99	1813.91	1.00	NS
Error	1392	173698.86	124.78		
Corrected Total	1427	572342.62			

Partitioning of Treatment Effects

Sprayed vs Unsprayed	1	296986.49	296986.49	163.73	**
D vs unsprayed	1	1114.22	1114.22	0.61	NS
A vs B	1	2274.53	2274.53	1.25	NS
A vs C	1	3341.72	3341.72	1.84	NS
B vs C	1	94.71	94.71	0.05	NS
E vs F	1	471.76	471.76	0.26	NS
E vs G	1	69.85	69.85	0.03	NS
F vs G	1	183.96	183.96	0.1	NS

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 15. Analysis of variance of height at age 3 years from planting with broom as covariate.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Broom	1	77045.76	77045.76	19.24	**
Rep	4	54552.07	13638.01	0.47	NS
Treatment	6	65662.76	10943.79	0.37	NS
Rep*Treatment	24	700863.32	29202.63	1.00	NS
Error	1392	5573252.53	4003.77		
Corrected Total	1427	6405491.52			

Partitioning of Treatment Effects

Sprayed vs Unsprayed	1	18410.05	18410.05	0.63	NS
D vs unsprayed	1	7734.74	7734.74	0.26	NS
A vs B	1	11907.80	11907.80	0.4	NS
A vs C	1	4334.42	4334.42	0.14	NS
B vs C	1	30468.00	30468.00	1.04	NS
E vs F	1	10789.29	10789.29	0.36	NS
E vs G	1	0.01	0.01	0.00	NS
F vs G	1	10916.56	10916.56	0.37	NS

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Table 16. Analysis of variance of diameter at age 3 years from planting with broom as covariate.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F[a]
Broom	1	26059.18	26059.18	104.95	**
Rep	4	5141.04	1285.26	0.76	NS
Treatments	6	5949.38	991.56	0.59	NS
Rep*Treatment	24	40421.95	1684.24	1.00	NS
Error	1344	333723.46	248.30		
Corrected Total	1379	417824.47			

Partitioning of Treatment Effects - Tested over Rep*Treatment effect

Sprayed vs Unsprayed	1	2039.48	2039.48	1.21	NS
D vs unsprayed	1	594.56	594.56	0.35	NS
A vs B	1	522.84	522.84	0.31	NS
A vs C	1	2.08	2.08	0.31	NS
B vs C	1	597.16	597.16	0.001	NS
E vs F	1	1806.02	1806.02	0.35	NS
E vs G	1	127.95	127.95	0.07	NS
F vs G	1	2922.81	2922.81	1.73	NS

a. NS = not significant, * = significant with $p \leq 0.05$, ** = significant with $p \leq 0.01$.

Figure 1. Assessment of broom levels and their relationship to single trees.

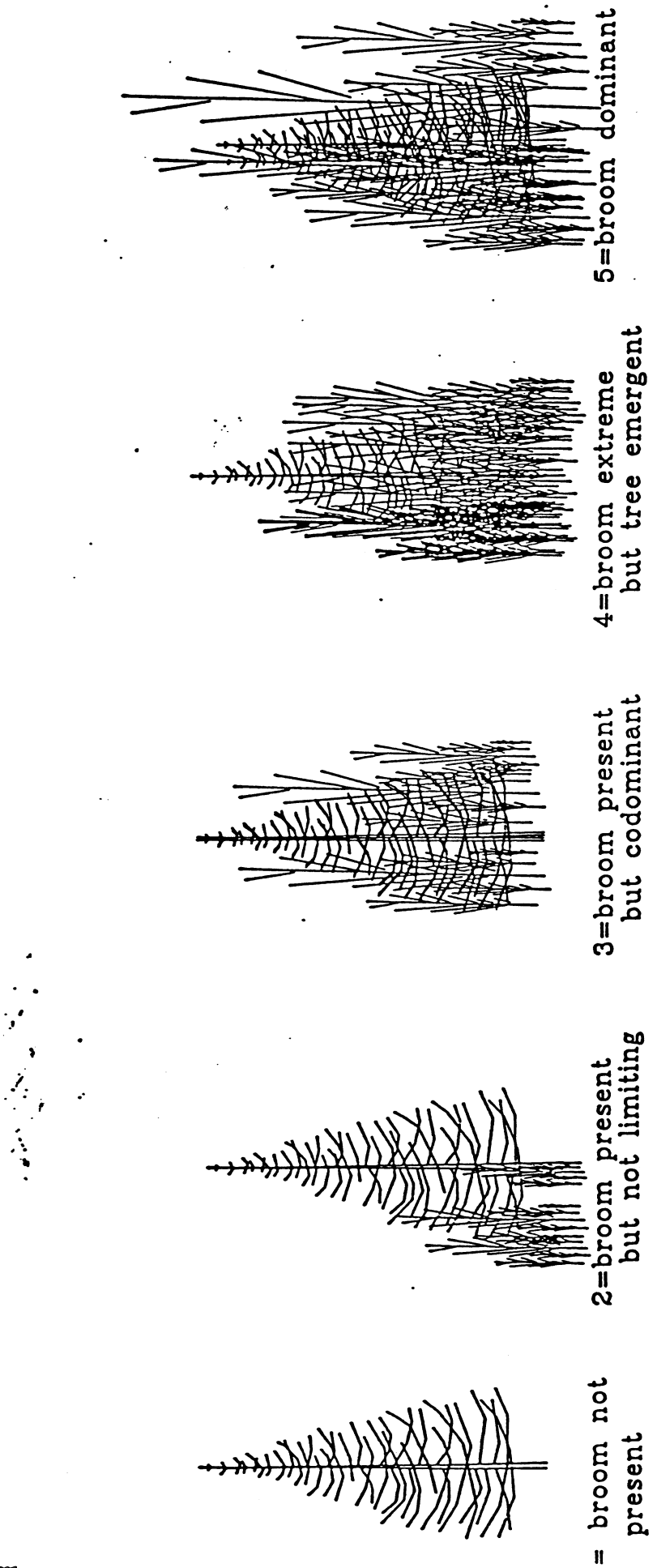
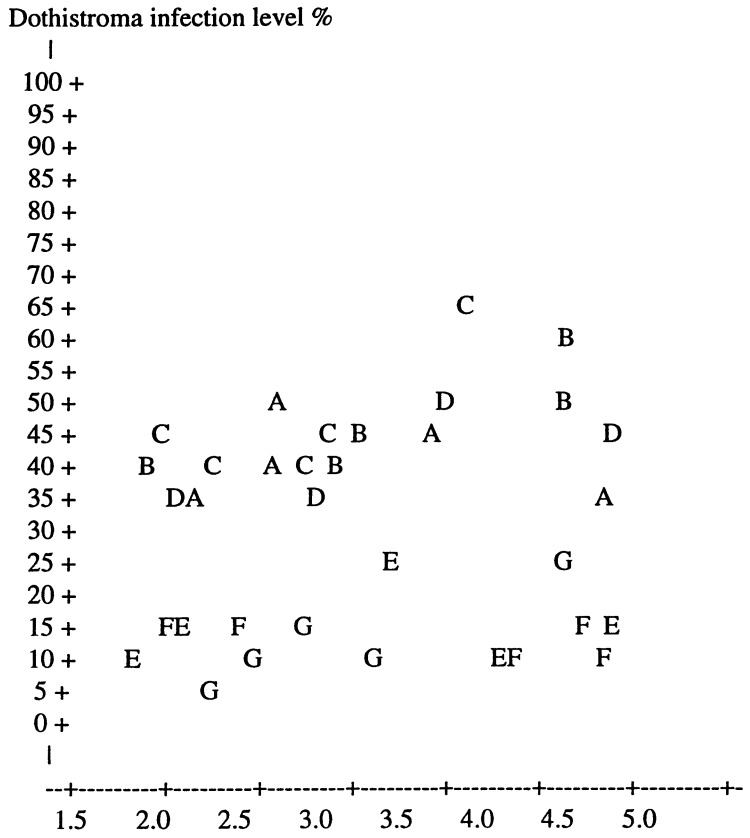
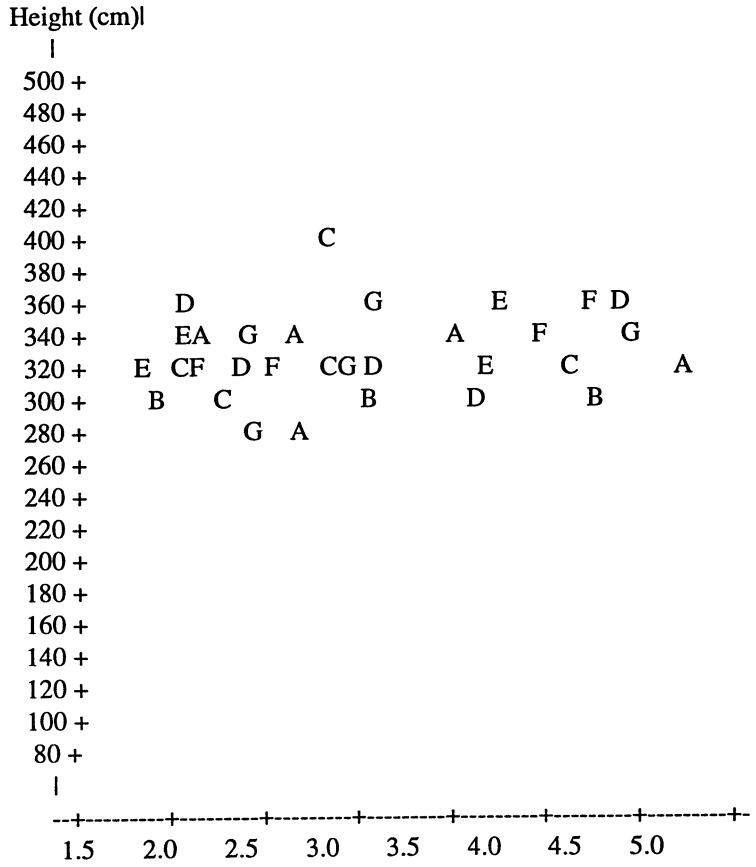


Figure 2. Mean Dothistroma infection levels and broom infestation for each treatment at age 3 years from planting. Symbols on graph indicate treatment.



NOTE: 1 obs hidden.

Figure 3. Mean Height and broom infestation for each treatment at age 3 years from planting. Symbols on graph indicate treatment.



NOTE: 4 obs hidden.

Figure 4. Mean Diameter and broom infestation for each treatment at age 3 years from planting. Symbols on graph indicate treatment.